

Guideline for Beneficial Use of Biosolids on Land



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This document supersedes the [Guidelines for the Safe Application of Biosolids to Land in New Zealand, 2003](#). This document builds on the work of the original document, and acknowledgement is owed to its authors. This updated Guide has been developed in two stages, many thanks to the submitters, workshop participants that contributed.

During both stages, substantial input has been made by the Project Management Steering Group, all of whom gave their time in kind, some without payment from employers. The Steering Group worked on the principle of consensus decision-making. Consensus was reached on most issues. Steering Group members contributed to decision-making within their areas of expertise and provided an industry or sector view according to their experience. They were not necessarily representing the entire sector group from which they were selected.

Financial support for the preparation of this Guide was received from WasteMINZ, Water New Zealand, the Water Service Managers Group and Watercare Services Ltd.

2017 Draft Guidelines for Beneficial Use of Organic Materials on Productive Land, Volumes one and two.

Four key waste sector partners, Water New Zealand, WasteMINZ, the Centre for Integrated Biowaste Research (CIBR) and the New Zealand Land Treatment Collective (NZLTC), in partnership with the ministries of Environment (MfE), Health (MoH) and Primary Industries (MPI) collaborated to deliver the draft guidance. Grateful thanks also to technical experts Jacqui Horswell, Grant Northcott, Louis Tremblay, Gerty Geilen, Joanne Hewitt, Brett Robinson and Jürgen Esperschütz who contributed to this project. The development of the draft was coordinated by Nick Wamsley of Water New Zealand and undertaken by the following people:

- George Fietje – Auckland Council and WasteMINZ Organic Material Sector Group
- Jacqui Horswell – Centre for Integrated Biowaste Research (CIBR) and Environmental Science and Research Limited (ESR) (to October 2017)
- Maria J Gutierrez-Gines – CIBR and ESR (from October 2017)
- Paul Bruce – Appropriate Technology for Living Association (ATLA)
- Katie Beecroft – Lowe Environmental Impact (LEI) and the New Zealand Land Treatment Collective (NZLTC)
- Nigel Clarke – Ministry for the Environment (MfE)
- John Harding – Ministry of Health (MoH)
- Andrew Pearson – Ministry for Primary Industry (MPI)

2023 Guidelines for Beneficial Use of Biosolids and other Organic Materials on Land

Updates to the 2017 draft were coordinated by Lesley Smith, contributed to by a number of Water New Zealand members, Regional Council staff, and other sector bodies, and overseen by the following advisory group:

- Maria J Gutierrez-Gines – ESR and University of Canterbury
- Katie Beecroft – Lowe Environmental Impact (LEI) and the New Zealand Land Treatment Collective (NZLTC)
- Sarah Burgess – Te Whatu Ora Health New Zealand and Beca
- Bruce Croucher – Ministry for the Environment
- Rob Tinholt – Watercare and the Australian New Zealand Biosolids Partnership
- Peter van der Logt and Jefferson Fowles – Ministry for Primary Industries (MPI)
- Chris French – Relier Project & Strategy

Our sincere thanks to all who contributed.

VERSION HISTORY

This Guide outlines the decision making and risk management processes that enable practitioners to select and manage the application of biosolids to land. It is not a standard.

Previous versions of the Guide, recent research reports, submissions and advice have been retained for reference and are available from the Water New Zealand resource library at <http://www.waternz.org.nz>.

2003 Safe Application of Biosolids to Land in New Zealand

The Guide supersedes Guidelines for the Safe Application of Biosolids to Land in New Zealand, 2003 and its reference in NZS 4454:2005, Composts, Soil Conditioners and Mulches. Key changes made to this version of the Guide were:

- Nitrogen limits are used as the primary land application control; assessments have shown this to be an effective means of limiting contaminant applications for good-quality products being applied to typical soils
- Modified the grading system; if the compliance level for contaminant grading is not met, application rates are required to be determined based on mass loadings
- Removed historically banned substances, eg, dioxins, and updated with contemporary emerging organic contaminants
- Excludes a soil specification; this is dealt with by other guidance
- Expanded scope to acknowledge areas where the framework can be applied to other organics.

2017 Draft Guidelines for Beneficial Use of Organic Materials on Productive Land, Volumes one and two

Revisions were first published in 2017 in Draft Guidelines for Beneficial Use of Organic Materials on Productive Land, Volumes one and two.

In developing the draft update, the following reviews were undertaken:

- [Tapu to Noa](#) (Ataria, et al., 2016)
- [Community Engagement Framework](#) (Baker, et al., 2016)
- [Pathogens Review 1](#) (Hewitt, July 2014)
- [Pathogens Review 2](#) (2017, ESR, Jacqui Horswell)
- [Contaminant Review](#) (2014, Centre for Integrated Biowaste Research, Jürgen Esperschütz, Brett Robinson, Jürgen Esperschütz)
- [Organic Contaminants 1](#) (Tremblay, Gielen, & Northcott, 2014) (2014, Centre for Integrated Biowaste Research, Louis Tremblay, Gerty Gielen and Grant Northcott)
- [Organic Contaminants Limits 2](#) (2016, Centre for Integrated Biowaste Research, Grant Northcott)

2025 Guidelines for Beneficial Use of Biosolids on Land

This version of the Guide maintains the same technical basis as the first section of the guidelines but has been restructured and updated to:

- Reflect contemporary information on limits to protect soil ecology (ecoSGVs), nitrogen build up, and typical biosolids characteristics
- Restructured to follow a risk-based management framework
- Emphasise issues relevant to iwi Māori.

Updates were informed by two reviews to capture developments in scientific knowledge:

- [Trace element review](#) recommended updates and a [revised report](#) (2024, Manaaki Whenua, Landcare Research, Jo Cavanagh, Hadee Thompson-Morrison, Brett Robinson)
- [Updates to the Organic Materials Guidelines – Organic Contaminants Review](#) (2024, Grant Northcott, Northcott Research Consultants Ltd and Dr Louis Tremblay, Manaaki Whenua-Landcare Research).

The document has also been informed by a review of biosolids characteristics:

- [Determining the nutritional and soil conditioning value of biosolids and sewage sludge in Aotearoa New Zealand](#) (2024, University of Canterbury, María J Gutiérrez Ginés & Claudia Garcés Hernández).

Future updates

The swift pace of change in waste minimisation policy and understanding of emerging contaminants means the Guide will need to be updated as new developments occur.

This guide was published shortly after the release of the PFAS National Environmental Monitoring Plan 3.0. Further work is underway to determine appropriate sampling frequencies for PFAS.

CONTENTS

1. How to Use this Document	7
1.1 Purpose of this Document	7
1.2 Scope of this Document	8
1.3 Structure of this Document	11
PART ONE: CONTEXT	15
2. The Case for the Beneficial Use of Biosolids	16
2.1 Drivers for Beneficial Use	16
2.2 Typical uses of Biosolids on land	17
2.3 Nutritional and soil conditioning value of biosolids and sewage sludge	17
2.4 Benefits of Beneficially using Biosolids and Other Organic Wastes	18
2.5 Creating a Case for Change	19
3. Māori views on management of biosolids	20
PART TWO: GOVERNANCE & OVERSIGHT	22
4. Establishing a Governance & Oversight Framework	23
5. Iwi Engagement	23
6. Community Engagement	24
7. Regulatory Frameworks	26
PART THREE: MANAGING THE RISKS OF PRODUCTS	29
8. Identifying Hazards Posed By Biosolids Products	30
9. Quantifying The Hazards Posed By Biosolids	32
9.1 Product Quality Framework	32
9.2 Determination of Stabilisation Grade	32
9.3 Determination of Contaminant Grade	39
9.4 Management of emerging organic contaminants	41
9.5 Labelling Standards	45
9.6 Monitoring and Sampling	45
10. Mitigating the Hazards Posed by Biosolids	52
10.1 Specific Management Approaches for Pathogens & Vector Attraction	52
10.2 Specific Management Approaches for Contaminants	54
10.3 General Product Handling Risks	56
PART FOUR: MANAGING THE RISKS TO RECEPTORS	58
11. Identifying Risks to Receptors	59
11.2 Risks to Environmental Health	60

11.3	<i>Risks to Human Health</i>	62
11.4	<i>Risks to Animal Health</i>	63
11.5	<i>Risks to Social and Cultural Values</i>	63
12.	Quantifying the Risk to Receptors	65
12.1	<i>Understanding Soil Chemical and Physical Properties</i>	65
12.2	<i>Soil Monitoring</i>	66
12.3	<i>Soil Characteristics</i>	68
12.4	<i>Maximum allowable soil concentration of PFAS</i>	69
12.5	<i>Proximity to Aquifers and Surface Water Bodies</i>	69
12.6	<i>Presence of 'Sensitive' Areas</i>	69
12.7	<i>Existing Land Uses</i>	70
13.	Mitigating the Risks to Receptors	71
13.1	<i>Planning Controls</i>	71
13.2	<i>Managing Application Rate to Land</i>	73
13.3	<i>Application Strategies To Manage Receptor risk</i>	78
13.4	<i>Managing Pathogen Risk</i>	81
13.5	<i>Managing Risks During product Storage</i>	82
PART FIVE: QUALITY ASSURANCE		85
14.	Quality Assurance Requirements	86
14.1	<i>Responsibility for Monitoring</i>	86
14.2	<i>Quality Assurance to Manage Risks to Receptors</i>	86
14.3	<i>Record Keeping</i>	88
Schedule 1 Example Safety Data sheet		91
Schedule 2 Recommended Test Methods		97
Appendix 1 Sources of wastewater treatment contaminants		98
Appendix 2 Example of Mass Loading Calculation		102
Appendix 3 Treatment Process Options		103
Appendix 4 Soil Characteristics and Interaction with Biosolids Contaminants		106
Appendix 5 Supporting Resources		116
Appendix 6 Typical Contaminant Concentrations in New Zealand Biosolids		118
Appendix 7 Justification for nitrogen (N) loading rates in different application scenarios		119
Appendix 8 Knowledge Gaps and Future Research Needs		121
References		125
Glossary		135

1. HOW TO USE THIS DOCUMENT

1.1 PURPOSE OF THIS DOCUMENT



This Guide provides detailed technical guidance on the safe and beneficial use of biosolids on land while protecting receptors which include soils, water, plants, animals and people.

The Guide may also be used to support the beneficial use of other organics. Its applicability to other waste streams is outlined in Section 1.2.2.

This document is intended to be used by regulators, product producers, end users and those providing technical services to facilitate the activities.

The guidelines are intended to:

- Identify how biosolids can be safely processed into appropriate products of suitable quality
- Identify practices for safe and appropriate storage, handling, transportation and land application that protect soil and other receptors
- Provide guidance on the application to land of these products so it is done in a way that protects receptors (the soil, waters, air, animals, plants and people who may be directly or indirectly exposed to the products)
- Highlight cultural values and interests of mana whenua so they are appropriately engaged and relevant issues considered.

The Guide adopts a risk management approach to identify, quantify and manage the risks presented by biosolids (and other organic waste) and to the receptors in the environment in which they are applied.

These Guidelines for Beneficial Use of Biosolids on Land (the Guide) cover the application of biosolids (treated organic wastes of human origin) to existing soils as fertiliser and/or conditioning agents.

The Guide is designed to safeguard the life-supporting capacity of soils, promote the responsible use of biosolids (and where possible, other organics) and protect public health and the environment. The quality criteria within this Guide are not a replacement soil specification.

The document supports the Government's priority of recycling more organic material, outlined in Te Rautaki Para/Waste Strategy (Ministry for the Environment, 2023). This Strategy sets a long-term direction towards a low-emissions, low-waste society built on a circular economy, where waste materials are reduced, reused or recycled, so they never get thrown away.

Returning carbon and nutrients to soil systems from biosolids is the circular economy in action. It delivers sustainability outcomes through carbon sequestration and economic benefits from transforming waste into a fertiliser product. Applied to soils, biosolids can have significant value, increasing organic matter content and water-holding capacity, and supplying nutrients for plant and soil biota growth.

Māori views on waste and recycling precede the concept of a circular economy (ōhanga āmiomio) but similarly acknowledge the mauri (life force) of natural resources (Ministry for the Environment, 2023). However, re-use of organic waste streams, particularly those that contain human wastes and chemical contaminants, create unique challenges from a Māori cultural perspective and meaningful engagement is required to reach sustainable solutions (Ataria, 17th August 2017).

There is a breadth of cultural knowledge on the topic of biowaste, biosolids and wastewater management, a willingness and openness to explore new forms of co-management, and an expectation of being involved in decision making. Where this is the case, Māori view biowastes and biosolids as something that should be owned and

responsibly managed, rather than forgotten about or left to the environment to cope with (Ataria, et al., 2016).

A fundamental premise of the Guide is that both biosolids can be beneficially recycled to land, providing that both the process of product manufacture and the process of applying the material to land are subject to adequate management control. This requires organic material to be applied at a rate that does not exceed the agronomic nitrogen requirements of crops, and adequate risk assessment and controls to protect environmental, human and animal health and social and cultural values.

This Guide provides requirements and supporting rationale to support appropriate risk management to unlock benefits of biosolids. The Guide has been informed by several supporting reviews, listed in Appendix 5 Supporting Resources.

Other organic materials can have similar benefits and pose similar risks to those posed by biosolids and so should be managed in a similar manner. A comprehensive body of research has been developed on reusing biosolids, which forms the basis of this Guide. Many of the principles in the Guide can also be applied to the use of other good-quality organic waste streams.

1.2 SCOPE OF THIS DOCUMENT

1.2.1 WHAT ARE BIOSOLIDS?



Biosolids are sewage sludges that have been treated and/or stabilised to the extent that they may be safely and beneficially used. Biosolids have significant fertilising and soil conditioning properties because of the nutrients and organic materials they contain.

The term “biosolids” does not include untreated raw sewage sludges, septic tank sludges or sludges solely from industrial processes¹. Sewage or septic sludge is regarded as having become biosolids once it has undergone further treatment to significantly reduce disease-causing pathogens and volatile organic matter, producing a stabilised product suitable for beneficial use.

Biosolids are derived from wastewater sludge, a mix of water, organic and inorganic materials that are a byproduct of sewage treatment processes. While not exhaustive, the primary sources of sludge from sewage treatment plants, including treatment ponds, include:

- Readily settleable organic and inorganic material, often referred to as “primary sludge”
- “Waste activated” or “secondary sludge”; during sewage treatment, microorganisms digest (eat) the sewage, breaking down the original organic solids in sewage leaving a low-solids effluent and a solids component known as sewage sludge
- Dissolved air flotation (DAF) sludges typically used to control algal load in pond systems.

Sewage sludge may be made up from one or more of these sources. These sludges in the raw form are liquids containing a low percentage, typically less than 5% by weight, of solids. To facilitate handling, storage and/or disposal, the water content of the sludge is typically reduced, usually by passing through mechanical processes. At this stage, the sludge has not undergone sufficient treatment to be considered biosolids. Further treatment processes, outlined in this guidance, are required to achieve a biosolids product.

¹ While biosolids contain material delivered from industrial inputs to sewers, such material is diluted by the organic material in domestic sewage inputs. Industrial sludges, on the other hand, may contain high concentrations of specific chemicals, little or no organic material, and the organic material this is present may be of a different nature to that contained in sewage. Consequently, any proposal to discharge industrial sludges to land should be treated on its merits.

Sewage consists of used water from household activities such as washing dishes and clothes, taking a shower, flushing the toilet and teeth cleaning. Industry also discharges into the sewerage system. This discharge is usually regulated with trade waste controls put in place to avoid compounds reaching levels that might harm the environment or people.

Sewage sludges may contain:

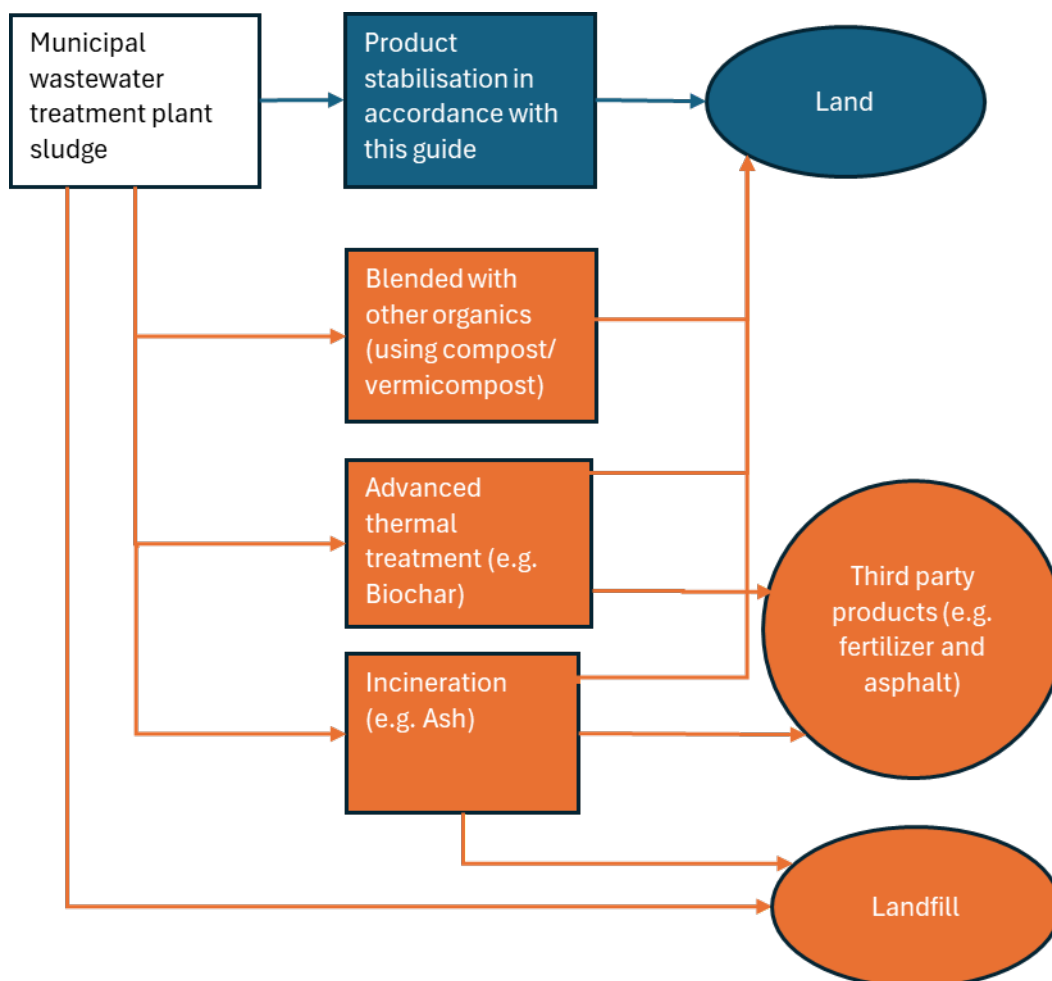
- Macronutrients, such as nitrogen, phosphorus, potassium and sulphur
- Micronutrients, such as copper, zinc, calcium, magnesium, iron, boron, molybdenum and manganese
- Traces of synthetic organic compounds such as PFAS, musks, pharmaceuticals and metals, including arsenic, cadmium, chromium, lead, mercury, nickel and selenium. The range of contaminants present in wastewater and their sources are addressed in Appendix 1 Sources of wastewater treatment contaminants.

When treated to produce biosolids, the concentration of these macronutrients, micronutrients and synthetic organic compounds may be concentrated, which require appropriate controls to protect receptors.

1.2.2 SEWAGE SLUDGE DISPOSAL PATHWAYS

Sewage sludge can be disposed of in a variety of ways. This guideline focuses on the beneficial reuse to land of sewage sludges that have been transformed into biosolids. Figure 1 provides an overview of potential disposal pathways, with those covered by this guideline shown in blue.

Figure 1: Biosolid disposal pathways. Those covered this guide are shown in blue.



Existing disposal routes in New Zealand have been collated by the Australian New Zealand Biosolids Partnership. In 2023, the largest proportion of biosolids, 43% was used for landform

restoration of a quarry. Biosolids being used for landscaping, agriculture, forestry, or land rehabilitation has remained essentially stagnant at or below 20%. A portion of the nation's biosolids are stockpiled and their disposal pathway delayed, but typically resulting in landform restoration or landfill. A small portion are incinerated (Richardson, Tinholt, & Vero, 2024).

Energy and other products can often be recovered during sewage sludge treatment. Most commonly, anaerobic biodigesters are used to produce biogas, sometimes using co-digestion with other waste sources. However advanced thermal destruction technologies (beyond the scope of this guide) can also be used to generate heat energy, biogas and biofuel, and other products with a range of end uses.

Conventional methods for biosolids treatment are the focus of this guideline, but it is well known and understood that other disposal pathways are immediately available for consideration by the market. Further work needed to develop guidelines for these technologies is outlined in Appendix 8.

Used as an input into composting and vermicomposting

Biosolids can be reprocessed into composts or vermicomposting by incorporating products with other organic wastes. NZS 4454:2005 Composts, soil conditioners and mulches (Standards New Zealand, 2005) prescribes compositional requirements, compliance requirements, sampling and testing methods for these products.

Advanced thermal treatment

Advanced thermal treatment technologies include pyrolysis, gasification and incineration (discussed further below). Application of these treatment pathways requires different considerations to those of conventional treatment approaches which are outside the scope of this document.

These processes involve thermal decomposition of organic materials at high temperatures and with varying levels of oxygen. Used appropriately they can reduce product volumes, achieve contaminant destruction, recover energy, reduce GHG emissions compared to landfill and produce reusable products such as biochar.

Globally use and development of these technologies is increasing as concerns about the impact of microplastic and other emerging contaminants entering the food chain by traditional biosolids to land application grows. Further work is needed to determine the role these technologies can play in managing New Zealand biosolids, outlined in Appendix 8: Knowledge Gaps and Future Research Needs.

Incineration

Biosolids incineration combusts treated sewage sludge at high temperatures to produce an ash product. Benefits are reduced volume, pathogen and contaminant destruction, and energy recovery. The resulting ash can sometimes be repurposed, for example for use in construction materials. While incineration significantly reduces landfill waste and can generate heat or electricity, concerns include air emissions, energy consumption to maintain temperature, and limited beneficial reuse of nutrients.

1.2.3 APPLICABILITY TO ORGANIC WASTES OTHER THAN BIOSOLIDS



This Guide was developed to enable beneficial use of biosolids to land. The extensive research on biosolids has some applicability to the beneficial reuse of other organic materials.

Soil contamination limits (specified in Item 7, Appendix 2) should not be exceeded, regardless of waste type. However, presence of contaminant and beneficial characteristics differ among organic wastes. This means that for wastes other than biosolids:

- Changes in sampling frequencies could be warranted to better represent the risk from contaminants in feedstocks
- Other contaminants may require addressing not covered by this Guide
- Beneficial characteristics will vary, meaning that loading rates suggested in this Guide are not an appropriate control for all organic streams.

The Guide does not address the broad range of issues associated with organic wastes other than biosolids, however references have been provided where possible. Types of contaminants found in organic wastes other than biosolids are provided in the supporting Contaminant Review (Esperschütz & Robinson, August 2014) and, for animal wastes, the supporting Pathogen Review (Hewitt, July 2014).

The risk management principles of assessing hazards, identifying risks and mitigating risks can be applied to support the beneficial use of other organic materials, such as:

- Food waste that has been collected and processed (e.g., kerbside collection)
- Processed sludges and biowastes that are byproducts of commercial wastewater treatment
- Processed waste from meat processing plants
- Solid animal manures that have been gathered and processed (not diseased animal wastes).

1.2.4 SOIL REPLACEMENT REQUIREMENTS



This Guide does not provide a specification for replacement soil:

- For urban, commercial, industrial and rural residential areas, refer to the Ministry for the Environment [National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health](#) (Ministry for the Environment, 2021) and related guidance
- For rural non-residential areas (agricultural land), refer to [An implementation framework for ecological soil guideline values](#) (Cavanagh and Hamworth, 2023)

1.3 STRUCTURE OF THIS DOCUMENT

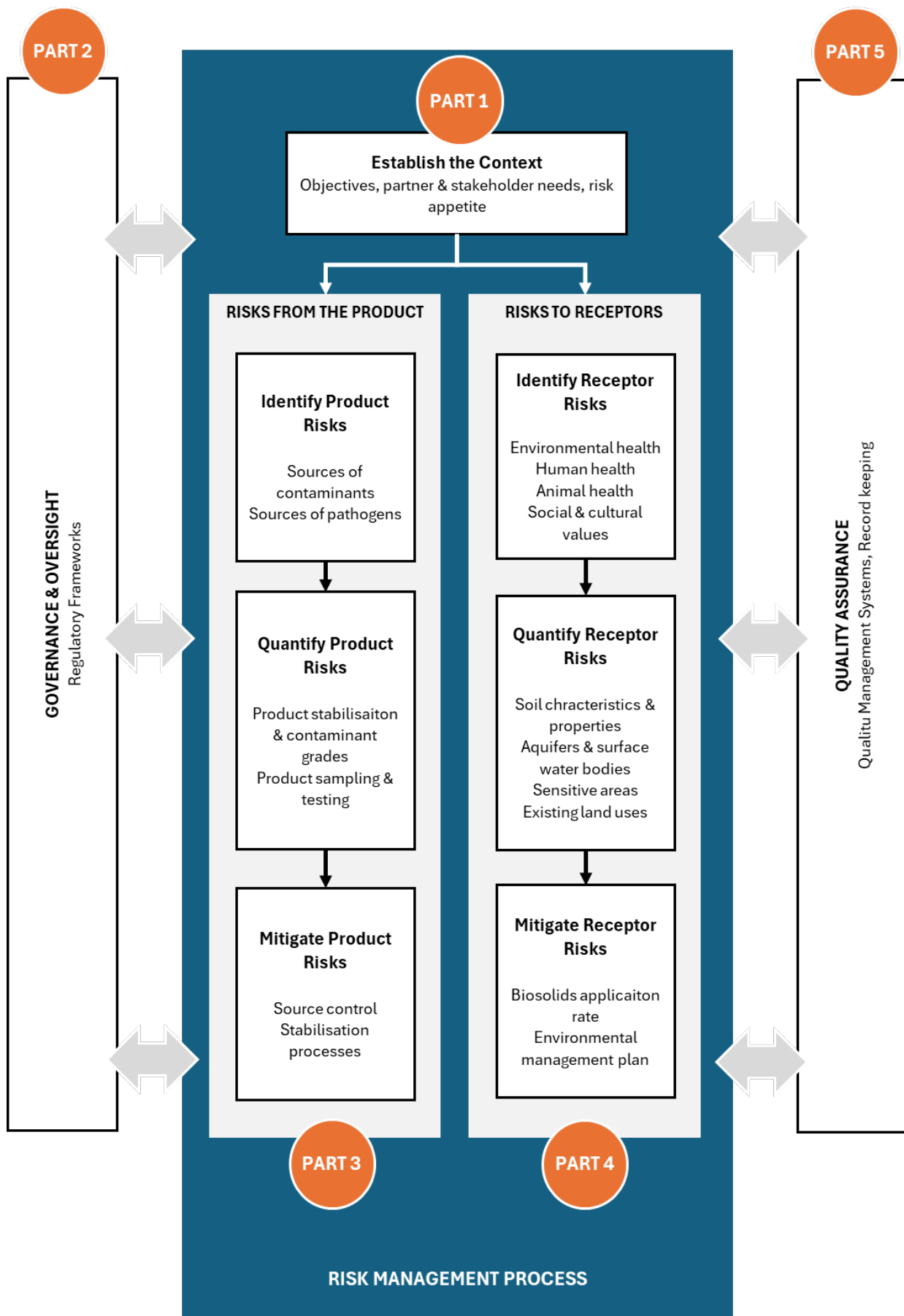


This guide is structured using a risk management framework to support the identification, quantification and management of risks posed by biosolids to receptors.

Appropriately identifying and managing risks requires an understanding of context – the key drivers for, and objectives of, producing and beneficially using the products. Further, the process of identifying and managing risks requires governance and oversight that aligns to New Zealand's regulatory framework, and ongoing monitoring processes to confirm if, and how, risks have changed.

The approach taken in this document broadly aligns with contemporary risk management approaches, as outlined in ISO 31000:2018 Risk management – Guidelines (ISO, 2023). Figure 2 provides a summary of the risk management framework used in this guide.

Figure 2: Risk Management Framework for Production and Beneficial Use of Biosolids (and Other Organic Materials).



Further information on suitable methodologies for assessing and managing risks are outlined in ISO 31000:2018. (ISO, 2023).



In alignment with Figure 2, this document is divided into five parts, as follows.

Part One: Context

Part One describes the key considerations that might influence the approach to managing product and receptor risks for biosolids and other organic materials when applied to land. This includes:

- The typical drivers for, and objectives of, biosolids (and other organic materials) management in New Zealand
- A framework for understanding the appetite for risk as it relates to biosolids management.

Part Two: Governance & Oversight

Part Two describes the key mechanisms for identifying and managing the risks of biosolids (and other organic materials) management. These include:

- The role of iwi, including Māori views on management of biosolids, and the role of iwi engagement in determining how to manage biosolids.
- Engaging with the community to understand and appropriately meet their expectations.
- Regulatory requirements. The Resource Management Act 1991 (RMA) is the primary legislation governing the application of any organic material (including biosolids) to land in Aotearoa New Zealand. The RMA is used by regional councils as a basis for development of region-specific resource management plans that ultimately define the rules applicable to the use of biosolids on land. Regional plan rules outline whether the use of material/product can be permitted (does not require a resource consent) or has a level of restriction and requires consent to reuse.

Part Three: Managing the Risks of Products

Part Three of this document is divided into three sections, as follows.

Section 8: Identifying Hazards Posed By Biosolids

The potential bio-physical hazards posed by biosolids requiring assessment in these guidelines are from contact with:

- Pathogens,
- Contaminants (metals, organic compounds)
- Vermin and insects
- Odour and dust

Section 9: Quantifying the Hazards Posed by Biosolids

The Guide classifies biosolids according to their stabilisation and contaminant grades. The grading of the product indicates how potentially hazardous it is.

The requirements for monitoring and sampling products to confirm compliance with the classifications is also provided.

Section 10: Mitigating the Hazards Posed by Biosolids

This section includes guidance on how to mitigate key risks/hazards often identified from biosolids, including:

- Source controls for contaminants

Part Four: Managing the Risks to Receptors

- Treatment requirements to achieve the prescribed grades for biosolids
- Transportation and storage techniques for biosolids.

Part Four of this document is divided into three sections, as follows.

Section 11: Identifying Risks to Receptors

The beneficial use of biosolids to land requires careful identification of potential risks to environmental, human and animal health as well as social and cultural values and trade. Receptors to the application may include:

- The soil, plants and biota of the application site
- Animals
- Farmers, neighbours and workers
- The community
- Groundwater
- Surface water.

Section 12: Quantifying the Risks to Receptors

The Guide identifies an approach to assessing risks to land through assessment of soils, proximity to water bodies and other sensitive areas and existing land uses.

Section 13: Mitigating the Risks to Receptors

A sustainable application of biosolids or other organic materials to land aims to avoid increasing concentrations of contaminants in the soil to a level that could cause an adverse effect to the receptors identified in the risk assessment. For typical biosolid and soil compositions in New Zealand, the risk to groundwater and surface water from nitrogen leaching is generally the most limiting parameter. Unless product or soil contaminants are elevated, limiting product application by nitrogen loading will ensure protection limits for soils are not exceeded for the term of the biosolids application (a maximum of 20 years).

The Guide provides the process for determining application rates based on product and soil composition. It also provides guidance on other land management techniques, such as exclusion periods.

Quality control and management practices are required to minimise risks associated with the use of organic materials and derived products. Quality assurance has a role in every stage of the production and discharge of biosolids and other organic materials starting from source control and extending to the monitoring of the receiving environment for the discharge.

Section 14.2: Quality Assurance to Manage Risks to Receptors

Products covered by these guidelines must come from a facility with a documented quality assurance system and have a system of formalised management plans in place as described in this section of the guide.

Section 14.3 Record Keeping

Quality assurance records demonstrate that processes, product quality and environmental outcomes are met. This section outlines required records.

Part Five: Quality Assurance Requirements

PART ONE:
CONTEXT

2. THE CASE FOR THE BENEFICIAL USE OF BIOSOLIDS

2.1 DRIVERS FOR BENEFICIAL USE



Understanding drivers for converting sewage sludge into biosolids is an important step in setting the objectives and understanding the risks involved in these activities. In New Zealand, there are legislative, environmental, social and economic drivers for biosolids reuse. Key factors of which are described below.

Legislative Requirements:	Increasing legislative requirements are driving the minimisation of waste disposal to landfill, especially for organic materials such as sludge, green and food waste. Untreated, wet sludges direct from WWTPs are difficult to handle and a potential source of odour. Some landfills are required to mix sludge with solid waste at minimum ratios required by resource consents or for landfill operational management. As solid waste quantities to landfills reduce through recycling and waste diversion activities, landfill operators may further restrict the acceptance of sludge to stay within required mixing ratios. Mixing sludge with general waste in this manner also adds cost to landfill operations, exacerbating already increasing disposal costs.
Carbon Emissions:	Sludge and organic waste disposal to landfill is a significant contributor to a landfill's carbon emissions. Even where landfill gas is captured, emissions are generally higher than alternative use pathways. As urban landfills near capacity, restrictions on landfill disposal near major centres are expected to increase, resulting in greater transport needs and associated emissions.
Community Expectations:	Community expectations are changing. There are increasing expectations on managing sludge in a way that does not create odour or public health risks, whether perceived or actual. Urban intensification also creates challenges for sludge transportation, which can be minimized if sludges are first transformed into biosolids.
Circular Economy	Biosolids provide fertiliser and soil conditioning benefits for soil. Biosolids typically contain large amounts of organic matter (Table 1), which, when added to the soil, has been shown to improve structure, porosity and water retention. They also contain a range of macro and micro nutrients, essential for plant growth. Beneficial reuse of biosolids to land returns nutrients, organic matter, from wastewater offsetting the use of virgin fertiliser products, the circular economy in action.
Costs Beyond Control:	All the factors described above could have cost impacts. When wastewater sludges have limited, inflexible disposal pathways they are exposed to increasing transportation and waste disposal levy costs beyond the control of owner/operator. Finding beneficial reuse pathways can be a mechanism to protect against these cost impacts.

2.2 TYPICAL USES OF BIOSOLIDS ON LAND

Biosolids treatment processes produce a stabilised product suitable for beneficial use that normally contains between 15% and 90% solids.

Biosolids can be applied as a fertiliser to improve and maintain productive soils and stimulate plant growth. They are also used to fertilise gardens and parks and rehabilitate mining sites. These guidelines outline processes to enable biosolid use in land applications such as:

- Agriculture (pastoral farming, arable cropping, tree and vine crops)
- Forestry
- Land rehabilitation (including landfill capping and mine site rehabilitation)
- Landscaping and topsoil amendment
- Composting as a soil amendment

Not all biosolids can be used for all applications. These guidelines provide a basis for determining which biosolids can be beneficially used for land application.

2.3 NUTRITIONAL AND SOIL CONDITIONING VALUE OF BIOSOLIDS AND SEWAGE SLUDGE

Plant macronutrients essential for plant growth and health and absorbed from the soil, are nitrogen, phosphorus, potassium, sulphur, magnesium and calcium. Other nutrients that plants need in smaller amounts (micronutrients) are iron, manganese, boron, zinc, copper, molybdenum, chlorine, nickel and selenium. These nutrients need to be frequently added to productive land (usually in the form of fertilisers) to restore those removed from the soil by crop and pasture harvesting and grazing. Sewage sludge and biosolids contain significant amounts of plant macro- and micronutrients (Table 1), a proportion of which are readily available for plants (such as nitrate, ammonia/um and Olsen phosphorus), and others that are slowly released during the decomposition of biosolids' organic matter.

Organic matter is the main soil component responsible for soil structure, porosity and water retention. Intensive agriculture causes the loss of organic matter from soils due to increased decomposition. Sewage sludge and biosolids generally contain large amounts of organic matter (Table 1), which, when added to the soil, has been shown to improve structure, porosity and water retention (Gutiérrez Ginés & Garcés Hernández, 2024).

A recent study of New Zealand biosolids characteristics (Gutiérrez Ginés & Garcés Hernández, 2024) found that more than 90% of the sewage sludge or biosolids observations had an adequate concentration of plant nutrients in readily available forms, and organic matter, to be considered fertilisers and/or soil conditioners (Table 1). As a point of caution, the amount of nitrogen in the form of ammonia or ammonium could potentially be too elevated, posing a risk of plant toxicity. For this reason, nitrogen loading rates are recommended as a principal control in this Guide.

Micronutrients such as zinc, copper and selenium are usually added to NZ soils because their concentration is lower than optimal for plant or animal health. These micronutrients are present in sewage sludge and biosolids. Biosolids application into productive land could bio-fortify crops with these essential micronutrients (Gutiérrez Ginés & Garcés Hernández, 2024). However, these elements can also be considered as potential contaminants because in high concentration in the soil, they can be toxic for soil organisms, plants and humans. This gives rise to the need for management controls outlined elsewhere in this Guide.

Table 1: Summary of data related to fertility (N, P, K, S, Ca, Mg) and soil conditioning (pH and organic matter/total carbon) potential of sewage sludge and biosolids (Gutiérrez Ginés & Garcés Hernández, 2024)

Parameter	Units	n of observations	Median	Range	Range 5 th - 95 th percentile	Soil quality target
pH		6	7.6	4.2 - 8.5	5.9 - 8.3	3.5 – 7.6 ¹
Organic matter	%	1,046	58	8.1 - 87	43 – 69	> 4.3 – 9.5 ²
Total Carbon	%	30	27	3.1 - 51	4.8 - 42	> 2.5 - 5.5 ¹
Total Nitrogen	%	81	3.1	0.2 - 9.8	0.4 - 6	0.1 – 0.7 ¹
C:N		28	8.7	5.7 - 26	6.5 - 23	10 – 15 ³
Nitrate Nitrogen	mg/kg	10	36	1.3 – 2,400	2.1 – 1,605	
Ammoniacal Nitrogen	mg/kg	39	2,375	6 – 38,100	218 – 12,550	
Phosphorus	%	92	1.2	0.02 - 3.5	0.1 - 2.5	
Olsen Phosphorus	mg/kg	4	388	49 - 506	82 - 506	5 – 90 ¹
Potassium	%	99	0.2	0.1 - 15	0.1 - 1	
Calcium	%	100	1.8	0.1 - 15	0.3 - 4.3	
Magnesium	%	99	0.2	0.1 - 2.8	0.1 - 0.9	
Sulphur	%	8	0.7	0.1 - 1.6	0.1 - 1.5	

¹ Range of suggested soil quality targets for different soil types under productive land use (pasture, crops, horticulture, forestry). (Taylor, 2013)

² Organic matter calculated as 1.72 times the concentration of total organic carbon (Waksman & Stevens, 1930)

³ Range for healthy soil; <8 excessive mineralisation; >24 excessive immobilisation (McLaren & Cameron, 1996).

2.4 BENEFITS OF BENEFICIALLY USING BIOSOLIDS AND OTHER ORGANIC WASTES



Biosolids provide fertiliser and soil conditioning benefits for soil. Adding quality organic matter to soils can improve soil structure and water retention. Biosolids are rich in nutrients such as nitrogen, phosphorus and micronutrients that can enhance soil fertility.

Some of the biggest environmental challenges facing New Zealand, and globally, include carbon emissions, depleting soil carbon and loss of nitrogen and phosphorus to water systems. Use of biosolids and other organic materials in our soil can significantly improve multiple outcomes, as outlined below.

Positive outcomes from beneficially using biosolids and other organic materials include:

Reducing Greenhouse Gas Emissions:

Sewage sludges not beneficially on land are generally landfilled or incinerated. If organic materials are placed in a landfill, they emit methane, a potent greenhouse gas with a warming effect 28 times greater than carbon dioxide. Incineration of organic materials releases combustion products such as carbon dioxide, a greenhouse gas.

Sequestering Carbon:

When applied to land, organic materials sequester carbon into the soil both through direct application of recalcitrant organic matter and through stimulation of soil biological activity to incorporate atmospheric carbon into the soil biomass. This can rebuild carbon stocks in soils depleted by land use and clearing.

Reducing Dependency on Chemical Fertilisers:

Organic renewable carbon rich fertilisers and soil conditioners contain a wide range of macro and micronutrients, which can reduce dependency on imported fertilisers. The production and transport of organic materials has lower environmental footprint than imported alternatives, and localised production can improve supply chain resilience. The slower release from

organic material compared with inorganic fertiliser can reduce the risk of nutrients travelling to other environments, such as surface water where they may have an adverse effect.

Supporting Local Economies:

Organic products are generally sourced and used locally, creating jobs associated with their production and processing that contribute to local economies.

Creating Resilience to Change:

Creating diverse, flexible pathways for uses of organic products, rather than singular inflexible disposal pathways, increases resilience to changing legislative, community and cost pressures.

Conservation of Landfill Space:

Without alternative disposal routes, biosolids are either stockpiled or, in municipal centres, generally disposed of in landfill. Enabling beneficial reuse conserves space in landfill.

2.5 CREATING A CASE FOR CHANGE



It is recommended when establishing or further developing a programme to produce and/or beneficially use sludge or other organic materials for land that a “Case for Change” be established. This provides an opportunity to engage with key partners and stakeholders, including iwi and the community, to confirm the drivers, objectives and scope for undertaking the programme. Further guidance on iwi and community engagement is provided in Part Two of this Guide.

The Case for Change should:

- Define the problem statements/challenges of the current way in which sludge, biosolids or other organic materials are managed
- Define the wider context, including the regulatory, policy or other drivers for change (the regulatory framework is described in Part Two of this Guide)
- Define the scope, including which organic products are to be considered and any geographical limitations
- Define the criteria for assessing options to change the way that sludge, biosolids or other organic materials are managed
- Identify the range of options available
- Assess and identify a preferred option.

3. MĀORI VIEWS ON MANAGEMENT OF BIOSOLIDS



Māori views on waste and recycling precede the concept of a circular economy (ōhanga āmiomio) but similarly acknowledge the mauri (life force) of natural resources (Ministry for the Environment, 2023). However, re-use of organic waste streams, particularly those that contain human wastes and chemical contaminants create unique challenges from a Māori cultural perspective, and meaningful engagement is required to reach sustainable solutions (Ataria, et al., 2016)

There is a breadth of cultural knowledge on the topic of biowaste, biosolids and wastewater management, a willingness and openness to explore new forms of co-management, and an expectation of being involved in decision making. Where this is the case Māori view biowastes and biosolids as something that should be owned and responsibly managed, rather than forgotten about or left to the environment to cope with (Ataria, et al., 2016).

Key cultural constructs, frameworks and language relevant to organic waste are introduced in *Tapu to Noa – Māori cultural views on biowastes management: a focus on biosolids* (Ataria, et al., 2016). This provides background to guide non-Māori towards knowing how to ask the right questions in their conversations and engagement with local hapū and iwi. The document introduces readers to Tapu (forbidden or restricted) and noa (ordinary or free from restriction), key Māori cultural concepts that relate to all aspects of society, including biosolids management.

Tapu to Noa draws on formative research in *Tiaki Para: A Study of Ngāi Tahu Values and Issues Regarding Waste* (Pauling & Ataria, 2010), which focuses on the management of human waste and municipal biosolids. The report identifies key cultural values, practices and issues that should influence current and future management practice for human waste in New Zealand.

Pauling and Ataria noted a consistent theme of the need to maintain separation between the human food chain and human waste streams, a view which is widely supported. This principle is deeply embedded in tikanga (customary practices) and reflects a sophisticated understanding of public health and environmental stewardship.

Traditional tikanga practices can be applied to a range of activities to transform them from states of Tapu (forbidden or restricted) to Noa (ordinary or free from restriction). Sewage sludges need to be transitioned from a state of Tapu to Noa before it is culturally appropriate to consider their reintroduction to land associated with the human food chain.

Customary and environmental factors will shape what processes and end uses will be considered culturally acceptable to enable this transformation, meaning local engagement is necessary to appropriately address cultural matters. Furthermore, there are several legislative drivers for Iwi involvement, outlined in Section 5 of these guidelines. Iwi engagement opens up collaborative opportunities where management solutions can be developed that incorporate local Māori cultural knowledge and perspectives alongside scientific and technical information.

The benefits of incorporating mātauranga Māori (indigenous knowledge) and circular approaches to resource use are increasingly being recognised. As case studies emerge there is an opportunity to develop our knowledge base. Appendix 8 outlines research needed to better align indigenous practices and knowledge with biosolids management.

Management of contaminants is an area of concern to tangata whenua and tangata tiriti alike. The government has sought to integrate Māori principles and perspectives into the management of contaminants in organic waste streams. To this end, the report *Māori Perspectives Approach: Prepared for Ministry for the Environment for the Options for Contaminants in Organic Waste Project* (Whetu & Ormsby, 2024) outlines a whakapapa-centred approach to consider contaminants and/or the various organics processes from a Māori perspective. The report stresses the importance of iwi engagement in organic wastes, addressed in Section 5 of this Guide:

The partnership between Tangata Whenua and Crown partners plays a pivotal role in establishing and supporting practices that manage organic contaminants in a culturally appropriate manner for Māori and in accordance with the principles of the Treaty of Waitangi. This partnership is not merely a legal or political obligation, but a critical element in the successful and sustainable management of environmental challenges.

Te Ao Māori provides unique insights into environmental stewardship, emphasising the interconnectedness of all things and the importance of maintaining the mauri of the environment. However, the implementation of these insights requires a respectful and inclusive engagement process with Māori and iwi. This process must acknowledge the unique context and challenges faced by iwi, including resource limitations and time constraints.

There are some wāhi tapu at which the application of wastes of human origin, including biosolids, is unacceptable to Māori, regardless of grade. Areas where issues are likely to arise are addressed in Section 11.5.2.

PART TWO:

GOVERNANCE & OVERSIGHT

4. ESTABLISHING A GOVERNANCE & OVERSIGHT FRAMEWORK



Governance and oversight requirements can vary significantly for any programme to produce and/or beneficially use biosolids or other organic materials. A “one size fits all” approach is not appropriate and depends on the scope of the programme of works, the level of interest from key stakeholders and partners, regulatory and policy requirements, and other factors.

A key decision is how to bring partners and stakeholders together to establish a programme of work, and then to monitor the risks presented. The degree of involvement of the stakeholders on an ongoing basis should be established through the engagement design process.

It is best practice to utilise a recognised framework for engagement, which considers the impact of stakeholders on decision making, the purpose of engagement and the modes of engagement. The Centre for Integrated Biowaste Research (CIBR) [community engagement framework for biowastes](#) (Baker, et al., 2016) can be used to this end. The framework;

- Recognises the importance of stakeholder and wider community consultation, as recommended by the Resource Management Act 1991 and Local Government Act 2002, in decision making, as well as the Treaty of Waitangi (1840) in guiding partnership with iwi.
- Highlights the benefits of community input into decision making about biowaste management.
- Proposes a transparent process for understanding the issues and mandate of the community, disseminating information and creating stakeholder and community dialogue.
- Draws on other established frameworks, for example, the International Association for Public Participation Australasia (iap2) guidelines for community engagement.
- Provides key considerations for engagement with iwi as partners and the wider community/stakeholders.
- Describes regulatory instruments, which provide the overall framework for governance.

5. IWI ENGAGEMENT



Māori are both a Treaty partner and key stakeholder for issues relating to environmental management. This duality of interest underpins a desire to be meaningfully involved in environmental decision-making that is founded on expectations as a Treaty partner and inherent obligations as kaitiaki of their local environments.

Local government bodies, which have delegated authority from central government for decision-making, are required under the Local Government Act (2002) to recognise and respect the Crown's obligations under the Treaty of Waitangi. This effectively obligates councils to consider all reasonable steps to encourage and assist Māori to participate in local affairs. Other requirements on councils, specified under other statutes such as the RMA, the Historic Places Act (1993) and the Biosecurity Act (1993), are that each have their own requirements for councils to consult with Māori.

Complying with the Treaty clauses requires local government to have robust relationships with relevant mana whenua organisations that are based on long-term partnerships, equity, transparent two-way communication and an ability to compromise when there are divergent views. This is particularly relevant for the management of organic materials, particularly those that contain

human wastes and chemical contaminants. Materials of this nature create unique challenges from a Māori cultural perspective, and meaningful engagement is required to reach sustainable solutions.

Best practice requires that Māori tribal authorities within whose rohe (tribal district/area) the application site is situated should be consulted for biosolids management. The RMA does not explicitly require consultation for a resource consent application with anyone, including Māori, unless this is required under other legislation. In practice, there are requirements of the RMA, specifically sections 6(e) and 7(a), that cannot be met without consultation.

Achieving these conditions also provides collaborative opportunities where unique management solutions to organic products can be developed that consider and incorporate local Māori cultural knowledge and perspectives alongside scientific and technical information. These collaborative approaches create tailored solutions that are more likely to be sustainable and ultimately more cost effective.

6. COMMUNITY ENGAGEMENT



Local communities are increasingly demanding more involvement in decision-making processes. While environmental management issues can be taken for granted by communities, where changes are proposed and/or where the public perceives that the processes are not open or transparent, this can be a cause of concern for communities. The Resource Management Act (RMA) 1991 consultation process provides an opportunity to proactively involve the community, identify likely adverse impacts and address concerns.

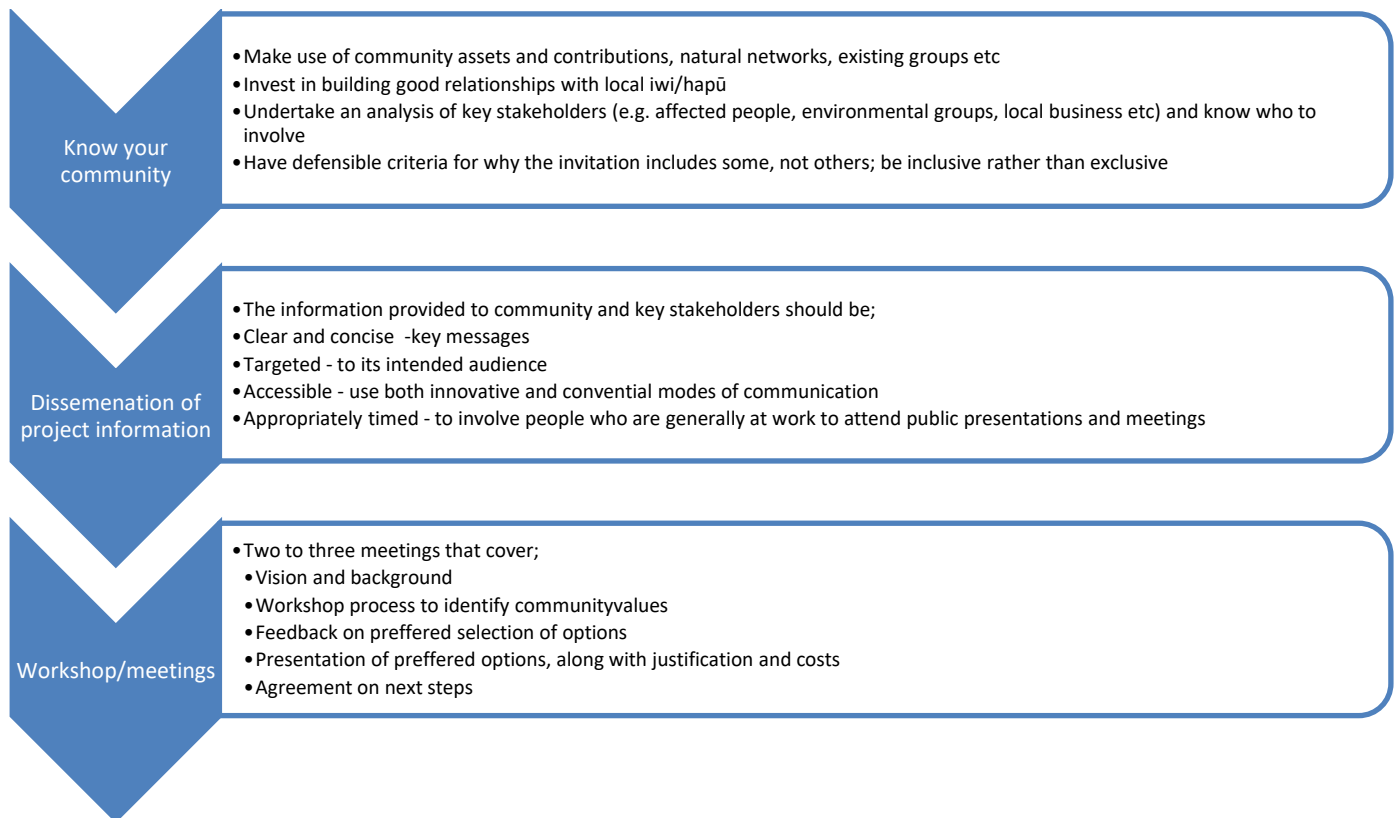
The [Community Engagement Framework for Biowastes](#) (Baker, et al., 2016) and outlined in Section 4 provides a best practice approach.

Stakeholder and wider community consultation is recommended, but not mandatory for RMA consenting. The Local Government Act 2002 recommends consultation when making decisions on behalf of the community. In addition, the Treaty of Waitangi 1840 guides partnerships with iwi for environmental management.

RMA resource consents can become contentious when neighbours or other stakeholders have conflicting views or values; or when environmental groups, recreational or customary land users contest a decision. Approaches that recognise, prioritise and balance environmental, cultural, social and economic criteria (or the quadruple bottom line – QBL) in decision making facilitate a greater understanding of “community” values.

Considering how a possible “technical” solution might affect these values, and negotiating changes or alignments may lead to new opportunities and solutions and will ensure an approach that is viable, robust and justifiable. Some of the essential steps to engage with the community, from knowing your community through to holding community workshops and meetings, are outlined in Figure 3.

Figure 3: Steps in community engagement for beneficial reuse of organic wastes



7. REGULATORY FRAMEWORKS

7.1.1 THE RESOURCE MANAGEMENT ACT 1991



Legislation governing the application of biosolids to land in Aotearoa New Zealand is part of the Resource Management Act 1991 (RMA) and regulated by regional councils through rules that determine what can be applied, how this can be applied and when it is applied.

Apart from direct regulations, the RMA is used as a basis for region-specific resource management plans that ultimately define the rules applicable to the use of biosolids to land. Regional plan rules outline whether use of material/product can be permitted (does not require a resource consent) or has a level of restriction and consent is required to allow use.

The Resource Management Act 1991 (RMA) covers waste streams and contaminants as part of its broader scope of managing New Zealand's natural and physical resources. It provides the legislative foundation and sets the principles and guidelines for addressing the discharge of contaminants into the environment and controlling pollution. Management of contaminants are enabled through:

- Regulation and Standards
- Resource Consents
- Environmental Impact Assessments (EIAs)
- Enforcement and Penalties
- Waste Management and Hazardous Substances
- Local Authority Oversight
- The RMA emphasises public participation and consultation in resource management decisions, including those related to contaminants.

The RMA works in conjunction with other specific laws and regulations related to hazardous substances, pollution, and waste management including the Hazardous Substances and New Organisms Act and the Waste Minimisation Act. Other legislation including the Agricultural Compounds and Veterinary Medicines Act, the Health Act, the Land Transport Act can also have a direct or indirect bearing depending on biosolids feedstocks, treatment and end use.

Section 13.1 sets out recommended RMA planning controls that can be applied to biosolids of different stabilisation and contaminant grades.

7.1.2 NATIONAL ENVIRONMENTAL STANDARD FOR ASSESSING AND MANAGING CONTAMINANTS IN SOIL TO PROTECT HUMAN HEALTH

There are several National Policy Statements and National Environmental Standards that direct the management of activities under the RMA. A common enquiry for application of biosolids and other organic materials to land is the applicability and interpretation of the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NESCS). Activities governed by the NESCS are given in the Hazardous Activities and Industries List (HAIL).



Biosolids application to land as a soil conditioner is specifically excluded from the HAIL (G5). In addition, beneficial use of biosolids and organic materials is most commonly applied to production land. The NESCS generally does not apply to production land except where there is a change of productive land use to a non-productive land use, eg, subdivision of a farm into lifestyle blocks.

Application of biosolids and other organic materials to land that has historic contamination present is not specifically excluded from the NESCS and may form part of remediation of such land. In this situation, soil monitoring requirements described in Section 12.2 will assist in the identification of historic contamination and in determining appropriate rates of application.

7.1.3 THE ANIMAL PRODUCTS ACT 1999 AND ANIMAL PRODUCTS AMENDMENT ACT 2012

The Animal Products Act 1999 is the primary legislation that governs the production, processing and export of animal products in New Zealand. It sets out the regulatory framework for ensuring the safety and suitability of animal products for human consumption and trade both domestically and internationally.

The Act covers various aspects, including the registration and licensing of premises involved in the production and processing of animal products, requirements for product labelling and the establishment of food safety programmes.

The Animal Products Amendment Act 2012 amended the Animal Products Act 1999, including the regulation of agricultural compounds and veterinary medicines and measures to address issues related to product recalls and contaminated animal products.

If biosolids are applied to land where animals graze, the Animal Products Act is relevant to ensure that products (meat, milk, etc) from such animals remain free of contaminants and safe for human consumption. The intent of this Guide is to outline such an approach.

7.1.4 HAZARDOUS SUBSTANCES AND NEW ORGANISMS (HSNO) ACT 1996

The HSNO Act regulates the import, development and use of hazardous substances and new organisms and is administered by the Environmental Protection Authority. The intent of the Act is to protect human health and the environment.

While biosolids are not classified as hazardous substances under the Act, the Act plays an important role in regulating the importation and manufacture of new substances that may pose a risk to biosolids.

7.1.5 AGRICULTURAL COMPOUNDS AND VETERINARY MEDICINES ACT 1997 AND THE AGRICULTURAL COMPOUNDS AND VETERINARY MEDICINES (EXEMPTIONS AND PROHIBITED SUBSTANCES) REGULATIONS 2011

The Agricultural Compounds and Veterinary Medicines Act 1997 is administered by the New Zealand Agricultural Compounds and Veterinary Medicines (ACVM) Group.

This Act regulates the manufacture, import, distribution, sale and use of agricultural compounds, including veterinary medicines and animal health products. The Act aims to ensure the safety, efficacy and quality of these products to protect human health, animal welfare and the environment.

The Agricultural Compounds and Veterinary Medicines (Exemptions and Prohibited Substances) Regulations 2011 complement the Agricultural Compounds and Veterinary Medicines Act 1997. The regulations exempt certain agricultural compounds, including fertilisers (Schedule 2, entry 42), plant biostimulants (Schedule 2, entry 43) and soil conditioners (Schedule 2, entry 44), from registration under the Act. However, the exemption is valid only if the agricultural compound complies with any relevant conditions specified in the regulations.

Regulations 7-13 prescribe conditions of general application to exempt agricultural compounds, including specifying that exempt agricultural compounds must be:

- Fit for their intended purpose
- Manufactured in accordance with a documented system
- Supplied with certain information.

Although regulatory assessment is not necessary for exempt agricultural compounds, it is essential that the person(s) responsible for the compound takes steps to ensure they always comply with the conditions of exemption specified in the regulations.



The ACVM [Notice: Fertilisers, Plant Biostimulants and Soil Conditioners Requirements for compliance with conditions of exemption](#) (New Zealand Government, 2024) specifies requirements for person(s) responsible for fertilisers, plant biostimulants and soil conditioners to give effect to and amplify the *Agricultural Compounds and Veterinary Medicines (Exemptions and Prohibited Substances) Regulations 2011*. These requirements apply to biosolids being reused for their fertilising, biostimulant or soil conditioning properties. The notice provides labelling requirements, further discussed in Section 9.5 of this Guide.

7.1.6 WASTE MINIMISATION ACT (WMA) 2008

The Act, administered by the Ministry for the Environment, focuses on waste minimisation, product stewardship and encouraging resource efficiency to promote waste reduction and sustainable waste management.

The WMA requires territorial authorities to develop and implement waste management and minimisation plans (WMMPs), outlining strategies to reduce waste within their regions. These plans must be reviewed and updated every six years to ensure they remain relevant. WMMPs address waste streams such as kerbside refuse, industrial waste, hazardous waste, recycling, organic waste and others with the emphasis on sustainable waste management practices. Sludge and biosolids have typically featured in WMMPs as a target stream for diversion from landfills.

PART THREE:

MANAGING THE RISKS OF PRODUCTS

8. IDENTIFYING HAZARDS POSED BY BIOSOLIDS PRODUCTS



Sludge is generated as the solid fraction of wastewater in the wastewater treatment process. As such, sludge contains many of the biological and chemical hazards found in wastewater, such as pathogens and chemical contaminants.

The sources of hazards from the conversion of sludge into biosolids and the beneficial use of those biosolids can be categorised into four key areas:

- Pathogens
- Volatile solids
- Chemical contaminants
- Emerging contaminants of concern.

A brief description of each hazard category is provided below.

Pathogens:

Pathogens are organisms that cause disease to their host. Pathogenic microorganisms are present in wastewater and through the biological activity that occurs in the treatment process.

A range of pathogens are found in sewage sludge, generally reflecting the prevalence of pathogens in the local human population from which the wastewater is generated. These include:

- Bacterial pathogens (eg, *Escherichia coli*) which have the potential to cause disease outbreaks with severe illness and/or death in humans
- Viruses that are naturally released in human faeces, including but not limited to adenoviruses, hepatitis, rotavirus and norovirus
- Protozoa, such as *Giardia* and *Cryptosporidium*, which are environmentally resistant and can cause severe disease in humans
- Helminths.

If not treated, some pathogens are adapted to survival in soil environments.

Volatile Solids:

The volatile solids content (organic material) of the sludge poses two key risks:

- The byproduct of the biological breakdown of the volatile solids is odorous gases
- It has the potential to attract vectors – organisms/animals such as flies, mosquitoes, birds and rodents that can potentially transmit pathogens to humans and other hosts physically, through contact, or biologically, by playing a specific role in the lifecycle of the pathogen. Reduction of the attractiveness of biosolids to vectors reduces their potential for transmitting such diseases. This process is known as vector attraction reduction (VAR). VAR can be achieved by either subjecting the biosolids to specific physico-chemical processes/conditions or preventing access to the biosolids by vectors, usually by incorporating the biosolids into soil.

Chemical Contaminants:

A diverse range of chemicals within our homes and businesses can make their way into our wastewater, with the potential to contaminate biosolids. Information on contaminants present in wastewater is outlined in *Appendix 1 Sources of wastewater treatment contaminants*.

Some forms of contaminants present in wastewater will accumulate in the generated biosolids (Esperschütz & Robinson, August 2014). These contaminants accumulate in the environment through a lack of degradation or sufficiently high usage in relation to their degradation rate and pose a risk to soil health, groundwater, surface water or the wider environment.

**Emerging
Contaminants of
Concern:**

Emerging contaminants of concern include pharmaceuticals, endocrine disruptors, flame retardants, antimicrobials, microplastics and other organic compounds such as per- and poly-fluoroalkyl substances (PFAS) (Northcott, 2024).

The emerging contaminants of concern adopted in the Guide represent classes of chemicals known to impact soil biota and environmental health that can be measured using existing methods (Northcott, G, 2017). The number of new compounds, and understanding of their impact in the environment, is growing. The Guide aspires to be flexible and responsive to new and relevant scientific knowledge.

Emerging organic contaminants include PFAS, a group of manufactured chemicals resistant to water, oil and heat. Management requirements for PFOS, PFHxS and PFOA in biosolids applications to land are outlined in the Supporting Document 1 of the PFAS National Environmental Management Plan 3.0 (Heads of EPA Australia and New Zealand (HEPA), 2025).

9. QUANTIFYING THE HAZARDS POSED BY BIOSOLIDS

9.1 PRODUCT QUALITY FRAMEWORK



This Guide adopts a product quality grading system to define the degree of pathogen and contaminant risk posed by biosolids products. The grading system is designed to differentiate between organic products that are of low risk and those that contain pathogens and/or contaminants that may pose a risk to the receptors. Higher risk products would therefore have stricter controls regarding where they can be used, and may require special management during handling, storage and application to land.

Using this system, biosolids are to be categorised by two grades, as follows:

- **Stabilisation, A or B.** This is determined by the pathogen content of the product and whether an approved pathogen reduction procedure and an approved vector attraction reduction method have been implemented.
- **Contaminant grade, 1 or 2.** This is determined by the levels of metals and organic contaminants in the product.

The grades are used as guidance to determine controls required for the safe application of the product to land.

9.2 DETERMINATION OF STABILISATION GRADE

9.2.1 STABILISATION GRADING PROCESS



The process for determining the stabilisation grade of biosolids or other organic materials is defined in Figure 3. In accordance with this process, two product grades are defined:

A product is classified as stabilisation **Grade A**, effectively determining it to be pathogen free, if:

- 1) It has a documented quality assurance system (refer Section 14.2)
- 2) It has undergone at least one of the listed vector attraction reduction methods specified in Section 9.2.2
- 3) It has undergone at least one of the pathogen reduction processes listed in Section 9.2.4
- 4) It meets all listed product pathogen standards (refer Section 9.2.3) after processing but prior to application.

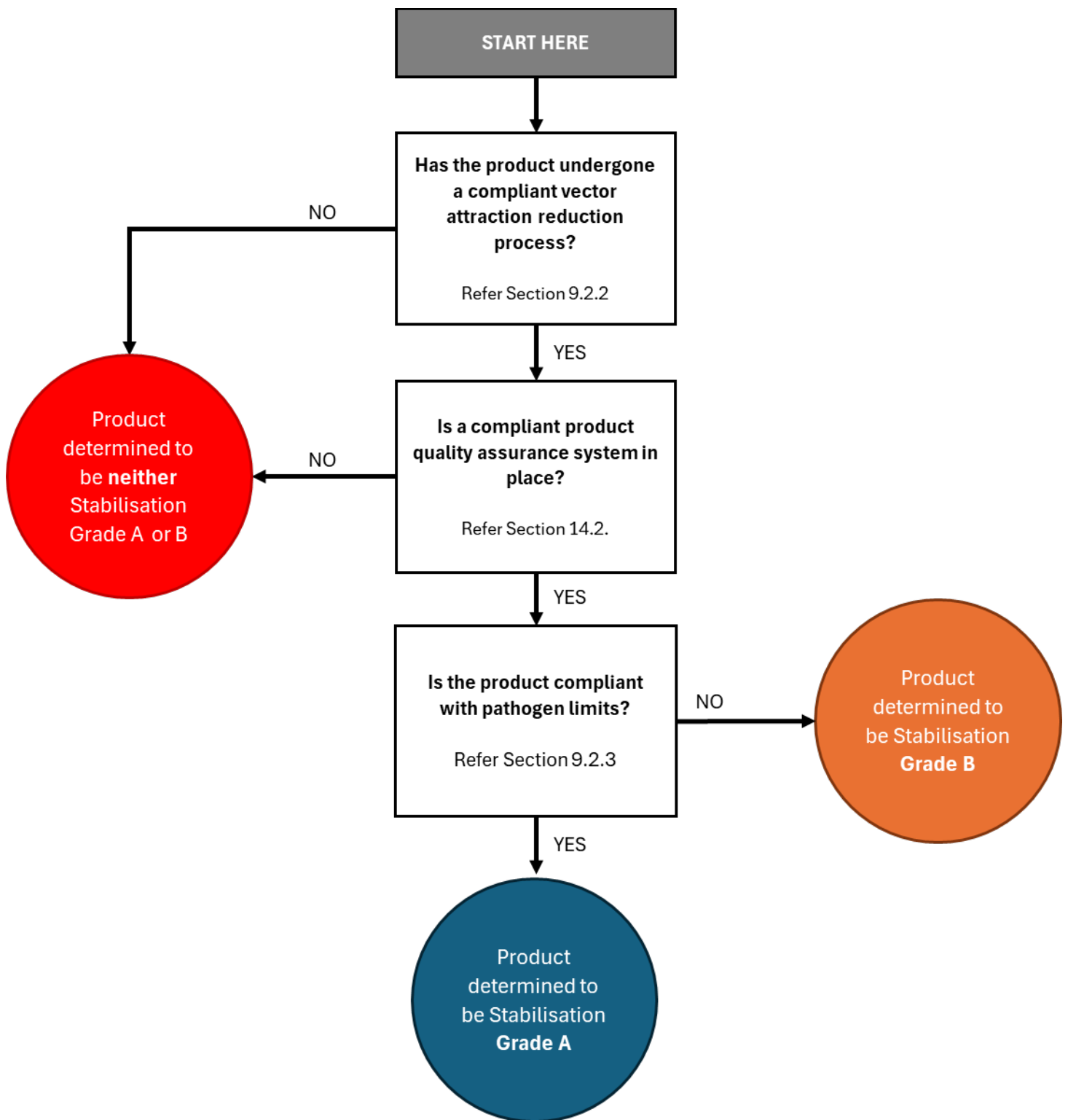
The product is determined to be stabilisation **Grade B** if:

- 1) It has a documented quality assurance system (refer Section 14.2)
- 2) It has undergone at least one of the accepted vector attraction reduction methods listed in Table 2.

Grade B products contain pathogens at levels that they may impose a risk to the receptors and would therefore have stricter controls regarding where they can be used, and may require special management during handling, storage and application to land.

If a product does not attain Grade B stabilisation, **it is not classified** as a biosolid and alternative disposal routes should be found.

Figure 4: Process for Determination of Stabilisation Grade



Confirmation of pathogen and contaminant grades requires two sets of sampling:

Verification sampling demonstrates whether a treatment process is producing a final product of consistent quality and is typified by a high-frequency sampling regime. Verification monitoring should occur whenever there could be a possible change to the quality of the final product, including:

- When a new process is commissioned
- When changes are made to an existing process
- When any of the routine samples exceed the limits set for pathogens or chemical contaminants.

Routine sampling is required to demonstrate continued compliance with the product standards. Table 3 and Table 5 specify the frequency and number of samples required in relation to the product grade, and whether the samples are being taken for verification or routine sampling.

Note that for any organic material or product sample returning lower than the limit of detection (LOD), the value of $0.5 \times \text{LOD}$ is to be used for statistical analysis.

9.2.2 STABILISATION GRADE REQUIREMENT 1: VECTOR ATTRACTION PROCESSES

Vectors such as flies, mosquitoes, birds and rodents are potential carriers of disease. They can transmit pathogens to humans and other living hosts physically, through contact, or biologically, by playing a specific role in the lifecycle of the pathogen. Reduction of the attractiveness of organic products to vectors reduces their potential for transmitting diseases. This process is known as vector attraction reduction (VAR).

Product that does not meet the VAR requirements is not covered by this Guide.



Suitable vector attraction reduction processing must be employed. VAR ensures that the product is stabilised to the point where it minimises attraction of flies, vermin and other undesirable vectors. This step assesses compliance with VAR processing. The process must include at least one of the VAR methods described in Table 2.

Table 2 Vector attraction reduction methods

Vector attraction reduction methods	Organic materials suited to these methods
Reduction of the mass of volatile solids by >38%	Anaerobically or aerobically digested sludge
Drying to $\geq 75\%$ dry solids by weight	Aerobically or anaerobically digested sludge
Heating at temperatures greater than 80°C to achieve a minimum dry solid content of 90% by weight	Heat dried unstabilised slurry or sludge
Maintaining $>40^{\circ}\text{C}$ for a minimum of 14 days, with an average minimum temperature of 45°C or greater	Compost products
Not exceeding a maximum SOUR at 20°C of 1.5 g/hr/m^3	Liquid sludge from aerobic processes operating at $10\text{-}30^{\circ}\text{C}$ and $\leq 2\%$ dry solids
Maintain a $\text{pH} \geq 12$ at 25°C , >2 hours and without further alkali addition a $\text{pH} \geq 11.5$ for an additional 22 hours	Alkali amended product
Drying to $\geq 75\%$ solids	Stabilised, anaerobically or aerobically digested sludge
Drying to $\geq 90\%$ solids	Heat dried unstabilised sludge
Soil incorporation is undertaken as soon as practicable and within at least 24 hours of the product discharge.	Partially stabilised or unstabilised slurries or sludges
On a surface disposal site, covering with soil or other material at the end of each working day	Sludge placed on a surface disposal site

9.2.3 STABILISATION GRADE REQUIREMENT 2: PATHOGEN LIMITS

Most organic materials contain pathogens, particularly when they derive from animals or humans. Manure from livestock and poultry contains a variety of pathogens; some are highly host-adapted and not pathogenic to humans, while others can produce infections in humans. Therefore, all such material requires careful management to minimise any health risks while gaining the benefits.

Bacteria present in the organic materials or derived products have the potential to regrow after treatment. Verification sampling is required to demonstrate that the treatment process is working effectively and that, in combination with normal end-use management controls, regrowth has not occurred.



Table 3 stipulates the pathogen limits and sampling requirements required to determine that biosolids or other organic material are suitable for Stabilisation Grade A.

Table 3: Pathogen Standards and Testing Requirements for Stabilisation Grade A Products

Pathogen	Standard	Verification Sampling	Routine Sampling
<i>E. coli</i>	< 100 MPN/g	≥7 evenly dispersed grab samples per month for a 3-month period with ≤ 3 failures. If > 3 failures, then the 7 following consecutive grab samples must comply. ¹	1 grab sample per week
<i>Campylobacter</i>	< 1/25g		NA
<i>Salmonella</i>	< 2 MPN/g		NA
human adenovirus	< 1 PFU/0.25g		NA
<i>helminth ova</i>	< 1/4g		NA
VAR		If a barrier ² is to be used for VAR no monitoring is required at the production stage.	1 grab sample per week

¹ No more than 3 samples should be taken per day during this period

² Vector attraction reduction methods are outlined in Table 2

Verification and routine sampling requirements listed in Table 3 apply to continuous production processes. For waste stabilisation ponds where sludges are produced irregularly in batches, testing frequencies may not be practically applicable. Alternative testing requirements for waste stabilisation ponds are outlined in 9.2.3.1.

The pathogen testing is to be in accordance with the procedures set out in Section 9.2.3.1.

9.2.3.1 WASTE STABILISATION POND PATHOGEN TESTING FREQUENCIES



In cases where a product is produced as a one-off or with a very long time period between batches, as is the case for most waste stabilisation ponds, sampling frequencies may not be practically applicable. For these instances an alternative sampling approach is provided in this section.

Waste Stabilisation Ponds are designed to settle out incoming wastewater solids, which accumulate in the bottom of the pond and decompose over time. To maintain an effective treatment system, the accumulated solids must be periodically removed, and if they are applied to land they need to meet the requirements set out in this Guide.

Dredges are generally used to remove the solids from the pond, and the dredged slurry sent to either mechanical dewatering equipment, geotextile bags in dewatering basins or drying beds.

If the solids are transported directly from mechanical dewatering to the point of application, the process can be treated as “continuous” and the product verification and routine sampling frequencies can be applied as per Table 3 for the duration of the dredging activity.

If the dewatered material is stockpiled for future use, or geobags/drying beds are used, the solids are often kept contained on the WWTP site for several years and applied to land in a one-off activity.

If this is the case, it is recommended to undertake one round of product verification sampling, as outlined in Table 3 on the accumulated solids prior to removal from site for land application. Each stockpile, geobag or bed (if there are more than one) should be treated as an individual “batch” for the purpose of this testing.

Where a stockpile has successively been added to over time, efforts should be made to take samples from the area most recently added to the stockpile.

If a single batch fails to meet the Grade A sample criteria, all batches shall be considered pathogenic and treated as Grade B.

9.2.3.2 STABILISATION GRADE SAMPLING REQUIREMENTS



When monitoring for pathogens, it is important to take grab samples and to report the actual (not the average) values from each grab sample.

During the process verification period, a total of 3 failures is allowed. If this number is exceeded, then the next 7 grab samples must comply. If any of the failures occur during the last month of verification sampling (ie, there are fewer than 7 samples left to take), samples must continue to be taken at the verification frequency until 7 consecutive compliant samples have been obtained.

When verification monitoring is complete, the sampling regime can change to a routine monitoring regime. If any routine monitoring samples fail then, for stabilisation Grade A, a return to the verification monitoring regime for all pathogens is required.

The samples taken during the verification period must be analysed for *E. coli*, *Salmonella*, *Campylobacter*, enteric viruses, Helminth ova and Vector Attraction Reduction. When consistent quality is confirmed then for Grade A, routine samples only need be analysed for *E. coli* and VAR. For Grade B, there is only a requirement for VAR monitoring during routine sampling, unless a barrier is to be used for VAR, in which case no monitoring is required.

9.2.4 STABILISATION GRADE REQUIREMENT 4: PATHOGEN REDUCTION PROCESS



Table 4 sets out appropriate pathogen reduction processes that can be used to achieve the pathogen requirements specified above for Grade A products.

Table 4 Pathogen Reduction Processes to Meet Pathogen Standards for Stabilisation Grade A Products

Starting material	Pathogen reduction process
For product > 7% dry solids by weight	Time temperature process within the relationship $t = \frac{131\,700\,000}{10^{0.14T}}$; t = days, T = °C where T is a minimum of 50°C and t > 20 minutes*. * t > 15 seconds if organic material is in small particles heated by contact with either warmed gases or an immiscible liquid.
For product < 7% dry solids by weight	Time temperature process within the relationship $t = \frac{50\,070\,000}{10^{0.14T}}$; t = days, T = °C where T is a minimum of 50°C and t > 30 minutes.
For all products: <u>Composting</u> ²	Either: (i) In-vessel: T ≥ 55°C for ≥ 3 days, or (ii) Windrow: T ≥ 55°C for ≥ 15 days with a minimum of 5 turnings during this period (5 x 3 days at T ≥ 55°C plus time periods to reach 55°C after each turning). All compost must have at least 30 days maturation pre-use.
For all products: <u>High pH – high temperature process</u>	Maintain a pH > 12 (measured at 25°C) for > 72 hours; and maintain a temperature > 52°C for 12 consecutive hours within the 72 hours, all from the same chemical application; then dry to > 50% dry solids by weight.
Alternative process	Any process that can demonstrate Grade A quality compliance using a rigorous documented process that can be replicated using the documented proven process parameters and quality controls.

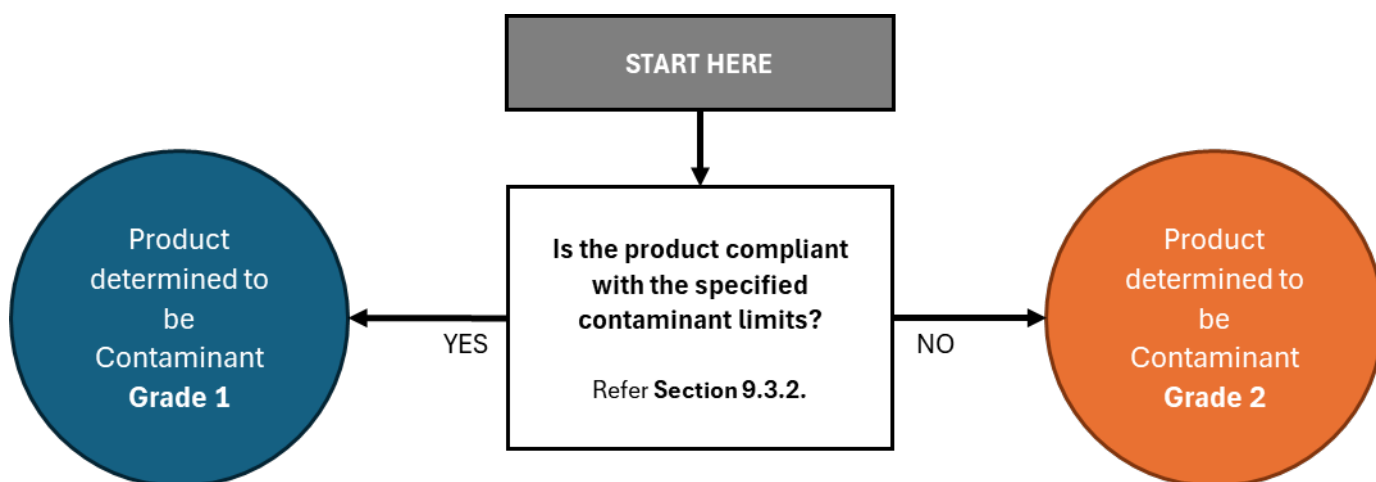
² Also refer NZS4454:2005 Composts, Soil Conditioners and Mulches for useful operational guidance.

9.3 DETERMINATION OF CONTAMINANT GRADE

9.3.1 CONTAMINANT GRADING PROCESS

The process for determining the contaminant grade of biosolids or other organic materials is shown in Figure 5. Anything that does not meet Grade 1 criteria, is considered Grade 2 and would require a consent with contaminant limit application rates, calculated as per the process outlined in Appendix II and on the attached calculator.

Figure 5 Process for Determination of Contaminant Grade



9.3.2 CONTAMINANT GRADE REQUIREMENT 1: CONTAMINANT LIMITS

The purpose of the contaminant grading is to assess the risk to receptors from exposure to contaminants. Two product grades are defined:

- Grade 1 is a product that has compliant levels for every contaminant
- Grade 2 is not compliant for at least one of the contaminants and may therefore impose an increased risk to the receptors and will therefore have stricter controls regarding where and how it can be used.

Table 5 gives the maximum contaminant concentrations required to achieve Grade 1. Grade 1 contaminant limits are based on contemporary technical knowledge and are considered to be protective of the most sensitive receptor, typically soil biota, after application and, in some cases, incorporation in the soil to which the material is applied. Table 13 outlines associated soil limits for each of the listed contaminants.

Biosolids meeting this contaminant grade can be applied at the nitrogen limited loading rate, so long as product contains a minimum of 2% total nitrogen, soil bulk density is greater than 0.97, and soil background concentrations do not exceed median soil background concentrations listed in Table 11. Monitoring and sampling approaches for soil guideline values are outlined in Section 12.2.

Table 5 Contaminant Grade Standards for Contaminant Grade 1

Contaminant	Grade 1 Limit mg/kg dry weight	Number of Samples: Verification	Number of Samples : Routine
Arsenic (As)	30	1 composite ² /week over a 3-month period	1 composite / 2 weeks
Cadmium (Cd)	6.5		
Chromium (Cr)	1500		
Copper (Cu)	750		
Lead (Pb)	300		
Mercury (Hg)	7.5		
Nickel (Ni)	135		
Zinc (Zn)	1250		
PFOS+PFHxS (µg/kg) ⁶ PFOA (µg/kg) ⁶	Refer PFAS NEMP Supporting Document 1	TBD	TBD

Notes:

1. Sampling methods are to comply with those specified in this Guide
2. All values are to be 95th percentiles from the data set
3. No individual value from the data set shall exceed the limits by more than 20%
4. Comprising the sum of technical nonylphenol, NPE10, NPE20 equivalents
5. Comprising the sum of technical C11-C13 homologues and corresponding mixtures of isomers
6. Limited correspond with the PFAS NEMP restricted use criteria. The NEMP provides three separate limits based on the desired margins of safety.

The PFAS NEMP 3.0 (National Chemicals Working Group of the Heads of EPAs Australia and New Zealand, 2025) outlines the national PFAS management approach. Supporting Document 1 provides Biosolids criteria derivation for PFOS, PFHxS and PFOA and a framework to assess biosolids for land application. This provides maximum allowable product contaminant concentrations for PFOS, PFHxS and PFOA, for restricted and unrestricted use biosolids. For products adhering to this guide, NEMP limits for restricted use should be adopted. The NEMP definition for restricted use assumes biosolids are land-applied and incorporated into the soil for agricultural use, the basis for biosolids management adopted in this guide.

There are an increasing number of other unregulated emerging organic contaminants being that may be present in sewage sludge, biosolids and other forms of organic wastes, addressed in Section 9.4. Contaminant limits will need to expand over time as testing capability and knowledge develops.

9.3.2.1 WASTE STABILISATION POND CONTAMINANT TESTING FREQUENCIES



Generally, both batch and continuous processes that regularly produce a biosolids product should follow the monitoring and testing procedures outlined in Table 5.

However, in cases where a product is produced as a one-off or with a very long time between batches (less than once a year), the testing frequencies set out in Table 5 for verification and routine sampling may not be practically applicable. Alternative sampling requirements for such cases are outlined here.

Waste Stabilisation Pond (WSP) are designed to settle out incoming wastewater solids, which accumulate in the bottom of the pond and decompose over time. To maintain an effective treatment system, the accumulated solids must be periodically removed, and if they are land applied need to meet the requirements of this Guide.

Dredges are generally used to remove the solids from the pond, and the dredged slurry sent to either mechanical dewatering equipment, geotextile bags in dewatering basins or drying beds.

- If the solids are transported directly from mechanical dewatering to the point of application, the process can be treated as “continuous” and the product verification and routine sampling frequencies can be applied as outlined in Table 3 for the duration of the dredging activity.
- If the dewatered material is stockpiled for future use, or geobags/drying beds are used, the solids are often kept contained on the WWTP site for several years and applied to land in a one-off activity.
 - If this is the case, one round of product verification sampling on the accumulated solids prior to removal from site for land application.
 - Each stockpile, geobag or bed (if there are more than one) should be treated as an individual “batch” for the purpose of this testing. If stockpiles are composed of multiple batches, a round of sampling should be taken for each separate batch.

9.3.2.2 CONTAMINANT GRADE SAMPLING REQUIREMENTS

Sampling is required to demonstrate that process controls are working and that the average levels of contaminants in the product are below the limits specified.

Composite samples are to be taken for contaminant grade monitoring. Section 9.6.5.2 outlines considerations for composite sampling process. Samples are to be taken at times and locations appropriate for the biosolids production process as outlined in Section 9.6.5.4.

Irrespective of whether the samples are taken as part of verification monitoring or of routine monitoring, they should all be analysed for the contaminants specified in this Guide.

If the concentration of any contaminant exceeds those specified in this Guide, then a return to verification monitoring is required for that contaminant only. All other contaminants should continue to be monitored at the routine sampling frequency. The failed contaminant can only return to the routine sampling frequency once it complies with the product limits from this additional verification sampling.

9.4 MANAGEMENT OF EMERGING ORGANIC CONTAMINANTS

Emerging contaminants of concern that could be present in biosolids include pharmaceuticals, endocrine disruptors, flame retardants, antimicrobials, microplastics and other organic compounds such as PFAS (Northcott, 2024).

Knowledge of emerging organic contaminants (EOCs) is rapidly evolving, however there is much to learn about their effects. Laboratory testing capacity within New Zealand are not yet widely commercially available, other than for PFAS. At the time of publishing this guide tests on emerging organic compounds in biosolids have either been undertaken at Northcott Research Laboratory in Hamilton or sent abroad.

This guideline outlines a phased approach for the introduction of testing for emerging contaminants, that aims to respond to the availability of laboratory testing. Section 9.4.1 outlines testing requirements for Initial contaminants proposed for measurement in the Guide.

It is highly likely “priority” CECs and associated concentration limits for other substances will be developed for biosolids and other organic waste materials being recycled to land. As international and local understanding grows new substances and limits will need to be adopted in New Zealand and reflected in this guide.

9.4.1 PRIORITY EMERGING ORGANIC CONTAMINANTS

The following emerging contaminants have been identified as priority for monitoring in biosolids. These represent classes of chemicals known to impact soil biota and environmental health, can be measured using existing methods, and have sufficient international information to develop corresponding product limits (Northcott, G, 2017).

Nonylphenol and ethoxylates (NP/NPE)

Alkylphenol ethoxylates are a class of non-ionic surfactants, produced by the reaction of a branched chain alkylphenols with ethylene oxide. Most commonly used are nonylphenol ethoxylates (NPEs), which make up approximately 80% of the world market. The use of NPEs in domestic detergents has largely ceased and they are mainly used as industrial surfactants. The principle concern regarding the toxicological risk of nonylphenols is their estrogenicity. NPs and NPEs are rapidly biodegraded in biosolid amended soil, and studies have concluded they pose a low risk to soils. Product concentration limits exist in the EU could be adopted in New Zealand.

Diethylhexylphthalate (DEHP)

Phthalates esters are incorporated into plastics as plasticisers and Bis-(2-ethyl-hexyl)-phthalate (DEHP) is the most commonly used worldwide. DEHP is rapidly degraded in soil and extremely inefficiently transferred into plants and through foodchains (Duarte-Davidson et al., 1995). Risk assessments completed to date on DEHP applied to land in sewage sludge demonstrate there is no increased risk to soil and aquatic ecosystems, or health risks to either animals or humans when sewage sludge is applied to land at agronomically realistic rates. Product concentration limits exist in the EU which could be adopted in New Zealand.

Linear alkylbenzene sulphonates (LAS)

Linear alkylbenzene sulphonates (LAS) are the most widely used anionic surfactant. LAS is one of the major ingredients in domestic and industrial detergents and surfactants and therefore is present at relatively high concentrations in sewage sludge. LAS are easily degraded under aerobic conditions so the concentration of residual LAS in biosolids is highly dependent on the type of sludge produced and the processes within the treatment works. LAS rapidly degrades in soil with half-lives of 1-3 weeks. Reviews of the fate and effects of LAS in soil conclude they present a low long-term risk to soil ecosystems when amended to soil at recommended agronomic rates. Product concentration limits from Belgium could be adopted in New Zealand.

Musk fragrances (Tonalide and Galaxolide)

Galaxolide and Tonalide are the two most widely used polycyclic musk fragrances and are estimated to represent over 95% of the worldwide market for polycyclic musks. Galaxolide and Tonalide are reasonably hydrophobic chemicals that adsorb to and concentrate in sewage sludge. The concentration of Galaxolide and Tonalide measured in biosolids from WWTPs in New Zealand is comparable to that in sewage sludge and biosolids from other Western countries

Antimony

Antimony (Sb) is a metalloid with industrial use including the production of flame retardants, batteries, plastics, and catalysts. Due to its toxicity, being a suspected carcinogen, and its adverse effects on ecosystems, Sb and its compounds are considered as priority pollutants by the United States Environmental Protection Agency and the European Union (He Li, 2022). Antimony is known to have been detected in biosolids (Office of Water Science and Technology, 2022) and its presence is likely to increase given its increasing use.

At the time of publication laboratory testing for these contaminants was limited to Northcott Research Consultants, with commercial tests being required to be sent abroad. This creates prohibitive costs and turn around times for introducing limits for these subjects, meaning the introduction of EOC limits will be phased over time. To encourage the development of local commercial laboratory testing a phased approach for requirements for EOC testing has been introduced, testing of EOCs above to follow the test frequencies outlined in Table 6.

Table 6: Testing frequencies for emerging organic contaminants

KNOWLEDGE STAGE	Number of Samples: Verification	Number of Samples: Routine
International testing facilities required for measurement	For biosolids produced at facilities with a population equivalence ¹ of greater than 10,000 ¹ ; 1 composite sample ²	For biosolids produced at facilities with a population equivalence of greater than 10,000 1 composite annually
Biosolids testing available within commercial New Zealand laboratories	For biosolids produced at facilities with a population equivalence of greater than 10,000; 1 composite sample ² /month over a 3-month period	For biosolids produced at facilities with a population equivalence of greater than 10,000 1 composite / 2 months
Established baseline and known presence of contaminants established to support development of limits	1 composite sample ² /month over a 3-month period	1 composite / 2 months

¹ p.e. (population equivalent)" means the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day

²All values are to be 95th percentiles from the data set

Preliminary contaminant limits have been proposed in Table 7. It is suggested that these limits are used as a starting point for contaminant limits when more information on their presence in biosolids, and equivalent soil limits have been established.

Table 7: Suggested values for future emerging organic contaminant future limits

Contaminant	Grade 1 Preliminary Limit mg/kg dry weight	Soil concentration limit ¹ mg/kg
Nonylphenol and ethoxylates (NP/NPE)	50	5.7
Phthalate (DEHP)	100	13
Linear alkylbenzene sulphonates (LAS)	2600	35
Musks – Tonalide	15	0.31
Musks – Galaxolid	50	0.31

¹To be used as Item 7 in Appendix 2 Example of Mass Loading Calculation.

9.4.2 PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS are a group of manufactured chemicals resistant to water, oil and heat. They have been used to make products such as personal care products, cleaning products and industrial products including metal plating and firefighting foam. The widespread presence of PFAS in the environment, its unusual chemical properties, the uncertainties associated with potential risks, mean there is a need for a precautionary approach to protect environment and/or human health.

PFAS may enter a WWTP through domestic, commercial or industrial sources. It will exit the WWTP via treated wastewater or in sludge/biosolids. From the scientific literature, it is known that PFAS substances are not readily removed in WWTP operations, which has implications for contamination of biosolids if such discharges are not controlled.



The PFAS NEMP 3.0 (National Chemicals Working Group of the Heads of EPAs Australia and New Zealand, 2025) outlines the national PFAS management approach. Supporting Document 1 provides criteria for managing PFOS, PFHxS and PFOA in the land application of biosolids that must be followed in addition to this guideline.

The NEMP outlines maximum allowable soil and product contaminant concentrations for PFOS, PFHxS and PFOA, for restricted and unrestricted use biosolids. All biosolids land applied in accordance with this guide, fit the NEMP restricted use criteria. The NEMP defines restricted use biosolids as those with restrictions on their application rate to land, which is the basis for biosolids management adopted in this guide.

The NEMP requires that biosolids are not applied at a rate above 50 dry t/ha, which will therefore be an upper limit that must be followed for all biosolids to land applications in New Zealand. Other requirements of the NEMP that should be considered along contaminant and soil assessments are outlined in 9.3.2 and Section 12.4 respectively.

Biosolid producers need to understand the PFAS NEMP (Heads of EPA Australia and New Zealand (HEPA), 2025) and apply this alongside this guidance, as well as supporting sampling guidance contained in Contaminated Land Management Guidelines No.5 Site Investigation and Analysis of Soils (Ministry for the Environment, 2021) and Sampling and Analysis of Per- and Poly-fluorinated Substances (Minsitry for the Environment, 2025) (still in draft at the time of issuing this report).

9.4.3 MICROPLASTICS

Microplastics (MPs) are typically defined as small pieces of plastic from 1 nanometer up to 5mm. Land application of biosolids are a pathway for the entry and accumulation of microplastics into agricultural soils and subsequent migration into waterways and groundwater. Concerns about the environmental and human health risks of MPs extends to the numerous chemical additives plastic contains. MPs and associated chemical additives present risks to soil health and function, the environment and wildlife, and humans (FAO and UNEP, 2021) (FAO, 2021).

The number of microplastic particles entering WWTPs varies but has been found to decrease significantly in the wastewater with each treatment stage (primary, secondary, tertiary) as the microplastics are concentrated in the sludge (Hidayaturrahman & Lee, 2019). With tertiary treatment, almost all microplastics can be removed from the wastewater and concentrated in the sludge (Carr, Liu, & Tesoro, 2016).

Successive applications of sewage sludge to land increase the load of MPs in soil, indicating that continued annual applications of sewage sludge to soil lead to an accumulation of MPs (Van den Berg, Huerta-Lwanga, Corradini, & Geissen, 2020). This is unsurprising as all types of plastic polymer, excluding biodegradable polyhydroxyalkanoates, are not degraded by soil microorganisms under ambient environmental conditions and will therefore persist and accumulate within soil.

A recent study has examined the concentrations of microplastics in biosolids, vermicompost and compost in Aotearoa New Zealand (Ruffell, Gaw, Pantos, & Robinson, 2025). Microplastics were found in all samples, with the highest volumes in biosolids. Distinguishable microplastics detected in biowastes included microbeads, glitter, foam sponge fragments, and multi-coloured films of remnants of packaging and embellishments. However, the majority were fragments, films, and fibers of indiscernible origin.

Understanding of the fate and impact of MPs and the additive chemicals they contain is rapidly increasing. The predominance of MPs in sewage sludge/biosolids and other organic waste materials applied to land is likely to result in future risk assessment and the introduction of concentration limits for MPs and the priority chemical additives they contain, within sewage sludge, biosolids, and other forms of organic waste destined for application to land. Knowledge gaps and future research needs in this area are outlined in Appendix 8.

9.5 LABELLING STANDARDS



All products must be appropriately labelled. For product applied in bulk, it is the producers responsibility to ensure the discharger of the product receives documentation providing the same information that would appear on a packaged product on delivery of the bulk order.

Where biosolids are being marketed for their agronomic benefits, as either fertilisers, plant stimulants or soil conditioners, labelling must adhere to the specifications in [ACVM Notice: Fertilisers, Plant Biostimulants and Soil Conditioners](#) (Ministry for Primary Industries, 2024).

Regardless of end use, all biosolids products should contain the following details (as applicable) and accompany all grades of material produced:

- Trade name (if it has one)
- Name and address of the producer/manufacturer
- Product grade and/or registration number
- Confirmation that the product has been manufactured in accordance with this Guide.
- Recommended nitrogen application limit
- Information on the product's origins (eg, that it includes treated human waste, or specific manure) and precautionary handling instructions. An example of wording for a biosolids compost is: "Made from the natural composting of garden trimmings and biosolids (treated human waste) that has been subject to temperatures of at least 55°C":
 - batch number (if applicable)
 - order number (if applicable)
 - delivery date (if applicable)
 - requirement to incorporate into soil if applied to agricultural land.
- Health warning – generally a health statement is printed on the packaging of all garden mixes and should similarly be used for all bagged organic materials. Suitable wording is:

"This product may contain a variety of living micro-organisms, some of which on rare occasions can cause illness in humans. Serious infection is rare but can happen for older people and those with reduced immunity. Please take the following precautions:

- avoid opening the bag in enclosed areas
- avoid inhaling the mix
- always wear gloves and wash hands after use
- work with damp or wet mix/soil to reduce the dust potential
- see your doctor if you develop a high fever, chill, breathlessness or cough."

9.6 MONITORING AND SAMPLING

This section summarises how, when and where samples should be obtained. It applies to all biosolids manufacturing.

A representative sample depends on several factors including the analyses required, the material samples, the sampling location and its objectives. Further detailed advice on the development of a sampling programme that represent the chemical, physical and biological characteristics of

biosolids is available in *The Wastewater Treatment Plant Operations Guide to Biosolids Sampling Plans* (New England Interstate Water Pollution Control Commission, 2006).

Further information for constructing sampling programmes for pathogens is included in the publication *Pathogens and Vector Attraction in Sewage Sludge* (Boczek, Herrmann, Resek, & Richman, 2023).

9.6.1 RESPONSIBILITY FOR MONITORING



Producers are responsible for conducting any monitoring that relates to production, storage and labelling for product they control on their site. The producer should develop a detailed process and product monitoring programme in accordance with this Guide.

Where product is transferred, stored or distributed from a third-party site, the organisation controlling that site and activity should be responsible for those functions.

The holder of the discharge consent, or when a consent is not required land owner, is responsible for monitoring in relation to land application activities. Consent holders or owners may contract others to undertake activities for them, including the monitoring,

Contractors undertaking work on behalf of consent holders or landowners may also be considered responsible and subject to enforcement action under the Resource Management Act depending on the nature of any breaches.

9.6.2 PROCESS MONITORING

Process monitoring provides assurance that stabilisation objectives are being achieved. Process monitoring should be managed within an auditable environmental management system as outlined in Section 14.2.



The production of organic products should include the management practices detailed below. Regardless of whether producers are monitoring VAR, pathogen reduction or both, all process conditions, design diagrams and calculations should be recorded as below:

- Any changes to the process and/or equipment should be noted and retained for future reference and they may initiate repeated verification sampling
- Equipment should be operated and calibrated in accordance with the manufacturer's instructions, with independent test records/certificates kept up to date
- Records should be maintained for all key process conditions, such as time, temperature and pH
- Production records should be maintained for at least two years.

9.6.3 PRODUCT MONITORING



Monitoring of the final product is required to determine the extent of vector attraction reduction, pathogen numbers and chemical contaminant concentrations. When determining the stabilisation grade, pathogen monitoring should be undertaken on both the unprocessed material and the final product to positively confirm pathogen removal. Verification sampling should occur directly after processing.

Routine sampling of the final product should occur for pathogen content just prior to use (or sale) as pathogenic organisms may regrow after treatment has taken place. Producers should inform the analytical laboratory of the need to complete the analysis as quickly as possible.

It is less important to undertake monitoring just before sale when determining product contaminant compliance, as the concentrations of these parameters are unlikely to change after treatment. When products are to be mixed with another material before sale, monitoring should be undertaken on the final product, after the mixing is complete.

For batch production, such as composts and vermi-composts, all batches should be tested.

Records should be kept of the results, and of results of any other testing conducted on the final product (eg, percentage solids, reduction in volatile solids, pH). Records are used to demonstrate compliance with the VAR requirements, pathogen requirements and chemical contaminant concentrations.

9.6.4 SAMPLING PROCEDURES

9.6.4.1 GRAB SAMPLES

A grab sample (also called “spot” or “catch” sample) is one where the whole sample volume is collected at a particular time and place and represents the composition of the source at that time and place. Duplicate samples should also be included as part of quality control.



Results from individual grab samples cannot be assumed to be representative of the sample source over time. Grab samples should be used for determinands that deteriorate or change quickly after sampling, such as pathogens.

9.6.4.2 COMPOSITE SAMPLES

Composite samples are prepared by mixing and sub-sampling several grab samples. Composite samples give an average concentration for the parameter in question over the bulk sample or period the sample was collected.



Composite samples are not suitable for parameters that degrade/alter because of storage or disturbance such as the introduction of air. Therefore, composite sampling should only be used for components that remain unchanged under the conditions of sample collection, preservation and storage. Composite samples should only be used for chemical contaminants (i.e. metals and organics) and nutrient quantification. Composite sampling should not be used for monitoring pathogens.

For organic parameters, care must be taken with sample collection and preservation. A detailed protocol for sampling, sample preservation, mixing, transport and analysis should be agreed with the laboratory beforehand. Advice on sampling protocols is available in *Contaminated Land Management Guidelines No. 5: Site Investigation and Analysis of Soils* (Ministry for the Environment, 2021).

9.6.4.3 MICROBIOLOGICAL SAMPLES



Microbiological samples are very susceptible to being contaminated by poor sampling technique. When taking microbiological samples, the following must be taken into account:

- Containers and tools should be sterilised
- The lids of sterile sampling containers should have a seal over them that has to be broken before taking the sample. If this seal is damaged in any way, do not use the container as it may no longer be sterile
- The container may have a use-by date on it. If it has and the date has passed, do not use the container as it may no longer be sterile

- When taking the sample, do not touch the neck of the container or the inside of the lid. The lid must not be put down on any surface as this can contaminate the sample
- When transporting microbiological samples, keep them separate from other non-sterile samples and cool with ice. Take care not to let melted ice come into contact with the container tops (this is best achieved by keeping the ice inside a plastic bag, separate from the sample container). Samples must not be exposed to direct sunlight and must reach the laboratory within the specified time limit.

9.6.4.4 WHERE TO SAMPLE



More representative sampling generally occurs when the materials being sampled are moving rather than stationary, but this is not always possible. Table 8 describes preferred locations for taking samples from some treatment processes.

Table 8: Sample points for treatment processes

Treatment Type	Sampling point
Anaerobic digestion	Collect sample from taps on the discharge side of positive displacement pumps.
Aerobic digestion	Collect sample from taps on discharge lines from pumps. If batch digestion is used, collect sample directly from the digester. Note that when aeration is shut off, solids may settle rapidly.
Thickener	Collect sample from the taps on the discharge side of positive displacement pumps.
Heat treatment	Collect sample from the taps on the side of positive displacement pumps after decanting. Be careful when sampling heat-treated sludges/slurries because of: • A high tendency for solids separation • The high temperature of the sample can cause problems with sample containers due to cooling and subsequent contraction of entrained gases.
Dewatering, drying, composting, vermicomposting or thermal reduction	Collect sample from material collection conveyors and bulk containers. Collect sample from many locations within the material mass, and at various depths.
Mechanical dewatering by belt filter press, centrifuge, vacuum filter press	Collect sample from discharge chute or storage bin (see below).
Mechanical dewatering by plate press	Collect sample from the storage bin; select 4 points from within the bin; collect an equal amount from each point and combine to form a composite sample.
Dewatering by drying beds	Divide bed into quarters, grab equal amounts of sample from the centre of each quarter and combine to form a composite sample of the total bed. Each

Treatment Type	Sampling point
	composite sample should include the entire depth of the material (down to the sand/drainage layer).
Compost or vermicompost piles	Collect sample directly from the front-end loader while materials are being transported or stockpiled within a few days of use.
Sludge ponds	Samples from representative grid pattern including variable depths. For metals samples may be composited.

9.6.4.5 SAMPLE EQUIPMENT



The sampling equipment will depend on the type of material being sampled, however, the following rules apply to all situations:

- Automatic sampling equipment (such as that used at wastewater treatment plants for watery samples) is not suitable for sampling sludges, slurries or dryer material – all such samples need to be taken manually
- Equipment should be easy to clean and constructed of non-corrosive materials, such as, glass or stainless steel
- Equipment used for raw material or product sampling should not be used for any other purpose
- Equipment should be well cleaned after use and stored in a clean location. It may be advisable to wrap any equipment between uses to ensure it stays clean.

9.6.4.6 SAMPLE CONTAINERS



The following factors must be considered when choosing a sample container:

- High resistance to breakage
- Good sealing efficiency
- Ease of reopening
- Good resistance to temperature extremes
- Practical size, shape and mass
- Good potential for cleaning – especially important for containers used to collect samples for microbiological analysis.

Sample containers are generally made out of glass or plastic. The type of determinand the sample is to be analysed for often controls the type of material the container is made from because some containers will react with the determinands and give false results when the sample is analysed. If a sample is to be analysed for more than one determinand, it may be necessary to use more than one type of sample container and sample size.

Laboratory staff should be consulted in the selection of appropriate containers and cleaning materials. This will help avoid potential issues e.g. leaching from plastic containers should be considered with samples to be analysed for organic contaminants, and the choice of PFAS free cleaning products such as Decon90.

Further considerations for sampling of PFAS are provided in *Guidance for Sampling and Analysis of Per- and Poly-fluorinated Substances* (Minsitry for the Environment, 2025).

9.6.4.7 SAMPLE PRESERVATION

To obtain representative samples it is usually necessary to preserve samples to prevent changes taking place during the period prior to analysis. The most common way of preserving samples is to cool them to between 0°C and 4°C. Once collected, samples should be stored at this temperature until analysis.



Agree procedures with the laboratory beforehand as it will often provide the container and have specific requirements for sample size, handling and transport. If the sample is not provided according to its protocols, the lab may decline to analyse it.

Minimising sample sizes ensures rapid and effective cooling. Samples less than 4 litres in size should ensure this.

Freezing should not be used to preserve samples being analysed for bacteria. Freezing is not a standard preservation technique for samples to be analysed for metals or organic contaminants. If samples are to be frozen, they should not be collected in borosilicate glass containers, which are liable to fracture.

If samples are being collected over an extended period, the preservation of the sample should form an integral part of the collection procedure. Keeping the samples in the dark can further enhance preservation.

9.6.4.8 SAMPLE TRANSPORTATION



Samples to be analysed for microbiological parameters should be transported to the laboratory within six hours of collection. All other samples should be transported within 24 hours, unless suitably preserved. Sample transportation should be undertaken in accordance with standard quality assurance procedures, including the use of chain of custody forms.

9.6.4.9 LABORATORY SELECTION



The primary accreditation agency in New Zealand for analytical laboratories is International Accreditation New Zealand (IANZ). This agency, formerly known as TELARC, is governed by an Act of Parliament. Generally, laboratories with IANZ accreditation should be selected for sample analysis because they will have quality assurance programmes in place to maintain analytical performance. IANZ accreditation is test-specific and therefore not all IANZ laboratories may be accredited for the particular test that is required. Confirm the status of the test (i.e. analyte *and* method) accreditation with the laboratory before sending samples for analysis.

There are several New Zealand laboratories that have accreditation for the analysis of metals and some of the organic contaminants governed by this Guide. There are, however, emerging organic contaminants (nonylphenol and ethoxylates (NP/NPE), phthalate (DEHP), linear alkylbenzene sulphonates (LAS), musks – Tonalide, musks – Galaxolid) for which no New Zealand laboratories have yet gained accreditation at the time of authoring this Guide. New Zealand laboratories with international connections have facilitated the testing for these substances with international counterparts.

There may also be microbiological tests for which no laboratory has the specific accreditation. In this case, choose a competent laboratory and discuss the selection of an appropriate standard test method.

9.6.4.10 AUDITING

All sample programmes should be audited to ensure that samples are being collected, transported and analysed correctly. If any problems are identified they should be resolved immediately to prevent the reporting of erroneous results.



To audit sampling procedures, a chain of custody form should be used throughout the sampling process. This should record the following information:

- Name and signature of person collecting sample
- Date and time sample collected
- Purpose of the sample
- Analysis required
- Location of sample point and unique reference number (if one has been assigned)
- Sampling method (grab or composite)
- Preservation method
- Name of person receiving the sample for analysis
- Time of receipt at the lab
- Temperature of the sample on receipt at the lab
- Date analysed
- Results, and whether these have been confirmed.

On-site sampling operation audits should be conducted to ensure that samples are being taken correctly.

9.6.4.11 DATA REPORTING

Analytical laboratories should provide reports that are complete, accurate and unambiguous so that clear conclusions can be drawn from the data without the need to make any assumptions. Laboratories must also maintain full records of samples, methodology and experimental data so that auditing can be done at any time to verify the reported results.



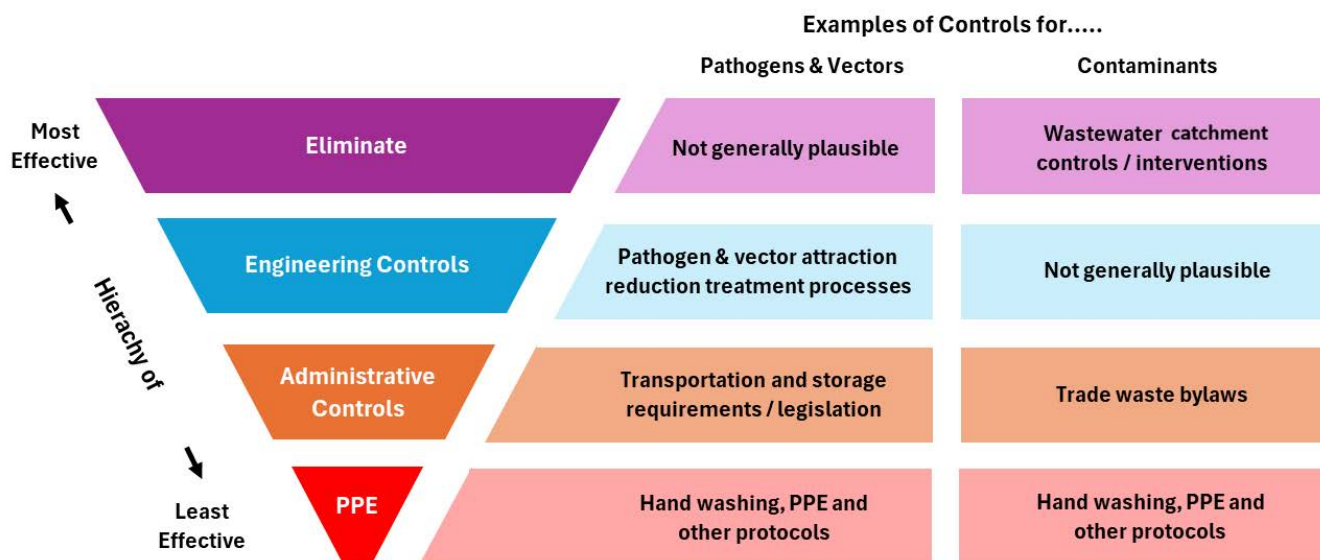
As a minimum, analytical reports should contain the following:

- Results
- Sample identification and description
- Date of receipt of the sample and conditions of storage
- Date that extraction of the sample commenced
- Details of the sample preparation and fraction of sample analysis
- Citation and summary of analytical procedure – it may be just the title for a validated regulatory method; any modifications to the protocol should be noted
- Quality assurance procedures, including any variation between batches
- Date of reporting and signature of laboratory manager or other authorised signatory.

10. MITIGATING THE HAZARDS POSED BY BIOSOLIDS

Managing the hazards posed by biosolids products requires a hierarchy of controls for pathogens, vectors and contaminants. The following diagram demonstrates the hierarchy approach to establishing controls and provides some examples of the types of controls that can be applied.

Figure 6 Hierarchy of Controls for Management of Hazards from Biosolids and other Organic Materials



10.1 SPECIFIC MANAGEMENT APPROACHES FOR PATHOGENS & VECTOR ATTRACTION

10.1.1 TREATMENT TO ACHIEVE STABILISATION GRADE



Sections 9.2.2 and 9.2.4 specify vector attraction reduction (VAR) and pathogen reduction processes and requirements to achieve different grades of product. Grade A products require a much greater degree of stabilisation than Grade B products.

Producers have access to a wide range of treatment processes to enable them to meet the required stabilisation levels. Some of these processes are effective at reducing both pathogens and vector attraction, whereas others may be better at one or the other. Depending on the process used, it may be necessary to combine different treatment processes to ensure that the final product achieves the required stabilisation grade. For some organic materials (e.g., food waste) levels of pathogens may be very low and the stabilisation process required may be minimal.



VAR should take place either at the same time as pathogen control or immediately after it. VAR control measures should also be taken during product storage.

There are six broad approaches to controlling pathogens in organic materials:

- High temperatures
- Radiation
- Chemical disinfectants
- pH adjustment
- Reducing volatile organic content
- Removing moisture.

VAR methods can apply to both manufacturing processes and land application processes. For Grade A products, the VAR treatment occurs during the manufacturing process rather than during the application process.

Within these six approaches there are several different processes and technologies that are proven and common in the marketplace, some of which can be categorised under more than one approach. Common processes are shown in Table 2. Further detail is provided in Appendix 3 for the process options listed. For each generic process type there will be several different physical configurations using a range of standard equipment.

There is “flexibility” of treatment processes to allow for new technologies, but it must be demonstrated through process verification and routine monitoring to ensure that any proposed treatment method meets an equivalent pathogen standard. The key issue is not the specific process type, physical arrangement or equipment types used, but whether the total facility can record and demonstrate consistent compliance with the process criteria.

For some treatment processes, such as vermicomposting, demonstration of process control may not be possible. Under these circumstances, each batch must be verified as meeting Grade A pathogen reduction requirements according to the specification in Section 9.2.3.

A summary of common production processes that, with appropriate design and operation, are capable of meeting the pathogen reduction, stabilisation and/or VAR requirements for Grade A is provided in Table 9. Producers must decide which process or equipment should be used to ensure the product standards are met.

Specific odour control measures may be required following processes that do not provide adequate stabilisation. There may also be opportunities to improve environmental sustainability practices and to reduce greenhouse gases, e.g. biogas collection from anaerobic processes with subsequent productive use as an energy source.

The primary goal, regardless of production process, is to demonstrate meeting the required product quality at point of use.

Table 9 Capability of common production processes

Process	Grade A Pathogen Reduction	VAR	Stabilisation
Pasteurisation	Yes	No	No
Irradiation	Yes	No	No
Lime stabilisation	Yes	Yes	Yes
Composting ¹	Yes	Yes	Yes
Vermicomposting	Yes	Yes	Yes
Aerobic digestion:			
Ambient	No	Yes	Yes
Thermophilic	Yes	Yes	Yes
Anaerobic digestion:			
Mesophilic	No	Yes	Yes
Thermophilic	Yes	Yes	Yes
plus Thermal hydrolysis	Yes	Yes	Yes
Thermal drying	Yes	Yes	Yes
Air drying	Yes	Yes	Yes
Sludge pond storage	No	Yes	Yes

¹ Also refer NZS4454:2005 Composts, Soil Conditioners and Mulches (Standards New Zealand, 2005).

10.1.2 LONG-TERM STORAGE



The storage of organic materials for extended periods can be used as a risk management technique to reduce the level of pathogens in the material prior to land application. Storage can be viewed either as an adjunct to other pathogen reduction or VAR methods or as a treatment process in its own right, particularly when further drying takes place.

Long-term storage of organic materials will result in the reduction of bacteria and viruses present. The effectiveness of storage depends on the type of prior treatment and the length of storage time. The ambient temperature also affects the efficiency of this process.

Storage of organic materials also reduces nitrogen level, which potentially reduces the product's agricultural value. It also creates increases localised nitrate leaching risks, which should be factored into design and siting of biosolids stores.

If the requirements for stabilisation Grade A products are met in full, storage is not necessary. However, where there is doubt about the ability of a new production facility to consistently achieve Grade A stabilisation requirements, it is prudent for producers to begin with an initial storage period, then, when confident, gradually reduce or phase it out entirely when it is established that pathogen standards are being met.

In the case of stabilisation Grade B products, such as those produced by mesophilic digestion, storage can be used to further reduce pathogen levels. This includes sludge pond storage and sludge from waste stabilisation ponds. It should be remembered that storage age is based on the time since the most recent sludge was deposited.

Guidelines for exclusion times are outlined in Section 13.3.2.

10.2 SPECIFIC MANAGEMENT APPROACHES FOR CONTAMINANTS

10.2.1 SOURCE CONTROLS

Contaminant levels in organic materials and derived products are determined by the inherent contaminant levels in the raw materials processed. Source controls are important in managing and limiting the amounts of these contaminants. Some contaminant risks to biosolids arising from industrial sources can be effectively managed through cleaner production initiatives and management of trade wastes from business and industrial customers to sewer. Others however, such as microplastic fragments from dishcloths, or PFAS coating or clothing, are ubiquitous in modern society, and cannot be removed without restrictions preventing their production and use.

10.2.1.1 TRADE WASTE MANAGEMENT



All organisations producing biosolids intended for beneficial reuse should have a robust trade waste management approach in place.

Any industrial or commercial inputs into wastewater treatment plants producing biosolids require either individual trade waste agreements or bylaws as a quality assurance mechanism.

Trade waste controls for municipal sewage networks are managed primarily through bylaws, as permitted by the Local Government Act 2002. NZS 9201.23:2004 Model General Bylaw – Trade Waste (Standards New Zealand, 2024) provides a basis for the development of local bylaws. The bylaw also includes a guideline (Trade waste plan permit guidelines, 2023) which should be read in conjunction with the model bylaw.

Consideration of substances that may pose unacceptable risks to the health, safety and wellbeing of the environment, operators and the public or wastewater network will need accounting for in the development of a trade waste management approach. Locally relevant concentration limits should be put in place to ensure product quality limits in Section 9.3.2 are not exceeded, and, where possible, minimised.

Trade waste management approaches should specify prohibited substances that have the potential to accumulate in biosolids. Substantive adverse impacts on the biosolids receiving environment include, but are not limited to, the following (Trade waste plan permit guidelines, 2023):

- **Organochlorine pesticides**, which persist in the environment and, accordingly, have had their use severely limited by global regulatory authorities. They are unlikely to be removed in standard wastewater treatment processes, which means they are likely to be present in effluent and biosolids if introduced at source.
- **Substances banned under the Hazardous Substances and New Organisms Act 1996**, which includes genetic wastes and other substances prohibited to ensure broader environmental and public health outcomes.
- **Healthcare, pathological and histological wastes**, which are prohibited for discharge to wastewater networks by NZS 4304:2002 Management of Health Waste.
- **Organo-metal compounds** including tin (as tributyl and other organotin compounds), which can be persistent in the environment and are particularly toxic to aquatic life causing significant harm to marine ecosystems even at very low concentrations.

10.2.1.2 PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

Per- and polyfluoroalkyl substances (PFAS) are a group of manufactured chemicals resistant to water, oil and heat. They have been used to make a range of products such as household items, personal care products, cleaning products, industrial products including metal plating and firefighting foam. PFAS have uncertainties associated with their potential risks, with the resulting need for a precautionary approach to protect the environment and human health.

PFAS may be in the wastewater coming into a WWTP through domestic, commercial or industrial sources. They will then exit the WWTP via treated wastewater or in biosolids (sludge). From the scientific literature, it is known that PFAS are not readily removed in WWTP operations, which has implications for contamination of biosolids if such discharges are not controlled.



The New Zealand Environmental Protection Agency (EPA) governs and administers the rules for use of PFAS in New Zealand. The PFAS National Environmental Management Plan 3.0 (Heads of EPA Australia and New Zealand (HEPA), 2025) outlines source controls for PFAS. The NEMP also outlines specific requirements for the management of PFAS in biosolids that are land applied, referenced in Sections 9.3.2, 9.4.2 and Section 12.4, 13.2.3 and 13.3.1.

10.2.1.3 SOURCE CONTROLS FOR OTHER ORGANICS

There are a range of similar measures for other organic wastes. For example, for livestock and poultry manure, practices include feed and bedding management as well as control over veterinary medicines. The Synthesis Report, Contaminants Present in Organic Waste: Phase 1 (Wilson, Anderson, & Hannon, 2023) prepared for the Ministry for the Environment provides an overview of legislation, standards and guidelines for managing contaminants to organic waste streams.

10.2.2 TREATMENT TO ACHIEVE CONTAMINANT GRADE

While there are few if any treatment processes currently available to reduce chemical contaminant loads, blending of products or raw materials with other substances (e.g., pumice, sand, sub-soils, bark, sawdust, green waste) before, during or after treatment is an acceptable way of reducing contaminant levels to attain contaminant grade compliance.

The potential for adverse environmental effects is governed by the quality of the organic product. Cleaner production and improved trade waste management (i.e., source control, waste minimisation) will be needed if producers are to consistently meet contaminant grade compliance and/or avoid the need to obtain large quantities of blending materials.

10.3 GENERAL PRODUCT HANDLING RISKS



The key risk management approaches to mitigating the hazards posed by the handling of biosolids are:

- Appropriately labelling the product so precautions can be taken by persons interacting with the product – requirements described in Section 9.4.
- General health and safety precautions, described in Section 10.3.1
- Transportation requirements, described in Section 10.3.3.

10.3.1 GENERAL HEALTH AND SAFETY PRECAUTIONS



Production, storage and handling of biosolids must be carried out in compliance with the NZ Health and Safety at Work Act 2015. Useful guidance can be found in:

WasteMINZ 2024: Health and Safety Guidelines for the Solid Waste and Resource Recovery Sector (WasteMINZ, 2024).

Biosolids may contain micro-organisms, therefore care should be exercised when working with them. Individuals handling them 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 consumed or smoking permitted for employees while working with biosolids, manures or their 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 available to production workers
- Eye protection is worn to protect against dust
- If dust or aerosols are considered a problem, masks conforming to a recognised standard should be worn to prevent inhalation
- Where possible, workers should be upwind of the land application process
- Organic material and product producers, transporters and applicators should provide an occupational health and safety plan to ensure workers handling these products are adequately protected from, and informed of, risks
- Employees working with biosolids, manures and/or wastewater residuals should review their immunisation history. As a minimum, anyone working in this type of environment should be immunised against tetanus, but also consider immunisations against hepatitis A and B. As inoculations vary over time, updated advice should periodically be sought from local district health boards.

10.3.2 STATEMENT OF HAZARDOUS NATURE



Documentation accompanying Grade B and Grade 2 material should also include a materials safety data sheet with the following information:

- Producer details (name, address, telephone number, emergency telephone number)
- Product name
- Dangerous goods class
- Hazchem code
- Uses
- Physical description/properties
- Appearance
- Specific gravity
- Ingredients
- Health effects (acute, swallowed, eye, skin, inhaled, chronic)
- First aid (swallowed, eye, skin, inhaled)
- Advice to doctor
- Personal protection
- Storage and transport
- Spills and disposal
- Other information as appropriate.

10.3.3 TRANSPORTATION



The transport of Grade B organic products is regulated under the Dangerous Goods Rule (Land Transport Act) and NZS 5433 Transportation of Dangerous Goods on Land. Consent authorities may wish to impose consent conditions covering issues such as action in the event of spillage (prevention of contamination of waterways), avoidance of nuisance odours or the timing of trucking movements.

The recommended tools for managing transportation risks are:

- Consignment papers must include the relevant Safety Data Sheet (refer Schedule 1 Example Safety Data sheet)
- The driver must be licensed for that class of goods
- The vehicle must display adequate signage for the class of goods.

PART FOUR:

MANAGING THE RISKS TO RECEPTORS

11. IDENTIFYING RISKS TO RECEPTORS

Beneficial use of appropriate organic materials as fertilisers and soil conditioners to land requires a thorough identification of potential risks as a first step to determining which measures are required to protect soil and other receptors.

Receptors include soil and water, animals, crops, fish, invertebrates, farmers, neighbours, organic materials workers and the wider community. These receptors might be exposed to the products by direct and indirect pathways, as illustrated in Figure 7.

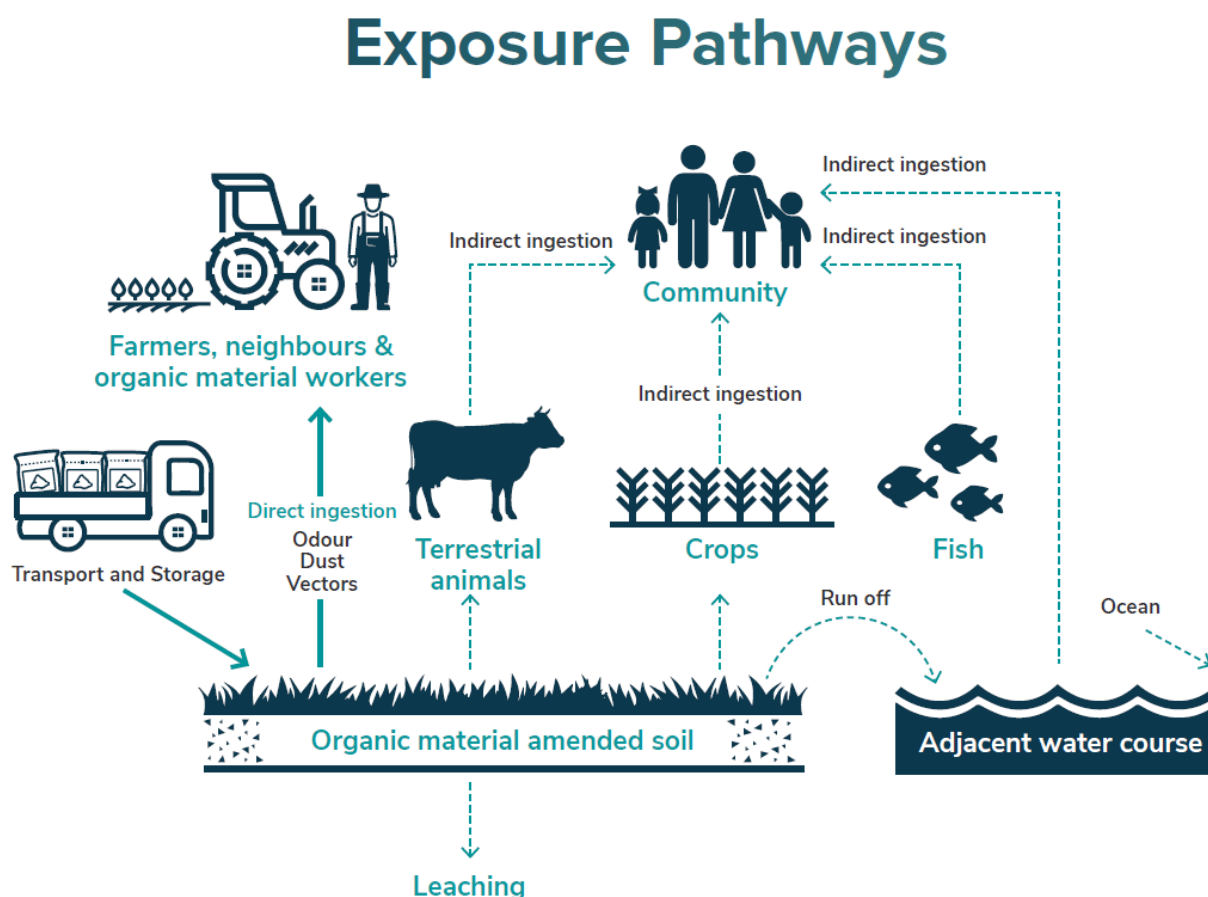
For example, a waterway adjacent to the application site might be at risk of exposure to runoff of concentrated amounts of product. This exposure risk can be managed by assessing the slope of the land and providing for appropriate setbacks from waterways. Grazing animals might be at risk of exposure from direct ingestion of product. This risk can be managed by ensuring the product is of a suitable quality (eg, pasteurised/pathogen free), as well as requiring exclusion times after application and/or incorporation of the product into the soil.



Receptors must be protected from risks associated with pathogens, contaminants, odour, etc. Protection is provided by ensuring product quality, and that appropriate procedures and methods are used in handling and application to land.

This section provides an overview of these hazards, receptors and pathways.

Figure 7 Receptor exposure pathways



11.1.1 CONSIDERATION FOR OTHER ORGANIC MATERIALS

The risks and hazards outlined in the Guide are most often determined from biosolids research and apply specifically to biosolids application to land. For application of other organic materials to land, some of the requirements for biosolids may not apply and there may be different hazards, such as pesticide residues in orchard green waste, which may require differing management and regulatory controls.

11.2 RISKS TO ENVIRONMENTAL HEALTH

11.2.1 SOIL ORGANISMS AND SOIL FERTILITY



The soil is the primary receiving environment for biosolids and organic materials application, resulting in a high degree of contact between the soil environment and the organic materials. The risk to soils is damage to, or alteration of, the soil microbial population and by affecting the presence and availability of key nutrients. As soil is the most exposed and sensitive receptor for biosolids and organic material application, managing the concentration of the adopted contaminants once the material has been applied to soil is necessary to manage risks to the soil.

Trace elements (TEs) in biosolids that need to be managed most carefully include chromium (Cr), copper (Cu), zinc (Zn), lead (Pb), nickel (Ni) and cadmium (Cd). However, biosolids may also contain significant levels of boron (B), manganese (Mn), iron (Fe), selenium (Se), arsenic (As) and mercury (Hg), depending on their origin and treatment methods. These TEs can be classified as either essential or nonessential for humans, plants and animals. Essential elements include Cr, Cu, Zn, B, Se, and Mn, while nonessential elements include Pb, Ni, Cd, As and Hg. While nonessential TEs pose significant health risks, essential TEs can also become toxic at high concentrations. Hence, limits in biowastes for soil application purposes are necessary to prevent high amounts of TEs accumulating and entering the food chain (Esperschütz & Robinson, August 2014).

There are many other chemicals produced from daily domestic activities, such as cooking, cleaning, personal grooming, medical care and gardening, that end up in sewers. In recent years, not only sewage effluent but also sewage-derived biosolids have been extensively characterised for emerging organic contaminants (EOCs). Despite gaps in knowledge, several assessments of a wide range of EOCs have evaluated the risks they may pose to human health and the environment. Three reviews of international and EOCs have been undertaken to inform priority contaminants for management in this Guide. Details of these reviews and the contaminants assessed are available in supporting resources in Appendix 5.

This Guide aims to protect the fertility of agricultural soils by ensuring biosolids application does not result in limits exceeding values in Table 13. Evidence to date has shown that limiting nitrogen loadings is a practical control to protect groundwater, surface water and soil health (Esperschütz & Robinson, August 2014). The use of the mass loading calculations in Appendix 2 gives the limiting application rate for soil protection. Application timing and method are used to protect the physical and structural condition of soil.

11.2.2 GROUNDWATER QUALITY



The main risk posed to groundwater by the application of organic material to land is if the transport of pathogens and leaching of nutrients, metals or organic substances from biosolids and other organic materials into groundwater renders the groundwater unsuitable for use.

The key to both minimising the risk of leaching (eg, of nitrate) and the efficient use of organic material by the soil and plant system is to match application rates as closely as

possible to the agronomic nutrient needs of crops. Nitrogen leaching can also be reduced by applying organic products at, or as close to, the time when maximum crop growth and nitrogen uptake occur.

A high proportion of pathogens present in the final product for application are removed through filtration, attrition and predation in the soil environment.

Metals are unlikely to move through the soil and into groundwater because of the binding mechanisms in soil. However, some leaching to groundwater (or surface water) may occur through acidic (for example acid sulphate soils), sandy soils under conditions of high organic product application, coupled with either irrigation or high rainfall.

Section 13.1 provides information on appropriate setback distances to mitigate risks to ground and surface water quality.

11.2.3 SURFACE WATERS



Risks to surface water are from surface water quality reduction due to elevated levels of contaminants in the surface water resulting from biosolids or other organic material application. The pathway for organic material-derived contaminants entering surface water are via groundwater and from applied organic material being transported across land into watercourses, if placed too close to them.

Risks to surface water can be managed by ensuring that applied organic material is not spread too close to watercourses, on waterlogged or steeply sloping land or during periods of heavy rainfall. Section 13.1 provides information on appropriate setback distances to mitigate risks to ground and surface water quality.

11.2.4 HABITAT AND BIODIVERSITY



It is inappropriate to apply organic material to areas where there is a risk of altering important natural habitat values through the addition of nutrients or contaminants, eg, in wetlands or the habitats of rare or endangered species. The increased level of nutrients resulting from applications of organic material may affect native plant communities that have adapted to soils of low fertility.

11.2.5 PLANT HEALTH AND CROP YIELD



Organic materials and derived products are generally applied to soils to enhance plant health and/or crop yield. Some constituents of these organic products can, however, have the opposite effect if applied in excessive quantities. Metals are generally more mobile in acid soils (pH<5.5) and in sandy soils due to the relative lack of clays and organic matter, which act to bind metals, which can affect soil health and yield.

Cadmium, while not apparently phytotoxic, can accumulate in plant tissues and present a potential health concern to humans and/or grazing animals. The levels given for cadmium in this Guide are designed to prevent this from occurring.

11.2.6 ODOUR GENERATION



The risk of odour generation from organic material after application can be minimised by selecting an appropriate product manufacturing process, quality control, appropriate choice of vector attraction reduction (VAR) method and land application method, and by soil incorporation. Grade A organic products should generate limited odour having met the Grade A stabilisation requirements.

There may also be specific rules around odour, odour management plans and incident reporting logs within the local regional plan.

11.2.7 DUST AND BIOAEROSOL GENERATION



Operations should be managed to avoid dust emission beyond the production premises or boundary of land application. Dust can occur during storage, grinding, mixing, screening, transport and spreading of all materials and products. Dust suppression, such as covering dusty materials or applying a light water spray and enclosing fixed mechanical equipment used to process raw and finished materials, should be considered.

Bioaerosols are airborne particulates or liquid droplets that may contain bacteria, fungi spores, pathogens or other microorganisms. Bioaerosols may be generated during the movement or agitation of materials at any stage of the operations. The generation and dispersion of bioaerosols should be minimised by appropriate handling and dust control procedures, including buffer zones and ceasing practices on particularly windy days.

Dust and bioaerosols controls should be considered within odour management plans.

11.3 RISKS TO HUMAN HEALTH

11.3.1 RISKS FROM PATHOGEN CONTENT

Grade A organic products have been treated to the point where they are deemed safe for use by the general public. They are essentially free of pathogens and there is a very low risk to people handling them.



Organic products that do not attain the required stabilisation Grade A standards potentially contain pathogens at infectious levels, so they cannot be sold or given away direct to the public and the associated risks need to be managed by:

- Employing appropriate pathogen-killing techniques during a production process
- Taking precautions with handling the material
- Careful choice of end use
- Temporary exclusion of people and other vectors from areas where Grade B1 and B2 organic materials have been applied (refer Section 13.3.2).

11.3.2 RISKS FROM METAL CONTENT



The main metals potentially contained in organic materials and of concern to human health are cadmium, lead and mercury. The direct ingestion of material by children is the most critical pathway of exposure to cadmium, lead and mercury, with the greatest risk being for domestic gardens. Neither lead nor mercury are taken up to any extent by crops and consequently do not pose a risk through the dietary intake of plant foods.

Cadmium can accumulate in crops; however, in practice, humans are largely protected from organic material-related cadmium toxicity because the high ratio of zinc to cadmium in most organic materials inhibits the uptake of cadmium in plants.

11.3.3 RISKS FROM ORGANIC CONTAMINANTS



Human exposure to organic contaminants is primarily via direct use, which subsequently leads to them entering wastewater and biosolids. Once incorporated into biosolids the potential exposure pathway is via the food chain, especially from the accumulation of contaminants in the body fat of grazing animals. The main risk arises from surface-applied organic material adhering to grass and being directly ingested by grazing animals.

Exposure to organic contaminants can be managed by minimising the soil-grazing animal exposure pathway, for example, by ensuring that applied materials are thoroughly incorporated into the soil where animals are to be grazed or by using an appropriate withholding period (refer Section 13.3.2).

11.4 RISKS TO ANIMAL HEALTH



The direct ingestion of organic material-treated soil is widely considered to be the principal risk to grazing livestock from application of such material. Animals may ingest contaminants by consuming plants that contain elevated concentrations of contaminants, or by ingestion of the soil and organic material itself. To reduce the ingestion of contaminants by grazing livestock, human waste derived products (biosolids) should be incorporated into the soil when pastures are re-sown, and withholding periods are required before allowing grazing animals on biosolids-treated land (refer Section 13.3.2).

This is not as necessary for animal manures but is still good practice, and agricultural guides commonly recommend that animals are not grazed on land or vegetation visibly contaminated with manure.

11.5 RISKS TO SOCIAL AND CULTURAL VALUES

Community and cultural perspectives are critical considerations in biosolids management. Section 5 and 6 address Community and Iwi Engagement respectively, and further advice on these topics is provided in the Supporting Resources outlined in Appendix 5.

11.5.1 COMMUNITY VALUES



The sensitivity of the receiving environment extends beyond bio-physical matters to include social and cultural considerations, such as the proximity of neighbours/dwellings, the presence of “sensitive areas”, existing public use, access to the proposed land application area or adjacent areas and existing traffic movements in the area. Such considerations are

relevant to site selection, effects assessment and/or the conditions that should be applied to a resource consent.

11.5.2 WĀHI TAPU



There are some locations or sites at which the application of wastes of human origin, including biosolids, is unacceptable to Māori, regardless of grade. Potential issues in relation to the application of organic products to land include, but are not restricted to:

- Potential for contamination of food sources
- Proximity to sites of food preparation, harvesting and processing
- Potential contamination of water bodies
- The need for potential mitigation measures (eg, riparian planting)
- Avoiding applying biosolids on, or in the vicinity of, wāhi tapu
- Potential constraints on future land use as a consequence of biosolids applications (eg, land subject to Treaty of Waitangi claims)
- Monitoring requirements.

11.5.3 TRADE



There are potential risks to domestic and international trade as a result of applying any organic materials, particularly biosolids, to food-producing land. Mitigating the potential for residues to transfer to export produce is key to managing these risks. Methods may include soil incorporation, soil pH control, stock exclusion periods and avoiding application to leaf or salad crops.

Market tolerances for biosolids use may vary widely on both scientific and societal/cultural grounds and should be identified before applying biosolids to any land producing food.

This Guide incorporates many accepted international practices and therefore should give international markets the assurance they require that there is an effective process in place for the management of soil health and subsequent crops.

12. QUANTIFYING THE RISK TO RECEPTORS

Understanding the land that is proposed to receive biosolids or other organic materials enables the suitability of materials to be determined and the material processing to be customised to produce a product suitable for the receiving environment.



In terms of quantifying the risks posed by the application of biosolids or other organic materials to land, regard must be given to the sensitivity of the proposed receiving environment to adverse effects. Matters relating to the sensitivity of the receiving environment, and hence to the nature and magnitude of environmental effects, include:

- Soil chemical and physical properties
- Soil pH
- Depth and proximity of local aquifers
- Slope of land and proximity of surface water bodies
- Presence/absence of sensitive areas such as sensitive plant habitats
- Existing land use(s)
- Social and cultural considerations, eg, proximity of neighbours/dwellings, schools, hospitals and wāhi tapu.

Many of these issues may be prescribed in detail within the local regional plan.

There are some locations or sites, wāhi tapu, at which the application of wastes of human origin, including biosolids, is unacceptable to Māori, regardless of grade. Areas where particular issues are likely to arise are addressed in Section 12.6.

12.1 UNDERSTANDING SOIL CHEMICAL AND PHYSICAL PROPERTIES



Soil chemical and physical properties determine the suitability of a soil to receive organic materials, and soils vary greatly in their ability to sustain and benefit from the application of such products.

It is good practice to test soils prior to determining the suitability of a site for application of all organic material and derived products.

The key measures of the capacity of soils to accept biosolids or other organic materials are:

- The capacity of the soils to retain contaminants, determined by:
 - Oxide (iron, aluminium, manganese) levels – soils that are high in oxides have a higher capacity to retain contaminants
 - Clay and organic matter content – soils that are high in clay and organic matter have a higher capacity to retain contaminants
 - pH – high soil pH contributes to greater contaminant retention capacity
- The capacity of the soils to retain metals, determined by:
 - The cation exchange capacity of the soil – a useful estimate of metal retention capacity
 - pH – maintaining the pH value of organic product treated agricultural soils above pH 5.5 minimises the risk of phytotoxicity or excessive metal uptake by crops. Soils tend to become more acid with time so regular pH monitoring of organic product amended soils should be carried out. Appendix 4 discussed the impacts of soil pH in further depth.

Some forestry soils are naturally acidic, with pH values of less than 5. Applying organic products to forestry soils under low pH conditions may be acceptable in some circumstances, as food crops

are not involved and therefore plant uptake of metals is not a health concern. The drainage regime of forest soils and the depth and proximity of local aquifers are important considerations.

Understanding of soil type is very important. For example:

- Some soils contain minerals well suited for holding some contaminants (but not all contaminants).
- Some soils lack the capacity to bind or otherwise treat contaminants, e.g. raw sands
- Smearing can occur if heavy machinery is run over wet or vulnerable soils;
- Soil microorganisms already present in the soil can utilise nutrients and organic contaminants, while nutrients should enhance plant growth – but only if the soil is kept well aerated.
- Biosolids consist of a range of particle sizes. Very fine particles can block soil pores. Fine pores in the soil filter out particles very effectively, but become stopped up by them, reducing the rate of percolation leading to increased surface flooding (and unintentional transport of biosolid materials);

Exceeding the capacity of a soil to manage/treat biosolids will have negative environmental outcomes, particularly for repeat applications.

12.2 SOIL MONITORING



Monitoring the build-up of contaminants in the receiving soil is an important risk management measure. Recommended test methods for contaminants and pathogens are listed in Schedule 2 Recommended Test Methods.

Table 8 prescribes recommended soil testing frequencies for different grades of products during different phases of product application.

Soil should be tested before any organic materials are applied to land to determine the existing soil contaminant concentration for parameters listed in Table 5 and the soil bulk density. When Grade B products are applied additional background testing of E. coli is required.

Testing for E. coli before repeat applications of Grade B1 and B2 products will demonstrate that the soil treatment process is working effectively and that, in combination with normal end-use management controls, regrowth has not occurred. Regrowth testing should be conducted annually, using three samples.

If product reaches the preliminary emerging organic contaminant limits proposed in Table 7, soil testing for those contaminants is suggested. Otherwise, soil testing is not required for EOCs other than PFAS.

Table 10 Summary of Recommended Soil Testing Frequencies

Application Stage	Parameters	Testing Requirements for Product Standard Applied			
		A1	A2	B1	B2
Pre-application:	Pathogens				
	Contaminants				
Pre-subsequent applications:	Pathogens				
	Contaminants				
5 yearly:	Pathogens				
	Contaminants				

12.2.1 SOIL SAMPLING



Soil from sites to which organic materials have been applied should be sampled using an unbiased pattern, such as a rectangle or grid. Samples should be taken from areas representative of the site as a whole. Avoid taking samples from non-representative areas such as fence lines, dung patches, areas where burning has taken place, fertiliser storage areas, swampy areas and near roads or buildings.

A minimum of 4 core samples, taken to a depth to which the organic materials were incorporated into the soil, up to a maximum of 200mm, should be collected per hectare of product application. If there is no soil incorporation, the sampling depth should be 200mm. All samples should be combined to form a composite and then tested for the contaminants listed in Table 5.

It is important to record the protocol used and depth of soil sampled, as well as soil pH. Other factors to consider in the development of a soil monitoring programme that is representative of application site are outlined in *The Contaminated land management guidelines No5* (Ministry for the Environment, 2021). This outlines approaches for the site investigation and analysis for soils which could also be used to help inform biosolids management plans.

In some cases there are approved protocols for monitoring soils in certain circumstances, for example the Tiered Fertiliser Management System (Fertiliser Association, 2019) provides detail on monitoring soils for cadmium.

Soil samples should be taken before product application to land and tested for background *E. coli* concentrations. Soil sampling should be repeated if a shorter than specified exclusion periods is used for Grade B1 and B2 products (refer Section 13.3.2) and exclusion periods should not be lessened unless it can be demonstrated that *E. coli* levels have reduced to the original background levels.

Control samples (i.e., from an adjacent site that has not had any organic material or derived products applied to it) should be taken before application and at the end of the restraint period to

determine “background” E. coli numbers as these may fluctuate naturally (by season), high background levels could also indicate input from feral animals, including birds.

If numbers of E. coli are found to be 100-fold higher than background counts, the local authorities (including the consent authority) and the Medical Officer of Health (via the local public health unit) should be notified. Decisions about further restricted access or land use should be made on a case-by-case basis after consultation with the local Medical Officer of Health (Health Act, 1956).

12.3 SOIL CHARACTERISTICS

The characteristics of the soil and landform that is proposed to receive a biosolids or organic material application will influence the behaviour of the biosolids in the environment.

Key measures of a soil’s capacity to receive biosolids are outlined in Section 12.1 and discussed in detail in Appendix 4 Soil Characteristics and Interaction with Biosolids Contaminants, and covered in supporting reviews underpinning this report;

- [Contaminant Review](#) (Esperschütz & Robinson, August 2014)
- [Organic Waste Guidelines – Trace Element Contaminant Review](#) (Thompson-Morrison, Cavanagh, & Robinson , 2024)
- [Organic Contaminants Review](#) (Tremblay, Gielen, & Northcott, 2014)
- [Review and recommendations on the selection of organic contaminants in the draft guideline for the Beneficial Use of Organic Waste Products on Land](#) (Northcott, G, 2017)

 A characterisation of the soil environment, including the wider area, may include:

- Landform and topography mapping or description, including slopes
- Soil type mapping
- Waterway mapping
- Existing soil fertility/soil quality sampling
- Soil drainage characteristics, including any subsurface drainage networks
- Soil profile descriptions and soil physical condition.

The determination of product contaminant limits has been based on soil assimilation capacity using median characteristics of New Zealand soils. Contaminant characteristics that form the basis for these calculations are listed in Table 11. Bulk soil density also impacts on assimilation capacity, and for this, 0.97 dry tonnes/m³ has been used based on the median value of national soil data (Ministry for the Environment, 2021).

If biosolids are applied to soils with contaminant levels above median concentrations of bulk density, assimilation capacity for soils will be lower. In these instances, calculations to determine loading rates that remain below soil contaminant limits outlined in will be required. Appendix 2 and the supporting calculator outline calculations to determine these.

Table 11: Median soil background concentrations in New Zealand

Contaminant	Median soil background concentration (mg/kg) ¹
Arsenic (As)	4.1
Cadmium (Cd)	0.08
Chromium (Cr)	16
Copper (Cu)	16
Lead (Pb)	11
Mercury (Hg) ²	0.1
Nickel (Ni)	9
Zinc (Zi)	48

1. Median soil background concentrations are based on predicted rural ambient (background) concentrations (mg/kg) (Cavanagh, et al., 2023).
2. Estimated nominal agricultural concentrations (Cavanagh, Thompson-Morrison, & Robinson, Updates to the Organic Materials Guidelines – Trace element contaminants review, 2024)

12.4 MAXIMUM ALLOWABLE SOIL CONCENTRATION OF PFAS

The PFAS NEMP (Heads of EPA Australia and New Zealand (HEPA), 2025) requires soil testing is undertaken prior to land application to determine levels of PFOS+PFHxS and PFOA in-situ prior to biosolids application.

The analysis used to measure concentrations of PFOS+PFHxS and PFOA in biosolids and soil should have the lowest limit of reporting achievable at the time of assessment. It is not suitable to request a less sensitive analytical method to try and meet the lowest limit of reporting requirement.

If concentrations of PFOS+PFHxS and PFOA are detected in soils at concentrations exceeding the lowest limit of reporting, the PFAS limited contaminant rate should be calculated in accordance with the requirements of the PFAS NEMP, as outlined in Section 13.2.3.

12.5 PROXIMITY TO AQUIFERS AND SURFACE WATER BODIES

If specified organic product application rates are followed and soil pH is maintained, groundwater contamination is unlikely. In some situations, however, the potential for leaching of contaminants, including nitrogen, may become an issue. See Section 13.1.2 for recommended setback distances.



An assessment should be undertaken of the likelihood of groundwater contamination to occur, based on:

- The depth and proximity of local aquifers
- Relative location of bores
- Site slope (slopes greater than 15% are unsuitable for biosolids application)
- The proximity of the discharge site to waterbodies or the coastal marine area
- Soil drainage characteristics
- Soil pH.

12.6 PRESENCE OF 'SENSITIVE' AREAS.



An assessment should be undertaken of the proximity of the following to the proposed application site:

- Sensitive areas such as wāhi tapu, archaeological sites, urupā (burial sites).
- Potable water sources
- Locations associated with wild-food harvest or resource collection
- Wildlife habitats
- Areas of importance from a biodiversity perspective
- Sites that support community recreational, social or Māori cultural activities.

12.7 EXISTING LAND USES



When selecting a site, it is important that specific regard is given to the existing land uses (eg, agriculture, forestry, public recreation or Māori cultural use) of adjacent land. Land use influences land application costs, risk management considerations (eg, soil pH trends and/or the ability to lime, plus the ability to incorporate organic materials within soil), permissible loading rates (if leaching is a potential issue), public health risks (exposure pathways) and the likely degree of local opposition to a proposal. While the existing land use can influence these factors, the primary concern should be with the risk profile of the site (its sensitivity), and whether or not the risks can be managed.

13. MITIGATING THE RISKS TO RECEPTORS

Risks from organic materials when applied to land are, or can be, managed in several ways, including:

- Planning controls (i.e., regional plan rules)
- The use of effective planning and quality assurance schemes
- Management of the product application rate to land
- Application techniques.

Each of these risk management mechanisms is described below, and in the quality assurance controls for managing risks to receptors outlined in Section 14.2.

13.1 PLANNING CONTROLS



This Guide recommends the adoption of the product grading system to determine what planning controls required for biosolids management in regional plans.

Regional plans prepared under the RMA by regional councils and unitary authorities set out objectives, policies, and rules to manage the adverse environmental effects of activities. Activities are classed as either permitted (they can go ahead, subject to meeting stated conditions in a rule), controlled (they require resource consent, and must be granted subject to a stated set of considerations), restricted discretionary (regional council discretion is limited to a list of a limited matters), discretionary, non-complying (which require resource consents and may or may not be authorised, depending on how they align with policies and meet certain tests), or prohibited (they cannot occur).

The following suggests recommended activity status based on product grade. Controls that should be adhered to are outlined in Section 13.1 Planning Controls.

The holder of the discharge consent, or owner of the land in instances where a consent is not required, is responsible for any activities or monitoring related to land application. Consent holders or owners may contract others to undertake activities for them, including the monitoring, but they will remain ultimately responsible. Producers are responsible for any activities or monitoring related to production, storage and labelling of product they control on their site. Where product is transferred, stored or distributed from a third-party site, the organisation controlling that site and activity should be responsible for those functions.

Table 12: Recommended Planning Controls According to Product Grade

	Contaminant grade 1	Contaminant grade 2
Stabilisation grade A	Permitted Activity planning control, if conditions met in 13.1.1 are met, Otherwise, Controlled Activity	Reuse under a specific discretionary resource consent or safely disposed of
Stabilisation grade B	Controlled Activity	

13.1.1 RECOMMENDED PLANNING CONTROLS

The discharge of biosolids onto or into land, and the associated discharge of odour to air is recommended as a permitted activity, providing the following requirements are met;

- i. Biosolids comply with the contaminant grade, Grade 1, requirements outlined in Section 9.3, and Section 9.4.
- ii. Biosolids comply with all applicable requirements for biosolids outlined in the National Environmental Management Plan for PFAS.
- iii. Biosolids comply with the stabilisation grade requirements, Grade A, outlined in Section 9.2.
- iv. Minimum proportion of nitrogen in product exceeds 2%.
- v. Soil pH where biosolids is discharged is not less than 5.5 (see Section 11.2.5 for rationale)
- vi. Soil samples indicated that background soil concentration of contaminants is at or below limits provided in Table 11.
- vii. Soil has a bulk density of 0.97 dry tonnes/cubic meter or less.
- viii. Application rates based on the nitrogen requirements for crop growth do not exceed a two year average of over 200kg total N/ha/year, or any lower limits listed in regional plans (as outlined in Section 13.2.1).
- ix. No other soil fertilising or conditioning products are used in addition to the biosolids application.
- x. Biosolids storage and application sites are setback from sensitive receptors in accordance with requirements outlined in Section 13.1.2
- xi. Biosolids storage and application does not occur upstream of abstraction points in any identified community drinking water supply protection areas.
- xii. Land slope is less than 15 degrees
- xiii. Biosolids application at the same site occurs no longer than 20 years, or for no longer than 10 years if applied every second year.
- xiv. A documented quality assurance system including management plans for environmental effects, land application and nutrients, provided to the regional council prior to land application.
- xv. Monitoring records demonstrating compliance with Section i to vi, should be held by the discharger and provided to the regional council prior to commencement of land application. These should include information on the sample method, location and results. Records should be held for at least as long as products are applied to that site and for a five-year period after application ceases.

For products not meeting all these conditions, a controlled activity resource consent should be used, require application rates to be determined using the process outlined in Section 13.2.

For Grade B biosolids consents should additionally require that;

- a) application methods and exclusion times provided in Table 14 are adhered to
- b) soil incorporation takes place within 24 hours of application (but preferably as soon as practicable)
- c) material is incorporated to a depth of at least 100mm, and preferably 200mm if soil type and plant root mass allows.

In these instances, requirements ii, v, viii, ix, x, xi, xii, xiii, xiv and xv should apply.

Where biosolids are being used to build degraded soils, or a higher loading rate is being sought a discretionary resource consent should be sought with application rates based on Sections 13.2.1.2 and 13.2.4.

13.1.2 SETBACK DISTANCES

Mitigation of risks outlined in Section 11 require setbacks between receptors and biosolids storage and application sites. Biosolids should be applied and stored no closer than²;

- i. 30m of a surface water body, coastal marine area, or surface geothermal feature for ground slope.
- ii. 85m to any groundwater abstraction bore.
- iii. 50m to any property boundary of public road. The distance to a property boundary may be reduced with the written agreement of the property owner or occupier.
- iv. 90m to any residential dwelling, unless the written agreement of the occupier has been obtained.
- v. 300m to any school, marae, community hall or residential zone or wāhi tapu as defined in the Heritage New Zealand Pouhere Taonga Act 2014 Act

Default values are adopted from other, similar discharge activities. If change these then need to provide evidence in support that they are protective of receptors. If other, or more stringent setback distances are defined in local regulations these must be met.

13.2 MANAGING APPLICATION RATE TO LAND



Maximum product application rates can be limited by nitrogen, PFAS, or other contaminants. Determining these requirements requires knowledge of both product and soil characteristics.

Biosolids should be applied at rates that meet the agronomic needs of crops, but to not exceed the maximum product limits.

Figure 9 outlines the process for determining nitrogen and contaminant limited biosolids application rates that should not be exceeded.

Repeat applications should not occur for a period of longer than 20 years, or for no longer than 10 years if biosolids are applied every second year at the nitrogen limited application rate.

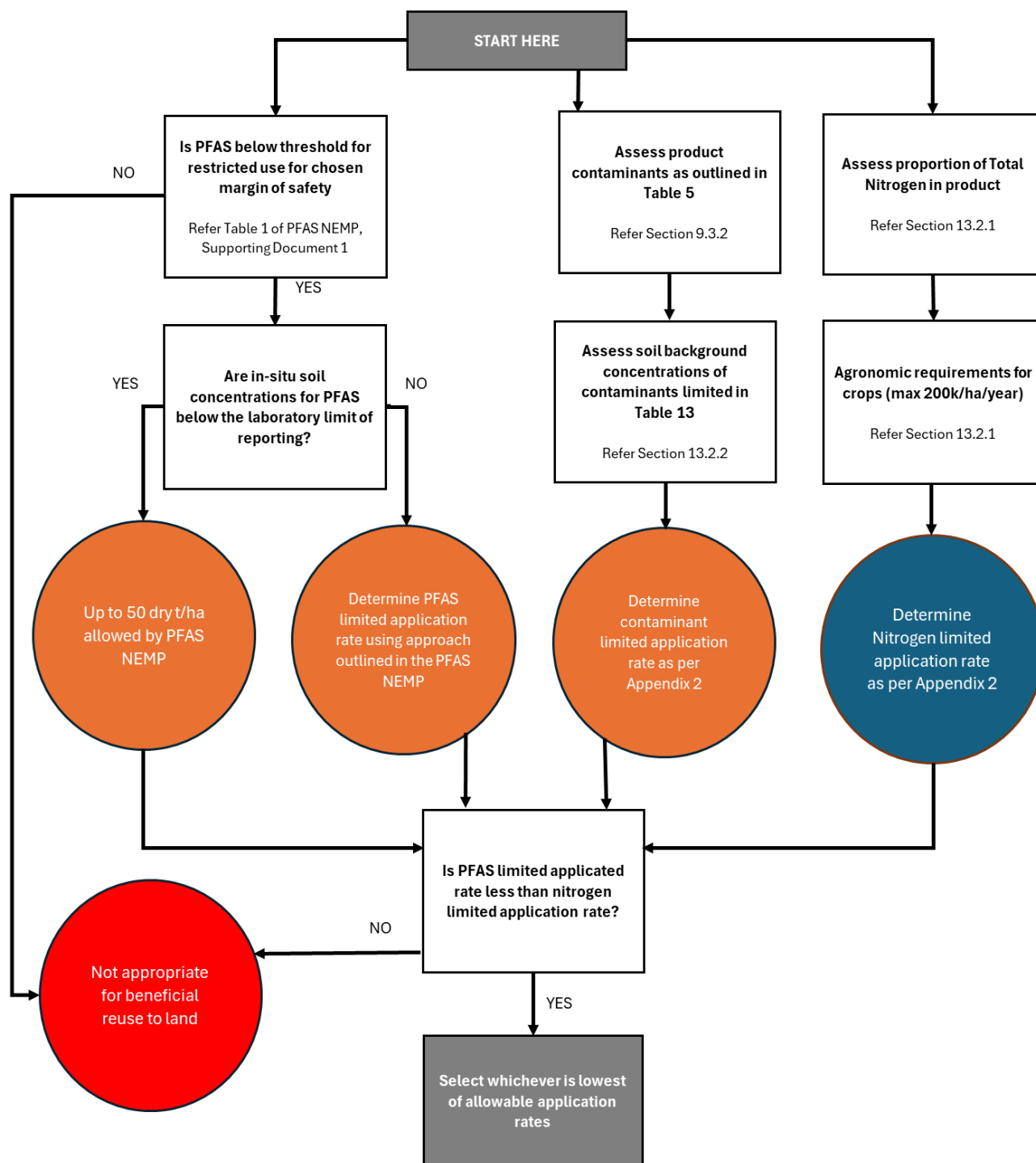
To avoid excessive runoff and leaching of nutrients into surface water and groundwater biosolids applications should be matched to agronomic needs. They must also be set to ensure soil contaminants remain below limits listed in Table 13, and unacceptable levels of PFAS contamination do not occur. Determination of the allowable application rate to manage each of these issues is outlined in this section. Figure 9 outlines a process for determining which of these considerations ultimately determine the biosolids application rate. A supporting calculator is supplied with these guidelines which can be used alongside *The PFAS NEMP, Supporting Document 1* (Heads of EPA Australia and New Zealand (HEPA), 2025) to determine maximum loading rates.

Repeat land applications of biosolids should be limited to 20 years, at soil application rates determined in accordance with the process outlined in Figure 9. If biosolids are applied every second year at maximum nitrogen loading rates (i.e. 400kg/ha/2 years) gradual mineralisation of the nitrogen in soils may occur, causing nitrogen build up over time which may lead to nitrogen

² Setback distances from abstraction bores have been determined in line with farm dairy effluent disposal setbacks (Dairy NZ, 2015)

leaching. Accordingly, applications undertaken every second year, should restrict repeat applications to a period of 10 years.

Figure 8: Process for Determining Application Rate of Products to Soil



13.2.1 NITROGEN APPLICATION RATE

Biosolids when applied at agronomic rates can increase grain yields compared to conventional N fertilisation (Koenig, Cogger, & Bary, 2011) (Sullivan, Bary, Cogger, & Shearin, 2009), but high rates can also lead to yield loss through waterlogging (Mantovi, Baldoni, & Toderi, 2005) or moisture stress (Cogger, Sullivan, Bary, & Kropf, 1998).

To avoid excessive runoff and leaching of nutrients into surface water and groundwater biosolids applications should be matched to agronomic needs. Influencing variables include the climate, soil

characteristics, biosolids characteristics (which influence mineralisation rates alongside soil characteristics) and agronomic N requirements of the crops.

Managing Nitrogen from Biosolids (Henry, Sullivan, Rynk, Dorsey, & Cogger, 1999) provides methods for designing site-specific biosolids application rates to suit agricultural, forest, and grazing (referred to in the document as rangeland) systems.

13.2.1.1 TOTAL NITROGEN



For the continual application of organic materials on productive land, the nitrogen application rate should be;

- be based on a location-specific site and crop assessment to match biosolids N content to the agronomic requirements for crop growth
- should not exceed an average of over 200kg total N/ha/year, or any lower limits listed in regional plans, for up to two years

To avoid nitrogen leaching from repeat applications, the applications period should be;

- annually (or less) at the calculated rate for 20 years, prior to a reassessment
- applied every second year at this rate for up to 10 years, prior to a reassessment (for example if it has been determined that 150kg/N a year can be applied to the site, 300kg/N could be applied every second year)
- should not be applied at determined rate at time intervals of less than two years (for example, if it is determined that 150kg/N a year, this does not mean that 450kg/N can be applied every third year)

At the end of the prescribed application period a reassessment should be made to determine site suitability into the future.

A supporting calculator has been provided to determine the maximum product loading rate. The calculator is based on calculations provided in Appendix 2.

A total maximum nitrogen load of 200kg/ha/y for productive land was first included in the 2003 Guidelines for the Safe Use of Biosolids to Land in New Zealand. The 200kg total N/ha/year has been based on evidence that the organic nitrogen present in the product is not immediately available but is eventually mineralised.

Justification of maintaining this maximum N loading rate in different application scenarios was reviewed by the Centre for Integrated Biowaste Research (Esperschütz & Robinson, August 2014) and is provided in Appendix 7. The same value has been adopted for this Guide as a level at which the effects due to nitrogen (in particular, the risk of mineralised N reaching surface or groundwater) are minimal. The maximum application rate is needed to ensure application does not exceed the ability of the soil and plant systems to beneficially use the applied nitrogen.

In biosolids, as with other organic materials, the predominant form of nitrogen is organically bound nitrogen. The rate of release of mineral nitrogen from organic materials depends on the origin and processing of the material so mineralisation rates. Factors impacting Mineralisation rates are outlined in the Manual, Managing Nitrogen from Biosolids (Henry, Sullivan, Rynk, Dorsey, & Cogger, 1999) and further discussed in Appendix 7.

Note that some regional councils have stricter regulations for nitrogen loading from effluent discharges. In such instances, these loading rates will be required to be observed. In these instances contaminant limits for Grade 1 products outlined in Table 5 will be additionally conservative.

13.2.1.2 EVALUATING HIGHER RATE APPLICATIONS

It is possible to apply a higher rate of nitrogen from biosolids without causing an adverse effect, however, a greater level of evaluation is needed to demonstrate that the effects due to nitrogen are acceptable. In addition, an application rate more than 200kg total N/ha/y would trigger the need to consider the contaminant loading to the soil (trace elements and organic compounds).

The loading rate calculator supplied to support these guidelines can be used to determine associated application rates that can be varied based on agronomic nitrogen loading rates. The calculator is based on calculations outlined in Appendix 2.

13.2.2 CONTAMINANTS AS A LIMITING FACTOR FOR APPLICATION RATE



In many circumstances nitrogen will be a limiting contaminant for biosolids application rates. However contaminant limited biosolids loading rates require calculations in all instances where:

- Biosolids exceed contaminant limits in Table 5 (i.e. contaminant Grade 2)
- Soils exceed median background rates of contaminants shown in Table 13
- Soils have a bulk density of greater than 0.97
- Total nitrogen in biosolids is less than 2%

The loading rate calculator supplied to support these guidelines can be used to determine contaminant limited application rates. Formula in this calculator have been based on calculations shown in Appendix 2 Example of Mass Loading Calculation.

In these instances, a discretionary resource consent should be required for their reuse.

Contaminant limits in receiving environments are based on the most sensitive receptor. These could be either ecological soil guideline values for soil biota or public health limits.

Additional controls would be required should biosolids or organic products be used as soil replacement rather than a fertiliser or soil conditioner, and these are beyond the scope of this Guide.

If soils have contaminants occurring at above rural ambient (background) concentrations, less assimilation capacity will exist in the soils and contaminant limited loading rates should be determined. Average background soil concentration rates, which have been used as the basis for calculations in this guideline are shown in Table 13.

Table 13: Median soil background concentrations and associated soil limits

Contaminant	Median soil background concentration (mg/kg) ¹	Soil Limit (mg/kg) ³
Arsenic (As)	4.1	17
Cadmium (Cd)	0.08	0.8
Chromium (Cr)	16	200
Copper (Cu)	16	95
Lead (Pb)	11	160
Mercury (Hg) ²	12	1
Nickel (Ni)	9	60
Zinc (Zi)	48	180

1. Median soil background concentrations are based on predicted rural ambient (background) concentrations (mg/kg) (Cavanagh, et al., 2023).

2. Median soil background concentration based the estimated nominal agricultural concentrations (Cavanagh, Thompson-Morrison, & Robinson, Updates to the Organic Materials Guidelines – Trace element contaminants review, 2024). Soil limit based have been maintained from the 2003 based guidelines at limits to protect human health (Water New Zealand, 2003).

3. Soil limits based on most stringent eco-SGV protection limits, or for arsenic and cadmium contaminant standards for the protection of human health, (Cavanagh & Harmsworth, An implementation framework for ecological soil guideline values, 2023)

13.2.3 PFAS AS A LIMITING FACTOR FOR APPLICATION RATE

The PFAS NEMP (Heads of EPA Australia and New Zealand (HEPA), 2025) outlines when, and how PFAS limited application rates should be determined. At the time of publishing the NEMP required that;

- Where biosolids are being applied to soils with PFAS detected at rates above the lowest limit of reporting, a contaminant limited application rate be determined.
- If biosolids application at the PFAS contaminant limited rate still provides nutrient benefit to crops then product application can occur.

If PFAS limits are below restricted use threshold concentrations, and no PFAS is detected in soils the PFAS limited calculation rate need not be determined and product can be applied at application rate set by other requirements of this guide, up to a maximum of 50 dry tonnes/year.

The PFAS NEMP should be referred to prior to land application for any updates to PFAS management, which would override the requirements of this guide.

13.2.4 APPLICATION TO DEGRADED SOILS

Biosolids are particularly valuable for the improvement or conditioning of soils that are degraded through overuse, topsoil loss or mechanical damage. Typically, application to degraded soils occurs as a single or few, high-volume applications.

When using biosolids to rebuild degraded land or low-fertility soil, biosolids are often applied at greater than agronomic rates to build up soil organic matter and improve soil fertility. The required high application rates can exceed guideline values for nutrients, which were set to avoid excessive leaching or runoff into lakes and streams causing eutrophication (Tian, Granato, Pietz, Carlson, & Abedin, 2006).

The environmental outcomes of application to degraded soils are distinct from a continual application for agronomic benefit. Consequently, different limits are likely to be required for the most beneficial and safe use.

Biosolids application to rebuild degraded soil or to refurbish contaminated land should be limited to a one-off nitrogen application of 150kg mineral N/ha. The mineral nitrogen represents the nitrogen immediately available for plant use.

For most product applications this will be greater than that for productive land. This is due to the dominant form of nitrogen being organically bound. A high proportion of this organically bound nitrogen will mineralise to plant-available nitrogen over time but that release is over 3 to 10 years.

In situations where biosolids and other organic materials are applied to land to improve degraded soil, suitable rates of application should be based on avoiding adverse effects due to contaminants, by evaluating the concentration in the soil that will occur following application, rather than contaminant concentrations in the source product outlined in Table 5.

In these instances a discretionary resource consent should be issued to determine specific application rates. The impact and accumulation of Trace Elements before and after application to either agricultural or degraded land should be assessed as part of resource consent conditions.

It should be noted that this applies to amelioration of soil and not to soil replacement, which is beyond the scope of this Guide.

13.3 APPLICATION STRATEGIES TO MANAGE RECEPTOR RISK

The method of applying organic materials and derived products to land (eg, spraying, ploughing, surface application, soil injection, etc) can determine the range of potentially adverse environmental effects and can therefore be an important risk management consideration.

Organic materials and derived products should only be applied to soils in ways, and under conditions, that will ensure they remain in place and do not move offsite. Set back distances, outlined in 13.1.2 should be maintained between biosolids storage and application sites to ensure that sensitive areas, such as waterways, are not directly affected (refer Section 11.2 for information on waterway risks).

The climatic conditions during application need to be accounted for to ensure that the material cannot be blown or washed onto non-target areas. This will depend on the method used for application and the physical nature of the material, particularly its moisture content. Incorporation of organic material and derived products into the soil will minimise losses during application and ensure good contact with the soil, and place contaminants near to sites where immobilisation reactions can occur. Organic material remaining on the land surface may be subject to runoff, so steeply sloping sites should be avoided.

13.3.1 SOIL INCORPORATION

Soil incorporation (eg, via ploughing, rotary hoeing, injection, etc) is an effective risk management technique. It has the effect of:

- Reducing exposure to pathogens (public or animal health risk)
- Reducing uptake of contaminants by grazing animals and transfer to the human food chain (animal health, public health and trade risks)
- Removing vector access to pathogens (public health risk)
- Maximising dilution and dispersal of contaminants, enhancing immobilisation reactions in soil
- Minimising losses after application from wind blow or surface runoff, and effects on non-target areas.

Soil incorporation for Grade B1 and B2 products avoids applying biosolids to leaf, salad or root crops where there is a risk of direct transfer to animals or humans and prevents contamination of meat and dairy produce via direct ingestion of pasture and/or surface soil.

At the time of publishing the PFAS NEMP (Heads of EPA Australia and New Zealand (HEPA), 2025) requires that unless PFAS limited contamination rates have been derived, soil incorporation by mechanical means is required.

Injection can be a good management practice on sites where established vegetation is present or for slopes greater than 6%.

When evaluating the use of soil injection both crop and soil type should be considered to determine its suitability. Biosolid applications disposed of at 200 mm may bypass the main processes for soil and plant uptake. The main root mass for pastures in New Zealand which occurs in the upper 100mm. Stones reduce the volume of soil available for treatment. Several soils in NZ are shallow or stoney.

These factors should be considered in the development of application strategies and associated discretionary resource consents.



For Grade B1 and B2 material of human origin, soil incorporation should take place within 24 hours of application, preferably as soon as practicable, and the material should be incorporated to a depth of at least 100mm, and preferably 200mm if soil type and plant root mass allows.

At the time of publishing the PFAS NEMP (Heads of EPA Australia and New Zealand (HEPA), 2025) requires that unless PFAS limited contamination rates have been derived soil incorporation by mechanical means is required.

Soil incorporation is preferred for other Grade A1 and A2 materials, for any application onto farmland and for any product application into forestry. Soil incorporation before planting annual crops is a way of using organic material and derived product as a fertiliser and soil conditioner and may therefore occur as a matter of course.

Care should be taken to ensure that soil mixing is sufficiently even in profile across the whole application area. Where surface ploughing or similar is used, a visual assessment will give an indication of the effectiveness of the mixing; checking, for example, that the soil has a consistent texture and colour vertically and laterally and has been broken down without large clods or clumps of turf or soil attached to roots.

13.3.2 EXCLUSION PERIODS

Imposing public exclusion or stock withdrawal periods following the application of organic material of human origin to land is an important risk management technique for Grade B1 and B2 products. It allows time for the natural die-off of pathogens in the soil and the re-establishment of vegetation cover on the land following soil incorporation.

Exclusion periods are particularly relevant where the organic material is surface-applied and is known to have a high pathogen content. Adequate publicity of exclusion periods is required, particularly where there has been a history of unconstrained public access and/or recreational use of the affected area. The establishment of buffer zones around the application area and/or erecting fences and warning signs should also be considered.

Soil testing should occur for E. coli before biosolids application and again afterwards to demonstrate that die-off to original background levels has occurred before removing exclusion controls (refer Section 12.2).



Table 10 summarises the application methods and exclusion times for Grade B1 and B2 products.

Table 14 Application methods and exclusion times for Grade B1 and B2 products

Land use	VAR requirement (refer Table 2 Vector attraction reduction methods)	Recommended controls
Salad crops, fruit, other crops for human consumption that may be eaten unpeeled or uncooked	- Mass of volatile solids in material shall be reduced by a minimum of 38%; or - SOUR @ 20°C ≤ 1.5 g/m³ for liquid sludges from aerobic processes; or	May be applied immediately plus soil incorporation plus a further waiting period of at least 1 year before crops are sown (the land may be used for other purposes in the meantime)

Land use	VAR requirement (refer Table 2 Vector attraction reduction methods)	Recommended controls
	pH ≥ 12 @ 25°C for at least 2 hours and pH ≥ 11.5 for 22 more hours.	
	Storage/restricted access	Store or lagoon for at least 1 year prior to application plus soil incorporation plus a further waiting period of at least 1 year before crops are sown (the land may be used for other purposes in the meantime)
Public amenities, sport fields, public parks, golf courses, play grounds, land reclamation	- Mass of volatile solids in material shall be reduced by a minimum of 38%; or - SOUR @ 20°C ≤ 1.5 g/m³ for liquid sludges from aerobic processes; or - pH ≥ 12 @ 25°C for at least 2 hours and pH ≥ 11.5 for 22 more hours.	Store or lagoon for at least 6 months prior to application plus soil incorporation plus restriction on public access for period of time necessary to establish a full vegetation cover on the land.
	Storage/restricted access	Store or lagoon for at least 1 year prior to application plus soil incorporation plus restriction on public access for a period of time necessary to establish a full vegetation cover on the land.
Fodder crops and pasture ¹ , orchards where dropped fruit is not harvested, turf farming, industrial or non-edible crops, crops that will be peeled or cooked before eating.	- Mass of volatile solids in material shall be reduced by a minimum of 38%; or - SOUR @ 20°C ≤ 1.5 g/m³ for liquid sludges from aerobic processes; or - pH ≥ 12 @ 25°C for at least 2 hours and pH ≥ 11.5 for 22 more hours.	May be applied immediately plus soil incorporation plus fruit and turf should not be harvested or pastures grazed for at least 6 months after application plus crops that will be peeled or cooked should not be harvested for at least 6 months after application
	Storage/restricted access	Store or lagoon for at least 1 year prior to application plus soil incorporation plus fruit and turf should not be harvested or pastures grazed for at least 6 months after application

Land use	VAR requirement (refer Table 2 Vector attraction reduction methods)	Recommended controls
		<i>plus</i> crops that will be peeled or cooked should not be harvested for at least 6 months after application
Forest, trees or bush scrubland	- Mass of volatile solids in material shall be reduced by a minimum of 38%; or - SOUR @ 20°C ≤ 1.5 g/m³ for liquid sludges from aerobic processes; or - pH ≥ 12 @ 25°C for at least 2 hours and pH ≥ 11.5 for 22 more hours.	May be applied immediately <i>plus</i> public access restricted for 6 months <i>plus</i> buffer zones should be fenced and signposted
	Storage/restricted access	Store or lagoon for at least 1 year prior to application <i>plus</i> public access restricted for 6 months <i>plus</i> buffer zones should be fenced and signposted

13.4 MANAGING PATHOGEN RISK

Grade A1 and A2 materials can be considered safe (i.e. essentially pathogen free) and no other risk management measures (other than precautionary handling instructions on the label) are necessary from a human health perspective.



Grade B1 and B2 materials potentially contain pathogens at levels constituting a risk to human health. Section 11.3 of this Guide covers the risk of human infection, having regard to land use. These must be carried out by the discharger.

13.4.1 OTHER CONSIDERATIONS

Organic material and derived products (regardless of grade) should not be applied to land that is:

- Frozen solid (or <4°C)
- Waterlogged
- Under snow.

If biosolids are being applied to contaminated land, regulatory oversight and additional monitoring controls may be required to ensure existing contaminant loads are not exceeded.

13.5 MANAGING RISKS DURING PRODUCT STORAGE

Many of the potential environmental and health risks associated with the land application of organic materials can be related to extended local storage prior to spreading. These potential risks include:

- Ground and surface water contamination
- Leaching of contaminants during heavy rainfall events and floods
- Public and occupational health risks from uncontrolled access and/or inappropriate storage, transport or handling.

The following factors can influence the severity of these risks:

- Stockpile size
- Product quality
- Length of time product will be stored
- Time of year (that is, effects of moisture, temperature and wind gradients)
- Stockpile design (capacity, runoff, leachate controls)
- Stockpile location.



Minimum in-field storage is encouraged to reduce these issues and nuisance potential.

Correct storage conditions ensure that the product is never contaminated with other chemicals or chemical products and does not escape from the storage facility. Some local authorities have specific requirements for storage and its signage.

If the initial short-term storage period becomes a long-term storage period (i.e. more than 30 days), a more permanent, specifically designed structure and signage may be needed to hold the stockpile.

The supplier and end recipient are both responsible for ensuring that the risks associated with stockpiling organic materials within a facility or application area are well managed.

13.5.1 SITING OF STOCKPILES



It is important that an appropriate location is selected when organic materials are stockpiled. Setback distances for determining appropriate siting locations are outlined in Section 13.1.2. In addition the following criteria should also be considered in determining stockpile sites:

- Flat (slope gradient $\leq 3\%$); raised land set well back from waterways and flood prone land
- Protected from unauthorised access
- Stockpiles should not be situated in an area deemed unsuitable for Grade B material application, for example, due to soil type, proximity to dwellings or sensitive areas or groundwater depth
- Stockpiles should not be located on any land where runoff or leachate could directly access a waterway.

The impact of odours on neighbouring properties is an important consideration in determining an appropriate location to site biosolids. Providing adequate buffer distances between stockpile sites and sensitive receptors, such as dwellings is a primary control. There are a range of other steps that can be taken to reduce odour emissions.

Further guidance for management of odour is provided in the Manual for Wastewater Odour Management (Water New Zealand, 2000) and the odour and corrosion management design guide (Christchurch City Council, 2022).

13.5.2 FENCING AND SIGNAGE



Grade B material should not be stored in areas where the public has ready access. The property owner must ensure that the location selected for the storage of organic materials is:

- Fenced to prevent unauthorised access
- Signposted at all entrances to the property, from the time of delivery of the material until the materials have been incorporated and stock exclusion periods are completed. Signs must be:
 - weatherproof (e.g., metal or sturdy plastic)
 - in compliance with NZS/AS 1319–1994, Safety signs for the occupational environment
 - worded, to include the following information at a minimum

BIOSOLIDS ARE BEING STORED AND USED IN THIS AREA. CONTACT MAY AFFECT HUMAN HEALTH. THEREFORE, UNAUTHORISED ACCESS IS PROHIBITED.

13.5.3 DRAINAGE



Organic material stockpiles, regardless of the length of storage, should be located on flat, raised land so that stormwater from other areas does not run through the stockpile, which may cause leaching of contaminants and nutrients into the environment.

If a flat, raised storage area is not possible, a drainage channel should be constructed to divert stormwater away from the stockpile and minimise the potential for contaminant and nutrient leaching and bunds should be constructed around the stockpile.

Any leachate collected inside the storage area should preferably be used within the product application area.

13.5.4 BUNDING



Bunds should be constructed around stockpiles if the material has to be stored for longer than 30 days or the stockpile is located on a slight slope (slope gradient of >3%).

Bunds serve several purposes; they ensure the organic materials are contained within a specific area; they assist in keeping stormwater away from stockpiles; and they provide a physical barrier to help restrict access. Bunds may, in most cases, be constructed from earth from the application site. Runoff diversion drains may be required around the upslope side of the bund.

13.5.5 COVERING

Stockpiles are not required to be covered provided that the storage period and monitoring requirements are met. Any monitoring or sampling should be conducted prior to use or when the covers (if used) are removed if stockpiling for more than 30 days.

Where stockpiles are likely to be subject to adverse weather conditions (i.e. strong wind or heavy rain), covering will help prevent discharges from the stockpile. Covers may be temporarily applied.

13.5.6 VECTOR CONTROL

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



Risks from vectors can be controlled by reducing the potential for physical contact (eg, minimising the storage time, covering stockpiles, and considering stockpile siting requirements outlined in Section 13.5.1).

Methods to manage vectors may vary between sites depending on the vectors to control, seasonal conditions and the type of organic materials used. If climatic conditions such as high temperature and humidity create a high probability of vector attraction, onsite storage should be reduced.

13.5.7 MONITORING



Stockpiles should be visually inspected by the recipient or their representative regularly, to ensure the integrity of the stockpile and/or bunds, drainage channels and check for potential fly breeding. If the integrity of the stockpile, bunds or drainage channels is found to be compromised, action to rectify the situation needs to be implemented as soon as possible. More frequent monitoring may be required after heavy rainfall.

PART FIVE:

QUALITY ASSURANCE

14. QUALITY ASSURANCE REQUIREMENTS

14.1 RESPONSIBILITY FOR MONITORING



Producers are responsible for conducting any monitoring that relates to production, storage and labelling of product they control on their site. The producer should develop a detailed process and product monitoring programme in accordance with this Guide.

Where product is transferred, stored or distributed from a third-party site, the organisation controlling that site and activity should be responsible for those functions.

The holder of the discharge consent, or owner of the land when a consent is not required, is responsible for monitoring in relation to land application activities. Consent holders or owners may contract others to undertake activities for them, including the monitoring, but they will remain ultimately responsible.

14.2 QUALITY ASSURANCE TO MANAGE RISKS TO RECEPTORS



Quality control and management practices are required to minimise risks associated with the use of organic materials and derived products. Products covered by this Guide must come from a facility with a documented quality assurance system.

The most effective way of ensuring a consistent high-quality product is to implement control and monitoring mechanisms at different stages in the organic product life cycle, rather than just one quality check of the final product. This means that if one check or control fails, any problems should be picked up by the other mechanisms.

The best quality management plans are site-specific and the specific lifecycle of each batch of organic material should be considered when devising management systems and plans.

14.2.1 ENVIRONMENTAL MANAGEMENT SYSTEMS (EMS)



It is recommended that all producers and bulk dischargers of organic materials and derived products have a system of formalised (auditable) management plans in place. The ISO management systems are widely adopted, e.g. *AS/NZS ISO 9001:2016 Quality management systems Requirements*, or *AS/NZS ISO 14001:2016 Environmental management systems – Requirements with guidance for use*. ISO 14001 can be used by any organisation regardless of its activity or sector and applies to the environmental aspects of its activities, products and services that the organisation determines it can either control or influence considering a lifecycle perspective.

Other in-house systems can be equally useful provided they can be audited and verified by an approved external agency.

An EMS would cover all activities relevant to the producer or discharger, including detailed operational activities (Standard Operational Procedures (SOPs)) with limit, process and key performance parameters, e.g. minimum retention, maximum odour, measured quality. If the producer is also the discharger, the EMS would cover all production, storage, transport and discharge activities.

Beyond ensuring full compliance with all resource conditions and other regulatory requirements, e.g. regional plan incident logs, an EMS can address such issues as odour, noise and other potential community concerns.

14.2.2 ENVIRONMENTAL MANAGEMENT PLAN

The foundation of an EMS is a written plan, which includes a description of responsibilities for managers, production workers, those responsible for transport and land application, and regulators. The plan usually has five sections: environmental policy, planning, implementation, monitoring, corrective actions and management review.

The Environmental Management Plan (EMP) sets out a risk-based approach to transporting, handling, storing and finally applying the product to land.



The EMP is required to document risk assessment and specify risk management practices based on the product and site-specific land conditions (presented in the land application site management plan (refer Section 14.2.3).

The EMP is to be developed using best practice by an experienced practitioner and must address:

1. Product handling
2. Product transportation
3. Product storage
4. Product application.

The EMP must also include an assessment of environmental policy, planning, monitoring, corrective actions, compliance with resource consent conditions and other regulatory requirements, plus odour, noise and any identified mana whenua or community concerns.

14.2.3 LAND APPLICATION SITE MANAGEMENT PLAN

A land application site management plan (LASMP) is a useful way of coordinating an approach to managing the risks associated with any specific land application project. Such a plan provides the detail of how it is proposed to implement, or ensure compliance with, the Guide and any consent conditions. It also provides an opportunity to integrate consent requirements with other desirable site management practices, such as public liaison and complaints procedures.

A LASMP may form part of an environmental management system and contain a nutrient management plan.



A LASMP would typically contain the following information:

- Site and ownership details
- Soil and drainage details
- Type of land use
- Proposed application; products, methods and timing
- Odour management
- Nutrient Management Plan
- Potential risks and management proposals
- Monitoring and record keeping
- Staffing and responsibilities
- Staff health and safety procedures.

14.2.4 NUTRIENT MANAGEMENT PLAN

Biosolids have useful fertilising and/or soil conditioning properties because of the nutrients and organic materials they contain. To ensure that appropriate consideration and management of the nutrients is applied, a Nutrient Management Plan (NMP) is required.



A Nutrient Management Plan (NMP) is based on a nutrient budget (NB), often using Overseer, SPASMO or other recognised nutrient planning tools. The NB should document all inputs and outputs, climatic and soil conditions and assess the potential for nitrogen and phosphorus losses.

Nitrogen application must align with the requirements outlined in Section 13.2.

The NMP then identifies actions to minimise any loss of nutrients from your production system. These actions may fall into one or several of the following categories:

- Fertiliser management
- Effluent management
- Soil management
- Pasture, tree or crop management
- Production and stock management
- Riparian management
- Cropping management
- Management of waterways risk from hot spots; silage pits, offal holes and farm dumps.

Some regional councils require a specific NMP to demonstrate compliance with fertiliser application rules and consent conditions.

The *Code of Practice for Nutrient Management* (Fertiliser Association, 2023) provides a useful framework for NMPs including a template and detailed guidance notes.

14.3 RECORD KEEPING



Manufacturers, dischargers and any third parties involved in the bulk transport of organic materials should keep appropriate records. The following sections detail the information that is required at each stage in a product's lifecycle. These sections relate to bulk and commercial operations and are not intended for purchasers and dischargers of bagged product for domestic use.

Records should be kept and maintained for as long as possible. In the case of records relating to contaminant loads applied to a site, they should be maintained for at least as long as products are applied to that site and for a five-year period after application ceases.

All organic products should have traceability of the source material as part of identifying risks and how they are being managed.

14.3.1 RECORDS TO BE MAINTAINED BY PRODUCERS



Products covered by this Guide must come from a facility with a documented quality assurance system that demonstrate the following:

- All process conditions, design diagrams and calculations
- Any process changes
- Operation and calibration of equipment in accordance with best practice and independent test records/certificates as required according to manufacturer's instructions
- Maintain records of key process conditions, such as time, pH, temperature
- Maintain records of the analysis in steps 1, 2 and 3 above.

This document must be up to date with the latest routine test results. Records must be maintained for at least two years.

All producers of all grades of product should maintain the following records:

- Batch number (if batched)
- Date of production
- Stabilisation grade, including microbiological results, frequency of sampling, method of achieving stabilisation grade and VAR method
- Contaminant grade, including contaminant concentrations and frequency of sampling
- Nature of any co-blended material (eg, green waste in compost)
- Quantity of product produced in that batch
- Treatment processes employed
- Monitoring of treatment processes and results
- Documented procedures for operations, sampling, monitoring and auditing
- Concentrations of nitrogen, phosphorus and potassium
- The address of destination for discharge of product if the product is intended for bulk use (> 50 m³) or it is a Grade B1 product or Grade B2 material, regardless of whether it is intended for bulk use.

14.3.2 RECORDS TO BE MAINTAINED BY STORERS OF ORGANIC MATERIALS



The following records are to be maintained by storers of loose bulk organic material:

- Complaints received and responses made
- Inputs and outputs
- Information on any monitoring carried out, including vector nuisance and odour
- Storage times.

14.3.3 RECORDS TO BE MAINTAINED DURING TRANSFER OF ORGANIC MATERIALS



This section applies to information that should be collected and passed on during the transfer of bulk organic materials from the producer to the end user. It is best collected on a chain of custody form. If the producer is also the discharger, then this phase of record keeping is not necessary.

The records to be maintained during transfer are:

- Source of the organic product, batch number and date of dispatch
- Mass of product
- Stabilisation grade
- Contaminant grade
- Location to which the products are transferred.

14.3.4 RECORDS TO BE MAINTAINED BY PRODUCT DISCHARGERS



Dischargers of bulk products should collect the following information:

- Location of application site
- Current land use
- Name of site occupier and owner (if different)
- Area of application with an accompanying map showing the area
- Date of application
- Soil pH before organic product application
- Soil pathogen and contaminant concentration before organic product application
- Organic product application rate
- Method of application
- Source of organic product and batch number
- Product Type
- Product certified N loading
- Monitoring methods
- Frequency of soil sampling.

SCHEDULE 1 EXAMPLE SAFETY DATA SHEET

Example Safety Data Sheet (SDS)

(Pg 1 of 5)

PRODUCT AND COMPANY IDENTIFICATION	
Product name:	ABC Compost
Company:	ABC Biowaste Ltd
Address:	
Telephone number:	
Emergency telephone numbers:	0800 CHEMCALL (0800 243 622) 24 hours 0800 POISON (0800 764 766) National Poisons Centre 111 – New Zealand Fire Service
HAZARD(S) IDENTIFICATION	
HSNO Hazard Classifications: Based on available information, not classified as hazardous according to criteria in the Health and Safety at Work (Hazardous Substances) Regulations 2017.	
COMPOSITION / INFORMATION ON INGREDIENTS:	
Ingredients	Proportion
Compost mixes are made by blending naturally occurring materials with composted plant material including bark and manure. The material contains a variety of living micro-organisms including bacteria, fungi and protozoa.	>90%
Minerals & fertilisers	>10%
FIRST-AID MEASURES	
For advice, contact the National Poisons Centre 0800 POISON (0800 764 766) or a doctor/physician. This product is made from organic materials that may contain living micro-organisms, including bacteria, fungi and protozoa. This product also contains mineral and fertiliser additives. Read the safety data sheet and packaging information before opening and using this product. ▪ Avoid breathing product dust or mists ▪ Always wear gloves and wash hands immediately after use.	

Seek medical attention if you develop a high fever or respiratory symptoms including chills, shortness of breath or a cough within two weeks of using this product.

Inhalation: Remove to area free from risk of further exposure. This product may contain micro-organisms that can be harmful to health and, though it occurs infrequently, some can result in serious illnesses (including Legionnaires' disease) in people, especially the elderly, smokers and those with impaired respiratory health or immunity. Serious infection is rare, however, in severe cases it can be life-threatening.

Avoid breathing dust, vapour, aerosols and/or liquid mist (bioaerosols) – inhalation may irritate, inflame or sensitise the nose, throat and lungs.

Ingestion: If swallowed, rinse mouth with water, do not induce vomiting. Give a glass of water to drink, seek medical advice.

Eye Contact: If in eyes, wash out immediately with water, continue to wash eye/eyes thoroughly for at least 15 minutes with clean fresh water. In all cases of eye contamination it is a sensible precaution to seek medical advice.

Direct contact with this material or its dust and/or liquid mists (bioaerosols) may cause eye infection or irritation. Seek medical attention if eye irritation or infection occurs.

Skin Contact: If skin contact occurs, remove contaminated clothing and wash skin with soap and water. Direct contact with this material or its dust and/or liquid mists (bioaerosols) may cause skin irritation (dermatitis) and/or skin infection. Seek medical attention if skin irritation or infection occurs.

Notes to Physician: Treat symptomatically taking into account product risks and potential for serious illness (including Legionnaires' disease) listed above.

FIRE-FIGHTING MEASURES

Suitable Extinguishing Media: Not combustible, however, if material is involved in a fire, use: Media applicable to surrounding fire.

Precautions for firefighters and special protective clothing: Not combustible, however, if material is involved in a fire, firefighters to wear breathing apparatus and suitable protective clothing applicable to surrounding fire.

Hazards from combustion products: Non-combustible.

SPILLAGE, ACCIDENTAL RELEASE MEASURES

Emergency Procedures: Keep unnecessary and unprotected personnel from entering the area. If contamination of sewers or waterways has occurred advise local emergency services.

Personal Precautions and Protective Equipment: Refer to SDS section 7 for handling and precautionary measures. Refer to SDS section 8 for additional information and personal protection equipment.

Environmental Precautions: Contain - prevent from entering sewers, waterways and/or groundwater.

Methods and Materials for Containment and Clean up: Sweep up spilled material, avoid creating and breathing in dust when cleaning up, eg, by wet sweeping, collect and store in properly labelled, sealed containers for safe disposal. If contamination of sewers or waterways has occurred advise local emergency services.

HANDLING AND STORAGE

Precautions for safe handling and storage: Read the safety data sheet and packaging information before opening and using this product. Seek medical attention if you develop high fever or respiratory symptoms including chills, shortness of breath or cough within two weeks of using this product.

Handling: Keep out of reach of children and animals. This product is made from organic materials which may contain living micro-organisms, including bacteria, fungi and protozoa that can be harmful to health and, though it occurs infrequently, some can result in serious illnesses (including Legionnaires' disease) in people, especially the elderly, smokers and those with impaired respiratory health or immunity. Serious infection is rare, however, in severe cases, it can be life-threatening.

This product also contains mineral and fertiliser additives.

To reduce risks when using this product, please take the following safety precautions:

- Always wear gloves (AS/NZS 2161 standard) when handling and wash hands immediately after use.
- Work in a well-ventilated area
- Avoid inhaling product dust or mist by wearing a disposable face mask or respirator securely covering the nose and mouth (AS/NZS 1715 and AS/NZS 1716 standard), especially if:
 - Handling the product in an enclosed space or in windy conditions
 - You are elderly or have impaired respiratory health or immunity
 - You are working with bulk quantities
- Open the bag carefully and direct the opening away from your face
- Keep the product damp to reduce airborne particles such as dust and avoid creating dust when cleaning up
- Water gardens, soil mix and potted plants gently, using a low-pressure hose
- Avoid skin, mouth and eye contact (eye protection AS/NZS 1336 standard)
- Avoid transferring product from hand to mouth
- After work, remove any protective clothing, wash hands, arms and face after handling
- Do not eat, drink or smoke when using this product or in the areas where they may become contaminated with this material
- Avoid raising soil near evaporative coolers.

Seek medical attention if you develop a high fever or respiratory symptoms including chills, shortness of breath or a cough within two weeks of using this product.

Storage: Store out of reach of children and animals. Store in the closed, original container in a dry, cool, well-ventilated area out of direct sunlight.

EXPOSURE CONTROLS AND PERSONAL PROTECTION	
Personal Protective Equipment: No WES values are set by EPA or NZ Department of Labour Health & Safety for this substance at this time. However, Workplace Exposure Standard(s) for particulates not otherwise classified are: ▪ Inhalable dust: WES-TWA 10mg/m³ ▪ Respirable dust: WES-TWA 3mg/m³ This product is made from organic materials that may contain living microorganisms, including bacteria, fungi and protozoa which can be harmful to health and, although it occurs infrequently, some can result in serious illness (including Legionnaires' disease) in people, especially the elderly, smokers and those with impaired respiratory health or immunity. Serious infection is rare, however, in severe cases, it can be life-threatening. This product also contains mineral and fertiliser additives. Ensure ventilation is adequate to maintain low air concentrations of dust, vapour, bioaerosols and mists. Keep packaging closed when not in use. Respiratory Protection: Use with adequate ventilation, avoid breathing dust, vapour, aerosols or mist. If there is a risk of inhalation of dust, vapour, aerosols and/or liquid mist (bioaerosols), wear a suitable particulate respirator meeting the requirements of AS/NZS 1715 and AS/NZS 1716. Skin protection: Avoid contact with skin. Wear standard light gloves, as specified in AS/NZS 2161 and keep product moist when handling. Wear protective clothing. After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water. Wash contaminated clothing and other protective equipment before storage or re-use. Eye protection: Avoid contact with eyes. If there is a risk of exposure to dust and/or liquid mists, also wear dust resistant eye protection, as specified in AS/NZS 1336.	
PHYSICAL AND CHEMICAL PROPERTIES	
Appearance	Coarse brown solid
Odour	Organic
Solubility in water	Insoluble in water
Specific gravity (kg/l @ 20°C)	0.4 – 0.8kg/litre (bulk density)
Flash point (°C)	Not applicable
STABILITY AND REACTIVITY	
Chemical stability	Stable under normal conditions of use
Conditions to avoid	Avoid contact with foodstuffs and with other chemicals

Incompatible materials Hazardous decomposition products Hazardous reactions	Incompatible with oxidising agents Oxides of carbon, oxides of phosphorus, oxides of sulphur and ammonia None known
TOXICOLOGICAL INFORMATION	
Potential health effects: This section includes possible adverse effects, which could occur if the product is not handled in the recommended manner. This product is made from organic materials which may contain living micro-organisms, including bacteria, fungi and protozoa which can be harmful to health and, though it occurs infrequently, some can result in serious illnesses (including Legionnaires' disease) in people, especially the elderly, smokers and those with impaired respiratory health or immunity. Serious infection is rare, however, in severe cases, it can be life-threatening. Seek medical attention if you develop high fever or respiratory symptoms including chills, shortness of breath or a cough within two weeks of using this product. All people working regularly with these and other landscaping products should ensure that they are adequately protected against tetanus. Eye contact: Dust and/or liquid mist (bioaerosols) may irritate the eye resulting in redness and watering, or eye infection. Skin contact: Contact with skin may cause irritation and in some people may lead to skin sensitisation, dermatitis or skin infection. Ingestion: Swallowing can result in abdominal discomfort. There is an increased risk of gastrointestinal infections. Inhalation: Avoid breathing dust, vapour, aerosols and/or liquid mist (bioaerosols). Inhalation may irritate, inflame or sensitise the nose, throat and lungs resulting in illnesses ranging from hay fever and asthma to pneumonia and pneumonia-like illnesses (eg, Legionnaires' disease) and aggravate pre-existing conditions such as asthma and bronchitis. Toxicological data: No LD50 information available for the product.	
ECOLOGICAL INFORMATION	
Ecotoxicity: Contain – prevent from entering sewers, waterways and/or groundwater.	
DISPOSAL INFORMATION	
Disposal methods: Dispose of this product by using in accordance with the product label directions. Packaging disposal – Dispose of packaging in accordance with the product label directions or empty packaging; wrap in paper, place in a plastic bag and dispose safely with domestic rubbish. If wastes and/or packaging cannot be disposed of according to the product label directions or instructions above, disposal must be in accordance with your local area regulatory authorities following all applicable regional, national and local laws and regulations.	

TRANSPORT INFORMATION	
Not classified as a Dangerous Good for Transport.	
REGULATORY INFORMATION	
EPA New Zealand Approval Code: Based on available information, not classified as hazardous according to criteria in the HS (Minimum Degrees of Hazard) Regulations 2001.	
OTHER INFORMATION	
Date of preparation of Safety Data Sheet:	November 2017.
Abbreviations in Safety Data Sheet:	EPA: The Environmental Protection Authority of New Zealand. LD50: Lethal Dose-50%. The doses of a chemical that will kill 50% of the test animals receiving it. WES: Work place exposure standard set by EPA or NZ Department of Labour Health & Safety.

SCHEDULE 2 RECOMMENDED TEST METHODS

There are several analytical methods for contaminants and pathogens. The following methods (or updates where available) are recommended:

Campylobacter: Either

- a) AgResearch Meat Industry Microbiological Methods (2011). Chapter 7 Testing Meats and Meat Products for Pathogens Section 7.3 – Thermotolerant *Campylobacter*. Edition 5 (Abbreviated as MIMM 2011)
- b) ISO 10272-1:2017 Microbiology of food and animal feeding stuffs - Horizontal method for detection and enumeration of *Campylobacter* spp. - Part 1: Detection method

Emergent Organic Compounds (EOCs): All of the chemicals can be analysed by GCMS after different extraction techniques. Refer CIBR report (Northcott, G, 2017) for comments on extraction techniques and reporting protocols. At the time of authoring not all tests were available in New Zealand laboratories.

Enteric Viruses: Specific test method

Adenoviruses are a group of enteric viruses transmitted by the faecal–oral route and are recognised as one of the more persistent enteric viruses when subjected to environmental stresses such as temperature, visible light and UV irradiation. Adenoviruses occur in high numbers in sewage and sludges. Adenoviruses were proposed as the sentinel virus for UV irradiation of wastewater effluent (USEPA, 2003) and virus contamination of shellfish (Pina, Puig, Lucena, Jofre, & Girones, 1998). Adenoviruses are proposed here as an indicator of virus persistence in biosolids.

The recommended methodology requires detection of infectious adenovirus by culture in a susceptible cell line followed by PCR detection (culture-PCR). The combined use of culture and molecular methods allow detection of those adenoviruses that do not produce clearly observable cytopathic effect (CPE), avoids misinterpretation of CPE caused by other viruses or non-infectious material, and only detects infectious viruses.

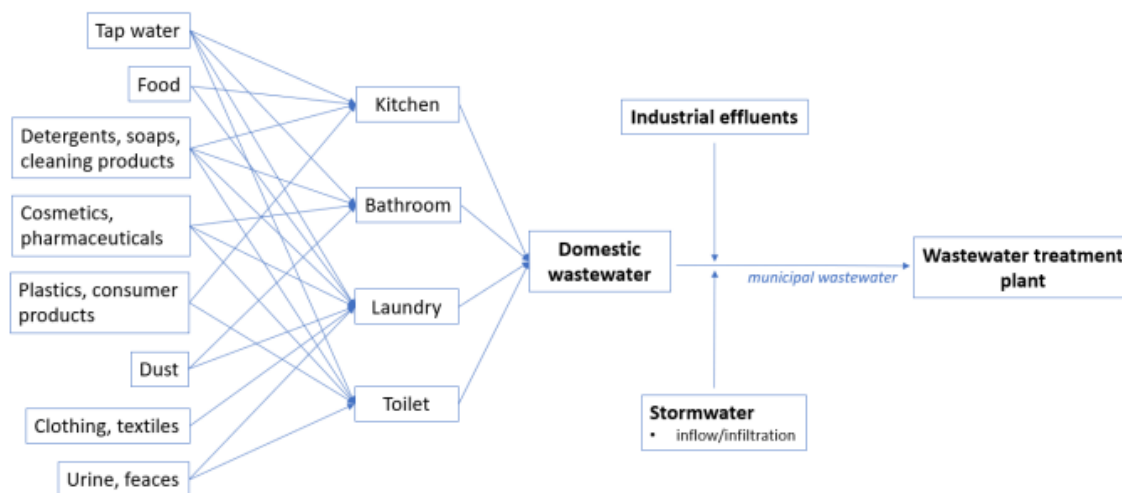
The method for their detection as described in the 2003 version of the Guidelines for the Safe Application of Biosolids to Land in New Zealand has been modified (by Joanne Hewitt, ESR). The amended method should include the addition of a PEG precipitation step for virus concentration, use of culture-PCR using HEK-293 cells with a generic adenovirus PCR or qPCR assay that will detect all adenovirus types (Lewis & Metcalf, 1988) (Chapron, Ballester, Fontaine, Frades, & Margolin, 2000) (Henroth, Conden-Hansson, Rehnstam-Holm, Girones, & Allard, 2002).

APPENDIX 1 SOURCES OF WASTEWATER TREATMENT CONTAMINANTS

Municipal wastewater can include microorganisms (bacteria, viruses, protozoa, helminths), biodegradable organic materials, nutrients (nitrogen, phosphorus), heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc), detergents and surfactants (alkylphenols), plasticisers (phthalates) pharmaceuticals and personal care products, and various other legacy and emerging organic contaminants (hydrocarbons, chlorobenzenes, pesticides, dioxins, polychlorinated biphenyls (PCBs), flame retardants, solvents, microplastics) (Coxon & Eaton, 2023).

An overview of different classes of contaminants commonly identified in municipal wastewater and/or stormwater is provided in the ESR Review of contaminants of potential human health concern in wastewater and stormwater (Coxon & Eaton, 2023) and reproduced in Table 1. Specific examples of the occurrence of contaminants in each matrix, and of the potential health effects associated with those contaminants, are described in further detail in the report. Sources of the pollutants outlined in the report are shown in Figure 8.

Figure 9: Sources of pollutants to domestic and municipal wastewater systems (Coxon & Eaton, 2023)



It is important to note that contaminants may be present in wastewater and/or stormwater in their dissolved, colloidal or particle-associated forms, which will influence both their fate through these networks (and hence potential human exposure), and their bioavailability (and hence toxicity). The specific metals and their concentrations in wastewater are highly variable depending on the relative contribution of domestic, commercial, industrial and stormwater contributions to the overall wastewater stream (Coxon & Eaton, 2023).

Table 0-1: Overview of contaminant classes present in municipal wastewater and/or stormwater that are of potential concern to human health, with common examples (Coxon & Eaton, 2023)

Contaminant class		Examples	Municipal wastewater	Stormwater
Microbial pathogens		<i>Campylobacter</i> spp. <i>Salmonella</i> spp. Norovirus Adenovirus <i>Cryptosporidium</i> spp. <i>Giardia</i> spp.	✓✓	✓✓
Heavy metals		Arsenic Cadmium Chromium Mercury Lead Zinc	✓✓	✓✓
Perfluoroalkyl substances		PFOA PFAS	✓✓	✓✓
Pesticides	Organochlorine pesticides	DDT Aldrin Chlordane	✓	✓✓
	Organophosphate pesticides	Chlorpyrifos Malathion		
	Carbamate pesticides	Aldicarb Carbofuran		
	Pyrethroids	Permethrin Cyfluthrin		
	Triazines	Atrazine		
	Phenoxy alkonates	2,4-D Mecoprop		
Polycyclic aromatic hydrocarbons		Naphthalene Fluorene Pyrene Benzo(a)pyrene	✓✓	✓✓
Endocrine-disrupting compounds	Plasticisers	BPA Phthalates	✓✓	✓✓
	Corrosion inhibitors	Benzotriazole		
	Surfactants	Nonylphenol		
	Dioxins and dioxin-like PCBs	TCDD PCB-138		
Brominated flame retardants	Polybrominated diphenyl ethers	BDE-47 BDE-99 BDE-153 BDE-209	✓✓	✓
	Polybrominated biphenyls	BB209		
	Hexabromocyclododecanes	HBDC		
	Tetrabromobisphenol A	TBBPA		

Contaminant class		Examples	Municipal wastewater	Stormwater
Pharmaceuticals and personal care products	Antibiotics	Trimethoprim Sulfamethoxazole Ciprofloxacin	✓✓	✓
	Analgesics and anti-inflammatories	Acetaminophen Naproxen Diclofenac Ibuprofen		
	Steroids and hormones	17 β -estradiol		
	Other prescription medications	Clofibric acid Atenolol Carbamazepine Gemfibrozil		
	UV filters	Benzophenone Camphor		
	Parabens and other preservatives	Methyl paraben 2-phenoxyethanol		
	Fragrances	Galaxolide Tonalide		
	Disinfectants	Triclosan Triclocarban		
Microplastics			✓✓	✓✓

✓✓ - Are consistently detected and/or at high concentrations.

✓ - Are detected less frequently and/or at low-level/trace concentrations.

Sources of metals in domestic (ie, household) wastewater may include the water supply itself, faeces (reflecting dietary intake and pharmaceutical use), detergents and washing powders, personal care products (toothpastes, shampoos, dental amalgam), household dusts, leaching or corrosion of plumbing systems, cleaning of metal cookware, pigments in paints and cosmetics, pesticides, and various other household chemicals. Industrial effluents are a key source of heavy metals where they are discharged to municipal wastewater networks as trade wastes and stormwaters (Coxon & Eaton, 2023).

Table 0-2: Concentrations of selected heavy metals ($\mu\text{g/L}$) in untreated municipal wastewater reported in international studies (Coxon & Eaton, 2023)

Country	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Reference
France			0.6	9	65	650			12	18		Buzier et al. (2006) [*]
Italy	786 $\pm$ 46%	4 [*]	<LOD	8.1 $\pm$ 11%	9.9 $\pm$ 56%	515 $\pm$ 29%	1.5 $\pm$ 58%			8 [*]	348 $\pm$ 31%	Carletti et al. (2008) [#]
Italy	1,940 $\pm$ 8%	<LOD	8.7 $\pm$ 13%	56.4 $\pm$ 24%	9.8 $\pm$ 44%	361 $\pm$ 10%	0.7 $\pm$ 8%			8.6 [*]	1,233 $\pm$ 20%	Carletti et al. (2008) [#]
Poland			20		100					50	450	Chipasa (2003)
France	1,300 Max. 3,400	1.0 Max. 1.5	0.2 Max. 0.4	15 Max. 70	75 Max. 110	600 Max. 1,500			20 Max. 90	8 Max. 15	200 Max. 400	Choubert et al. (2011)
China		6.2 $\pm$ 4.8 Max. 95	15 $\pm$ 9 Max. 78	170 $\pm$ 64 Max. 650			0.67 $\pm$ 1.5 Max. 38			160 $\pm$ 100 Max. 940		Du et al. (2020)
UK		12	1.7	35	300		2.5		40	600	290	Goldstone et al. (1990a, 1990b, 1990c)
India		1.12 $\pm$ 0.66 Max. 2.22		3.5 $\pm$ 1.3 Max. 5.5	14.2 $\pm$ 13.9 Max. 38	235 $\pm$ 56 Max. 298			4.1 $\pm$ 1.8 Max. 6.5	0.18 $\pm$ 0.09 Max. 0.31	19.8 $\pm$ 4.3 Max. 26.9	Joshua et al. (2017)
Greece			3.3 $\pm$ 1.1	40 $\pm$ 12	79 $\pm$ 35	480 $\pm$ 87		67 $\pm$ 12	770 $\pm$ 200	39 $\pm$ 9.4	470 $\pm$ 140	Karvelas et al. (2003)
Spain			5 Max. 5				0.37 Max. 0.37		47.5 Max. 107.6	2.5 Max. 17.6		Teijon et al. (2010)
Turkey	1,891 $\pm$ 872 Max. 3,753		19 $\pm$ 40 137	1,086 $\pm$ 509 2,120	60 $\pm$ 43 Max. 179	1,975 $\pm$ 712 3,580		126 $\pm$ 33 Max. 217	100 $\pm$ 41 Max. 202	84 $\pm$ 100 Max. 385	533 $\pm$ 209 Max. 982	Üstün et al. (2009)

Data are shown as mean values, with standard deviation and maximum concentration shown where that data was available. LOD – limit of detection.

^{*}only one sample above LOD; ^{*} combined sewer network; [#] data shown as mean $\pm$ variation coefficient; ⁻WWTPs receiving municipal or municipal and hospital effluent.

Wastewater treatment plants are not designed to remove metal contaminants, although some metals will be removed through their association with particulate matter and partitioning to the solid phase of treatment systems, so that sewage sludge becomes a temporary sink. Overall, approximately 80-90% of heavy metals may accumulate in sludge, though this may vary widely between technologies used in different countries and contexts, and some metals have much lower removal efficiencies (eg, arsenic and cobalt may be less than 20%) (Coxon & Eaton, 2023).

APPENDIX 2 EXAMPLE OF MASS LOADING CALCULATION

EXAMPLE BIOSOLIDS APPLICATION RATE (MASS LOADING CALCULATION) FOR RESTRICTED USE BIOSOLIDS

ASSUMED BIOSOLIDS DETAILS

Total nitrogen content of biosolids (dry matter)	2 % w/w	Item [1]
Maximum agronomic total nitrogen application rate	200kg TN/ha/yr	Item [2]
Nitrogen limited biosolids application rate	10 dry tonnes/ha/yr	Item [3] = Item [2] / (Item [1] * 10)
Moisture content of biosolids	64 %	Item [13]
Maximum actual application rate	15.6 wet tonnes/ha/yr	Item [14] = Item [13] * Item [3]

ASSUMED SOIL DETAILS

Soil bulk density	1.0 dry tonnes/m ³	Item [4]
Soil depth	200 mm	Item [5]
Incorporated soil mass per hectare (dry tonnes/ha)	2,000 (dry tonnes/ha)	Item [6] = Item [4] * Item [5] * 10

CHECK CONTAMINANTS

Contaminant	Soil limit or ceiling concentrations (mg/dry kg) (Item [7])	Soil contaminant concentration measured in situ (mg/dry kg) (Item [8])	Available capacity of soil to assimilate contaminants (mg/dry kg) (Item [9]) = Item [7] - Item [8])	Biosolids contaminant concentration (mg/dry kg) (Item [10])	Contaminant limited biosolids total application (dry tonnes/ha) (Item [11]) = Item [6] * Item [9] / Item [10])	Limited rate per application to reach soil contaminant limit over 20 years* (dry tonnes/ha/year)	Years of application before soil limits are reached if applied at maximum nitrogen rate (Item [12]) = Item [11] / Item [3]
Metals							
Arsenic	17	4.1	12.9	8	3225	161	323
Cadmium	0.8	0.08	0.72	2	720	36	72
Chromium	200	16	184	125	2944	147	294
Copper	95	16	79	359	440	22	44
Lead	160	11	149	85	3506	175	351
Mercury	1	0.1	0.90	4	450	23	45
Nickel	60	9	51	45	2267	113	227
Zinc	180	48	132	867	304	15	30
PFOS+PFHxS		Refer to the PFAS NEMP (Heads of EPA Australia and New Zealand (HEPA), 2025)					
PFOA							

*assuming no system losses

The overall limit on biosolids application rates will be whatever is lowest of the Nitrogen limited biosolids application rate [Item 3] or the contaminant limited biosolids total application rate [Item 11] or PFAS limited application rate. Refer to Section 13.2 for a process of determining which applies.

APPENDIX 3 TREATMENT PROCESS OPTIONS

Biosolids producers have access to a wide range of treatment processes to enable them to meet the different stabilisation grades of biosolids recommended in this Guide. Some of these processes are effective at reducing both pathogens and vector attraction, whereas others may be better at one or the other. In the latter case, it may sometimes be necessary to combine different treatment processes to ensure that the final product achieves a specific stabilisation grade. These treatment processes do little to change the mass of contaminants, but concentrations may increase due to reductions in volatile solids, and/or decrease due to the addition of chemicals (eg, lime).

There are five broad approaches to controlling pathogens in biosolids:

- High temperatures
- Radiation
- Chemical disinfectants
- Reducing volatile organic content
- Removing moisture.

Within these five approaches there are several different processes and technologies, some of which can be categorised under more than one approach. These processes and the approaches they are based on are briefly discussed below.

PASTEURISATION

Pasteurisation involves heating the sludge to a temperature of 70–80°C for approximately 30 minutes. This treatment will reduce the number of pathogens, but it cannot be considered a stabilisation process in its own right and is usually used in conjunction with other processes, such as mesophilic digestion.

Pasteurisation can be achieved by using heat exchangers or steam injection. In theory, the addition of quicklime (an exothermic or heat-producing reaction) could result in pasteurisation, but this is a difficult process to control as it requires thorough mixing. Odour can be an issue with pasteurised biosolids because the process does not stabilise organic matter but increases the soluble volatile content.

IRRADIATION

Irradiation of sewage sludge reduces pathogens by disrupting their cell content, which either destroys the organism or prevents it from reproducing. The irradiation used can be gamma or beta ray-based, and its effectiveness relates to the length of dose applied to the sludge. Though irradiation is commonly used as a pathogen-reduction technique in several countries in Europe, it is not used in the United States or New Zealand.

LIME STABILISATION

Lime stabilisation of sewage sludge to form biosolids works by raising the pH to 12 or more, which has the effect of destroying or inhibiting the pathogens present. However, the effectiveness of this treatment process is related to the length of time the pH is constantly above 12. Lime can be added to liquid sludge or to dewatered sludge, but effective treatment depends on adequate mixing of the lime with the sludge to ensure the pH is raised uniformly. The addition of lime to sludge also has the benefit of increasing the level of dry matter present and making handling of the final product easier.

The main problem associated with lime stabilisation is the development of odours if the pH falls below 10.5. This is particularly an issue following land application. Soil incorporation of the biosolids as part of the application process can overcome this.

Lime stabilisation is effective in reducing bacteria and viruses as well as reducing vector attractant properties. Protozoan cysts may be inactivated, but the addition of lime is not thought to be effective on helminth ova, unless combined with heat (USEPA, 1999).

COMPOSTING

Composting is an aerobic process, which involves mixing treated sludge with a co-product such as sawdust, green waste or wood chips³. The co-product provides a source of carbon, increases porosity (and therefore oxygen flow) and absorbs moisture. Heat generated as a result of the aerobic biological activity that takes place destroys the pathogens in the sludge.

Organic material will compost on its own over time without any control, but the use of composting as a biosolids treatment process must be carefully designed, controlled and managed to ensure appropriate time/temperature criteria are achieved throughout the process. There are three types of composting process.

- **Windrow** – the sludge/co-product mixture is placed in long rows, which are turned periodically to introduce air, reduce moisture levels and maintain even temperatures.
- **Aerated static piles** – the sludge/co-product mixture is laid over perforated pipes, through which air is blown or sucked. This introduces oxygen, which aids decomposition and also reduces moisture. If the air is sucked through the compost rather than blown it can also help odour control.
- **In-vessel systems** – there are many different types of vessel system in use, but all operate under carefully controlled conditions, including active aeration.

Composting, if done under the right conditions, is effective at reducing bacteria, viruses, helminth eggs, protozoa, vector attraction and odour. Composting also reduces the water content in the final product to as much as 60% dry matter, which makes handling much easier and results in a commercially attractive product.

Windrow composting may not be as effective at pathogen reduction as in-vessel and aerated static pile composting.

While pathogen and VAR can be achieved without a curing process, such a process can enhance odour reduction.

ANAEROBIC DIGESTION

Anaerobic digestion is undertaken in closed tanks in the absence of oxygen and with or without additional heating. There are two types: high-rate, which involves mechanical mixing and heating of the sludge, and standard-rate, which is generally conducted at ambient temperature with no mechanical mixing. The majority of plants use high-rate digestion. Both types of anaerobic digestion result in a reduction of volatile solids of between 40 and 50% (according to (European Commission, 2001) and between 35 and 60% (according to (USEPA, 1999). This reduction in volatile solids reduces the likelihood of regrowth of pathogens after treatment.

Depending on how the system is managed, anaerobic digestion can be operated in either a mesophilic (>35°C) mode or a combination of thermophilic (> 50°C) mode followed by mesophilic mode.

Methane is a byproduct of anaerobic digestion, and this can be recovered and used to heat the process, thus reducing costs. Anaerobic digestion reduces bacteria, protozoa and viruses, though viable helminth eggs may not be significantly affected.

AEROBIC DIGESTION

Aerobic digestion of sludge is carried out in either open or closed vessels. To supply enough oxygen to the bacteria in the sludge, the mixture either has to be agitated or have air injected into it. Heat is generated when the bacteria present break down organic matter to carbon dioxide, nitrate nitrogen and water. Depending on how the system is managed, aerobic digestion can operate in either the mesophilic or thermophilic temperature ranges. If operated correctly, aerobic digestion can result in a 40% reduction of volatile matter in the mesophilic range, and up to a 70%

³ Treated timber must not be used as a co-product

reduction if thermophilic aerobic digestion is used. It is also effective at reducing bacteria, protozoa, viruses and helminth eggs, though the latter is more effective at the higher temperatures associated with thermophilic aerobic digestion.

The operation of an aerobic digester can either be batch or continuous. The length of time the sludge needs to remain within the digester for effective pathogen reduction, irrespective of the process used, is based on the temperature the process is operating at.

THERMAL AND AIR DRYING

In air drying, the sludge is applied to a sand or gravel bed and allowed to dry naturally over a period of months. During drying, biological processes take place, such as decomposition of organic matter, formation of ammonia and reduction in moisture, which in turn reduce bacteria, protozoa and viruses. Viable helminth eggs may also be reduced if the drying temperature is high enough, but this is dependent on the species involved, as some are much hardier than others.

Air drying is a simple process, but it requires a lot of land and is dependent on ambient temperatures for its effectiveness (higher temperatures are better). A dry matter content of up to 50% can be reached depending on local climatic conditions (European Commission, 2001). Sludge should also be partly digested before it is applied to the drying bed. The USEPA (USEPA, 1999) has recommended that air drying be used as an additional process to aerobic or anaerobic digestion to meet the 38% volatile solids reduction requirement.

In thermal drying, sludge is dried by direct or indirect contact with heat. If conducted properly this has the effect of reducing bacteria, viruses, protozoa and viable helminth eggs. It is also effective at VAR, provided the biosolids remain dry after treatment.

There are four main types of thermal driers: flash, spray, rotary and steam. All operate at different temperatures, and as a result the percentage of dry matter in the final product can range from 35% to 90%. This type of treatment process results in a product that is greatly reduced in volume from the raw sludge, and can be applied to land like a mineral fertiliser.

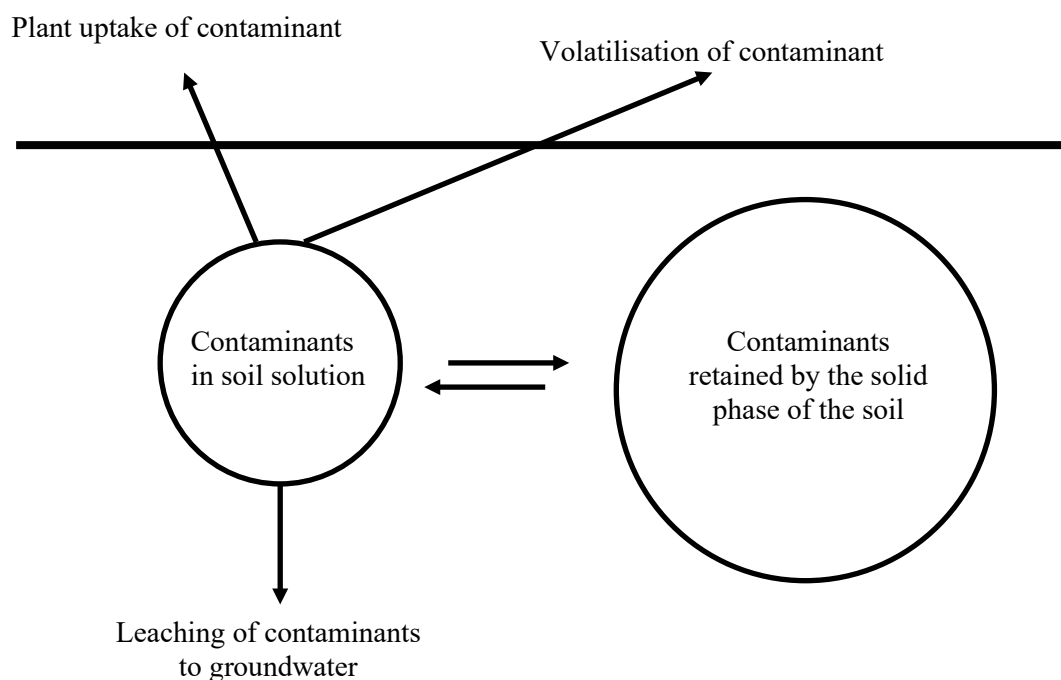
APPENDIX 4 SOIL CHARACTERISTICS AND INTERACTION WITH BIOSOLIDS CONTAMINANTS

The interaction and fate of contaminants in biosolids applied to the soil are fundamental to the short- and long-term effects of biosolids use. This appendix is reproduced from the 2003 Guide. It summarises the behaviour of contaminants in soil in sufficient detail to enable the user to understand the issues and complexities. It also discusses the effects of land management practices on contaminant uptake and mobility.

Contaminants can be involved in many different reactions and processes in the soil, but their ultimate fate can be summarised as shown in Figure 9. Essentially, biosolids-derived contaminants can:

- React with and become retained by the solid phase of the soil
- Be volatilised into the atmosphere as a result of various physical, chemical and biological transformations
- Be taken up by plants
- Be leached out of the soil into drainage water
- Be removed in soil ingested by grazing animals
- Be transported to another location in surface runoff.

Figure 10 Simplified depiction of the fate of contaminants in the soil



Not every contaminant is subject to all the above processes, and in some cases a single process may dominate the fate and potential adverse effects of a contaminant. For example, most metals are not subject to volatilisation losses, and the fate of nitrogen is often dominated by leaching from the soil.

RETENTION PROCESSES

Contaminants entering the soil, whether metals or organic compounds, are subject to numerous chemical and biological processes that have implications for contaminant bio-availability and mobility. Some of the most important processes are those responsible for the accumulation of contaminants in the solid-phase components of the soil, processes collectively referred to as

“contaminant retention”. Metals or organic chemicals retained by the soil are generally considered to be less bio-available and mobile than those remaining in the soil solution.

METAL RETENTION

EXCHANGEABLE METALS

Metals that occur as cationic species might be expected to take part in normal cation exchange mechanisms in the soil (ie, non-specific, electrostatic attraction of cations to negatively charged soil colloids). Similarly, metals that occur in anionic forms may interact with anion exchange sites. However, it seems unlikely that ion exchange is a particularly important mechanism for the metallic elements (Swift & McLaren, 1991); (Barow, 1999). The concentrations of major nutrient ions (eg, Ca^{2+} , Mg^{2+} , K^+ , NO_3^- , SO_4^{2-}) in the soil solution are several orders of magnitude greater than those of the metals. Thus, mass action (competition) effects should prevent the occurrence of significant concentrations of metals on exchange sites, except in grossly contaminated soils. This is confirmed by the observation that only extremely small concentrations of exchangeable metals are determined in soils using standard techniques of extraction; ie, extraction with salt solutions (Tiller, Honeysett, & De Vries, 1972) (McLaren & Crawford, Studies on soil copper. I: The fractionation of copper in soils, 1973) (Shuman, 1979).

METALS SPECIFICALLY SORBED BY INORGANIC SOIL COLLOIDS

The sorption of trace metals by inorganic soil colloids, such as alumino-silicate clays and iron, aluminium and manganese oxides and hydroxides, are considered to occur mainly by specific sorption mechanisms (Swift & McLaren, 1991). This means that the soil colloid shows a preference for the sorbed substance, so that metal ions such as Cu^{2+} or Zn^{2+} may be sorbed despite the presence of much higher concentrations of Ca^{2+} or Mg^{2+} (Barow, 1999). Unlike the mechanism of ion exchange that involves electrostatic bonding only, specific sorption involves the formation of a stable chemical bond between a trace element ion and certain functional groups at the surface of the soil colloid. Evidence for the formation of these bonds has been obtained by both indirect and direct methods (McBride, 1989). However, it should be appreciated that as a result of the large number of chemical species, surfaces and bonding mechanisms involved, specific sorption processes in soil are extremely complex.

METALS COMPLEXED OR CHELATED BY ORGANIC COLLOIDS

As with inorganic colloids, soil organic colloids are able to bind substantial concentrations of metals, and with some metals (eg, copper) the bonds formed are very strong. It is generally assumed that bonding is the result of complex formations involving the various functional groups (carboxyl, hydroxyl, etc) found in soil organic matter in general, and humic substances in particular (Stevenson, 1982). Where ring structures are formed by this type of reaction, the element is said to be chelated. The complexation of trace metals by organic colloids can also be regarded as an example of a specific sorption mechanism.

METALS OCCLUDED BY, OR AS STRUCTURAL COMPONENTS OF, SECONDARY MINERALS AND OTHER INORGANIC COMPOUNDS

Trace elements sorbed on to the surfaces of iron, aluminium and manganese oxides may eventually be occluded by further growth of the oxides. Alternatively, metals may be substituted in the structures of oxide minerals during their formation in soils. For example, there is good evidence for the substitution of trace metals in the structures of a range of iron oxides and oxyhydroxides (Giles & McKenzie, 1988) (Cornell & Schwertmann, 1996) (Gilkes and McKenzie, 1988). In some cases, it may also be possible that metals are precipitated in the form of simple inorganic compounds such as carbonates, phosphates, sulphides or hydroxides. However, this is most likely to happen only in heavily contaminated soils, under waterlogged or high pH conditions, or in calcareous soils. For most soils there is little evidence for the existence of such compounds (Swift & McLaren, 1991).

FACTORS AFFECTING METAL RETENTION

SOIL COMPOSITION

Since metals are retained predominantly by soil organic matter, soil oxides and clay minerals, those soils with high contents of these constituents will have a larger capacity to retain metals. Conversely, soils with low organic matter, low oxide and low clay contents are likely to have a limited ability to retain metals.

SOIL PH

Numerous studies have examined the effect of pH on metal retention processes. In general, it has been observed that pH has a profound effect on metal retention behaviour by all major soil constituents (Swift & McLaren, 1991). For example, metal retention by soil organic matter increases substantially from pH 2 to 6 (Kerndorff & Schnitzer, 1980) (McLaren & Crawford, Studies on soil copper. II: The specific adsorption of copper by soils, 1973) (McLaren, Lawson, & Swift, Sorption and desorption of cobalt by soils and soil components, 1986). Similarly, for those metals occurring as cations, retention by inorganic soil constituents (oxides and clay minerals) also increases with an increase in soil pH.

For metals or metalloids occurring as anions, the picture is more complex (eg, molybdenum, selenium and arsenic). In some cases, retention of these metals decreases with an increase in pH (eg, (Hingston, Posner, & Quirk, 1972), and in other cases retention increases to a maximum and then decreases with a further increase in pH (eg, (Smith, Naidu, & Alston, 1999). The exact nature of the pH effect in these cases will be determined by factors such as the types of soil constituent involved and the presence of co- or competing ions.

SOIL REDOX CONDITIONS

Redox (reduction–oxidation) conditions affect metal retention in two main ways. Firstly, under waterlogged, anaerobic conditions oxides of iron and manganese become reduced and are solubilised, releasing any bound metals back into solution. Secondly, a small group of metals or metalloids (arsenic, selenium and mercury) are capable of being volatilised from the soil under reducing conditions.

CONTAMINANT VOLATILISATION

Under anaerobic conditions, both bacteria and fungi have the ability to transform arsenic into volatile forms, predominantly dimethylarsine and trimethylarsine gases (Tamaki & Frankenberger, 1992). Similarly, selenium volatilisation from soils can occur as a result of microbial methylation reactions (Haygarth, 1994). Numerous bacteria and fungi appear to be responsible for this process, and the main volatile species produced is the non-toxic dimethyl selenide (Frankenberger & Losi, 1995).

Mercury, like arsenic and selenium, can also undergo microbial methylation reactions in the soil to produce methyl mercury species (Kabata-Pendias & Pendias, 1984). Another naturally occurring process is microbial reduction of mercuric ions (Hg^{2+}) to elemental mercury (Hg^0), which can then be volatilised from the soil. There is good evidence that Hg can be volatilised from soils contaminated with a variety of mercury-containing materials, including municipal sewage sludge (Carpi & Lindberg, 1997).

Some organic compounds (eg, some pesticides) will also volatilise, a process determined predominantly by the solubility and vapour pressure of the particular compound. In addition, all organic molecules will undergo some biological and/or chemical decomposition or transformation in the soil. For those organic compounds that are easily decomposed, their retention in the soil will not be a major issue. However, for the persistent pesticides, PCBs and dioxins that are addressed by this Guide, they decompose only extremely slowly and, as they are not lost by volatilisation or leaching to any significant extent, they will be retained in the soil for considerable periods of time (years to decades).

The nitrogen added in biosolids can also be lost from the soil to the atmosphere through volatilisation as ammonia (NH_3), or by denitrification, predominantly in the form of nitrous oxide (N_2O), but also possibly as nitric oxide (NO) and nitrogen gas (N_2) (McLaren & Cameron, *Soil Science: Sustainable Production and Environmental Protection*, 2nd edition, 1996). Some biosolids are rich in ammonium-N, and substantial volatilisation of ammonia gas may take place immediately following application to the soil, particularly under conditions of high pH and with surface applications. Denitrification is most likely to take place under wet, anaerobic conditions.

CONTAMINANT BIO-AVAILABILITY

METAL BIO-AVAILABILITY

To be available for uptake by plants (or soil micro-organisms), metals must be present in the soil solution. Solution metal concentrations are controlled in two main ways:

- By the solubility of solid-phase compounds containing the metal of interest
- By sorption/desorption reactions at the surfaces of soil colloids.

Solubility of their respective oxides is probably the main factor controlling solution concentrations of aluminium, iron and manganese but for all other trace metals, sorption/desorption reactions are likely to be the major types of mechanism involved (Swift & McLaren, 1991). Those trace metals present in the crystal structures of primary and secondary silicate minerals, or occluded by oxides (unless soil conditions favour their dissolution), will clearly be unavailable for plant uptake.

To a large extent, metal concentrations in the soil solution will be inversely related to the metal retention properties of the soil solid phase; that is, the greater the retention, the lower the metal concentration in solution. Thus, any factor that affects metal retention (see above) will also affect metal solution concentrations (eg, pH and soil composition).

However, other factors may also influence solution metal concentrations and hence bio-availability. For example, the role of the soil biomass, though by no means clear, is likely to be important. Only small amounts of trace metals will be present in the biomass, but the release of decaying organic materials and the continual cycling of trace metals through the soil microbial population could have a significant effect on maintaining solution metal concentrations.

CHEMICAL SPECIATION OF TRACE METALS IN THE SOIL SOLUTION

There is considerable evidence that the chemical speciation of trace metals in solution affects their availability and/or toxicity to plants (Parker et al., 1995) (Parker, Chaney, & Norvell, 1995). For example, many studies have shown a high level of correlation between plant uptake of trace metals and the activity of free, uncomplexed metal ions in solution, such as Cu^{2+} (Graham, 1981) and Cd^{2+} (Cabrera, Young, & Rowell, 1988), rather than with total metal concentrations. Such studies have been interpreted as demonstrating that complexed forms of trace metals in solution are unavailable for plant uptake. However, other studies have suggested that this is not necessarily the case. For example, (DeKock & Mitchell, 1957) demonstrated increased uptake of aluminium and other trivalent metals by chelators such as EDTA and DTPA. More recently, (Smolders & McLaughlin, 1996) and (Wegglar-Beaton, McLaughlin, & Graham, 2000) have demonstrated that Cl-complexed Cd may also be available for plant uptake (in addition to Cd^{2+}).

The importance of complexed trace metal species for plant uptake from soils is difficult to assess at this stage. Much of the research has been carried out in solution cultures rather than in soil. Whether some complexed species are indeed taken up by plants, or whether complexation can enhance availability primarily by increasing the diffusion of trace metals to plant roots, remains to be determined.

SOIL PH

Soil pH is recognised as having a major influence on the availability of trace metals. For those trace metals that occur predominantly as cations (e.g., Cu^{2+} , Co^{2+} , Pb^{2+}), their availability to plants is highest in acid soils, and decreases as the soil pH increases. Conversely, those trace metals such as arsenic, molybdenum and selenium that occur as anions are most available in soils of high pH and least available in acid soils.

The influence of soil pH on trace metal availability is due mainly to its effect on the reactions controlling trace metal concentrations in the soil solution. Under acid conditions, sorption of trace metal cations by soil colloids is at a minimum and, thus, solution concentrations are relatively high. In addition, the solubilities of iron and manganese oxides are high under low pH conditions. As the soil pH rises, the sorption of trace metals increases and the solubility of oxides decreases. The sorption of those metals that occur in anionic forms decreases with increasing soil pH, and hence solution concentrations and their availability increase.

A complicating factor with certain trace metal cations (e.g., Cu^{2+} and Pb^{2+}) is that as soil pH increases, metal solubility reaches a minimum between pH 6 and 7 and then rises again at even higher pH (eg, (McBride & Blasiak, Zinc and copper solubility as a function of pH in an acid soil, 1979) (Bruemmer, Gerth, & Herms, 1986). This is mainly due to increased solubility of organic matter at high pH, causing the retention of trace metals in solution in the form of soluble organic complexes. However, as discussed above, the extent to which trace metals occurring as complexes will be available for plant uptake is unclear.

METAL DESORPTION

The immediate bio-availability of trace metals depends primarily on their concentration and speciation in the soil solution. However, continuing bio-availability depends on the soil's ability to release trace metals from the solid phase to replenish those removed by plant uptake. It is now generally accepted that in the medium to long term, solution concentrations of trace metals are most likely to be controlled by sorption–desorption reactions at the surfaces of soil colloids (Swift & McLaren, 1991).

Desorption of soil-retained trace metals shows a variety of trends, depending on the nature of both the surface and the trace metal being studied. These trends range from (a) complete desorption to (b) significant desorption, but with a proportion of trace metal retained, to (c) minimal desorption, with a high proportion retained by the surface. Many trace metals fall into category (c), appearing to be strongly retained by soils and showing limited reversibility of sorption (desorption).

As with sorption, desorption of trace metals from soils is affected markedly by soil pH. In particular, desorption of both native (ie, naturally occurring) and applied trace metals has been observed to decrease with increasing soil pH (eg, (McLaren, Singh, & Cameron, Influence of pH on the desorption of native and applied zinc from soils, 1997) (Gray, McLaren, Roberts, & Condon, 1998)).

AGEING EFFECTS

The issue of whether the bio-availability of contaminant metals added to soils decreases with time is somewhat contentious, particularly in relation to metals added in biosolids. However, there is good evidence from laboratory studies using simple metal salts that increasing the contact time between soil and added metal can decrease the metal's subsequent ability to desorb from the soil (Barrow, 1986) (Hogg, McLaren, & Swift, 1993) (Gray C. , McLaren, Roberts, & Condon, 1998). Such findings have been linked to observations that following the initial rapid sorption of metals by soil oxide materials, continuing slow reactions between the metal and the oxides take place (Benjamin & Leckie, 1981) (Bruemmer, Gerth, & Tiller, Reaction kinetics of the adsorption and desorption of nickel, zinc and cadmium by goethite. I: Adsorption and diffusion of metals, 1988). Whether such processes involve solid diffusion of metals into the lattice structure of oxides (which would be expected to be extremely slow) or diffusion of ions into very small pores and inter-particle spaces remains to be determined (McBride, Processes of heavy and transition metal sorption by soil minerals, 1991).

Whatever the mechanism, there is evidence to link such slow reactions with decreased availability of metals to plants. For example, Brennan et al. (Brennan, Gartrell, & Robson, 1980) have reported reduced copper availability to plants with increasing contact time between added copper and the soil. Similar observations have been made by (Brennan, Reaction of zinc with soil affecting its availability to subterranean clover. II: Effect of soil properties on the relative effectiveness of applied zinc, 1990) in relation to the availability of zinc to plants. More recently, (Hamon, McLaughlin, Naidu, & Correll, 1998) have produced evidence that cadmium added to soils in superphosphate fertiliser becomes less bio-available with time. These researchers estimated that cadmium was being fixed very slowly in non-bio-available forms at a rate of 1–1.5% of the total cadmium added per year. This observation is supported by the work of Gray et al. (Gray C. , McLaren, Roberts, & Condon, 1999), who, using a sequential fractionation technique, determined that a substantial proportion of cadmium applied to a soil in superphosphate over a 44-year period had been incorporated into a residual soil fraction. (McLaren & Ritchie, 1993) have made similar observations in relation to the long-term fate of copper in soil.

The evidence referred to above suggests that the bio-availability of metals, in simple forms and at relatively low levels of contamination, may well decrease significantly over time. However, with metals added in biosolids the picture is far from clear. Research in this area has been discussed in detail by (Smith S. , 1996). In summary, whereas some studies have indicated a decrease in metal bio-availability with time after biosolids application has ceased, others have not. A major complicating factor with biosolids studies is that in addition to metals, large amounts of organic matter are also added to the soil, sometimes along with substantial quantities of other inorganic materials. The effect of the decomposition of this organic matter and the presence of inorganic metal sorbents on the long-term bio-availability of metals is probably the major issue facing sludge researchers at present.

BIO-AVAILABILITY OF ORGANIC CHEMICALS

Compared with research on metals in biosolids, comparatively little work has been done on the fate of the organic chemicals present in such material. However, O'Connor et al. (O'Connor, Chaney, & Ryan, 1991) carried out a detailed review of the bio-availability to plants of sludge-borne toxic organics. They concluded that the vast majority of these chemicals in sludges occur initially in sludge-amended soils at low concentrations and are so strongly sorbed in the sludge–soil matrix as to have low bio-availabilities to plants. In addition, the large size of many organic molecules precludes their uptake by plants.

CONTAMINANT MOBILITY

Contaminants added to soil in biosolids can be mobilised by two main processes: surface runoff and leaching downwards through the soil profile. Surface runoff involves bulk movement of material (biosolids or a soil/biosolids mixture) and associated contaminants over the surface of the land in water that is unable to infiltrate readily into the soil. If such material finds its way into surface water bodies (eg, streams), serious contamination of the water may result.

Leaching through the soil profile is probably more complex and difficult to control and occurs because water moving through the soil generally transports any dissolved solutes with it. These solutes may be trace metals, organic molecules or nutrient ions, such as nitrate nitrogen, all of which are added to the soil in biosolids applications. In some cases, such transport can result in the pollution of groundwater.

PRINCIPLES OF SOLUTE TRANSPORT

Solute movement occurs through a combination of three main mechanisms: convection, diffusion and dispersion (McLaren & Cameron, Soil Science: Sustainable Production and Environmental Protection, 2nd edition, 1996). Convective transport results from the movement of solutes with the mass flow of water in soil and can be described by a modified form of Darcy's Law. Convective transport is often referred to as "piston displacement", and the distance of transport per unit time depends on the average pore water velocity. In reality, the solute does not remain as a sharp band

but tends to spread throughout the profile due to the processes of diffusion and hydrodynamic dispersion.

Diffusion occurs when there is an uneven distribution of solutes in a solution, causing a diffusive flux of solute from areas of high concentration to areas of lower concentration. Hydrodynamic dispersion is caused by the mechanical action of a solution flowing through soil, which tends to cause mixing and equalises the solute distribution. This process enhances the dispersive effect of diffusion and during flow it usually completely masks it.

Hydrodynamic dispersion occurs because (i) the flow velocity within a single pore is not uniform, (ii) the large variation in pore size in soil causes an extremely wide range of pore water velocities, and (iii) the tortuosity of pores results in a range of flow path lengths (McLaren & Cameron, *Soil Science: Sustainable Production and Environmental Protection*, 2nd edition, 1996).

Solute transport is also affected by a number of other factors, including macropore effects, reactivity with and transformations in the soil, and plant uptake of solutes. Earthworm activity, root growth, freezing and thawing and wetting and drying cycles can lead to the development of surface-connected macropores in the soil. Water flow through these pores can have two distinct effects on leaching:

- When water is applied immediately after a solute, macropore flow may lead to extensive leaching at a faster rate than normal
- When solutes are present within aggregate micropores they may be bypassed by the bulk of the flowing water and thus protected from leaching.

Reaction of solutes with the soil may also reduce the rate of leaching. Cations (including metals), which are adsorbed by soil surfaces, are generally less prone to leaching than non-adsorbed anions, such as nitrate and sulphate. Some solutes are also involved in biological transformation processes that can either decrease (immobilisation) or increase (mineralisation) solute concentrations. Plant uptake of solutes decreases their concentration in the soil solution and therefore reduces their rate of leaching loss from the soil.

NUTRIENT LEACHING

Although the nutrient elements present in biosolids (eg, nitrogen, sulphur, phosphorus, potassium, calcium and magnesium) are considered beneficial for plant growth, some of them can be regarded as contaminants if they leach into groundwater. The main element in this category is nitrogen, which in the form of nitrate (NO_3^-) is extremely mobile and has a high potential for leaching. Indeed, in the short term, the potential for nitrate to leach is the main limitation on the amount of biosolids that can be applied to the soil. Applying amounts of nitrogen in excess of crop requirements is likely to result in increased concentrations of potentially leachable nitrogen in the soil.

Phosphorus contamination of water is also a potential problem in relation to eutrophication, though little research has been reported on phosphate leaching from biosolids-amended soils. There is no doubt that phosphorus is likely to accumulate in soils that receive repeated applications of biosolids, and the implications of this in relation to phosphate leaching require attention. There is currently considerable concern worldwide regarding the build-up of phosphate in soils as a result of inorganic fertiliser applications, with the realisation that phosphate leaching from such soils may be environmentally significant (Haygarth & Jarvis, 2000).

LEACHING OF ORGANIC CHEMICALS

There is little data on the leaching of organic chemicals from biosolids-treated soils. However, for the organochlorine pesticides, PCBs and dioxins, their extremely low water solubility and strong binding ability with soil means they are unlikely to be measured in groundwater. However, it should be noted that some pesticides are known to be reasonably mobile in the soil and have the potential to contaminate groundwater.

LEACHING OF METALS

With some exceptions, trace metals tend to be sorbed relatively strongly by soils, and only small concentrations are present in the soil solution. They are therefore generally considered to be rather immobile in soils and their leaching down through the soil profile minimal (Dowdy & Volk, 1983) (Ellis, Knezek, & Jacobs, 1983). However, evidence is accumulating that the leaching of both trace metal cations and anions does occur, and in some circumstances may result in significant movement of trace metals down the soil profile and into groundwater.

The suggestion by many researchers that no substantial long-term leaching losses of trace metals occur from surface soils contaminated by biosolids is often based on the observation that little trace metal accumulation is observed in the subsoil. For example, studies by Chang et al (Chang, Warneke, Page, & Lund, 1984) and Williams et al (Williams, Vlamis, Pukite, & Corey, 1985) both showed that despite large applications of sewage sludge to soils, most trace metals did not appear to move below the depth of sludge incorporation. However, this assumption ignores the possibilities that (i) drainage leachate may move through preferential flow channels in the subsoil, thus bypassing most of the soil mass, and (ii) sorption of some trace metals in the subsoil may be minimal due to the dominance of organically complexed or colloid-associated forms.

The possibility that trace metals might be transported to lower depths in the soil through cracks and macropores has been suggested by (Dowdy, Latterell, Hinsley, Grossman, & Sullivan, 1991). Such a process could be conducive to significant leaching of trace metals without markedly increasing concentrations in the subsoil (Sidie & Kardos, 1977). It is interesting to note that at many sites where trace metals have been added in sewage sludge treatments, mass balances calculated several years after application have been unable to account for all the trace metals applied (eg, (McGrath, 1995). It seems possible that these deficits could be explained, at least in part, by leaching.

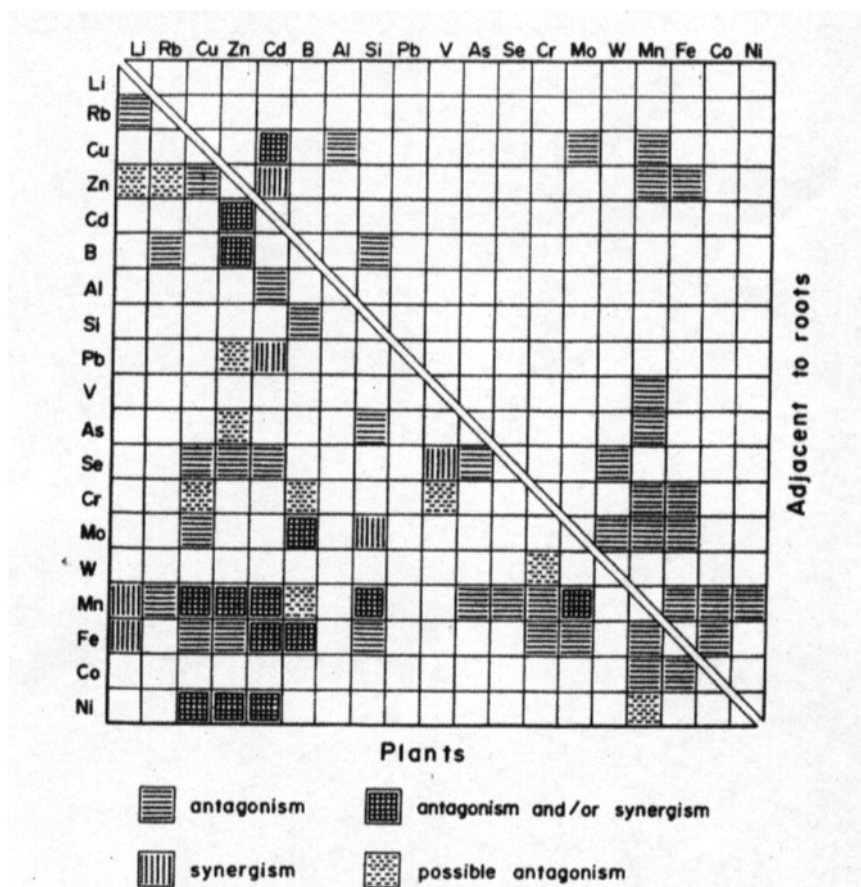
Apart from field study data, knowledge of metal movement through soils is based primarily on studies using homogenised, repacked soil columns (Camobreco, Richards, Steenhuis, Peverly, & McBride, 1996). Such studies, even when using coarse-textured soils, have tended to support the contention that cationic trace metals are basically immobile (eg, (Giordano & Mortvedt, 1976); (Gerritse, Vriesema, Dalenberg, & DeRoos, 1982). However, studies using undisturbed soil columns (or lysimeters) have demonstrated the potential importance of preferential flow for trace metal leaching. For example, Camobreco et al (Camobreco, Richards, Steenhuis, Peverly, & McBride, 1996) compared the movement of cadmium, zinc, copper and lead through undisturbed and homogenised soil columns. The homogenised columns retained all added metals, whereas substantial amounts of all four metals were present in the effluent from the undisturbed columns.

More recently, (McLaren & Gray, LEJV Biosolids Compost Trials: Soil and Plant Analysis and Data Interpretation, 1999) have demonstrated increased metal leaching from undisturbed soil lysimeters treated with metal-spiked sewage sludge. In this study there were clear examples of the preferential flow of metals taking place, with increased metal concentrations in leachates occurring well before a pore volume of water had passed through the lysimeters. The study also revealed considerable differences between different soil types in the extent of metal leaching. It should be noted that the amounts of metals leached represented a very small fraction of the metals applied to the soil. Nevertheless, the cumulative effect of several decades of leaching has the potential to substantially influence the concentrations and distribution of trace metals in the soil.

INTERACTIONS BETWEEN CONTAMINANTS

Plants require a balance of elements for their proper growth and development, and imbalance between elements may cause chemical stress. Imbalances may result from both antagonistic and synergistic effects operating within the plant or may influence absorption of elements from the soil. Antagonism between elements occurs when the combined effect of two or more elements is less than the sum of their independent effects, and synergism occurs when the combined effects of the elements is greater. Interaction processes are controlled by several factors and the exact mechanisms are still poorly understood, though some data are available (Kabata-Pendias & Pendias, Trace Elements in Soils and Plants (3rd edition), 2001).

Interactions have been observed between major elements and trace metals, and between different trace metals. However, the interrelationships between elements are extremely complex, being at times both antagonistic and synergistic (see Figure 10), and often difficult if not impossible to predict. Unfortunately, many of the studies in which metal interactions have been observed have been carried out under conditions, or at metal concentrations, that have little practical relevance.



Source: Kabata-Pendias and Pendias, 2001 (Kabata-Pendias & Pendias, Trace Elements in Soils and Plants (3rd edition), 2001)

Figure 11 Interactions of trace elements within plants and adjacent to plant roots

IMPLICATIONS OF METAL INTERACTIONS FOR BIOSOLIDS APPLICATIONS

When recommendations for the regulation of zinc, copper and nickel in biosolids-amended soils were first established in the UK (Chumbley, 1971), they implied that the phytotoxic responses of these three metals were additive (the zinc equivalent concept). However, subsequent experimental work has suggested that the toxicity to these metals was not additive but acted independently for each metal below the critical plant tissue concentration values (Beckett & Davis, 1982). Certainly, subsequent reviews of research in this area have concluded that synergistic interactions between trace metals are not commonly observed (eg, (Smith S. , 1996) (Kabata-Pendias & Pendias, Trace Elements in Soils and Plants (3rd edition), 2001).

In contrast, antagonistic effects are likely to be more common. In particular, zinc is commonly documented as being a competitive inhibitor of the plant uptake of cadmium (eg, (Chaney & Oliver, 1996). Since zinc concentrations in biosolids are usually much higher than cadmium concentrations, the antagonism between these metals is generally regarded as likely to restrict plant uptake of excessive cadmium. Other antagonistic reactions may also occur between iron, manganese, copper and zinc (Kabata-Pendias & Pendias, Trace Elements in Soils and Plants (3rd edition), 2001), but would appear to be impossible to predict.

One type of interaction that takes place in soil may be of particular significance for biosolids applications. It has been proposed that the iron, manganese and aluminium present in biosolids may be oxidised in the soil to form oxide or hydrous oxide minerals (if not already present in these forms), which are then capable of adsorbing other metals, thus reducing their solubility, mobility

and bio-availability (Corey, et al., 1987). Some data from long-term biosolids plots have indeed been interpreted in this way (Chaney & Oliver, 1996). However, data for New Zealand sewage sludges (Ogilvie, 1998) would suggest that iron, manganese and aluminium concentrations are generally not high enough for such an effect to be significant.

APPENDIX 5 SUPPORTING RESOURCES

The following reports were commissioned to support the development of the Guide. They provide further detailed information on content contained in the report and supporting rationale for many of the Guide's recommendations.

Iwi and community considerations		
Community Engagement Framework (Baker, et al., 2016)	Provides a framework to assist waste producers and regulators undertake effective consultation with communities with respect to organic materials such as biosolids, which provides: - A process for integrating technical and social factors into the reuse of organic materials - A mechanism to identify issues of local significance as well as diverse community concerns and interest	February 2016
Tapu to Noa - Māori cultural views on human biowaste management (Ataria, et al., 2016)	Designed to support local government staff and engineers to better understand and incorporate Māori world views into biosolids management. The document discusses cultural frameworks from a generic perspective to provide insight, language and context to help non-Māori have confidence in asking the right questions in their conversations with hapū and iwi. The document does not represent all Māori views and does not replace the need for local consultation.	March 2016
Pathogen considerations		
CIBR Publication 010 Organic Material Guidelines - Pathogens Review (Hewitt, July 2014)	- Summarises existing knowledge on potentially pathogenic organisms in organic wastes - Reviews the justification for the inclusions of selected pathogens - Reviews the recommended detection methods	January 2015
ESR Letter titled: Submissions on first draft of Organic Materials Guidelines (Horswell , 2017)	Following public consultation of the first public draft documents, a subsequent review of selected queries was provided by Dr Jacqui Horswell. The letter principally responded to suggestions to shorten the period of time required for stock exclusion	July 2017
Contaminant considerations		
Contaminant Review (Esperschütz & Robinson, August 2014) Organic Waste Guidelines – Trace Element Contaminant Review (Thompson-Morrison, Cavanagh, & Robinson , 2024)	- Summarises existing knowledge on trace element contaminants in organic wastes - Reviews justification for the guidelines on nitrogen (N) loading - Reviews the justification for inclusions of limits for specific trace elements previously listed in the Guide - Determines which trace elements of concern should be included in the Guide	August 2014 Reviewed and

	A revision of the Guide was done in June 2024 to incorporate new understanding of ecological soil guideline values.	updated June 2024
Updates to the Organic Materials Guideline (Cavanagh, Thompson-Morrison, & Robinson, 2024)	Supporting memorandum outlining updates made to the contaminant review, which outlines advances in knowledge and associated updates to the Trace Element Contaminant Review above	June 2024
Organic Contaminants Review (Tremblay, Gielen, & Northcott, 2014)	- Summarises existing knowledge on the range of organic contaminants in organic wastes, including emerging organic contaminants - Reviews the justification for the inclusion of the Guide's list of organics - Reviews the existing allowable concentrations with supporting recommendations and logic	August 2014
Review and recommendations on the selection of organic contaminants in the draft guideline for the Beneficial Use of Organic Waste Products on Land (Northcott, G, 2017)	Following public consultation of the first public draft documents, a subsequent review of selected queries was provided by Dr Grant Northcott. The letter provides: - A justification for changing the list of organic contaminants - An updated list of organic contaminants for monitoring - Recommended product limits for the new list of organic contaminants - Recommended methodologies for their analysis	August 2017
Updates to the Organic Contaminants Review (Northcott, 2024)	- Updates the review of the selection of organic contaminants and their respective product contaminant concentration limits, undertaken in 2017. - Summarises developments that have taken place in the interim. - Does not recommend any changes to those outlined in the 2017 review.	August 2024
Determining the nutritional and soil conditioning value of biosolids and sewage sludge in Aotearoa New Zealand (Gutiérrez Ginés & Garcés Hernández, 2024)	- Summarises data from 13 wastewater treatment plants servicing 2.5 million New Zealanders - Demonstrates the range of nutrients provided by biosolids - Demonstrates the range of contaminant concentrations and compares them with the current draft Guide values.	September 2024

APPENDIX 6 TYPICAL CONTAMINANT CONCENTRATIONS IN NEW ZEALAND BIOSOLIDS

Data obtained directly from councils was combined in a study (Gutiérrez Ginés & Garcés Hernández, 2024) to provide an overview of typical trace element characteristics, illustrated in the table and figures below. Values for emerging organic contaminants were also collated and are reported in the study, but a key finding was that data was insufficient to provide a robust assessment of typical values.

Table 3: Summary of inorganic contaminant concentrations in sewage sludge and biosolids data from 2020–2025 compiled from 13 WWTP, serving a total population of 2,574,778

Contaminant	Median	95 th percentile ¹	Range	Guideline compliance limit
Arsenic	5.60 (n= 429)	20	2.00 – 39.0	30
Cadmium	0.78 (n=434)	1.8	<0.1 ³ – 3.20	10
Chromium	43 (n=432)	155	2.50 – 280	1,500
Copper	197 (n= 642)	350	15 – 749	1,250
Lead	18 (n=423)	71	1.04 – 317	300
Mercury	0.82 (n= 400)	1.6	<0.01 ³ – 3.30	7.5
Nickel	20 (n= 641)	30	1.0 – 46	135
Zinc	600 (n= 612)	1,700 ²	56 – 6,000 ⁴	1,500

¹ 95% of the observations have a concentration equal or lower than the one in this column.

² High Zn levels are due to a single WWTP. Omitting values from that WWTP results in a 95th percentile of 773 mg/kg.

³ Detection limit for Cd varied among WWTP reports between 0.01 and 0.1, and for Hg between 0.001 and 0.01

⁴ 6000 mg/kg of Zn is an outlier, the next value below this one is 2,200 mg/kg.

Figure 12: Biosolids/guideline index for contaminant results from 2020-2024. Each observation has been normalised by the guideline limits. Different colours represent different WWTP, each point represent a single observation. One observation of 6000.



APPENDIX 7 JUSTIFICATION FOR NITROGEN (N) LOADING RATES IN DIFFERENT APPLICATION SCENARIOS

Current guidelines recommend that biosolids are applied in accordance with the agronomic N needs of crops and assumes all N will eventually become mineralised and hence have potential for leaching as nitrate (Barbarick, Ippolito, & McDaniel, 2010) (Lagae, Langemeier, Lybecker, & Barbarick, 2009) (Sullivan, Bary, Cogger, & Shearin, 2009). Currently there is no regulation of biosolids P application, but because of concerns of effects of repeated applications on soil P and P loss to surface waters, a similar approach was considered as for fertiliser P and manure P application (Lu, He, & Stoffella, 2012).

When using biosolids to rebuild degraded land or low-fertility soil, biosolids are often applied at greater than agronomic rates to build up soil organic matter and improve soil fertility. The required high application rates can exceed guideline values for nutrients, which were set to avoid excessive leaching or runoff into lakes and streams causing eutrophication (Tian, Granato, Pietz, Carlson, & Abedin, 2006). These guidelines take into account these application scenarios with recommendations outlined in 13.2.4. However, the impact and accumulation of Trace Elements after application to either agricultural or degraded land has to be assessed.

Biosolids application in a continual application scenario

Biosolids when applied at agronomic rates can increase grain yields compared to conventional N fertilisation (Koenig, Cogger, & bary, 2011) (Sullivan, Bary, Cogger, & Shearin, 2009), but high rates can also lead to yield loss through waterlogging (Mantovi, Baldoni, & Toderi, 2005) or moisture stress (Cogger, Sullivan, Bary, & Kropf, 1998). Within the European Union, specific directives have been established to ensure correct biowaste application management to avoid excessive runoff and leaching of nutrients into surface water and groundwater (Park, et al., 2011). A continual application of biosolids can increase the soil N supply, which requires an adaption of application rates to avoid N loss in the long term (Cogger, Bary, Kennedy, & Fortuna, 2013) (Hernandez-Soriano, Degryse, Lombi, & Smolders, 2012) (Moss, Epstein, & Logan, 2002) (Uggetti, et al., 2012) (Walter, Cuevas, García, & Martínez, 2000). Active soil testing would provide valuable information for a sustainable management of biosolids at sites with repeated applications, whereas determining residual soil nitrate in the autumn will help guide N application rates at long-term application sites.

In New Zealand, an application rate of 200kg N per ha per year is recommended for pasture. However, this rate is based on plant-available N, and, as stated in the previous *Guidelines for the Safe Application of Biosolids to Land in New Zealand 2003* (Water New Zealand, 2003), application rates should be based on site-specific assessments including climate, soil characteristics, mineralisation rates and agronomic N requirements of the crops. A 2013 study suggested that high agronomic biosolids application rates of between 450kg and 600kg N per ha every two years have resulted in more vigorous vegetative plant growth, which probably led to more rapid soil moisture depletion hence depressing grain yields (Cogger, Bary, Kennedy, & Fortuna, 2013). Effects like this should be taken into account when averaging application rates over several years.

However, for a continuous biosolids application to agricultural productive land, a rate of 200kg N per ha per year still represents an adequate guideline value. According to decreasing mineralisation rates after the first year of application, it is unlikely that the total amount of available (mineralised) N each year, including plant-available N already present in soil, will add up to cause excessive N leaching.

Biosolids applications to rebuild a degraded soil

Depending on its composition and treatment, biosolids can contain high concentrations of nutrients. A soil application of biosolids can restore organic matter and provide nitrogen, phosphorus and

sulphur (Uggetti, et al., 2012). Several studies have demonstrated that biosolids can reclaim degraded lands (Dere, Stehouwer, Aboukila, & McDonald, 2012) (Mbakwe, De Jager, Annandale, & Matema, 2013) (Meyer, Redente, Barbarick, & Brobst, 2001) (Oladeji, et al., 2013) (Speir, Van Schaik, Percival, Close, & Pang, 2003) (Stehouwer, Day, & Macneal, 2006). Large amounts of organic material added via biosolids have been found to promote topsoil development, increase water holding capacity and stimulate microbial activity and nutrient cycling (Stehouwer, Day, & Macneal, 2006). Most N that exists in biosolids is present in organic form, hence unavailable for plant uptake and not subject to leaching (Pu, Bell, Barry, & Want, 2008). To minimise N leaching and runoff, N mineralisation rates need to be estimated.

Biosolids application for reclamation purposes often only requires one single application. After biosolids application to soil, between 15% and 55% of the organic N can be mineralised during the first year after application (Adegbedi & Briggs, 2003) (Binder, Dobermann, Sander, & Cassman, 2002) (Mendoza, Assadian, & Lindemann, 2006) (Robinson, Green, Chancerel, Mills, & Clothier, 2007) (Eldridge, Chan, Xu, Chen, & Barbarchia, 2008) (Vieira, Maia, A. H. N., & Teixeira, 2005). Degraded lands are characterised by a loss of soil organic matter, soil structure and nutrient availability, hence a biosolids application rate based on 200kg total N per ha won't provide enough Nmin to ensure proper plant growth. Conversely, high application rates of between 50-100 tons of biosolids (2500-5000kg total N assuming a biosolids N content of 5%) per ha have been proven suitable for revegetation and long-term plant growth (Hearing, Daniels, & Feagley, 2000), but excessive N can be lost from these systems via leaching (Dere, Stehouwer, Aboukila, & McDonald, 2012) (Stehouwer, Day, & Macneal, 2006).

However, mineralisation rates are highly dependent on the composition of biosolids on the one hand, and the soil properties on the other hand (Pu G. , Bell, Barry, & Want, 2012), making it difficult to determine the appropriate amount of biosolids to be applied unless they are assessed on a case-by-case basis. Generally, in the first year after application, mineralisation rates are 30% for aerobically digested biosolids, 20% for anaerobically digested biosolids and 10% for composted biosolids. These figures may provide a good starting point for further calculations (Hearing *et al.*, 2000). Since the biosolids total N content varies from 1% to 6% depending on its origin and treatment (Water New Zealand, 2003) an application of 50 tons of biosolids per ha could result in either 125kg Nmin per ha or 750kg Nmin per ha, assuming a mineralisation rate of 25% within 12 months after application. Runoff and loss of N via leaching is likely in the latter, but negligible in the first case.

For a more appropriate and safe application of biosolids for reclamation purposes, the revised Guide could allow one-off applications based on a biosolids Nmin value of 150kg Nmin per ha. Further applications can be made with a time-lag of three years and a biosolids application rate of 150kg Nmin less Nmin content measured in soil prior to application. Guidelines should be flexible enough to allow assessments on a case-by-case basis.

APPENDIX 8 KNOWLEDGE GAPS AND FUTURE RESEARCH NEEDS

The pace of change in biosolids management is rapid, driven by an evolving understanding of environmental processes, existing and emerging contaminants, new technologies and shifting cultural norms.

These guidelines are based on the best available information at the time of publication. There remain several gaps in our knowledge that need to be addressed, outlined in this Appendix. Collaboration of researchers and industry professionals in expanding our understanding of these areas will be needed to develop more effective and sustainable management practices.

ALIGNING MĀORI AND WESTERN APPROACHES

Work to bridge western science and indigenous knowledge and practices are needed to advance the beneficial reuse of biosolids in Aotearoa New Zealand, where cultural perceptions are a key barrier to use. To advance our knowledge we need to build our knowledge of;

- how different iwi and hapū perceive biosolids application on land
- how principles of *tapu* and *noa* can be applied to different biosolids production processes (including emerging advanced thermal treatment processes) based on locally appropriate tikanga
- what knowledge-sharing frameworks can be effectively applied to support iwi and hapū in making informed decisions about biosolids management
- how governance frameworks that enable co-management of biosolids projects with tangata whenua can be applied to ensure shared responsibility and alignment with cultural values.

EMERGING CONTAMINANTS

Emerging contaminant watchlist

It is important that a watching brief is maintained on developments regarding contaminants of emerging concern in sewage sludge/biosolids. Development of a contaminants watchlist would provide a structured approach for prioritising efforts. The Northcote report (Northcott, 2024) that forms the basis of emerging organic contaminant consideration in this guide, provides a starting point that could be used to inform management of freshwater, drinking water, and wastewater effluent streams, by the EPA, Taumata Arowai and Regional Councils.

The European Union's Water Framework Directive (WFD) watchlist (European Commission, 2025) is an international example used to identify emerging pollutants that may pose a risk to aquatic environments but are not yet regulated. It helps prioritize monitoring efforts across member states, guiding future policy.

Antimony

Antimony has become increasingly prevalent in electrical and energy related technologies. Its expanded use mean that is more likely to become a contaminant of concern for biosolids in the future. Surveillance efforts to understand its presence are required to understand if it could pose risks to biosolids receptors.

Laboratory Capacity for Emerging Organic Contaminant Testing

At the time of publishing this guideline no commercial laboratories operating in Aotearoa New Zealand have gained accreditation to test for the priority emerging organic contaminants identified in Section 9.4.1 (nonylphenol and ethoxylates (NP/NPE), phthalate (DEHP), linear alkylbenzene sulphonates (LAS), musks – Tonalide, musks – Galaxolid).

To date all test undertaken on these substances in biosolids in New Zealand have been undertaken by Northcott Research Consultants or sent to international laboratories. Laboratory capability to provide for the commercial testing of these contaminants is needed to enable their management.

Establish New Zealand Health and Ecological Limits In Soils For Priority Emerging Organic Contaminants

A range of studies have been completed on the ecological impacts on the priority emerging organic contaminants identified in Section 9.4.1. However further work is needed to translate these studies into equivalent ecological soil guideline values, to determine appropriate soil limits for their use. Such soil limits are necessary if the mass balance method used to develop product limits for other contaminants is to be applied.

Guidance on applying PFAS NEMP Margins of Safety

In the current form of the draft PFAS NEMP 3.0, the unrestricted biosolids differing concentration limits based on the margin of safety desired. Those looking to determine appropriate limits would benefit from guidance on what margin of safety should be applied in which circumstances.

Management of all forms of PFAS

Currently the PFAS NEMP provides limits for three PFAS: PFOS, PFOA and PFHxS. There are a range of other PFAS not yet covered by this management plan.

Advancing Source Controls for Microplastic Pollution

Management of microplastics in sludges will require prevention of them at their source. A starting point for this would be to build understanding sources of microplastic pollution into treatment plant. For example understanding the relative of contributions of residential versus industrial contaminants could help target effort to prevent microplastic entering sewers to areas with most impact.

Sodium

Sodium has not been regarded as a contaminant of concern in biosolids and accordingly has not been included in contemporary biosolids monitoring programmes in New Zealand. In coastal areas with high infiltration rates, particularly those where saline intrusion into groundwater, there is a potential for increased amounts of sodium to enter our wastewater treatment plants in the future.

Sodium has much less flocculating power to hold clays together than other exchangeable cations (calcium, magnesium and potassium). Clays can be mobilised to block soil pores. When looking at soil, not only must the absolute amount of sodium in the soil be considered, but also the proportion of sodium to all exchangeable cations. An exchangeable sodium percentage (ESP) above 15% (w/w) is of concern as it can cause soil clays to deflocculate. Calcium is the most common cation present in NZ soils and has a strong influence on the ESP. Calcium (and magnesium) leaching can be increased by adding effluent with a high proportion of potassium and/or sodium because a soil has only a limited number of sites to store exchangeable cations and adding potassium and/or sodium increases competition for those sites. As the amount of calcium decreases over time, the ESP increases. Monitoring biosolids for sodium is needed to confirm if these issues require further examination.

PHOSPHOROUS MANAGEMENT

The build-up of phosphorous (P) in soils, particularly in areas with a long history of receiving effluents, is a significant issue that requires further investigation. This concern extends beyond biosolids to encompass all biowaste and effluents. Initial research in the USA has explored limiting biosolids and effluent applications to agriculture based on P rather than nitrogen (N). However,

there is a pressing need for additional research within the New Zealand context to develop a robust knowledge base for phosphorous management recommendations.

Preliminary findings indicate that P accumulation becomes problematic in regions where effluents, especially from municipal and dairy factory sources, have been applied at high rates over extended periods (more than 20-30 years). Projections by the University of Canterbury suggest that P accumulation in soils receiving municipal effluent may only become an issue after approximately 30-50 years. While this implies that new areas receiving biosolids are unlikely to face immediate problems, it is a consideration that will become increasingly relevant.

Further research is essential to understand the implications of effluent application on P accumulation and to translate these findings to biosolids management. One of the main challenges is that limiting applications based on P will necessitate N supplementation, which can be complex in practice. Additionally, since P is not always in excess, determining whether to base application rates on N or P can be challenging.

The following graph (not published) illustrates the range of N:P ratios in plants, biosolids, and effluents analysed by the University of Canterbury, suggesting a decent overlap between the N:P ratios provided by biosolids/effluents and the needs of various plants.

DEVELOPMENT OF FOR BIOSOLID END USERS

End user focused support for biosolid use

Expanding on the types of land that could benefit from biosolids application and providing more accessible end user guidance could support biosolids uptake, and enable its safe use. Such guidance would benefit from further information on;

- Benefits that could be obtained from biosolids application in a variety of settings (such as cropping, forestry, land rehabilitation)
- Further describing suitability of biosolids for these applications
- More accessible resources on timing and management strategies for matching biosolids to crop applications
- Considerations for nutrient management plans that provide guidance on factors such as temperature and timing of application.

Move focus from median soil characteristics to soil type

The current limits have been determined based on the soil assimilation capacity using median characteristics of New Zealand soils. An approach that reflects new Zealand soils would be more user-friendly and account for different soil characteristics. For example;

- Some soils contain minerals well suited for holding some contaminants (but not all contaminants).
- Some soils lack the capacity to bind or otherwise treat contaminants, e.g. raw sands.
- Smearing can occur if heavy machinery is run over wet or vulnerable soils.
- Soil microorganisms already present in the soil can utilise nutrients and organic contaminants, while nutrients should enhance plant growth – but only if the soil is kept well aerated.
- Biosolids consist of a range of particle sizes. Very fine particles can block soil pores. Fine pores in the soil filter out particles very effectively, but become stopped up by them, reducing the rate of percolation leading to increased surface flooding (and unintentional transport of biosolid materials).

Physical effects of biosolids application

It has been suggested that multiple applications of biosolid, especially within short times, can lead to accumulation and potentially negative physical effects for soils such as crusting/pore blockage etc. Further work is needed to;

- Understand what biosolids characteristics lead to negative effects for soils
- Determine appropriate mitigations to avoid these.

GUIDANCE ON ADVANCED THERMAL TREATMENT PROCESSES

Conventional methods for biosolids treatment are the focus of this guideline, but it is well known and understood that other disposal pathways are immediately available for consideration by the market. Further work needed to develop guidelines for these technologies, which result in products different nutrient and contaminant characteristics and so require alternate considerations to enable their safe application.

SETBACK DISTANCES

Setback distances in these guidelines have been based on equivalent requirements for similar activities. The dairy effluent guidelines (Dairy NZ, 2015), were used as a starting point for most setback distances, supplemented with consent requirements from previous biosolids disposal consents, and bore setbacks for drinking water consents. These were then edited with regional council planning staff to support implementation.

Risks for biosolids are likely to differ from these characteristics, and also for stabilised and un-stabilised biosolids. Setback distances could be refined to be more representative of biosolid risks using either modelled or measured approaches.

GUIDANCE ON REPRESENTATIVE SAMPLING PROTOCOLS

The current sampling regimes proposed do not provide an indication as to the volume of material each sample should represent. For smaller operations/producers this quantity of sampling may be considered excessive, and for much larger operations/producers the results may be so sparse that they are not considered a good indicator of the overall product quality. Alternative references have been provide to advice on the development of representative sampling plans. This guideline would benefit from further exploring sampling requirements to ensure product representativeness.

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GLOSSARY

Agricultural land: Horticultural, cropping and pastoral land.

Agronomic rate: The agronomic rate for biosolids application is designed to provide the amount of nutrients needed by a crop or vegetation to attain a defined yield, while minimising the amount of nitrogen that will pass below the root zone of the crop or vegetation to the groundwater.

Beneficial: In the context of organic material applied to productive land, the product must improve soil physical, chemical or biological health.

Beneficial reuse: When a material destined for landfill is captured and made into a high-value material or product that will feed into, or benefit, another system or product. For example, transforming food waste into compost, or soil conditioner that will be used to improve the health of the soil to grow food or plant life that will be beneficial to the community or environment.

Bio-availability: The availability of substances for uptake by plant and animal species.

Biosolid: A sewage or sewage sludge derived from a sewage treatment plant that has been treated and/or stabilised to the extent that it is able to be safely and beneficially applied to land. Biosolid is a biowaste product that contains waste material of human origin.

Bulk use: Application of organic waste material to land equalling or exceeding 50m³ by volume per application.

Composting: A product manufacturing process that biologically stabilises organic materials. It is ordinarily an aerobic process taking place at thermophilic temperatures (about 55°C) because of heat released by biochemical transformations.

Contaminant: Any substance (including heavy metals, organic compounds and micro-organisms) that, either by itself or in combination with other substances, when discharged onto or into land or water changes, or is likely to change, the physical, chemical or biological condition of that land or water.

Contaminant concentration limits: The maximum permissible amount of a given contaminant in organic materials or derived products.

Degraded land: Land where there is a decrease in the optimum functioning of soil in ecosystems.

DEHP: The most common member of the class of phthalates used as plasticisers.

Discharger of organic waste products: The party responsible for applying biosolids, manures or derived products to land; the discharge consent holder.

DS: Dry solids.

EMS: Environmental management system.

Grazed land: Land that is being grazed or will be grazed in the next 12 months. Grazed land may have a cover of pasture or fodder crops.

Groundwater: Sub-surface water from which wells or springs are fed; strictly, the term applies only to water below the water table.

Hazard: A hazard is a source or a situation with the potential to cause harm. In the context of this Guide, hazards are used to refer to the ways in which biosolids or other organics could cause harm to human, animal, environmental, cultural or societal health.

Heat drying: A manufacturing process whereby sludges or slurries are dried by direct or indirect contact with hot gases to reduce the moisture content, typically to 10% or lower.

Helminth: Parasitic worm-like invertebrate.

Horticultural land: Land used for process food crops, leaf crops, root crops.

LAS: Linear alkylbenzene sulfonates commonly used in cleaning agents.

Lime stabilisation: A manufacturing process involving the addition of sufficient lime or lime mixtures to raise the pH of the material to 12 after 2 hours of contact.

Manure: Organic matter, mostly derived from animal faeces.

Maturation: The conversion and amendment of the rapidly biodegradable components in the organic material (eg, sludges and manures) to substances like soil humus that slowly decompose. Compost that is insufficiently mature will reheat and generate odours in storage and upon rewetting. It may also inhibit seed germination by generating organic acids and inhibit plant growth by removing nitrogen as it decomposes in the soil.

Monitoring: Monitoring involves the continuous measurement of product parameters, variables, or to track changes over time.

Most probable number (MPN): A sample analysed by dispersion in an extracting solution, by excessive dilution, and then using statistical analysis based on the positive or negative growth for each sample.

NP/NPE: Nonylphenols and nonylphenolethoxylates are surfactants.

Nuisance: Something which is noxious, dangerous or offensive.

Organic product: A good quality product manufactured from a mixture of natural organic material.

Pastoral land: Grazed land, including land used for dairy, beef, sheep and deer production.

Pathogens: Disease-causing micro-organisms such as certain bacteria, viruses and parasites.

PFAS: Per- and polyfluoroalkyl substances (PFAS) are a large, complex group of synthetic chemicals that have been used in consumer products around the world since about the 1950s.

PFOA: Perfluorooctanoic acid is a synthetic surfactant commonly used in the emulsion polymerization of fluoropolymers.

PFOS: Perfluorooctanesulfonic acid is a fluorosurfactant commonly used in stain repellents.

PFU: Plaque-forming unit.

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); increasing values, above 7, indicate decreasing hydrogen ion concentration (alkalinity).

Phyto-availability: The availability of substances (eg, metals, nutrients) for plant uptake.

Phyto-toxic effects: Adverse toxic effects of contaminants on plant growth and development.

Producer of organic products: A person or organisation that either produces organic material by operating a product manufacturing facility (eg, a composting, heat-drying, lime stabilisation or digestion plant) or who manufactures a blended product from organic materials.

Protozoa: Small, single-celled animals including amoebae, ciliates and flagellates.

Receptor: A component of the natural, social or built environment (ie, a human being, water, air or a site of cultural significance) that is affected by the application of biosolids or other organic materials.

Risk A risk exists when there is a hazard present that could cause harm. In the context of this Guide, the magnitude of the risk will depend on the nature of hazards to human, animal, environmental or cultural health, and product quality.

Resource recovery: The selective extraction of disposed materials for a specific next use, such as recycling, composting or energy generation to extract the maximum benefits from products, delay the consumption of virgin resources and reduce the amount of waste generated.

Sampling: A single, or series of single measurements of product provided for analysis. The goal of sampling is to draw valid inferences about the population based on the characteristics of the sample.

Sensitive sites: Sites at which organic material should not be applied due to the ecological, social or cultural values associated with them.

Sewage sludge: The unstabilised organic solid material settled out from domestic and industrial wastewater during the treatment process. It contains pathogens, organic material, nutrients, metals and other chemicals from residential (human waste) and commercial properties, and trade-waste discharges. Sewage sludge is an unavoidable product of wastewater treatment. Untreated sewage sludge would not meet the stabilisation and/or contaminant grades defined in this Guide and cannot be beneficially used without further treatment and stabilisation.

SOUR: Standard oxygen uptake rate.

Testing: Testing in this document refers to an assessment of a product to determine its quality, against predetermined standards outlined in this Guide.

Urban land: Domestic gardens, lawns, public parks and gardens, golf courses, sports fields, turf farming, land rehabilitation.

VAR: Vector attraction reduction (see below).

Vectors: Organisms such as rodents and insects that are attracted to putrescible organic matter and may spread disease by carrying and transferring pathogens.

Vector attraction reduction: Processes by which organic material is treated to remove or reduce substances that attract vectors.

Verified: Independently checked or audited.

Vermicompost: Mixture of vermicast and partly unprocessed organic matter.

Vermicomposting: The use of earthworms to convert organic waste into fertiliser.

Vermicast (also called worm castings, worm humus or worm manure): Solid organic product resulting from the transformation of compostable organic materials in a controlled vermiculture process, which complies with the characteristics of Table 3.1, NZS4454:2005.

Wāhi tapu: Māori sacred site.

Waste: An unwanted or undesired material or substance left over or used inefficiently from a manufacturing process (industrial, commercial, or agricultural operations,) or from commercial activities.

Worm tea (or compost tea): A liquid fertiliser made by steeping finished compost in water.

WSP: Waste stabilisation pond.

WWTP: Wastewater treatment plant.