BS ISO 19698:2020

BSI Standards Publication

Sludge recovery, recycling, treatment and disposal — Beneficial use of biosolids — Land application

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National foreword

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Valorisation, recyclage, traitement et élimination des boues — Utilisation bénéfique des boues d'épuration — Épandage

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Contents

Page

Foreword ... **vi**
Introduction ... **vii**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **1**
4 Benefits of biosolids land application ... **4**
5 Nutrients in biosolids ... **5**
5.1 General ... 5
5.2 Nitrogen ... 5
5.2.1 General ... 5
5.2.2 Nitrogen content and availability in biosolids ... 5
5.2.3 Determination of biosolids application rate according to nitrogen content ... 6
5.3 Phosphorus ... 6
5.4 Potassium ... 6
5.5 Calcium ... 6
5.6 Sulfur ... 6
6 Nuisance and risks associated with biosolids land application ... **7**
6.1 General ... 7
6.2 Odours ... 7
6.3 Vector attraction ... 7
6.4 Pathogens ... 7
6.4.1 General ... 7
6.4.2 Viruses ... 8
6.4.3 Bacteria ... 8
6.4.4 Protozoa ... 8
6.4.5 Helminths ... 8
6.5 Trace elements ... 9
6.6 Organic compounds ... 9
6.6.1 General ... 9
6.6.2 Source control of potential contaminants ... 9
6.7 Environmental considerations ... 10
6.7.1 General ... 10
6.7.2 Climate and season ... 10
6.7.3 Topography ... 10
6.7.4 Protection of water sources ... 11
6.7.5 Identification of sensitive uses and associated setbacks ... 11
6.8 Biosolids treatment ... 11
6.8.1 General ... 11
6.8.2 Foreign matter ... 12
6.8.3 Odour reduction ... 12
6.8.4 Vector attraction reduction ... 13
6.8.5 Pathogen reduction ... 13
6.9 Biosolids quality criteria — Groups of biosolids ... 15
6.9.1 General ... 15
6.9.2 Group 1 biosolids ... 15
6.9.3 Group 2 biosolids ... 15
6.10 Potential uses ... 15
6.11 Biosolids and soil monitoring ... 16
7 Biosolids application programme development and management ... **16**
7.1 General ... 16
7.2 Community consultation ... 16
7.2.1 Involving the community ... 16

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AVA Documents
Document Sharing Hub
Full document details: BS ISO 19698:2020

7.2.2 Consultation principles ... 17
7.3 Programme development ... 18
7.3.1 General ... 18
7.3.2 Programme design and decision considerations ... 18
7.4 Programme management ... 19
7.4.1 General ... 19
7.4.2 Programme management considerations ... 19
7.4.3 Biosolids and soil monitoring ... 21
7.4.4 Continuous improvement ... 24
7.4.5 Voluntary agreement and quality assurance ... 24

8 Objectives of agricultural land application ... 26
8.1 General ... 26
8.2 Agronomic considerations ... 26
8.2.1 Nitrogen management — General ... 26
8.2.2 Nitrogen in biosolids ... 26
8.3 Phosphorus management ... 30
8.3.1 General ... 30
8.3.2 Determination of biosolids application rate according to phosphorus content ... 30
8.4 Annual biosolids application rate ... 31

9 Storage, staging, fencing and signage ... 31
9.1 General ... 31
9.2 Signage ... 32

10 Haulage and field deliveries ... 33

11 Application techniques ... 33

12 Specific pathogen mitigation measures for agricultural land application ... 34

13 Record keeping ... 34
13.1 General ... 34
13.2 Spreading records ... 35
13.3 Field inspection ... 35

14 Objectives of land reclamation ... 36
14.1 General ... 36
14.2 Site management ... 37
14.2.1 General ... 37
14.2.2 Soil/substrate properties ... 37
14.3 Environmental considerations ... 38
14.3.1 Climate and season ... 38
14.3.2 Topography ... 38
14.3.3 Protection of water sources ... 39
14.3.4 Identification of sensitive uses and associated buffer zones ... 39
14.4 Operations management ... 39
14.4.1 Site preparation ... 39
14.4.2 Biosolids batch management and transport ... 40
14.4.3 Substrate sampling ... 41
14.4.4 Substrate analysis ... 41
14.5 Biosolids applications equipment and considerations ... 42
14.6 Determination of biosolids application rate ... 43
14.6.1 General ... 43
14.6.2 Biosolids application rates based on agronomic nitrogen application rate ... 43
14.6.3 Biosolids application rates based on maximum nutrient loads ... 43
14.6.4 Biosolids application rates based on target carbon to nitrogen ratio (C:N) ... 43
14.6.5 Biosolids application rates based on target organic matter ... 44
14.6.6 Biosolids application rates based on target pH adjustment ... 44
14.7 Revegetation ... 45
14.8 Environmental post application monitoring ... 45
14.8.1 General ... 45

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AVA Documents Document Sharing Hub
Full document details: BS ISO 19698:2020

14.8.2 Soil monitoring ... 46
14.8.3 Water monitoring ... 46
14.8.4 Foliage monitoring ... 47
14.9 Quality assurance ... 47

15 Nuisance and risk management for biosolids use for land reclamation ... 47

16 Biosolids treatment ... 47
16.1 Biosolids quality criteria ... 47
16.2 Pathogens ... 48
16.3 Vector attraction ... 48
16.4 Odour ... 48
16.5 Fencing and signage ... 48
16.6 Record keeping ... 48

Annex A (informative) **Soil carbon dynamics ... 49**

Annex B (informative) **Benefits of biosolids land application ... 51**

Annex C (informative) **Average concentrations of organic matter and plant macronutrients in biosolids ... 54**

Annex D (informative) **Comparative pathogen and indicator limits for Group 1 biosolids ... 55**

Annex E (informative) **Source of trace elements in wastewater and biosolids and examples of trace elements standards in biosolids and in soil after biosolids application ... 56**

Annex F (informative) **Standards for maximum concentration of organic compounds in biosolids ... 62**

Annex G (informative) **Organic compounds ... 63**

Annex H (informative) **Setbacks (buffer zones) in different regions ... 64**

Annex I (informative) **Biosolids quality based on treatment method ... 66**

Annex J (informative) **Determination of plant available phosphate ... 67**

Annex K (informative) **Determination of maximum biosolids application rates based on trace elements ... 68**

Annex L (informative) **Examples of source control/pollution prevention tools and regulating industrial discharges ... 73**

Annex M (informative) **Biosolids sampling frequencies ... 74**

Annex N (informative) **Soil and biosolids tests and methodologies ... 75**

Annex O (informative) **Community consultative workshop ... 82**

Annex P (informative) **Benefits and value of biosolids use in rehabilitation ... 84**

Annex Q (informative) **Examples of restricted activities and withholding periods for Group 2 biosolids ... 85**

Annex R (informative) **Revegetation ... 86**

Bibliography ... 87

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Documents
Document Sharing Hub
Full document details: BS ISO 19698:2020

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 275, *Sludge recovery, recycling, treatment and disposal*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Biosolids are organic–based materials from industrial or municipal sludge and municipal biosolids derived products, in the form of solids, semi–solids, semi–liquids, and liquids which have been treated to meet applicable standards, guidelines or requirements including the reduction of pathogens, vector attraction and contaminant criteria.

The land application of biosolids, which is considered an integrated approach to sustainable management of this resource, can be beneficial in many ways such as:

— increasing soil organic matter;

— increasing biological activity in soil;

— decreasing soil bulk density and improving soil porosity;

— improving water infiltration rate, water holding capacity and erosion prevention;

— improving soil aggregate stability;

— increasing cation exchange capacity, which can result in a lower frequency of fertilizer application;

— increasing soil pH;

— providing additional nutrients to the soil for plant growth;

— recovering phosphorus from the urban and industrial environment;

— providing potential for carbon sequestration in soil; and

— decreasing the use of mineral fertilizers and related greenhouse gas (GHG) emissions related to production and application of mineral fertilizers.

This document does not prioritize, or suggest a hierarchy amongst various beneficial use options, but aims to identify and address the different criteria that could be considered to develop a sustainable and environmentally successful land application programme. These criteria include the nature of the treatment process, the selection of an appropriate application site, the method of application, the rate of application and the establishment of protective barriers or setbacks to environmentally and socially sensitive areas such as surface water and residences.

Control of non–beneficial substances, odour and potential risk to human, animal and environmental health are important parts of any beneficial use strategy. These can be managed by employing tools such as point source control, appropriate treatment methods and land–use restrictions.

Application of this document presupposes awareness of applicable legal requirements.

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Sludge recovery, recycling, treatment and disposal — Beneficial use of biosolids — Land application

1 Scope

This document provides guidance on the conditions of beneficial use of biosolids produced from industrial and municipal sludge and municipal biosolids derived products (e.g. composts, growing media) in the production of food and feed crops, energy crops, forestry crops and for the remediation of disturbed sites.

This document applies to biosolids for land application and includes biosolids from wastewater treatment (municipal, industrial and private onsite systems).

This document does not apply to hazardous sludge that originates from wastewater which, due to its nature, physical, chemical or infectious properties, is potentially hazardous to human health and/or the environment during use, handling, storage or transportation and which requires special disposal techniques to eliminate or reduce the hazard.

This document includes:

— general guidelines for the land application of biosolids and biosolids derived products;

— specific guidelines for the land application of biosolids and biosolids derived products for food and feed crop production and for non–food and non–feed crop production (e.g. horticulture, fibre for bio–mass, silviculture, etc.); and

— specific guidelines for the land application of biosolids and biosolids derived products for other beneficial uses (e.g. land reclamation or rehabilitation).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
alkaline stabilized biosolids
biosolids or non–toxic sludge which has undergone alkaline treatment to meet specific requirements for reduction of pathogens and vector attraction

3.2
alkaline treatment
process where biosolids or non–toxic sludge is mixed with alkaline additives to enhance wastewater solids stabilization by increasing the pH of the biosolids up to 12 or higher for a minimum amount of time

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3.3
batch
definite quantity of material manufactured or produced under conditions which are presumed to be uniform

3.4
biocenosis
community of biologically integrated and interdependent plants and animals

3.5
biosolids
organic–based materials from industrial or municipal wastewater sludge and their derived products, in the form of solids, semi–solids, semi–liquids (pasty), and liquids which have been treated to meet specific standards, guidelines or requirements including the reduction of pathogens, vector attraction and contaminant criteria

3.6
cation exchange capacity
measure of the soil's ability to hold positively charged ions (cations)

3.7
compost
organic soil improver obtained by decomposition of a mixture consisting principally of various plant residues, occasionally with organic materials of animal origin, and having a limited mineral content

[SOURCE: ISO 8157:2015, 2.2.8.6]

3.8
composting
natural aerobic biological process, carried out under controlled conditions, which converts organic material into a stable humus–like product

Note 1 to entry: During the composting process, various microorganisms, including bacteria and fungi, break down organic material into simpler substances.

3.9
contaminant
biological, chemical, physical, or radiological substance released to the environment from anthropogenic sources which, in sufficient concentration, can adversely affect living organisms through air, water, soil, and/or food

3.10
dewatered biosolids
biosolids that have undergone a reduction of the water content to produce paste-like biosolids or solid biosolids by the use of one or several technologies, usually by natural or mechanical means

Note 1 to entry: These treatments lead to the production of biosolids whose mechanical characteristics allow a storage in heap on a minimum height of 1 m. As an indication, the dryness obtained is generally within a range between 15 % and 40 % (wet mass).

3.11
foreign matter
material of anthropogenic origin as opposed to natural objects such as sand, stones and wood fibres

EXAMPLE Plastics, glass, metal, small/large or sharp debris.

3.12
industrial sludge
mixture of water and solids separated from various types of industrial wastewater (e.g. food processing plants) as a result of natural or artificial processes and meet specific standards, guidelines or requirements including the reduction of pathogens, vector attraction and contaminant criteria

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3.13
mineralization
final stage of the biodegradation of organic matter or organic substances into carbon dioxide, water and the hydrides, oxides and other mineral salts

[SOURCE: ISO 11074:2015, 3.3.19]

3.14
mesophilic anaerobic digestion
biological conversion of organic matter to biogas and residual solids at temperatures between 20 °C and about 40 °C, typically 37 °C with a mean residence time of 15 to 30 days

3.15
micronutrient
element, such as boron, manganese, iron, zinc, copper, molybdenum, cobalt, and/or chlorine, which are essential, in relatively small quantities, for plant growth

[SOURCE: ISO 8157:2015, 2.1.3.3, modified — Note 1 to entry has been deleted.]

3.16
municipal biosolids
biosolids produced from municipal sludge which has been treated to meet jurisdictional standards, guidelines or requirements including the reduction of pathogens and vector attraction

3.17
municipal sludge
mixture of water and non–stabilized solids separated from various types of municipal wastewater as a result of natural or artificial processes

3.18
organic matter
matter consisting of plant and/or animal organic materials, and the conversion products of those materials

[SOURCE: ISO 11074:2015, 2.1.8]

3.19
organic compound
any of a large class of chemical compounds in which one or more atoms of carbon are covalently linked to atoms of other elements, most commonly hydrogen, oxygen or nitrogen

3.20
plant nutrient
chemical element, which is essential for plant growth

[SOURCE: ISO 8157:2015, 2.1.2]

3.21
sample
part of a defined bulk product taken for the purpose of characterization

[SOURCE: ISO 14488:2007, 3.8]

3.22
setback
buffer
determined distance, sometimes based on risk assessment, that provides protection to environmentally sensitive features such as humans and water

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3.23
sludge
mixture of water and solids originating from various types of wastewater during natural and artificial treatment

3.24
sodium adsorption ratio
measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste

3.25
soil quality
all current positive or negative properties with regard to soil utilization and soil functions

[SOURCE: ISO 11074:2015, 2.1.15]

3.26
stakeholder
person or organization that can affect, be affected by or perceive themselves to be affected by a decision or activity

[SOURCE: ISO 28007-1:2015, 3.6, modified — Note 1 to entry has been deleted.]

3.27
thermophilic anaerobic digestion
biological conversion of organic matter to biogas and residual solids, that takes place between 49 °C and 57 °C

3.28
total organic carbon
TOC
amount of carbon found in an organic compound

3.29
trace element
element present in very low concentrations

3.30
vector
living organism capable of transmitting a pathogen from one organism to another either mechanically (by simply transporting the pathogen) or biologically by playing a specific role in the life cycle of the pathogen

[SOURCE: EPA/625/R–92/013 Revised July 2003: Control of Pathogens and Vector Attraction in Sewage Sludge]

3.31
vector attraction reduction
treatment processes that stabilize and reduce the odours and other aspects of biosolids that attract flies, rodents and other potential vectors

4 Benefits of biosolids land application

The land application of biosolids can be beneficial in many ways including:

— adding organic matter to the soil which can have a positive impact on soil biological activity, soil porosity, soil bulk density, soil water infiltration rate, aggregate stability and cation exchange capacity;

— increased soil organic matter can also reduce soil erosion;

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— potential to increase carbon sequestration in the soil while reducing chemical fertilizer input and greenhouse gas emissions from their production (see Annex A); and

— responsible utilization of essential macro and micro nutrients that could otherwise be wasted.

Alkaline stabilized biosolids, in the context of the many positive soil effects, can also be an economical and effective soil amendment to increase the pH of acidic soils.

The use of biosolids should go through a global assessment taking into account the various factors, in order to ensure the positive effect on crops and soils.

See Annex B for further information regarding benefits of biosolids.

5 Nutrients in biosolids

5.1 General

Biosolids contain organic matter and plant nutrients. See Annex C for average concentrations of organic matter and plant macronutrients in biosolids.

5.2 Nitrogen

5.2.1 General

Growing plants require a continuous source of nitrogen (N), which is an essential component of proteins that build cell material and plant tissue. It is also necessary for other plant functions.

Nitrogen applied to soils in mineral fertilizers, biosolids or other organic amendments is subjected to biochemical and physical processes which form the nitrogen cycle. Inorganic forms of nitrogen are the available forms to plants. All forms of nitrogen can be present in the soil at any point of time, mainly because nitrogen readily shifts from one form to another.

5.2.2 Nitrogen content and availability in biosolids

Nitrogen content and availability in biosolids can vary greatly depending on the source of the wastewater and the treatment process. Biosolids produced from some industrial sludges can have a high content of nitrogen while it is the opposite for others such as paper mill biosolids. Forms of nitrogen that can be present in biosolids include organic nitrogen (i.e. nitrogen bound in organic molecules such as proteins), nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3) and ammonium (NH_4^+).

As plants can only assimilate mineral nitrogen, a primary factor in determining the nutrient value of biosolids should be the mineralization rate of its organic nitrogen. The nitrogen mineralization rate is dependant in part on the sludge treatment process. Other factors that can influence the availability of the nitrogen are intrinsic to the land application sites such as:

— temperature (air and soil);

— moisture;

— soil porosity;

— pH and texture;

— microbial activity; and

— method of application to the land.

Two main mechanisms for nitrogen loss should also be considered:

— volatilisation of the ammonia; and

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— nitrate leaching.

5.2.3 Determination of biosolids application rate according to nitrogen content

The rate for biosolids application should be determined to provide the amount of nitrogen needed by the crop vegetation, or in reclamation scenarios, by the biosolids application management plan, to attain a desired result. For information regarding application rates for reclamation projects see 14.6. Whatever the project target is, special care should be applied to minimize or manage the amount of nitrogen that could be leached below the root zone of the crop, or through the soil to the ground water. Specifics related to nitrogen management on agricultural and non–agricultural lands are further explored in 8.2.2 and 14.6.2.

Biosolids application rates should be adjusted to avoid excess trace elements or phosphorus loading. In such case, if insufficient nitrogen is applied in the biosolids, inorganic fertilizer nitrogen can be applied. The addition of biosolids in a fertility plan adds multiple beneficial aspects.

5.3 Phosphorus

Phosphorus (P) is a macronutrient that is present in many organic materials including biosolids, and is important for healthy plant development. Specifically, phosphorus is needed for plant growth, rigidity of cell walls, and for the development of the root system. Phosphorus is of particular value as it is a limited natural resource.

Phosphorus is present in biosolids in organic and inorganic (phosphate) forms. Organic phosphorus undergoes mineralization through a (bio)degradation process in the soil before plant assimilation. Inorganic phosphorus is often predominant in biosolids[6].

The solubility and availability of phosphorus in biosolids is also dependant on soil pH. Plant available phosphorus is the phosphorus that is in the soil solution or is weakly adsorbed by soil particles and organic matter. Biological wastewater treatment does not change the availability of phosphorus. Nitrogen and phosphorus are found in similar concentrations in biosolids but often crop requirements are significantly lower for phosphorus. Subsequently application rates are based on the most restrictive element: nitrogen or phosphorus.

5.4 Potassium

Potassium (K) is soluble in wastewater and remains in the liquid stream. Therefore, potassium is not typically found in biosolids in high concentrations and the ratios K:N or K:P are much lower than with livestock manures, thus additional potassium can be required through the addition of inorganic fertilizers for soil health and plant growth.

5.5 Calcium

Most biosolids contain concentrations of calcium, approximately 2,1 % – 3,92 % (wet mass), similar to the content in animal manures. When lime is added to biosolids during an alkaline stabilization process, (e.g. 30 % lime addition by dry mass to the biosolids) the calcium content is increased. Applying biosolids at agronomic rates can supply a sufficient amount of calcium to correct deficiencies or the application of alkaline stabilized biosolids may be used to increase the soil pH where necessary or maintain the soil pH within a range that is optimum for plant growth.

5.6 Sulfur

Most biosolids contain sulfur, approximately 0,01 % to 2,42 % of SO_3 (wet mass) which promotes plant growth, development and seed formation. In biosolids, sulfur exists in available and slow–release forms resulting from the oxidation of sulphides and decomposition of organic matter respectively. When biosolids are applied at agronomic rates the sulfur demand of the crops can also be met.

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6 Nuisance and risks associated with biosolids land application

6.1 General

The beneficial use of biosolids can pose potential nuisance and risks which should be considered to help determine appropriate mitigation measures for public health and environmental protection.

Many of the potential environmental and health risks associated with the land application of biosolids are related to storage prior to spreading. These potential risks include:

— flystrike[1)] in stockpiles < 8 weeks aged;

— ground and surface water contamination;

— leaching of contaminants during heavy rainfall events and floods;

— ammonia volatilisation; and

— 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:

— quantity stored;

— biosolids quality;

— length of time biosolids will be stored;

— time of the year (that is, effects of moisture, temperature and wind gradients); and

— storage design and location.

6.2 Odours

Biosolids are an abundant source of food for microorganisms due to the fact that they contain proteins, amino–acids and carbohydrates. The degradation of these energy sources leads to the emission of odorous compounds in organic and inorganic forms such as hydrogen sulfide, mercaptan, ammonia, amines and organic fatty acids. These compounds can be released from biosolids during treatment, storage, transport and spreading, causing trouble with the neighbourhood.

6.3 Vector attraction

Vectors which include insects, rodents and birds can transmit pathogens to human and other hosts, physically through contact, and biologically by playing a specific role in the life cycle of the pathogen. Pathogens in biosolids may pose a risk when they are brought in contact with humans and other susceptible hosts such as plants or animals. Vectors can be attracted to a land application site by odour and the potential for food sources.

6.4 Pathogens

6.4.1 General

Biosolids can contain microorganisms, some of which could be pathogens. The species and concentrations of organisms that are present in biosolids are dependent on the wastewater treatment

1) Flystrike (Myiasis) is often caused by the green bottle fly (*Lucilia sericata*) and related fly species laying eggs on rabbits, sheep and other animals and is used in Australia as a measure for vector attraction reduction effectiveness.

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stream and catchment, as well as the type of treatment. Pathogens can be harmful to animal and human health and may include for example:

— viruses (e.g. adenoviruses, hepatitis, norovirus);

— bacteria (e.g. Salmonella and Campylobacter);

— protozoa (e.g. Cryptosporidium and Giardia); and

— helminths (e.g. Ascaris, Ancylostoma).

The major routes of potential human exposure to pathogens could be:

— air, as land application of biosolids can result in the formation of bio–aerosols;

— direct soil ingestion due to unrestricted access by the public to application sites;

— eating vegetables raw, as some crops are directly in contact with the ground; and

— water, as a consequence of potential run-off and leaching.

6.4.2 Viruses

Various types of enteric viruses can occur in wastewater and biosolids including Hepatitis A virus, Norovirus, and Adenovirus.

6.4.3 Bacteria

Amongst bacterial species that could be found in the biosolids are *Salmonella spp.,* which can be common in the environment with exposure routes including food and water. *Salmonella enterica* can cause gastro-enteritis in humans and could potentially regrow during storage of biosolids.

The presence of *Salmonella spp.* at low levels (or absence) in biosolids along with low levels of faecal indicators such as *Escherichia coli* (*E. coli)* and faecal coliforms should provide a high degree of assurance that other bacterial pathogens such as *Campylobacter spp.* do not present a health risk.

Specific bacterial pathogens that can be prevalent in industrial biosolids are *Campylobacter spp.* from meat processing facilities, or *Listeria spp.* in dairies.

6.4.4 Protozoa

Protozoan pathogens found in biosolids can include *Entamoeba histolytica* (amoebic dysentery), *Giardia intestinalis* (gastro–enteritis), *Cryptosporidium* (gastro–enteritis) and *Balantidum coli* (gastro–enteritis). The protozoan pathogens generally occur as oocysts. They can be less resistant to inactivation compared to helminths ova and are inactivated by heat and/or lime treatment.

6.4.5 Helminths

A wide range of helminths can often be found in biosolids including nematodes (roundworms and hookworms), cestodes (tapeworms) and trematodes (flukes). Helminth ova can be highly resistant to the environmental factors that reduce the numbers of indicator bacteria and enteric virus. Due to their resistance to inactivation, the presence/absence of viable helminth ova may be used as a criterion to evaluate the quality of biosolids to be applied to land. However, measurement of helminth ova is difficult.

For more information on pathogen limits, see Annex D.

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6.5 Trace elements

Trace elements in biosolids come from a variety of sources and their concentrations in biosolids depend on the inputs to the wastewater stream. As rural and urban jurisdictions can have different inputs to the wastewater stream, trace element concentrations in biosolids can differ.

Trace elements including fluoride, manganese, selenium, and boron are naturally present in the environment, in very low concentrations. Other trace elements with heavier molecular weight (known colloquially as 'heavy metals') including chromium, cobalt, nickel, copper, molybdenum, zinc, mercury and cadmium are also naturally present in very low concentrations.

Plant micronutrients are required for optimal crop health, but excess presence should be avoided to prevent detriment to plant health. For example, boron is important for a number of aspects of plant health and development including cell wall integrity, seed development and protein metabolism, however, excess boron can be toxic to many crops.

Long–term increases in trace element concentrations can cause toxicity in plants, with further potential to enter the food chain at concentrations that can cause human and animal toxicity. Migration rates for trace elements are generally low, but are affected by soil pH, where in areas of low pH some are more mobile and/or more bioavailable. Inadvertent, excessive or repeated application in setback areas or in aquifer recharge areas can have long–term health or environmental risk potential.

For information regarding the source of trace elements in biosolids and examples of jurisdictional trace elements standards in biosolids and soil after biosolids application, see Annex E.

6.6 Organic compounds

6.6.1 General

Some of the organic compounds which can be found in biosolids include:

— halogenated compounds such as polychlorinated biphenyl (PCB), polychlorinated dibenzodioxins and furans (PCDD/F), polybrominated diphenylethers (PBDE);

— perfluorinated compounds (PFC) including perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA);

— other organic compounds such as linear alkyl benzene sulphonates (LAS), nonylphenol and nonylphenol–ethoxylates (NP, NPEO), polycyclic aromatic hydrocarbons (PAH), di–(2–ethylhexyl) phthalate (DEHP); and

— antibiotics, personal care products and pharmaceuticals.

These organic compounds can be partially degraded during the wastewater and sludge treatment processes, but many can be found in biosolids depending on their lipophilic characteristics. Concentrations of organic compounds in biosolids can range broadly depending on the influent characteristics and the treatment processes employed (i.e. magnitude can be of 1 or 2 $\log_{10}$).

See examples of standards for maximum concentration of organic compounds in biosolids in Annex F.

NOTE Numerous scientific research and analysis campaigns have been undertaken to quantify these substances in biosolids and to provide a better understanding of their transfer into the environment and the food chain. This information has been used to assess potential risks for animals and human beings when biosolids are applied on land. A synthesis is made in Annex G.

6.6.2 Source control of potential contaminants

Inputs of potential contaminants to the sewer network occur from domestic, commercial or industrial discharges but also from urban run-off.

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Source control is an effective tool to reduce the transfer of potential contaminants into the wastewater treatment system and therefore to improve biosolids quality.

Regarding domestic sources, potential contaminants are most often in direct contact with consumers through the use of detergents or personal care products before being released to the sewer. Therefore, marketing of a new substance or product that could have harmful effects on public health or the environment should be subject to an authorization granted by regulatory authorities like the REACH regulation in the EU. Approval procedure should include a risk assessment to determine the potential impact of the new substance or product on the wastewater treatment process including biosolids quality.

Reductions in domestic discharges of potential contaminants may also be possible through increased public awareness of appropriate waste disposal practices and the provision of accessible waste collection points. Return of unused pharmaceuticals to specific collection points should also be encouraged. Ecolabels and public education should be provided and extended where possible to raise awareness of ecological impacts of various domestic products on urban wastewater.

Industrial or commercial activities as well as hospitals or health establishments are also at the origin of potential contamination of biosolids. Any non-domestic discharge to the sewer should be subject to permission. Consequently, competent authorities should issue requirements on the origins and contents of any non-domestic discharge to the sewer. These requirements shall be integrated, where applicable, into discharge permits that should set quality criteria limits in terms of maximum concentration of potential contaminants and also in terms of their daily flow rates. Compliance with these limits should be monitored on a regular basis.

Concerning urban run-off, the overall mass balance suggests that its contribution to the potential contaminant flows in the wastewater system is generally low in comparison with other sources and discontinuous depending on rainfall episodes.

There are a number of possible measures that can help reduce potential contaminants entry into the wastewater system from run-off. For industrial and other impermeable urban grounds, interception through pre-treatment systems should be implemented to retain contaminants bound to suspended solids. Regular maintenance and inspection of this equipment should be undertaken.

6.7 Environmental considerations

6.7.1 General

The climatic and physical environment in which biosolids are utilized can play a significant role in risk management and the avoidance of nuisance concerns. These factors should be taken into consideration in the development of a sustainable biosolids management programme.

6.7.2 Climate and season

The timing of biosolids application should be considered in relation to the potential for nutrient losses through leaching or runoff. Timing of biosolids application should take into consideration precipitation (rain or snow), season of application and soil moisture.

It is not recommended to apply biosolids when the soil is saturated, snow-covered, frozen or during periods of heavy rainfall, since these conditions will increase the risk of runoff. Application of biosolids during heavy rainfall or on top of snow can increase the risk of nutrient movement/leaching. Precipitation can increase the potential for macropore flow (movement of water through pores in the soil) through previously dry and cracked soil and surface run–off during heavy rainfall or snowmelt.

6.7.3 Topography

Sloping land can increase the potential for surface runoff, surface soil erosion, and subsurface leaching losses, which could lead to adverse surface or groundwater impacts.

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Biosolids may be applied to sloping sites provided any potential for overland flow, surface soil erosion, and subsurface leaching loss is minimal.

Mitigation of adverse effects may be achieved by setting maximum slopes, above which application is prohibited and setting standards that become more restrictive as the slope of the land increases. For example, if a slope is a concern, biosolids application could be subject to a reduced application rate or restricted to fields with crop residue or increased setbacks to surface water.

6.7.4 Protection of water sources

Potential risk of water pollution should be avoided. Key considerations in evaluating a land application area should include:

— depth to groundwater with consideration given to seasonal variations;

— soil and sub–soil hydraulic conductivity;

— proximity to wells, and surface water;

— subsurface/tile drainage; and

— flood potential.

Nitrate leaching should be considered as an indicator of potential groundwater pollution risk that can occur if the amount of available nitrogen in the biosolids applied does not correspond to plant needs or if the biosolids degrade rapidly.

Biosolids use can be prohibited or restricted when the site is located near drinking water catchment areas, or in nitrate vulnerable zones. Extra care should be taken in selecting land application sites in known areas of hydrogeologic sensitivity.

The risks of groundwater pollution are higher on sites where the groundwater level might be very near to the surface or where soil hydraulic conductivity is high, e.g. when dealing with sandy soils.

Jurisdictions can require that buffer strips of a minimum width in which biosolids are not to be applied, are established, along streams, watercourses and other bodies of water.

Buffer width should be determined by run–off risk, but would normally be at least 10 m. In some jurisdictions due to scarcity of water a larger distance of 100 m should be applied. For a range of buffer zones in different regions, see Annex H.

6.7.5 Identification of sensitive uses and associated setbacks

If the land application site is close to a residence or residential area biosolids should meet all applicable odour standards and setbacks. Aspects such as the type of biosolids (odorous or dusty biosolids), application systems (potential aerosol or dust generation due to application method or incorporation), biosolids transport and storage and weather conditions should be evaluated carefully.

Moreover, the residents and other stakeholders potentially affected should be informed.

6.8 Biosolids treatment

6.8.1 General

Biosolids should be stabilized through treatment to applicable standards, to reduce volatile solids, which indirectly result in pathogen reduction and reduced vector attraction potential.

The purpose of stabilization should be to reduce sludge putrescibility, which causes odours. A putrescible product is a matrix which contains organic substances that can be decomposed by microorganisms in the order of days.

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A stabilized sludge is characterized by low putrescibility, i.e. in a treatment process the level of microbial activity has slowed to a point where it will not resurge under altered conditions.

The degree of treatment (e.g. temperature and time) can result in varying grades of biosolids based on the resultant level of indicator organisms such as *E. coli* and percentage volatile solids in the treated biosolids. Accepted treatment practices require a temperature of 35 °C, with a minimum retention time of 30 days, for mesophilic anaerobic digestion, and a minimum temperature of 55 °C, with a minimum retention time of 20 days for thermophilic anaerobic digestion.

High-quality (stabilized) biosolids should have pathogens and vector-attracting compounds, such as volatile solids, substantially reduced or removed.

Various methods to determine the degree of stabilization and hence quality of biosolids exist.

— The BOD_5 to COD ratio can provide a value to define the degree of stabilization. A value lower than or equal to 0,15 is accepted as an indication of sufficient stabilization. The benefit of employing this approach is its validity for both aerobic and anaerobic treatment processes.

— The biological methane potential (BMP) test allows the residual production of biogas from sludge anaerobically treated to be measured and employed to determine stability.

The above methods require a number of days for results to be obtained, however faster assessments are often required for operation and technical/legal control purposes. If that is the case, the volatile solids to total solids ratio may be measured, where reduction of volatile solids content of 30 % to 50 % should be used as an indication of good stability (depending on the stabilization process).

Ultimately, biosolids type and quality should be matched with appropriate end use applications based on:

— characteristics of the biosolids (nutrient content, odour, pathogens, trace elements);

— potential risks to human and environmental health (exposure, set back distances, proximity of water (surface or groundwater);

— characteristics of the soil (pH, nutrient content, trace element content, texture);

— characteristics of the site (topography, proximity to surface water, depth to ground water and bedrock);

— proximity to neighbours (distance to roads, dwellings, recreation areas, wells); and

— the end use of the crop/vegetation grown on the application site, including:

  — food crops for direct animal/human consumption;

  — food and feed crops which require further processing prior to consumption;

  — biofuel or biomass crops/non-food or feed crops/silviculture; and

  — land reclamation (recreational and non-recreational).

6.8.2 Foreign matter

Jurisdictions commonly place restrictions on the foreign matter content in land applied biosolids to mitigate risks to human health and the environment. There may be separate restrictions for sharps, total plastic content and total foreign matter.

6.8.3 Odour reduction

Odour is a parameter related to biosolids stability and degree of treatment. Biosolids which have undergone a higher degree of treatment will emit fewer odours and should be considered higher quality. Biosolids should be adequately treated to avoid being associated with odours which generate complaints from the public and attract vectors.

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Odour emission reduction should be applied as a key component of any biosolids land application programme. The following three main approaches to mitigate odours at land application sites may be used:

— maximizing the quality of biosolids thereby minimizing the odour generating potential of the biosolids, e.g. subjecting the biosolids to further treatment such as anaerobic digestion or lime stabilization;

— managing the site and application of biosolids to minimize the potential for odorous emissions; and

— storing odorous biosolids at production or in a non–sensitive location until the odours have abated.

The following can be implemented for odour emissions reduction[7]. One or both approaches may be used to minimize odour issues:

— increasing distance from nearby residents; or

— selecting application techniques to reduce odour emissions (e.g. injection or incorporation into the soil within a set time limit).

6.8.4 Vector attraction reduction

Vector attraction reduction processes should be implemented to reduce the potential transport of pathogens from the application site, and thereby minimize human exposure. Vector attraction reduction may be achieved by:

— biological processes such as aerobic or anaerobic digestion or composting which break down volatile solids, thereby reducing the organic content of biosolids;

— reducing the available food nutrients for microbial activity and odour producing potential by heating, composting, anaerobic or aerobic digestion of the biosolids;

— chemical or physical conditions which stop microbial activity such as reducing the moisture content or raising the pH of the biosolids; and

— physical barriers between vectors and volatile solids in biosolids such as incorporation or injection of biosolids into the soil.

6.8.5 Pathogen reduction

6.8.5.1 General

To reduce the likelihood of spreading pathogens into the environment and to improve consumer confidence, biosolids subjected to advanced biosolids treatment should be utilized in sensitive or higher risk areas or applications where there is significant public exposure.

Pathogen reduction in biosolids may be achieved by different types of technologies which include heat exposure, moisture reduction, significant increase or decrease in pH and long-term storage.

Advanced treatment can achieve biosolids hygienization and potentially result in classification as a Group 1 category, whereas conventional treatment focuses on significantly reducing the pathogen content of biosolids. Examples of conventional and advanced treatment are outlined in 6.8.5.2 and 6.8.5.3.

After land application, natural conditions such as heat, sunlight, drying, soil pH and predation by native soil microorganisms can further reduce pathogen concentration. Incorporation of the biosolids into the soil can also reduce the potential for pathogen contact with animals and humans.

In the case of agricultural land application, it should be noted that:

— natural environmental processes do reduce pathogens; and

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— pathogens in the upper layers (horizons) of the soil have low motility.

Some exceptions to these general conditions include, for example, farm sites where there is a highwater table, active soil erosion, or exposed bedrock.

For more information on pathogen limits, see Annex D.

6.8.5.2 Conventional treatments

Conventional municipal sludge treatments may include:

— thermophilic aerobic stabilization at a temperature of at least 55 °C with a mean retention period of 10 – 15 days;

— thermophilic anaerobic digestion at a temperature of at least 53 °C with a mean retention period of 10 – 15 days;

— conditioning with lime ensuring a homogenous mixture of lime and sludge; the mixture should reach a pH of more than 12 directly after liming and keep a pH of at least 12 for a specified period of time;

— mesophilic anaerobic digestion at a temperature of 35 °C with a mean retention period of 20 – 30 days;

— extended aeration at ambient temperature as a batch, without adding feedstock or withdrawal during the treatment period;

— simultaneous aerobic stabilization at ambient temperature;

— biosolids dewatering in conventional (sand/clay) drying beds or solar drying beds (with a target minimum of 75 % dry matter); and

— storage in liquid form at ambient temperature as a batch, without adding feedstock or withdrawal during the storage period.

If the initial concentration needs to be reduced, biosolids should at least achieve a 2 log reduction in *E. coli*.

6.8.5.3 Advanced treatments

Advanced municipal biosolids treatments may include:

— thermal drying ensuring that the temperature of the sludge particles is higher than 80 °C with a reduction of water content to less than 10 %;

— thermophilic aerobic stabilization at a temperature of at least 55 °C for 20 h as a batch, without adding feedstock or withdrawal during the treatment;

— thermophilic anaerobic digestion at a temperature of at least 53 °C for 20 h as a batch, without adding feedstock or withdrawal during the treatment;

— thermal treatment of liquid sludge for a minimum of 30 min at a temperature of at least 70 °C followed by mesophilic anaerobic digestion at a temperature of 35 °C with a mean retention period of 12 days;

— conditioning with lime reaching a pH of 12 or more and maintaining a temperature of at least 55 °C for 2 h;

— mixing with lime and the mixture should reach a pH of more than 12 directly after liming and keep a pH of at least 12 for a minimum of time; and

— composting at a temperature of minimum 55 °C for at least two weeks or 65 °C for at least one week.

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The process should be initially validated by appropriate tests on pathogen reduction to attain specific requirements.

The relevant process parameters should be monitored at least daily, and preferably continuously if practicable. Records should be kept and made available upon request to the competent authority for inspection purposes.

The treatment process should consider adopting a quality assurance system and meet at least one of the accepted pathogen reduction standards.

6.9 Biosolids quality criteria — Groups of biosolids

6.9.1 General

Biosolids may be divided into two groups as described in 6.9.2 and 6.9.3.

Examples of treatment-based standards can be found in Annex I.

6.9.2 Group 1 biosolids

Group 1 biosolids are essentially free of pathogens and present a very low risk to people handling them, and may be marketed with fewer restrictions for its use, in comparison to Group 2 biosolids. Due to the fewer restrictions placed on the use of Group 1 biosolids, it is typically required to meet more stringent standards for pathogens, metals and other contaminants (e.g. organic compounds).

Marketed biosolids or biosolids derived materials should comply with relevant local standards or requirements that define quality criteria in accordance with their specific use.

NOTE National regulations can apply. In some jurisdictions Group 1 is referred to as Class A.

6.9.3 Group 2 biosolids

Group 2 biosolids, which do not attain Group 1 stabilization criteria, can potentially contain higher levels of pathogens but shall meet minimum applicable standards for metals, pathogens and other contaminants (e.g. organic compounds). Therefore, their use shall be subject to appropriate restrictions.

NOTE In some jurisdictions Group 2 is referred to as Class B.

6.10 Potential uses

Use of biosolids should depend on the quality and includes:

— biosolids derived products that are sold to the general public;

— agriculture – biosolids suitable for land used for the grazing of livestock, crops consumed raw, crops consumed cooked or processed;

— agriculture – biosolids suitable for land application for the production of non–food and feed crops (e.g. horticulture, bio–mass, fibre, agro forestry);

— institutional landscaping – recreational – biosolids suitable for urban land application (e.g. parks, race courses);

— institutional landscaping – non recreational – biosolids suitable for urban land application such as freeway road and landscaping where public access is limited. Subject to specific site management and environmental protection practices; and

— forestry, land rehabilitation – mine sites or similar land application such as landfill final surface rehabilitation, subject to specific site management and environmental protection practices;

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NOTE Some countries do not allow biosolids application on crops which can be consumed uncooked, root crops, fruit crops or in organic farming production.

6.11 Biosolids and soil monitoring

Addition of trace elements into the soil should be limited and controlled, as the removal of excess trace elements from the soil is very difficult and plant uptake of these elements can lead to plants unfit for human or livestock consumption.

The concentration of trace elements in biosolids as well as the loading rate should be limited.

The parameters that should be measured include any applicable requirements as well as other parameters that are use–dependent.

For information regarding the source of trace elements in biosolids and examples of jurisdictional trace element standards in biosolids and soil, see Annex E.

The application of biosolids containing trace elements should only be undertaken after calculating the potential loading capacity based on first performing an analysis of the soils to determine current levels of trace elements and secondly analysing the trace element levels in the biosolids.

Calculation methods are available in Annex K.

7 Biosolids application programme development and management

7.1 General

A biosolids programme should be planned to include two stages:

— programme development; and

— programme management.

There should be careful consideration of all factors when developing the programme. Open communication with stakeholders should be a priority to ensure that decisions made in the early stages are well–informed and minimize the risk of unanticipated opposition that can de–rail the progress of the programme.

There should be conscientious and vigilant programme management to maintain the confidence of all the stakeholders, which should include a practitioner experienced not only with the technical aspects, but also experienced in a variety of other areas including health and safety, applicable regulatory frameworks, data management and risk communication.

The biosolids programme should include procedures to identify all applicable legal requirements and to demonstrate how these legal requirements are met.

7.2 Community consultation

7.2.1 Involving the community

Biosolids management should involve the local community. The following aspects should be considered:

— citizens care about the decisions made by their authorities, as well as the processes used;

— the management of biosolids is a community expense;

— decisions about biosolids management can have impacts on cultural and community values, especially if there is a mishap or if plans do not work as expected; and

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— understanding 'community' knowledge systems and aspirations can ultimately strengthen the 'technical' approaches, helping to develop a solution that is justifiable and acceptable to the community.

More information on conducting a community consultative workshop can be found in Annex O.

7.2.2 Consultation principles

7.2.2.1 Knowing the community

— Community assets and contributions, social networks, existing groups, etc. should be used.

— An analysis of key stakeholders should be undertaken (e.g. affected people, environmental groups, local businesses, agricultural, mining, forestry, community/industry).

— The involved stakeholders should be identified.

— Defensible criteria should be made for why the invitation includes some stakeholders and not others.

— Invitation should be inclusive rather than exclusive.

7.2.2.2 Timing consideration

— Consultation should be undertaken as soon as possible, when there is still the flexibility to make changes to address issues raised by interested and affected persons, rather than embarking on consultation within a crisis.

— It should be known that if consultation is too far in advance, it is likely that few will be very interested; if consultation is too late, stakeholders will think engagement on the issue is being avoided or there is no intention of taking their views into account.

7.2.2.3 Transparency and open mindedness

— Project objectives should be clear.

— There should be clear indication which aspects of the proposal are open to change, and why there might be elements that may not be able to change.

— Views should be kept open to the responses stakeholders make and the benefits that might arise from consultation.

— While consultation is not an open–ended, never ending process, it should not be seen merely as an item on a list of things to do that should be crossed off as soon as possible.

7.2.2.4 Dissemination of information

Dissemination of information on the project to the community and key stakeholders should be:

— relevant and necessary: as there is a lot of information available;

— clear and concise: to gain the community's attention, information should get key messages across clearly and efficiently;

— targeted: information should be targeted to its intended audience;

— accessible and innovative: in addition to more traditional methods such as newspaper and radio advertising, other methods may be appropriate, such as internet-based resources or social media; and

— appropriately timed: communication to the wider public should be timed so that people who are generally at work can attend public presentations and meetings.

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7.2.2.5 Consultation process

Consultation, or at least communication with stakeholders, should continue after the decision has been made. This may be established through a local advisory committee.

Consultation does not necessarily require that all parties agree to a proposal, although it is expected that all parties will make a genuine effort. While it is possible that an agreement is not reached on all issues, points of difference can become clearer or more specific.

Consultation is a two-way process involving the exchange of information. It should not only include presentation of the material but also active listening to all stakeholders and constructive discussions among the various parties involved.

For information regarding consultative workshops, see Annex O.

7.3 Programme development

7.3.1 General

The development of a biosolids management programme should begin with a biosolids master plan possibly in conjunction with an environmental management system plan.

Biosolids development and management programmes should include the characterization of the material in terms of quality and quantity and the identification of the availability of end–uses while considering economic, environmental, applicable regulatory and social factors.

The programme should endeavour to consider the various perspectives of all stakeholders, which is important for the overall success of the programme.

7.3.2 Programme design and decision considerations

The programme development should first identify the purpose of the project including the problem and/or any opportunities, for example:

— the programme may no longer be socially/environmentally/economically acceptable; or

— the programme is non–compliant with applicable regulations.

The next step in programme development should identify the legal requirements and how these legal requirements are addressed, as they can limit the options available.

The third step should be the identification of all stakeholders. Stakeholder identification may be an iterative process where, as some stakeholders are invited to participate, they identify additional stakeholders. As stakeholders are identified, their area of interest, needs, and preferred method of providing input should be recorded.

While stakeholder identification is occurring, programme development should be simultaneously looking at social considerations, for example:

— is biosolids application acceptable to the local culture, or state of the area (rural/urban)?

— what are the potential benefits to the community?

— what is the attitude of influential citizens?

— is the community environmentally sensitive?

— has the community experienced negative or positive environment–related projects in the past?

— what is the potential for modifying public opinion?

— are the biosolids generated in the same region as the application site(s)?

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NOTE Stakeholders are an important resource for understanding the social considerations of the programme.

Technical considerations of programme development should include:

— biosolids quality;

— level of treatment;

— biosolids quantity;

— available and accessible land;

— storage requirements;

— transport/hauling options;

— seasonal considerations; and

— odour management.

Similar to the technical considerations, the economic considerations should be documented in applicable protocols. General economic considerations should include:

— staff/human resources;

— operating/capital costs;

— assessment of available options;

— cost benefit analysis of the options; and

— in–house or contracted servicing options.

The final step in programme development, which can be most critical should be decision making. Clear communication should be undertaken with stakeholders throughout the programme development to encourage buy–in and limit issues at this final stage when the options are presented for consultation and approval (e.g. public, regulatory, political, internal).

7.4 Programme management

7.4.1 General

Programme management should address the ongoing day to day operation of the chosen management option. The management considerations listed in 7.4.2 should be addressed in order to successfully manage a programme. The time or effort for each should depend on a case–by–case basis. For example, some jurisdictions have more extensive data management and reporting requirements than others.

7.4.2 Programme management considerations

The programme manager may consider adopting more stringent standards. One of the following framework examples, or other frameworks, should be chosen:

— best management practices (voluntary);

— industry standards; or

— international standards.

Contracts may be administered for the selected management option. Contract development may include:

— competitive procurement process;

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— strategic sourcing (contract duration for best value);

— insurance;

— financial securities;

— identification of roles and responsibilities; and

— the fair distribution and attribution of risks.

Biosolids management should include clear and readily available emergency response policies and procedures. These policies and procedures should include:

— applicable regulatory, legal and contractual requirements (spills, accidents); and

— wastewater treatment plant, land applicator or jurisdictional protocols.

Similarly, a programme specific health and safety protocol should be prepared. The protocol should include:

— biosolids or biosolids derived product safe handling document;

— traffic control at application sites;

— dust control and road maintenance;

— injury/accident reporting/procedures;

— training and certification;

— loading /hauling/unloading/use considerations;

— hazards; and

— personal and collective protective equipment requirements.

Record keeping and data management requirements should be considered an important aspect of the biosolids management programme. An information management system/database should be developed and include:

— reporting;

— tracking biosolids from wastewater treatment plant to application field;

— tracking of biosolids quality data, communications, incidents, application site information/maps etc.;

— tracking of nutrients and trace elements over the life of the programme which may allow additional biosolids application in the future;

— possible use of computer technologies and applications [geographic information system (GIS), spreadsheets, IT support]; and

— easy access to information, such as a dedicated system that can accurately track all sources of historical information.

Programme management should be operationally flexible and include contingencies to ensure that if the preferred management option suddenly becomes unavailable, the programme can respond and continue without a crisis developing. Operational flexibility considerations should include:

— maintaining programme flexibility by securing options (diversified end use strategy); and

— operational contingencies (contingency plan for alternate end use or disposal) such as:

  — backup storage availability,

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— merchant capacity and availability of alternate processing facilities,

— emergency dewatering,

— disposal options (land filling), and

— availability of other companies/contractors for haulage/handling/spills clean–up.

Records should be accessible to wastewater treatment plant and land application operators and maintained for a period of time, as applicable.

NOTE Regulations can apply to determine the period of time.

7.4.3 Biosolids and soil monitoring

7.4.3.1 Biosolids sampling and analyses

The first step in determining biosolids quality should be the adoption of a statistically sound sampling methodology to collect representative samples that accurately characterize the material being land applied.

Biosolids quality analyses results can vary according to a number of factors, including:

— the frequency of sampling and the extent to which the monitoring programme captures changes in biosolids quality;

— the origin of the wastewater (industrial or municipal) discharged to the wastewater treatment plant;

— consistency in processing upstream to the wastewater treatment plant, particularly in the case of an on–site industrial wastewater treatment plant;

— consistency of sludge processing at the wastewater treatment site itself, i.e. addressing the effects of fluctuations in the quality of the final product;

— the type of sample (e.g. grab samples versus composite samples), sample number and size relative to the total volume of biosolids;

— the timing of sample collection;

— quality assurance procedures; and

— analytical methods and techniques, including detection limits, reproducibility, quality assurance and quality control.

Biosolids should be regularly tested to determine:

— compliance with applicable requirements regarding trace element content, volatile solids and pathogen reduction;

— efficiency of sanitation processes if relevant; and

— nutrient content that will be used to determine application rate and to provide final users with reliable information.

7.4.3.1.1 Frequency of sampling

Biosolids should be sampled prior to land application, to ensure minimum quality standards are met and risks to human health and the environment are minimized. The location and timing of sampling should be considered to ensure that the goal of obtaining samples is to be representative of what is being land applied.

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