



**Food Safety Implications of Land-spreading  
Agricultural, Municipal and Industrial  
Organic Materials on Agricultural Land  
used for Food Production in Ireland**





# **Food Safety Implications of Land-spreading Agricultural, Municipal and Industrial Organic Materials on Agricultural Land used for Food Production in Ireland**

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## CONTENTS

<b>FOREWORD</b>	<b>4</b>
<b>MEMBERS OF THE SCIENTIFIC COMMITTEE</b>	<b>5</b>
<b>MEMBERS OF THE MICROBIOLOGY SUB-COMMITTEE</b>	<b>5</b>
<b>MEMBERS OF THE WORKING GROUP</b>	<b>6</b>
<b>ABBREVIATIONS</b>	<b>7</b>
<b>EXECUTIVE SUMMARY</b>	<b>8</b>
<b>1. PREAMBLE</b>	<b>10</b>
1.1 Background	10
1.2 Terms of Reference	11
1.3 Scope	11
1.4 Disclaimer	11
<b>2. LEGISLATION</b>	<b>12</b>
2.1 Roles and Responsibilities	12
<b>3. SOURCE, TYPE AND VOLUME OF MATERIALS</b>	<b>15</b>
3.1 Introduction	15
3.2 Organic Agricultural Materials	16
3.3 Organic Municipal Materials	17
3.4 Organic Industrial Materials	22
<b>4. MANAGEMENT AND TREATMENT OF MATERIALS</b>	<b>25</b>
4.1 Introduction	25
4.2 Soil Type, Characteristics and Suitability	25
4.3 Management	28
4.4 Treatment	28
4.5 Management of Organic Agricultural Materials	29
4.6 Management of Organic Municipal Materials	31
4.7 Management of Organic Industrial Materials	32
4.8 Current Best Practice for Land-spreading on Agricultural Land used for Ready-to-Eat Food Crops	34
<b>5. MICROBIOLOGICAL AND CHEMICAL HAZARDS</b>	<b>36</b>
5.1 Introduction	36
5.2 Microbiological Hazards	37
5.3 Chemical Hazards	38

<b>6. CURRENT AND EMERGING ISSUES</b>	<b>40</b>
6.1 Introduction	40
6.2 Antimicrobial Resistance	40
6.3 Influenza	41
6.4 Composts and Associated Risks	41
6.5 Landfill	42
6.6 Exposure to Accidental Contamination	42
6.7 On-site Waste Water Treatment Systems	43
6.8 Gaps in Current Knowledge and Legislation	44
<b>7. HAZARD IDENTIFICATION AND RISK</b>	<b>46</b>
7.1 Introduction	46
7.2 Definition of Risk in Respect of Hazards	46
7.3 Biological Hazard Identification and Risk	47
7.4 Transmissible Spongiform Encephalopathies	54
7.5 Chemical Hazard Identification and Risk	55
<b>8. DISCUSSION</b>	<b>61</b>
<b>9. CONCLUSIONS</b>	<b>65</b>
<b>10. RECOMMENDATIONS</b>	<b>67</b>
<b>APPENDIX 1: LEGISLATION</b>	<b>69</b>
1.1 Food	69
1.2 Drinking Water	70
1.3 Animal By-products	71
1.4 Environmental	72
<b>APPENDIX 2: SOURCE, TYPE AND VOLUME OF MATERIALS</b>	<b>77</b>
2.1 Agricultural Materials	77
2.2 Municipal Materials	80

<b>APPENDIX 3: TREATMENTS</b>	<b>83</b>
3.1 Agricultural Materials	83
3.2 Municipal Materials	88
3.3 Industrial Materials	90
<b>APPENDIX 4: DESCRIPTION OF MICROBIOLOGICAL HAZARDS</b>	<b>91</b>
4.1 Introduction	91
4.2 Viruses	91
4.3 Bacteria	93
4.4 Parasites	99
4.5 Transmissible Spongiform Encephalopathies	103
4.6 Pathogen Survival	104
<b>APPENDIX 5: DESCRIPTION OF CHEMICAL HAZARDS</b>	<b>118</b>
5.1 Introduction	118
5.2 Exposure and Sources of Chemical Contaminants	118
5.3 Metals	121
5.4 Organic Pollutants	124
5.5 Disinfectants and Detergents	126
5.6 Musk Compounds	130
5.7 Medicines and Illicit Drugs	131
5.8 Bacterial Endotoxins	134
5.9 Endocrine Disrupting Substances	135
5.10 Nitrates	135
<b>GLOSSARY</b>	<b>137</b>
<b>BIBLIOGRAPHY</b>	<b>143</b>

## FOREWORD

This report was prepared by a Working Group on behalf of the Microbiology Sub-committee and adopted by the Scientific Committee for presentation to the Food Safety Authority of Ireland (FSAI). It aims to provide the FSAI and other stakeholders with an overview of the science and related issues surrounding the land-spreading of organic agricultural (OA) materials and organic municipal and industrial (OMI) materials on agricultural land used for safe food production.

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## ABBREVIATIONS

<b>ABP</b>	Animal By-products
<b>BSE</b>	Bovine Spongiform Encephalopathy
<b>COP</b>	Code of Good Practice
<b>DAFF</b>	Department of Agriculture, Fisheries and Food
<b>DEHP</b>	Di-2-(Ethyhexyl) Phthalate
<b>DEHLG</b>	Department of the Environment, Heritage and Local Government
<b>EU</b>	European Union(s)
<b>EPA</b>	Environmental Protection Agency
<b>EFSA</b>	European Food Safety Authority
<b>FSA</b>	Food Standards Agency (United Kingdom)
<b>FSAI</b>	Food Safety Authority of Ireland
<b>HSE</b>	Health Service Executive
<b>IPPC</b>	Integrated Pollution Prevention and Control
<b>LA</b>	Local Authority
<b>LAS</b>	Linear Alkyl Benzene Sulphonates
<b>NPE</b>	Nonylphenol and Nonylphenol Ethoxylates
<b>MBM</b>	Meat and Bone Meal
<b>OA</b>	Organic Agricultural
<b>OMI</b>	Organic Municipal and Industrial
<b>PAHs</b>	Polycyclic Aromatic Hydrocarbons
<b>PCBs</b>	Polychlorinated Biphenyls
<b>PCDD/Fs</b>	Polychlorinated Dibenzo-p-Dioxins and Furans
<b>RTE</b>	Ready-to-Eat
<b>S.I.</b>	Statutory Instrument
<b>TSEs</b>	Transmissible Spongiform Encephalopathies
<b>VTEC</b>	Verocytotoxigenic <i>Escherichia coli</i>
<b>WHO</b>	World Health Organization

## EXECUTIVE SUMMARY

Appropriately managed land-spreading provides a sustainable option for the utilisation of organic agricultural (OA) materials and some treated organic municipal and industrial (OMI) materials. Such use is conditional, however, on the implementation of effective controls as detailed in this report and the consistent application of good practice at every level. Otherwise, in the absence of these measures, the land-spreading of OA and OMI materials on agricultural land used for food production may pose risks, associated with microbiological and chemical hazards, to food safety.

This report provides a scientific opinion on the food safety implications most likely to be associated with land-spreading OA and OMI materials on agricultural land used for food production in Ireland against the background of current practices. The report reviews the current scientific knowledge in relation to the treatment, management and best practice options available to prevent and control known hazards to food safety related to land-spreading of these materials. The report also acknowledges opinions from other bodies on the level of compliance with these best practices and highlights the implications this may have for food safety.

The use of both OMI and OA materials, may pose risks to food safety from microbiological or chemical hazards. The possible sources, type and routes of exposure to microbiological or chemical hazards that can contaminate food and water supplies either directly or indirectly through land-spreading are varied. OMI materials such as sludge<sup>a</sup> are more likely to contain chemical contaminants, e.g. metals, than OA materials. There are gaps in current knowledge concerning the transfer of chemical contaminants and pathogens into the food chain through land-spreading of OMI materials on agricultural land used for food production.

Control and monitoring of the source material is of particular importance in the case of OMI, as the source of the material is likely to stem from many different industrial and municipal sources, some of which may not be readily traceable. Trends indicate a significant increase in the use of treated OMI materials in agriculture in Ireland, although at present, the proportion of OMI relative to OA materials spread on agricultural land is very small.

Current best practice for treatment and management of OMI materials from urban waste water treatment is stipulated in the Department of the Environment, Heritage and Local Government's (DEHLG) Codes of Good Practice for the use of Biosolids<sup>b</sup> in Agriculture. However, these codes have no statutory basis since the current legislation does not define treatment options and associated process conditions nor makes reference to suitable code(s) of good practices or standard(s).

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<sup>a</sup> Sludge means: (i) residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters (ii) residual sludge from septic tanks and other similar installations for the treatment of sewage (iii) residual sludge from sewage plants other than those referred to in paragraphs (i) and (ii). A specific type of sludge (referred to in legislation) is treated sludge which is sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use<sup>1</sup>.

The report draws attention to the absence, in Ireland, of statutory controls or uniform standards for natural biological degradation processes including composting of OA and OMI materials that would be necessary for consistent effective treatment of such materials. The absence of standards is a recognised impediment to the appropriate use of composts in the Government's National Strategy on Biodegradable Waste.

Human pathogenic microorganisms present in untreated OMI materials, can be recycled in the human population via food when these materials are used on agricultural land. Therefore, the use of untreated OMI materials in any form on agricultural land is a matter of concern for food safety. Current legislation restricts the use of untreated OMI materials, only allowing certain untreated OMI materials to be used on agricultural land under prescribed circumstances. However, this report recommends that all untreated OMI materials including residual sludge from septic tanks should not be allowed to be spread on agricultural land used for food production.

As stated previously, food may be contaminated with chemicals and microorganisms from OMI and OA materials when these are spread on agricultural land used for food production. However, the processes applied to food before it reaches the consumer and by the consumer often reduce or eliminates this risk. The exception to this is fresh produce that is ready-to-eat with little or no further processing<sup>c</sup>. This report has identified these foods as posing a particular food safety risk when land on which they are grown is spread with untreated OA or OMI materials.

Regulatory enforcement of OA and OMI materials transcends the responsibilities of several Government departments, State agencies and individual local authorities. As such coordination and greater transparency between these groups is necessary to ensure a coherent approach to risk assessment in the area of food safety. Provision of adequate resources to allow enforcement, coordination and greater cooperation between these groups is required to ensure best practice for management and treatment of OA and in particular OMI materials such as sludge from urban waste water treatment.

At present, an assessment of any risks to food safety that may be related to the spreading of OMI materials on land used for food production is impeded by the scarcity of data of relevance to the Irish situation as it is now evolving. Further research which addresses this issue is warranted. The report contains recommendations, based on its conclusions, which address these issues.

**Keywords:** Agricultural, biosolids, crops, contamination, food safety, industrial, land-spreading, municipal, organic, sewage, sludge

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<sup>b</sup> Biosolids is the organic by-product of urban wastewater treatment which, by being treated to an approved standard, can be used beneficially as a fertiliser/soil conditioner in agriculture<sup>2</sup>.

<sup>c</sup> Fresh produce that is ready-to-eat may on occasion include some root crops.

## I. PREAMBLE

### I.1 Background

There has been a major increase in public awareness in relation to food safety in Ireland and across the European Union (EU). Consequently, there have been significant changes in the regulatory requirements for food safety and the protection of public health such as the European Communities Hygiene of Foodstuffs Regulations, 2006<sup>3</sup>.

Likewise, public awareness and concern in relation to environmental issues have also increased and there have been significant changes in the regulatory requirements for the protection of the environment such as the European Communities Good Agricultural Practice for Protection of Waters Regulations, 2006<sup>4</sup>.

Ireland has a total land area of just over seven million hectares<sup>5</sup>. Based on 2004 figures, Irish agriculture utilises approximately 4.3 million hectares of this total area with pasture land accounting for 2.2 million hectares, silage one million hectares and the remaining one million hectares used for rough grazing (i.e. 453,500 hectares), hay (i.e. 189,000 hectares), cereals (i.e. 310,200 hectares), potatoes and sugar beet (i.e. 44,400 hectares) and other crops, fruit and horticulture (i.e. 69,400 hectares)<sup>5</sup>.

The land-spreading of organic agricultural (OA) materials such as animal manure and slurry on agricultural land used for food production is a long established farming practice in Ireland and elsewhere. Appropriately managed and/or treated OA materials are effective fertilisers. Furthermore, appropriately treated and managed organic municipal and industrial (OMI) materials originating from meat and dairy plants (including poultry meat plants), domestic dwellings and urban waste water treatment plants, and farms, are used in different forms as fertilisers on agricultural land used for food production<sup>6</sup>. By-products of the food industry and urban waste water treatment plants are increasingly being managed by land-spreading to agricultural land used for food production. When appropriately managed, land-spreading provides a sustainable option particularly for the utilisation of OA materials and some treated OMI materials. However, the use of OA and OMI materials may pose risks to food safety associated with microbiological or chemical hazards.

Mismanaged, untreated, inadequately treated, or re-contaminated OMI and OA materials may contain pathogens<sup>7</sup> or harmful chemicals<sup>8-9</sup> that can contaminate food and water supplies either directly or indirectly. At an international level, the land-spreading of organic materials on agricultural land used for food production has been associated with contaminated fresh produce and human enteric illness<sup>8-15</sup>.

## **1.2 Terms of Reference**

The Food Safety Authority of Ireland (FSAI) requested the FSAI Scientific Committee to prepare a scientific assessment of the food safety implications of spreading OA and OMI materials on agricultural land used for food production in Ireland. An expert working group under the FSAI Microbiology Sub-committee was convened in March 2006 to identify the food safety hazards associated with this practice, with particular attention given to the following:

1. identification of OA and OMI materials produced in Ireland and current practice(s) of spreading these materials to agricultural land used for food production in Ireland
2. identification of the hazards associated with the current practice(s) of spreading OA and OMI materials to agricultural land used for food production in Ireland
3. identification of the relative risk associated with the current practice(s) of spreading OA and OMI materials to agricultural land used for food production in Ireland
4. identification of management and treatment options to address any associated risks for the purpose of improving food safety.

This report provides a scientific opinion on the risks most likely to be associated with the consumption of a number of classes of crops, fruits, water and animal products against the background of the current legal position and practices relating to the spreading OA and OMI materials on agricultural land used for food production in Ireland.

## **1.3 Scope**

The scope of the report is confined to the food safety<sup>d</sup> implications of spreading OA and OMI materials on agricultural land used for food production in Ireland. The consequences of the direct excretion by grazing livestock, onto on agricultural land used for food production are outside the scope of this report. Consideration of environmental implications including occupational exposure is also outside the scope of the report.

## **1.4 Disclaimer**

This report is intended to serve as a review of the current practice(s) of spreading OA and OMI materials on agricultural land used for food production in Ireland and the subsequent implications for food safety resulting from these practice(s). The report does not purport to be a legal interpretation or to constitute legal advice.

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<sup>d</sup> For the purpose of this report, drinking water is included under the definition of food<sup>10</sup> (Chapter 11).

## 2. LEGISLATION

The legislation that governs the utilisation and management of OA and OMI materials on agricultural land used for food production transcends a variety of environmental and food related themes. As such, the legislation is complex in its interpretation, implementation and enforcement. A non-exhaustive list of the major legislative or Statutory Instruments includes the following:

1. European Communities (Hygiene of Foodstuffs) Regulations, 2006<sup>3</sup>
2. Regulation (EC) No. 178/2002 Laying Down the General Principles and Requirements of Food Law, Establishing the European Food Safety Authority and Laying Down Procedures in Matters of Food Safety<sup>16</sup>
3. European Communities (Drinking Water) (No. 2) Regulations, 2007<sup>17</sup>
4. European Communities (Transmissible Spongiform Encephalopathies and Animal By-Products) Regulations, 2006 (S.I. No. 612 of 2006)<sup>18</sup>
5. Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1991 to 2001<sup>1</sup> (S.I. No. 183 of 1991, S.I. No. 148 of 1998 and S.I. No. 267 of 2001)
6. European Communities (Good Agricultural Practice) for Protection of Waters Regulations<sup>e</sup>, 2006 and 2007<sup>4</sup>

Further detail on the above legislation and relevant legislative requirements for food safety and the environment are outlined in Appendix 1.

### 2.1 Roles and Responsibilities

There are a number of Government agencies and departments with responsibilities in the area of land-spreading of OA and OMI materials. In addition, those involved in land-spreading and food production also have a critical role to play and legal responsibilities.

Farmers are considered to be food business operators under Irish food law<sup>16</sup> and as such, they have a primary obligation not to place unsafe food on the market. Consequently, farmers have an obligation to ensure that OA and OMI materials, when spread on land used for food, are used in such a way that the safety of the food is not compromised. Farmers must comply with best practice guidelines and legislative requirements in this respect.

<sup>e</sup> This regulation is often referred to as the Nitrates Directive as it gives effect to Directive 75/442/EEC of 15 July 1975, Directive 76/464/EEC of 4 May 1976, Directive 80/68/EEC of 17 December 1979, Directive 91/676/EEC of 12 December 1991, Directive 2000/60/EC of 23 October 2000 and Directive 2003/35/EC of 26 May 2003. The Department of Agriculture, Fisheries and Food have produced an explanatory handbook for good agricultural practice regulations<sup>19</sup>. Under the regulations<sup>4</sup> a “fertiliser” is defined as any substance containing phosphorus or a nitrogen compound utilised on land to enhance growth of vegetation and may include livestock manure, residues from fish farms and sewage sludge. The current regulations<sup>4</sup> are due to be revoked in 2008 for the purposes of responding to the requirements of a judgment of the European Court of Justice in 2005 in relation to the Dangerous Substances Directive and a derogation under the Nitrates Directive granted by the European Commission to Ireland in October 2007.

Under the Common Agricultural Policy Single Payment Scheme, farmers are required to respect the various statutory management requirements set down in EU legislation on the environment, public, animal and plant health and animal welfare and maintain land in good agricultural and environmental condition. This is known as cross-compliance. The environmental directives covered under cross-compliance are sewage, nitrates, groundwater, habitats and birds.

The local authorities (LA) are responsible for the management of sludge (i.e. an OMI material) from municipal waste water treatment plants, and the supervision of the supply and use of sludge in their functional area. LAs are also responsible for establishing and maintaining a sludge register and require advance notification of proposed land banks to be used for biosolids spreading<sup>1</sup>. Local authorities were, in the past, audited by the Environmental Protection Agency (EPA) on a three year cycle and not annually. Article 8(3) of the Use of Sewage Sludge in Agriculture Regulations, 1991 to 2001<sup>1</sup> requires a supplier of sludge to notify the LA in whose functional area the sludge is to be used which implies advance notice, but in practice for the most part, this is done after the fact. DEHLG has indicated that any person using biosolids in agriculture is required to do so only in accordance with an approved nutrient management plan and the DEHLG Codes of Good Practice for the Use of Biosolids in Agriculture<sup>2</sup>.

Inspections for compliance with the statutory management requirements relating to the environmental Directives in so far as they relate to cross compliance are carried out by Department of Agriculture, Fisheries and Food (DAFF) inspectors on behalf of the National Parks and Wildlife Service and the LAs who are the competent authorities for these Directives. Existing arrangements established from earlier schemes allowing cross reporting of non compliances are to be retained and enhanced.

Implementation and responsibility for animal-by-products (ABP) is handled by a number of bodies: DAFF is the central competent authority with responsibility for most ABP processing plants and the largest meat plants; the Sea-Fisheries Protection Authority, which deals with marine ABP; the Local Authority Veterinary Service is responsible for ABP issues in smaller local abattoirs; and the Health Service Executive, which deals with retail outlets handling ABP, such as butchers<sup>20</sup>. The EPA has an interest in ABP from the perspective of general environmental protection, good agricultural practice for protection of waters<sup>4</sup> and various other water protection regulations. The DAFF veterinary inspectors engaged at export slaughter plants have no input in relation to supervision of effluent plants. The monitoring of these effluent plants is primarily carried out by quality control staff employed by each slaughter plant. Each plant has a discharge license to discharge into receiving waters at a certain rate provided the quality meets the parameters outlined in the discharge license. The LA also takes samples periodically to check on the slaughter plants own checks. The EPA and the LA are the regulatory bodies covering the effluent plants.

DEHLG is responsible for policy and legislation in relation to water quality issues and, together with other relevant authorities, for the implementation of EU Directives including Bathing Waters (76/160/EEC), Dangerous Substances (76/464/EEC), Freshwater Fish (78/659/EEC), Shellfish Waters (79/923/EEC), Groundwaters (80/68/EEC), Drinking Water (80/778/EEC), Urban Waste Water Treatment (91/271/EEC) Nitrates (91/676/EEC), Framework for Community Action in the Field of Water Policy (2000/60/EC) and Management of Bathing Water Quality (2006/7/EC). Statutory responsibility for water management and protection rests primarily with local authorities. The Water Pollution Acts, 1977 and 1990 and Regulations made thereunder, including regulations giving effect to EU Directives, constitute the main national legislation in this regard.

Regional fisheries boards, as part of their fisheries management function, are also in a position to take prosecutions for water pollution offences. However, the boards do not have the range of powers, which is available to local authorities to prevent pollution. The EPA is responsible for water pollution control insofar as activities licensable by the agency may be involved; these concern complex industrial activities, as well as large intensive pig and poultry production units - operations having a potential to cause significant pollution which are controlled under the Environmental Protection Agency Act, 1992.

The EPA is the supervisory authority over public water supplies and has powers of enforcement over LAs in this regard<sup>21</sup>. Prior to introduction of the European Communities (Drinking Water) Regulations (No.2) in March 2007<sup>17</sup> the role of the EPA was restricted to assessment and reporting of monitoring results and the provision of advice and assistance to the LA. The EPA now has enforcement powers to ensure that LA take action where there is a quality deficiency in a public water supply and can serve a legally binding direction on the LA. Failure to comply with a direction is an offence which can lead to prosecution by the EPA<sup>21</sup>.

The FSAI is a statutory, independent and science-based body, dedicated to protecting public health and consumer interests in the area of food safety and hygiene. It comes under the aegis of the Minister for Health and Children and has national responsibility for co-coordinating the enforcement of food safety legislation in Ireland. The principal function of the FSAI is to take all reasonable steps to ensure that food produced, distributed or marketed in the State meets the highest standards of food safety and hygiene reasonably available and to ensure that food complies with legal requirements, or where appropriate with recognised codes of good practice.

## 3. SOURCE, TYPE AND VOLUME OF MATERIALS

### 3.1 Introduction

Organic agricultural (OA) materials and organic municipal and industrial (OMI) materials for use in land-spreading are the result of modern agricultural, municipal and industrial practices and may be in solid or liquid forms. The types of organic material suitable for land-spreading also include those that are created intentionally as a soil amendment such as compost (Appendix 3.1.3). The raw material for these soil amendments may be organic materials that are by-products from other processes, e.g. urban waste water treatment sludges, garden trimmings, source separated organics (Appendix 3.2.2) from households and businesses, e.g. food scraps, or a mixture of these materials. Spent mushroom compost (Chapter 4.5.1) from the mushroom industry and poultry litter (including imported poultry litter) are also spread on agricultural land used for food production<sup>f</sup>.

The estimated quantity of organic materials (including OA materials) land-spread in Ireland in 2004 was approximately 60.75 million tonnes<sup>22-23</sup>. While the specific types of organic material produced in Ireland are varied, the vast majority (i.e. 99.05%) of these materials are of agricultural origin (Table 1)<sup>22-23</sup>.

<b>Category</b>	<b>Quantity (% of Total)</b>
Agricultural Materials <sup>2</sup>	60,170,025 (99.05%)
Municipal Materials <sup>3</sup>	80,775 (0.13%)
Industrial Materials <sup>4</sup>	495,745 (0.82%)
<b>Total</b>	<b>60,746,545 (100%)</b>

<sup>1</sup> Source of Data: Agricultural Materials<sup>23</sup>; Municipal Materials<sup>23-24</sup>; Industrial Materials<sup>22-23</sup>

<sup>2</sup> See Table 2 for breakdown of components

<sup>3</sup> See Table 3 for breakdown of components

<sup>4</sup> See Table 4 for breakdown of components

Further information on the source, type and volume of materials produced and land-spread in Ireland is given in Appendix 2.

<sup>f</sup> DAFF has produced an advice leaflet on good farming practice with regard to spreading of poultry litter on land in Ireland<sup>25</sup>. The poultry industry should be aware of the correct procedures for the disposal of poultry carcasses, as prescribed by the European Communities Regulation (EC) 1774/2002 and the European Communities (Transmissible Spongiform Encephalopathies and Animal By-Products) Regulations, 2006 (S.I. No. 612 of 2006)<sup>18</sup> (Appendix 1.3)

### 3.2 Organic Agricultural (OA) Materials

Animal manure is the excreta produced by all types of farmed livestock. Animal manure is produced and deposited on agricultural land during outdoor grazing periods for livestock, e.g. dairy cows, cattle and sheep, from as early as February to as late as November, depending on the region. During winter months, livestock may also be housed and animal manure is collected and stored for subsequent spreading on to agricultural land. Pig and poultry enterprises generally keep animals indoors all year round.

Animal manure can be either in liquid or solid form with the latter generally implying that it is mixed with a quantity of bedding material. Animal manure is categorised as a component of agricultural waste in the National Waste Report 2004<sup>23</sup>. However, recent European Court Judgements raise questions about the classification of animal manures as a waste<sup>26</sup>. Animal manure accounted for over 60% of the total agricultural organic material inventory of over 60.17 million tonnes in 2004 (Table 1). The estimated quantities of OA categories land-spread in Ireland in 2004 are given in Table 2<sup>23</sup>.

<b>Category<sup>2-3</sup></b>	<b>Quantity (% of Total)</b>
Cattle manure and slurry	36,443,603 (60.56%)
Soiled water (dairy farms)	18,337,550 (30.54%)
Pig slurry <sup>4</sup>	2,431,819 (4.04%)
Sheep manure	1,336,336 (2.22%)
Silage effluent	1,139,231 (1.89%)
Spent mushroom compost <sup>5</sup>	274,050 (0.46%)
Poultry litter <sup>6-7</sup>	172,435 (0.29%)
<b>Total</b>	<b>60,175,024 (100%)</b>

<sup>1</sup> Source of data<sup>23</sup>. Table 2 does not include horse manure due to its small contribution relative to other animal manures.

<sup>2</sup> Excreta from wild animals and minor farming enterprises such as deer and ostrich farming is not included as their relative contributions are either unknown or insignificant. It is unclear if the land these organic materials were land-spread on was used for food production. Likewise, information regarding the amount injected or otherwise spread to such land is unavailable.

<sup>3</sup> Not all categories are regulated by the Integrated Pollution Prevention Control (IPPC) Directive. Also the conditions of individual specific IPPC licences may differ between facilities (Appendix I.4.6).

<sup>4</sup> Facilities with 2,000 places for pigs over 30kg, and those with more than 750 sow places, must acquire an IPPC licence from the relevant authority (Appendix I.4.6).

<sup>5</sup> See Appendix 2.1.4.

<sup>6</sup> Facilities with 40,000 or more poultry places must acquire an IPPC licence from the relevant authority (Appendix I.4.6).

<sup>7</sup> Poultry manures imported into Ireland must have a health certificate.

### 3.3 Organic Municipal Materials

Several terms are used to define materials generated in solid form by households, businesses, etc. and/or collected by local authorities such as municipal or residential solid waste. The EPA categorises municipal solid waste, as waste from households, commercial operations and street cleansing<sup>23</sup>. In EU legislation, the definition of municipal solid waste is waste from households, as well as other waste, which, because of its nature or composition, is similar to waste from households<sup>27</sup>. However, this description of municipal solid waste does not include materials derived from composting (Appendix 3.1.3) or from urban waste water treatment processes which may also be spread on agricultural land used for food production<sup>28</sup>.

Municipal material which is spread on agricultural land used for food production in Ireland may include municipal compost created from biodegradable organic materials such as household waste and garden trimmings (Appendix 3.2) and materials derived from urban waste water treatment plants. Inputs to urban waste water treatment plants can come from a number of sources including run-off rain water, domestic dwellings, industrial processes, some agricultural processes, hospitals and health care centres, such as nursing homes. However, current data indicate that municipal materials represent only 0.13% of the total quantity of materials (Table 1) which are spread onto Irish agricultural land<sup>22</sup>.

The estimated volumes of specific organic municipal materials land-spread in Ireland in 2004 are given in Table 3<sup>23-24</sup>. However, the data provided in Table 3 do not include data for on-site waste water treatment systems serving private individual residential houses, communal developments and sewage treatment plants with a treatment capacity below a population equivalent of 500 as these data are limited or unavailable (Chapter 3.3.1).

<b>Category</b>	<b>Volume Quantity (% of Total)</b>
Urban Waste Water Treatment <sup>2-3</sup>	47,123 (58.34%)
Municipal Compost <sup>4</sup>	33,652 (41.66%)
<b>Total</b>	<b>80,775 (100%)</b>

<sup>1</sup> Source of data<sup>23-24</sup>

<sup>2</sup> The EPA has reported that a total of 121,750 tonnes (2004 – 61,923 tonnes and 2005 – 59,827 tonnes) of dried sludge was produced nationally by wastewater treatment plants in the period 2004 - 2005. A total of 76.1% of this went to agriculture (92,530 tonnes) and 17% went to landfill<sup>24</sup>. As the total produced in 2004 was 61,923 tonnes dry weight, a total of 76.1% (47,123 tonnes) of this was used for agriculture<sup>24</sup>. However, its unclear if the land these organic materials were land-spread on was used for food production. Likewise, information regarding the amount injected or otherwise spread to such land is unavailable. For the period 2001-2003, seven EU Member States (Ireland, Belgium, Denmark, Spain, France, the UK and Hungary) reported that they apply 50% or more of the sludge they generate on land. At the other end, Finland, Sweden and Slovenia apply less than 17% of the sludge they generate on land, while Greece, the Netherlands, Belgium (Flanders), Slovakia and the Czech Republic spread very little, or no, sludge on agricultural land<sup>29</sup>.

<sup>3</sup> Sewage sludge from the Ringsend Wastewater Treatment Plant in Dublin, is treated by thermal drying and reused as an agriculture fertiliser, called Biofert (i.e. biosolids). An estimated 12,000 tonnes of Biofert per annum is used according to the DEHLG website (last accessed 13/06/2008).

<sup>4</sup> In 2004, 780,460 tonnes of organic biodegradable material was managed in Ireland<sup>23</sup>. Of this total, 83,505 tonnes was recovered with 40.3% (33,652 tonnes) of this, composed of organic materials (i.e. food and garden waste) which were composted<sup>23</sup> (Appendix 3.2.2) and presumed to be land-spread. However, it is unclear if the land to which this organic material went was used for food production. It is also unclear if this figure is dry or wet weight. Currently, there are no Irish statutory requirements or quality standards that composts must meet (Chapter 6.4).

### **3.3.1 Urban waste water treatment**

Urban waste water requires treatment prior to discharge in order to reduce or limit pollution in addition to achieving compliance with relevant legislation<sup>28</sup>. Mechanical or primary treatments are designed to remove oils, grease, fats, sand, grit, and coarse solids from the water by mechanical means. Following this, the waste water is subjected to further treatment generally involving biological processes, with a secondary settlement and in some cases, disinfection prior to discharge.

Sewage sludge produced as a result of urban waste water treatment processes and later used in agriculture is subject to the provisions of the Waste Management (Use of Sewage Sludge in Agriculture) Regulations 1998-2001<sup>1</sup>. The Regulations prescribe standards for the use of sewage sludge in agriculture and give effect to Council Directive 86/278/EEC, on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture<sup>1</sup>. However, treatment and associated process conditions for sewage sludge to be later used in agriculture are not defined in this legislation but are elaborated in the DEHLG codes of good practice<sup>2</sup>. This omission in legislation is a matter of concern.

While the legislation<sup>1</sup> stipulates that only treated sludge may be used in agriculture, it provides for two exceptions, namely; that untreated sludge may be used in agriculture<sup>g</sup> provided that it is previously injected or otherwise worked into land; and that residual sludge from septic tanks may be used on grassland provided that the grassland is not grazed within six months following such use. However, there is no evidence or data to suggest that these methods of land-spreading are complied with consistently in practice. Furthermore, data in relation to quantities of untreated sludge or residual sludge used in agriculture are not available. It is possible that the use of residual sludge from septic tanks may introduce new enteric pathogens into the food chain or recycle existing pathogens. Therefore, the provision under the legislation<sup>1</sup> for the use of residual sludge from septic tanks on grassland and untreated sludge in agriculture is a matter of concern.

The legislation<sup>1</sup> also requires LAs to establish and maintain a record of all sludge supplied and used on agricultural land in their functional area. This is known as a sludge register. The purpose of the sludge register is to record details on the sludge produced and supplied for use in agriculture in a local authority's functional area, including such details as chemical composition<sup>1</sup>. Essentially the sludge register contains the information required for the safe use of sewage sludge in agriculture. However, in the case of sludge from septic tanks or sewage treatment plants designed primarily for the treatment of domestic waste water and with a treatment capacity corresponding to less than 300kg BOD<sub>5</sub> per day (i.e. population equivalent of 5,000 persons), important details of these materials<sup>h</sup> do not have to be provided to the LA for inclusion in the sludge register<sup>1</sup>. This represents a breakdown in traceability and monitoring necessary for the safe use of sludge in agriculture and is a matter of concern.

Article 14 of Urban Waste Water Treatment Directive encourages the use of sludge and the minimisation of sludge disposal to landfill<sup>28</sup>. In 1993, DEHLG published a report<sup>30</sup> on strategy options in Ireland for the treatment and disposal of sewage sludge. In this report a principal recommendation was that LAs would prepare plans for the management of urban waste water sludge. In 1996, the Waste Management Act<sup>31</sup> reinforced the LA responsibility for sludge management planning by including the management of all non-hazardous sludges as part of a Waste Management Plan<sup>31</sup>.

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<sup>g</sup> Agriculture means the growing of all types of commercial food crops, including food crops for stock-rearing purposes<sup>1</sup>.

<sup>h</sup> A supplier of this sludge for use in agriculture doesn't have to provide regular analysis results to the users of that sludge. The composition and properties of the sludge, the treatment which the sludge has undergone, the name and address of each recipient of the sludge and the location of each site where the sludge is to be used, do not have to be provided to the local authority<sup>1</sup>.

In 1999, codes of good practice<sup>i</sup> (COP) were prepared for DEHLG to assist LAs and waste water treatment plant operatives in planning for the use of biosolids in agriculture<sup>2</sup>. The COP defines biosolids<sup>j</sup> as “the organic by-product of urban waste water treatment which, by being treated to an approved standard, can be used beneficially as a fertiliser/soil conditioner in agriculture”. Typically the choice of treatment process for sludge depends on the amount of solids generated and other site-specific conditions. However, when process conditions as outlined in Appendix 3 of the COP are maintained the treatments<sup>k</sup> listed below will ensure a pasteurised biosolids product which meets the microbiological standards<sup>l</sup> outlined in the COP<sup>2</sup>:

1. Mesophilic anaerobic digestion with pre or post sanitation (pasteurisation)
2. Thermophilic anaerobic digestion
3. Thermophilic aerobic digestion
4. Composting (windrows or static pile or in-vessel)
5. Alkaline stabilisation
6. Thermal drying.

In addition to the microbiological standards, the COP also sets out limits for metal concentrations in biosolids which are intended to be used in agriculture<sup>2</sup>. Biosolids can then either be spread or otherwise worked into the soil as a fertiliser or soil conditioner in accordance with the requirements of the code of good practice<sup>2</sup>. The COP states that untreated wastewater sludge should not be land-spread or injected into soil<sup>2</sup>. However, the legislation<sup>1</sup> allows for the latter practice. While the COP<sup>2</sup> outlines some of the crops and conditions under which biosolids can be land-spread not all crops and conditions are described (Chapter 4.8). The EPA is currently developing its own guidance on the land-spreading of industrial organic wastes in Ireland (Appendix 3.3)<sup>22</sup>.

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<sup>i</sup> The COP was reissued by DEHLG in 2008 as Guidelines for local authorities and Wastewater Treatment Plant Operatives and Guidelines for Farmers<sup>2</sup>.

<sup>j</sup> In the United Kingdom (UK) similar guidelines for the application of sewage sludge to agricultural land are set out in the Safe Sludge Matrix<sup>32</sup> which is underpinned by research<sup>33-36</sup>.

<sup>k</sup> In Ireland anaerobic digestion (Appendix 3.1.5) for large-scale municipal applications, followed by lime treatment or thermal drying, are the treatment processes most commonly used.

<sup>l</sup> Faecal coliform < 1,000 MPN (Most Probable Number).g-1 dry solids and *Salmonella* spp. < 3 MPN.4 g-1 dry solids.

In December 2007, DEHLG indicated to the FSAI that revision of Directive 86/278/EEC was delayed at a European level until possibly 2009. Accordingly, in the interim, DEHLG intend to provide a limited revision of the Regulations with a draft for circulation available in 2008. DEHLG has proposed that the revision will include provisions to set standards for treated sludges; prohibit use of untreated sludge; confine permitted domestic septic tank sludge use to the land owner's own septic tank; provide for more explicit LA powers to perform their supervisory function, e.g. right to reject Nutrient Management Plans, and resolve some practical difficulties that have arisen, e.g. application of ten year averaging and conflict with terms of REPS 4, subject to agreement with DAFF.

### 3.3.2 Hospitals and the health care sector

Hospitals and health-care establishments also discharge waste water into public sewers. This waste water while similar to urban waste water may also contain various potentially hazardous components<sup>38</sup>. These may include a residual medical drug load, particularly antimicrobials, cancer drugs and metabolites which may be subsequently present in sludge or biosolids which are land spread on agricultural land used for food production. In addition, a 2006 study on waste water from hospital laundry units found that rotaviral ribonucleic acid (RNA) (Appendix 4.2.4) was discharged in waste water after the laundry washing process<sup>39</sup>.

The World Health Organization (WHO) has indicated that in countries that do not experience epidemics of enteric disease and that are not endemic for intestinal helminthiasis (i.e. such as Ireland) it is acceptable to discharge the sewage of health-care establishments to municipal sewers without pre-treatment, provided specific requirements are met<sup>38</sup>. If these requirements cannot be met, the wastewater should be managed and treated accordingly<sup>38</sup>. While uncommon in Ireland, hospitals that are not connected to a municipal urban waste water treatment plants, should have their own sewage treatment plants.

Research on antibiotic resistance funded by the EPA has been performed at the Department of Bacteriology, National University of Ireland (NUI), Galway. Hospital effluent has been demonstrated to contain a high proportion of antibiotic resistant *Escherichia coli*<sup>40-41</sup> with enterococci isolated from hospital effluent resistant to vancomycin in some cases<sup>42</sup>. City sewage downstream of hospital discharges showed a higher proportion of antimicrobial-resistant *E. coli* on average compared with urban sewage upstream from the hospital<sup>40-42</sup>. In addition to antimicrobial resistant bacteria, antimicrobial substances have also been detected in hospital effluent. Quinolones and fluoroquinolones were detectable in city sewage downstream of the hospital effluent discharge point, with no detectable levels upstream<sup>40, 43</sup>. These data suggest that sewage effluent from hospitals represent a relatively concentrated source of antimicrobial resistant bacteria and may also carry biologically active antimicrobial agents. There is a wider implication in that traces of other potentially toxic compounds (such as cytotoxic compounds) that are administered as treatment to patients and that are excreted in the urine or faeces may be also be present in hospital effluent.

### 3.3.3 Drinking water treatment

Raw water extracted from surface or ground water sources and destined for use in public supplies usually requires treatment in order to achieve compliance with drinking water regulations<sup>17</sup>. Water treatment sludge is classified as a non-hazardous waste<sup>23</sup> and as such the management and disposal of this sludge is required to be carried out in compliance with the Waste Management Act, 1996-2003, its associated amendments and regulations<sup>31</sup>. Accordingly, management and disposal arrangements for this sludge are subject to licensing conditions or permit<sup>23</sup>. LAs are requested to submit an annual inventory of water abstracted for human consumption, including quality and treatment to the EPA. This information is summarised in the EPA annual publication on the Quality of Drinking Water in Ireland<sup>44</sup>. In 2007, the EPA recommended<sup>21</sup> that all LA should review current methods of handling and disposal of water treatment sludge to ensure that the practice is not in contravention of the Waste Management Act, 1996-2003<sup>31</sup>.

### 3.4 Organic Industrial Materials

Some classes of organic industrial materials are collected for use for land-spreading. Current data indicate that industrial materials represent approximately 0.82% of the total quantity of materials (Table 1) which are spread on Irish agricultural land<sup>22</sup>. The approximate quantities of specific industrial materials that were land-spread in Ireland in 2004 are given in Table 4<sup>22-23</sup>.

<b>Category</b>	<b>Quantity (% of Total)</b>
River Dredgings	238,565 (48.12%)
Dairy Industry	120,661 (24.34%)
Meat Industry	92,555 (18.67%)
Brewing Industry	28,487 (5.75%)
Other Food Processing <sup>3</sup>	7,990 (1.61%)
Pharmaceutical Industry	7,385 (1.49%)
Wood Industry	102 (0.02%)
<b>Total</b>	<b>495,745 (100%)</b>

<sup>1</sup> Source of Data<sup>22</sup> except river dredgings<sup>23</sup>

<sup>2</sup> It is unclear if the land these organic materials were land-spread on was used for food production. Likewise, information regarding the amount injected or otherwise spread to such land is unavailable.

<sup>3</sup> It is not clear what the exact components of this category are. However, Annex III of Directive 91/271/EEC<sup>28</sup> concerning urban waste-water treatment lists industrial sectors as the following; Milk-processing; Manufacture of fruit and vegetable products; Manufacture and bottling of soft drinks; Potato-processing; Meat industry; Breweries; Production of alcohol and alcoholic beverages; Manufacture of animal feed from plant products; Manufacture of gelatine and of glue from hides, skin and bones; Malt-houses; Fish-processing industry.

There is a considerable body of knowledge and many legislative controls related to the land-spreading of OA, e.g. animal manure, and organic municipal materials, e.g. biosolids,<sup>22</sup>. However, industrial materials at times may contain biological or chemical hazards which are not addressed by current practices and legislation<sup>1</sup> related to the control either of agricultural and municipal materials. Furthermore, the impact and interaction of industrial materials and the possible effects on food safety are not fully elucidated or understood.

At European level there has been debate over the last number of years regarding possible revisions to Council Directive 86/278/EEC, on the protection of the environment, and in particular of soil, when sewage sludge is used in agriculture<sup>1</sup>. Issues under consideration included revised metal limits for soils and sludge and proposed new limits for organic compounds in biosolids destined for re-use in agriculture. However, to date no agreement has been reached. The REACH Regulation<sup>45</sup> which came into force in June 2007 gives greater responsibility to industry to manage the risks from chemicals and to provide safety information on the substances of concern. Manufacturers and importers will be required to gather information on the properties of the substances they produce or import. This information must be registered at a central database to facilitate safe management of the chemicals. The Regulation<sup>45</sup> also requires the progressive substitution of the most dangerous chemicals with less dangerous ones, when suitable alternatives have been identified.

#### **3.4.1 Animal by-products**

Animal by-products (ABP) are entire bodies or parts of animals or products of animal origin (i.e. as referred to in Articles 4, 5 and 6 of current legislation) not intended for human consumption including ova, embryos and semen<sup>18</sup>. Each year around 550,000 tonnes of raw ABP is produced in Ireland<sup>20,46</sup>. A large amount of catering waste and former foodstuffs also fall within the definition of ABP. The use or disposal of this material is strictly controlled under both EU and national Regulations<sup>18</sup> (Chapter 2). The Regulations<sup>18</sup> determine both the uses ABP may be put to and the manner in which they must be treated and handled<sup>46</sup> in order to protect both public and animal health<sup>20</sup>.

Most raw ABP is processed in rendering plants, and converted after rendering to tallow and meat-and-bone-meal (MBM). Tallow is used increasingly as an alternative to heavy fuel oil. The bulk of MBM produced is exported for incineration<sup>20</sup>. However, the amount exported has declined as alternative domestic disposal routes (such as co-incineration in the manufacture of cement; and inclusion in the manufacture of pet food) have opened up. DAFF is also aware of proposals to use MBM in the generation of electricity and production of fertilizer. Composting and anaerobic digestion provide an outlet for safe disposal of some types of ABP.

ABP are also used in the manufacture of technical products such as gelatine and leather from animal hides<sup>20</sup>. Grass, lairage manures and slurries from meat plants are spread on agricultural land in an untreated form which is permissible under current legislation<sup>18</sup>. Washings from meat plants including truck washings, blood bath washings, etc., enters the plants own waste water treatment system. The resultant effluent from this treatment system enters adjacent waterways while the resultant solid material (i.e. sludge) is often spread on agricultural land.

It is estimated that over 92,500 tonnes of organic material from the meat industry was land-spread in Ireland in 2004 (Table 4), however, the exact nature of the land onto which this material was land-spread is unclear.

Some food processors, e.g. ready meal manufacturers, with on-site primary wastewater treatment plants will also produce sludge. Many of these food processors land spread this sludge on agricultural land under waste permits issued by their local authorities (Table 4). Further information on ABP is given in Appendix I.3.

## 4. MANAGEMENT AND TREATMENT OF MATERIALS

### 4.1 Introduction

As a general principle there should be a clearly defined benefit to agriculture from the spreading of OA and OMI materials on agricultural land if it is to be regarded as something other than simply a waste disposal practice. A number of management, treatment and prevention strategies are available and should be employed to prevent and/or minimise the migration, contamination and accumulation of chemical contaminants and pathogens and/or their toxins in foods produced on land on which OA or OMI materials have or are to be land-spread. In some cases these strategies are prescribed under legislation, or are incorporated in advisory documents, codes of good practice, and in other protocols pertaining to agriculture.

The likelihood of a risk to food safety arising as a result of spreading OA materials and in particular OMI materials on agricultural land used for food production will depend on a number of factors. These include, inter alia:

1. the source and characteristics of the OA or OMI materials
2. efficient control and monitoring of OA or OMI source materials
3. the treatment and management the OA or OMI material receives prior to land-spreading
4. the nature of the food products derived from the land where spreading has taken place, e.g. RTE fruit and vegetables, produce from grazing livestock
5. the soil type, characteristics, e.g. pH, moisture content etc., and suitability
6. the vulnerability and susceptibility of groundwater and surface waters to contamination
7. the use of buffer zones for the protection of water sources
8. the method of land-spreading (i.e. application method is important for the potential movement of pathogens<sup>47</sup> and could for example result in the formation of aerosols<sup>48-51</sup> which may cause airborne dispersal of pathogens and contamination of crops)
9. the timing of land-spreading relative to soil and climatic conditions, and the appropriate rate of application
10. the prevailing weather conditions, e.g. rainfall
11. the type and state of vegetation on the land.

### 4.2 Soil Type, Characteristics and Suitability

Soil type and the suitability for land-spreading of OA and OMI materials vary across Ireland. Some soils and subsoils are shallow<sup>1</sup>, highly permeable or prone to flooding or run-off<sup>47</sup>. Given that OA and OMI materials can contain pathogens<sup>7, 10, 52</sup> and chemical contaminants<sup>8, 53</sup> such soils or subsoils may render underlying groundwaters vulnerable to contamination from surface activities such as land-spreading<sup>54</sup>.

Soils and subsoils provide protection to groundwater by filtering out microorganisms, or retarding their multiplication<sup>54</sup>. The degree of protection depends on the type and thickness of the soils/subsoils, with greater protection being afforded by thick soils/subsoils with high clay content<sup>54</sup>. As such, before OA and OMI materials are land-spread, the suitability of the agricultural land for such treatment, in terms of the type and thickness of the soil/subsoil, should be determined so as to take account of the vulnerability of the groundwater in the vicinity<sup>54</sup>. As there is a relationship between the degree to which soils and sub-soils protect groundwater and the extent to which they promote surface overland flow (i.e. runoff) to watercourses, it is imperative that, when assessing the suitability of sites with regard to the land-spreading of OA and OMI materials, the risk to both groundwater and surface waters is considered and balanced.

The vulnerability of the groundwater to contamination can be assessed by referring to the Groundwater Protection Scheme Matrix for Land-spreading<sup>54</sup>, which includes a requirement for the demonstration of a sufficient soil/subsoil cover over the underlying aquifer resource to limit the risk of contamination. The matrix implies that spreading organic materials on lands is acceptable where it can be demonstrated that a consistent soil/subsoil thickness of at least 2m exists over regionally important aquifers and at least 1m exists over locally important or poor aquifers<sup>54</sup>. Further information on this scheme is available from the EPA, DEHLG and the Geological Survey of Ireland.

No comparable prescriptive assessment scheme exists for evaluating sites with regard to their potential contribution to surface water contamination. This is because a variety of physical soil characteristics, including soil moisture content, interact with morphological and physical characteristics of the landscape, contaminant characteristics, and climatic variables, in determining such a contribution. A generalised scheme for assessing “runoff risk” has been developed based on the physical characteristics of soil<sup>55</sup>. However, its scale of applicability severely impedes its usefulness in site-specific assessments. In practice, local knowledge of landowners, sometimes assisted by trained professionals, is typically relied upon for site assessments.

#### **4.2.1 Persistence of pathogens in the environment**

Understanding the environmental persistence and survival of enteric pathogens introduced into soil by land-spreading, is required to provide a scientific basis for management practices designed to mitigate the potential microbiological risks to health associated with land-spreading OA and OMI materials on agricultural land used for food production<sup>35</sup>. The persistence and survival of pathogens in the environment is influenced by many variables (Chapters 4.1-4.2), including land-spreading method, climatic conditions, properties of the soil, e.g. pH, temperature, moisture content, soil texture, organic matter content and adsorption properties, and interactions with soil biota<sup>35, 47, 56-59</sup>.

The moisture content and temperature of soil have been identified as principal variables influencing pathogen survival<sup>56, 60-61</sup>. Sandy soils are considered to be less favourable than clay soils to pathogen survival, because they are more susceptible to moisture loss<sup>56, 62</sup>. However, pathogen persistence and survival in soil is determined by complex and interacting biological and environmental factors and fundamental understanding of these processes is currently inadequate to predict inactivation rates of pathogens under different field and sludge application conditions<sup>35</sup>. Pathogens can adapt to soil environments and survive variations in soil and environmental conditions<sup>56</sup>. A recent report investigating the survival of *Escherichia coli* O157:H7 in naturally contaminated soil stressed the importance of avoiding the use of raw cattle manure to amend soil for cultivation of foods, including soils in residential garden plots<sup>61</sup>. Furthermore, as both humans and animals may ingest soil adhering to crops, there should be a sufficient interval between land-spreading, planting and harvesting of crops (particularly ready-to-eat crops) or resumption of grazing, to allow pathogen die off<sup>60, 63-64</sup>. Further detail on pathogen persistence is given in Appendix 4.6.

#### **4.2.2 Method of land-spreading**

The method of land-spreading is important for the potential movement of pathogens in the environment<sup>47</sup>. Research has indicated that the method of land-spreading OA and OMI materials can significantly increase bacterial contamination of surface water from runoff, especially if good agricultural practices are not followed<sup>47</sup>. Recent data also provide evidence that the method of land-spreading can significantly influence the survival of pathogens such as *E. coli* O157:H7 in OA or OMI amended soils<sup>65</sup>.

The typical equipment used for land-spreading of liquid OA materials such as slurry, is the vacuum tanker fitted with a splash plate. This system can transport and surface-apply large volumes of slurry<sup>60, 66</sup>. However, control of application rates using the vacuum tanker is poor on many farms and this can result in either under or over application of slurry to the land<sup>66</sup>. Recent developments with slurry spreading technology include low-trajectory injection and band spreading<sup>60, 66-67</sup>. These techniques reduce the risk of aerosol generation and potential contamination by aerosol drift to adjacent crops, grazing land, livestock and waterways<sup>60</sup>. However, slurry applied in this way is likely to dry more slowly and be less exposed to ultra-violet radiation thereby increasing the potential for pathogen survival<sup>60</sup>. Solid manures and sludge are typically surface applied using the rear discharge spreader or side-flinger spreader<sup>66</sup> which then requires a second tillage operation, e.g. ploughing, for incorporation into the soil<sup>47</sup>. Better control of solid manure can be achieved with rear discharge spreaders than with side-flinger machines<sup>66</sup>.

Pathogen-survival times are likely to be longer in soils than on the surface of soils<sup>59</sup> or crops due to reduced exposure to ultra-violet radiation. Some pathogens may still be viable in soil several months or years after land-spreading<sup>10, 60, 62, 64</sup>. Sub-surface injection of organic materials into soil may reduce the risk of pathogen persistence in the environment in comparison with surface spread organic materials<sup>65</sup>. However, incorporating OA and OMI materials into soil through injection and ploughing may increase the time enteric pathogens remain viable in the soil after land-spreading<sup>59</sup> while decreasing the likelihood of any pathogens becoming airborne during spreading<sup>47</sup>. It has been reported that the incorporation of sludge into soil introduces a significant dilution factor which influences the practical ability to detect target organisms<sup>65</sup>. Land-spreading OA and OMI materials on the soil surface may increase the likelihood of pathogen spread<sup>65</sup>. Furthermore, leaving OA and OMI materials on the soil surface may increase the possibility that rainfall could cause surface runoff and wash pathogens and chemical contaminants directly into watercourses<sup>65</sup>. DAFF has indicated the precautions farmers should take when spreading fertilisers (including manure and sludge) to land<sup>19</sup>.

#### 4.3 Management

For some organic materials, particularly animal manure, appropriate management and best practice entail their spreading on land as a soil amendment<sup>68</sup>. Many organic materials have intrinsic value as agricultural inputs. For this reason, spreading on land has long been an acceptable means of managing these materials, particularly animal manures collected during the winter housing period, in addition to excreta which are deposited directly onto grassland by grazing livestock<sup>66</sup>.

Management and treatment options for OA and OMI materials are available to attain reduced levels of pathogens and chemical contamination. The safety characteristics of managed and/or treated OA and OMI materials will largely depend on the source of these materials and on the level of pathogens and chemical contaminants in the untreated source material. Therefore, while management and treatment of OA and OMI materials are important, efficient control and monitoring of the source material, particularly in the case of OMI materials, are essential prerequisites for food safety if these materials are intended to be spread on agricultural land used for food production.

#### 4.4 Treatment

A wide variety of strategies are available for the treatment of OMI, and to a lesser extent OA materials. As a general rule, many of these strategies can be applied routinely when local knowledge of current management practices, the material and area to be treated are taken into account. In addition to OA materials such as animal manures, OMI materials such as sludge from urban waste water treatment (Chapter 3.3.1) are permitted under certain circumstances to be land-spread in Ireland. These materials contain substances of agricultural value, e.g. nitrogen, phosphorus etc. but on occasion can also contain metals, e.g. cadmium, lead etc. and chemical contaminants, as well as pathogenic microorganisms and their toxins. Additional information on the treatment strategies available for OMI and other organic materials is presented in Appendix 3.

#### 4.5 Management of Organic Agricultural Materials

Management of OA materials entails the careful handling of these materials so as to avoid environmental problems, food safety issues, and other adverse consequences. Treatment of OA materials by one or more specific treatment options, e.g. composting, aeration, addition of lime etc.<sup>69</sup> can be part of the management of OA materials. However, there is a limited range of validated and effective treatment options available for OA materials.

Deriving agronomic benefit from OA materials and preventing environmental and other adverse consequences are fundamental principles on which good management is based. It is the case in Ireland and elsewhere in the EU that treatment, other than storage, is considered unnecessary for compliance with accepted and regulated practice of animal manure management. Exceptions to this rule exist such as a mandated treatment of manure following an outbreak of a controlled notifiable disease (Appendices 3.1.4 and 3.1.6).

In most EU countries, including Ireland, manure management on farms is regulated in terms of generic environmental protection which is mainly focused on nutrient emissions. However, as the risk (to environmental quality) is recognised as being proportional to the magnitude of a potential hazard, large and intensive animal production facilities that generate large volumes of manure with a limited access to land area to safely assimilate the load, are regulated under the Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC)<sup>70</sup>. Further details on the IPPC directive are given in Appendix 1.4.6.

Management of OA materials is also legislated for under the Good Agricultural Practice for Protection of Waters Regulations, 2006<sup>4</sup> (Chapter 2). The objective of this legislation is to reduce water pollution induced by nitrates from agricultural sources and to prevent further such pollution. Its primary emphasis, however, is on the management of manures and other fertilisers. While this legislation is environmentally focused and does not specify particular treatments for OA materials such as manure prior to land-spreading, it does outline the appropriate management of these materials. This involves handling, storage, spreading and monitoring to minimise risks predominately to the environment and indirectly to food and drinking water safety.

#### 4.5.1 Best practice for management of organic agricultural materials

Management of OA materials can directly control pathogen load and indirectly influence survival and transport of pathogens from the soil to water resources through modifying the microbial environment<sup>47</sup>. Food safety concerns resulting from the spreading of OA materials to agricultural land has given rise to the development of best practice techniques that are widely recognised as being effective in protecting human and animal health, as well as the environment. These practices are articulated in advisory documents<sup>66, 71-72</sup>, codes of good practice<sup>2, 19, 73-74</sup> and with increasing frequency, in regulations<sup>4, 18</sup>. As the focus of most codes of good practice is on protecting the environment, the provisions of such codes are oriented towards minimising the seepage of OA materials (and the associated microbiological agents, nutrients, organic substances, etc.) into water resources. These strategies protect water resources on an environmental basis and also afford some protection to these water resources on a food safety basis.

An adequately designed, maintained and implemented management system that is subject to regular review is fundamental to managing OA materials in a way that maximises the agronomic benefit that can be derived from the materials whilst minimising the likelihood of detrimental effects on the environment, human and animal health. Guidelines that describe the required elements of an effective management system, as well as the appropriate managerial processes, are now available<sup>66</sup>.

At the core of an acceptable management system for OA materials is adequately sized manure storage facilities constructed to an approved standard<sup>47, 75</sup>. Adequate storage is essential to facilitate the spreading of animal manures to land at the appropriate time and rate. As noted below, some pathogen decline occurs as a consequence of manure storage; however, this is a useful coincidence, not an objective of storage<sup>7</sup>. Research has concluded that temperature, aeration, pH and dry matter content, determine pathogen declination rates during storage. However, many of these factors vary with management practices<sup>64</sup> and there are uncertainties about the nature and management of OA materials, in particular storage conditions and storage capacity. As such there is a reasonable likelihood<sup>76-77</sup> that land-spreading OA on agricultural land used for food production could contaminate field crops, water supplies, grazing animals and aquatic life and thereby compromise food safety. A recent American study indicated that the use of improperly ageing, untreated animal manure for fertilisation of produce plants (i.e. fruits and vegetables) significantly increased the risk of *Escherichia coli* contamination in organic produce grown using such manure as a fertiliser<sup>78</sup>. A 2007 European Food Safety Authority (EFSA) opinion on mesophilic composting indicated that the practice does not ensure the kill-off of all pathogenic microorganisms present while the rate of die-off in liquid OA material (i.e. slurry) is variable, depending on the spectrum of animal and/or human pathogens present<sup>79</sup>.

Manure management practices alone are insufficient to ensure that the spreading of animal manure to agricultural land used for food production is safe. The process of spreading OA materials and their placement are also critical. The three equally important elements of rate, timing and method of spreading are essential to ensuring that manure is spread on land in the correct quantities, at appropriate times and by the appropriate technique<sup>66</sup>. Considerations regarding the placement of manure are guided by the twin objectives of utilising the material beneficially and minimising the potential for the material to be lost to water resources. In the United Kingdom the Chilled Food Association stated in 2002 that manures and slurries must not be applied within a 50-metre radius of a water source<sup>80</sup>. Scientific research has established the appropriate rates, dates and methods for spreading manure to land, as well as safeguards, e.g., buffer zones, exclusion areas, to protect surface and groundwater resources (Chapter 4.2).

Spent mushroom compost is a residual by-product from the mushroom industry and is applied as a soil amendment in Ireland (typically in horticulture or agriculture). At present in Ireland, there are no statutory controls or uniform standards for natural biological degradation processes such as the composting of materials derived from OA and OMI sources<sup>m</sup>. Because of this, there is no accepted “best practice” for the composting of organic materials destined for land-spreading. The lack of quality standards is a recognised impediment to the appropriate use of municipal composts in the Government’s National Strategy on Biodegradable Waste<sup>81</sup>. The Compost Association of Ireland (Cré) is addressing this need by developing compost quality standards under the auspices of the EPA. Meanwhile, guidance for the appropriate land-spreading of spent mushroom compost is available<sup>72</sup>.

#### **4.6 Management of Organic Municipal Materials**

Usage trends associated with organic municipal materials indicate a significant increase in the use of sludge in agriculture with a corresponding decrease in disposal of sewage sludge to landfill<sup>24</sup> (Appendix 2.2). However, the land-spreading of municipal materials where pre-treatment, e.g. pasteurisation<sup>2</sup>, or source control and monitoring are inadequate may lead to the migration, contamination and accumulation of metals, e.g. lead, cadmium etc., chemical contaminants and pathogens in soil, groundwater or surface waters<sup>1-2, 8, 53, 82-84</sup>. This may subsequently lead to contamination of herbage, crops and exposure of animals, e.g. grazing livestock, to these hazards and the risk of concentration of contaminants in the human food chain via animal and vegetable/crop products.

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<sup>m</sup> At the moment there is no compost standard in Ireland. In the absence of composting standards in Ireland the EPA and local authorities are using a technical discussion document produced by the European Commission “Biological Treatment of Biowaste”, when regulating composting facilities.

Adequate source control and monitoring of municipal materials are essential prerequisites for food safety when spreading these materials on agricultural land used for food production. Some composted source-separated organics arising from biodegradable municipal materials, e.g. garden trimmings, are ultimately utilised on land (Appendix 3.3.2). These materials are also potential contaminants if not appropriately managed and can pose a risk to food and drinking water safety.

#### **4.6.1 Best practice for management of organic municipal materials from urban waste water treatment**

Typically, in the case of urban waste water treatment, LAs employ a specific method of treatment (Chapter 3.3.1) or a combination of treatments based on the characteristics of the waste water received at a treatment plant and the current end-use option(s) identified by the local county council in its sludge management plan for that county<sup>24</sup>. Current best practice for management and treatment of sewage sludge from urban waste water treatment for use in agriculture is in accordance with DEHLG Codes of Good Practice<sup>2</sup> (Chapter 3.3.1). However, the potential for the use of sludge in agriculture can only be evaluated by referring to the requirements of a specific county under the terms of its sludge management plan.

The EPA has recommended that all LAs should audit the chain of custody of sludge consignments under their supervision and ensure that Sludge Registers are kept up to date and are compliant with the requirements of the Regulations<sup>1, 24</sup>. However, the EPA has found that sampling programmes at some LAs where sludge is used in agriculture are either non-existent or in need of improvement, and that there is inadequate maintenance of sludge registers<sup>85</sup>. Provision of adequate resources to allow enforcement, coordination and greater cooperation between Government departments, local authorities and State agencies is required to ensure best practice for management and treatment of sewage sludge from urban waste water treatment.

#### **4.7 Management of Organic Industrial Materials<sup>n</sup>**

As with the LAs and their handling of urban waste water treatment derived materials (Chapter 4.6), some sectors of industry may be required to employ a specific method of treatment (Appendix 3) or a combination of treatments based on the characteristics of the waste water they produce. While appropriate treatment(s) of organic industrial materials are important, appropriate control and monitoring of source material are the essential prerequisites for food safety if organic industrial materials are to be land-spread on agricultural land used for food production. This concern is also important in the context of urban waste water treatment, as the nature of industrial waste water entering a treatment plant will depend on the category of the industry in the local authority area serviced by that treatment plant.

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<sup>n</sup> No distinction is drawn in Chapter 4.7 between industrial materials which are pre-treated and those which are not pre-treated prior to discharge.

There is considerable knowledge, along with legislative controls, regarding the land-spreading of OA materials and sludge from municipal materials originating from urban waste water treatment plants<sup>22</sup>. However, unlike OA and municipal materials, there can be a large diversity of industrial materials in industrial waste water, some of which may contain contaminants, including some not naturally found in that environment served by a local urban waste water treatment plant, and some which may fall outside current legislative controls<sup>22</sup>. Sludge, especially industrial sludge, may contain potentially high concentrations of metals and organic micro-pollutants<sup>86-87</sup>. Sludge has been found to also contain large amounts of pathogens<sup>88</sup>. In many cases there is a lack of knowledge and understanding regarding the effects these materials may have on food safety if land-spread on agricultural land used for food production<sup>22</sup>.

#### **4.7.1 Best practice for management of organic industrial materials**

Some industries operate in accordance with IPPC licences (Appendix I.4.6) and as such manage and/or treat materials they produce prior to discharge into municipal sewers. For those industries to which an IPPC licence applies, specific strategies for sludge management are subject to prior agreement with the EPA. Each individual company or its plant to which the IPPC licence applies must submit annually an environmental report on the successful implementation of its sludge management strategy to the EPA. Local authorities may also highlight concerns they have in relation to aspects of specific industrial sludge management to the EPA.

In the case of industries not operating under an IPPC licence from the EPA, a LA may demand specific requirements relating to the treatment of waste water before discharge, along with the management of materials derived from that treatment, by that specific company. However, regardless of any specific requirements imposed upon an industry or company under an individual IPPC licence or specific legislation such as the Waste Management Acts<sup>31</sup>, best practice for management of industrial materials for use in land-spreading will include:

1. compliance with the requirements of relevant legislation and/or IPPC licence if applicable
2. provision of adequate pre-treatment and storage facilities for materials as required
3. observation and adoption of codes of good practice for land-spreading if available and/or applicable
4. regular analyses of sludges and/or treated materials prior to discharge and/or land-spreading
5. prevention strategies can be considered as an element of management, though these already focus on increasing process efficiencies so as to minimise the creation of by-products.

As with agriculture, if an industry is engaged in the practice of land-spreading then a nutrient management plan for all lands on which materials is to be spread is required by the relevant local authority. Regular updates and revisions of this plan, along with copies of all nutrient management plans, soil and sludge analysis and land-spreading agreements, are also required to be sent to local authorities for annual review. Furthermore, regular soil and water monitoring is required to be undertaken before and after land-spreading. As prescribed in their IPPC licence, if an industry is using contractors to transport and/or spread materials, there are responsibilities on that industry to ensure that the contractor is a recognised/licensed agricultural contractor<sup>15</sup>. Details of specific IPPC licences are available through the EPA website [www.epa.ie](http://www.epa.ie)

#### **4.8 Current Best Practice for Land-spreading on Agricultural Land used for Ready-to-Eat Food Crops**

Ready-to-eat (RTE) food is food intended by the producer or the manufacturer for direct consumption without the need for further cooking or processing<sup>89</sup>. RTE food crops include salad vegetables, e.g. cucumbers, lettuce, radish, onions, herbs, etc., and fruits, e.g. tomatoes, plums, strawberries, apples etc.<sup>90-91</sup>. On occasion, other fruits and vegetables, e.g. leeks, squashes, rhubarb etc. may be consumed without further cooking or processing. Crops such as salad vegetables and fruits which grow close to the surface of the soil can become exposed to microbiological and chemical contamination from land-spreading of OA and OMI materials<sup>73</sup>. Current best practice for the land-spreading of OA and OMI materials on agricultural land to be used for RTE food crops in Ireland includes:

- I. adherence to the relevant sections of legislation for the use of sewage sludge in agriculture<sup>1</sup>:
  - only treated sludge may be used in agriculture except:
    - untreated sludge may be used in agriculture provided that it is previously injected or otherwise worked into land
  - sludge shall not be used or supplied for use on:
    - land on which fruit, other than fruit trees, or vegetable crops are growing or
    - land intended for the cultivation of fruit or vegetable crops which are normally in direct contact with the soil and eaten raw, for a period commencing ten months prior to harvesting, and during harvesting
    - treated sludge should not be used or supplied for use on grassland or forage crops where the grassland is to be grazed or forage crops to be harvested within three weeks of such use.

2. adherence to the relevant sections of the current DEHLG codes of good practice for the use of biosolids<sup>o</sup> in agriculture<sup>2</sup>. These codes state that:
  - untreated wastewater sludge should not be land-spread or injected into soil
3. adherence to the current FSAI code of practice for food safety in the fresh produce supply chain in Ireland<sup>73</sup> which includes the following:
  - the treatment of manure is not an exact science and there is a chance that some pathogens may survive. The risk of contaminating fresh produce can be minimised further by maximising the interval between manure application and produce harvest
  - untreated manure or leachate from raw manure or animal slurry should not be used on produce fields after the crop is sown
  - raw farmyard manure or slurry should not be used in horticulture. If its use is unavoidable, raw manure should only be applied for ground preparation purposes and should be at least partially rotten
  - raw manure should be mixed into the soil rather than being spread on the surface so that pathogens are reduced and the risk of run-off into a water source is avoided.

#### **4.8.1 Additional best practice considerations for land-spreading on agricultural land used for ready-to-eat food crops**

While taking into consideration the current best practice for land-spreading on agricultural land used for RTE food crops in Ireland, it should be noted that this report will in subsequent chapters, propose amendments which would further augment the food safety provided by current best practice including:

- the interval between the land-spreading of treated sewage sludge and harvesting of ready-to-eat food crops should be a minimum of 12 months
- given the limited range of practical, validated and effective treatment options available for OA materials and the uncertainties about the nature and management of OA materials, untreated OA materials should not be land-spread on land to be used for RTE food crops
- treated or untreated OA and OMI materials should not be land-spread after the planting of RTE food crops
- during land-spreading the formation of aerosols should be minimised to avoid airborne dispersal of pathogens and contamination of RTE food crops growing in adjacent fields.

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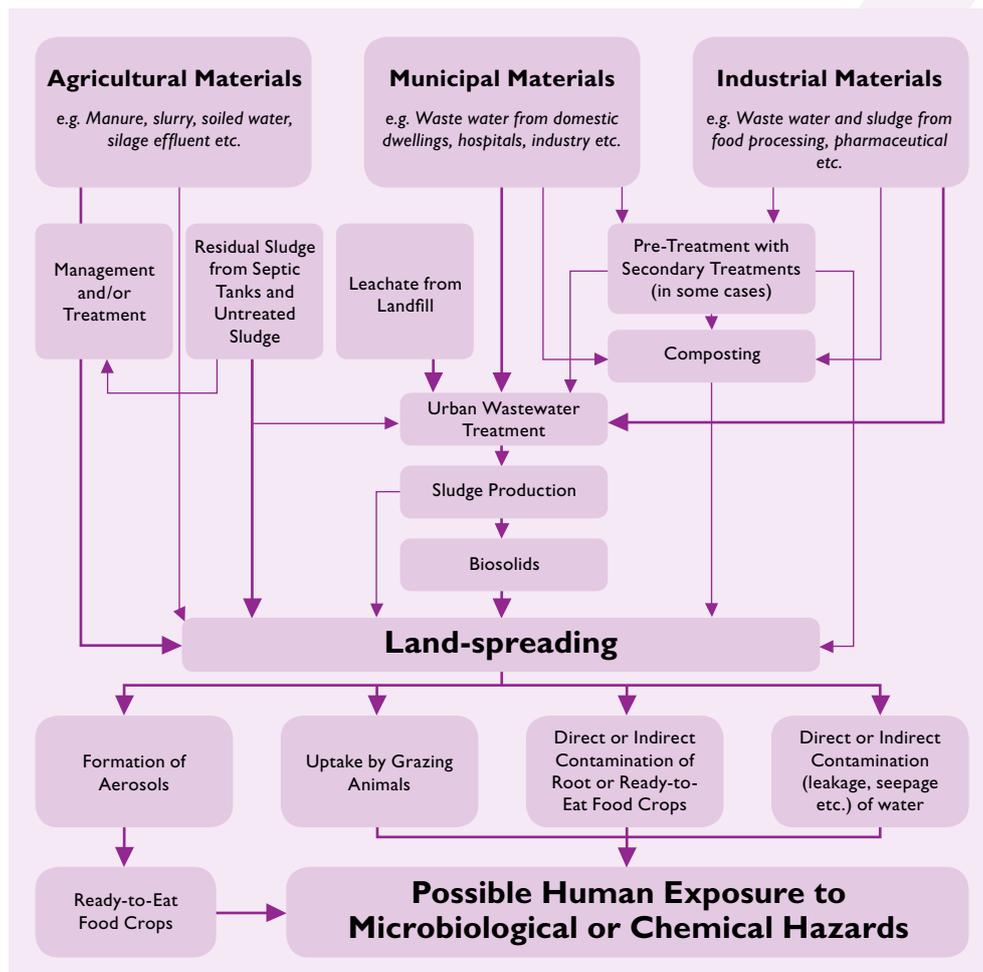
<sup>o</sup> While not specifically stated in the codes of good practice for the use of biosolids in agriculture, the DEHLG has confirmed to the FSAI that the codes of good practice prohibit the use of biosolids on RTE food crops. The land spreading of biosolids is only permitted in the circumstances outlined under Parts 4.2 to 4.4 and Table 1 of Appendix 5 of the Guidelines for Local Authorities and Wastewater Treatment Plant Operatives and Parts 5.2 to 5.4 and Table 1 of Appendix 5 of the Guidelines for Farmers<sup>2</sup>. Therefore, other uses are not permitted.

## 5. MICROBIOLOGICAL AND CHEMICAL HAZARDS

### 5.1 Introduction

Appropriately managed organic agricultural (OA) materials, e.g. manure, and appropriately treated and managed organic municipal and industrial (OMI) materials, e.g. sludge, can be an effective source of nutrients for plants and crops<sup>92</sup>. However, mismanaged, untreated, inadequately treated, or re-contaminated OA and in particular OMI materials are risks to food safety. Subsequent contamination of foods as outlined in Figure 1 can occur directly or indirectly<sup>73</sup>.

**Figure 1. Potential Routes of Exposure to Microbiological and Chemical Hazards through Land-spreading of Contaminated Organic Materials**



## 5.2 Microbiological Hazards

Zoonoses are diseases or infections, which are transmissible from animals to humans<sup>93</sup>. These can be acquired directly from animals, or through ingestion of contaminated foodstuffs<sup>93-95</sup>. Food producing animals as well as domestic pets can harbour zoonotic pathogens.

In the EU in 2005, the most frequently reported zoonotic disease in humans were campylobacteriosis, salmonellosis and those caused by foodborne viruses<sup>96</sup>. In Ireland for the year 2007 up to the end of week forty-four, the most frequently reported foodborne diseases in humans included campylobacteriosis (1,686 cases), Norovirus (946 cases), cryptosporidiosis (589 cases), salmonellosis (402 cases), Verocytotoxin producing *E. coli* (VTEC)<sup>P</sup> (123 cases), giardiasis (54 cases), shigellosis (41 cases) and listeriosis (17 cases)<sup>97</sup>. Norovirus infections are the most common cause worldwide of epidemic food and waterborne viral gastroenteritis<sup>94, 98-99</sup>.

Animal and human faeces harbour a wide range of bacterial, viral and protozoan pathogens. Outbreaks of VTEC illness in humans have been associated with a range of products including consumption of under cooked beef products<sup>100</sup>, milk<sup>10</sup>, fruit and vegetable products<sup>101</sup> and drinking water<sup>102-103</sup>. Many case studies demonstrating the risk of land-spreading on food safety have been documented. An outbreak of listeriosis in Canada in 1981 involving coleslaw was linked to cabbage harvested from fields fertilised with untreated sheep manure taken from a farm with a history of ovine listeriosis<sup>13</sup>. Following an outbreak of *Escherichia coli* O157 (i.e. VTEC) infection in the United Kingdom epidemiological evidence indicated that the outbreak was associated with the use of manure from cows to fertilise ground for growing potatoes that were then offered for sale unwashed<sup>14</sup>. Contamination of a municipal water supply in Ontario, Canada in 2000 led to an outbreak of illness due to *E. coli* O157 and *Campylobacter* that affected more than 2,300 people, of whom seven died. A subsequent report concluded that the primary, if not the only, source of contamination was manure that had been spread on a farm near to a shallow well that supplied the municipal water system<sup>15</sup>.

In Ireland, there is increasing concern about the potential of drinking water as a transmission route for VTEC and other water-linked diseases such as cryptosporidiosis and Norovirus infection<sup>104-105</sup>. Two reports by the FSAI<sup>104</sup> and the EPA<sup>106</sup> in 2006 highlighted the fact that the majority of drinking water health related problems in Ireland are due to microbiological contamination.

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<sup>P</sup> *Escherichia coli* are microorganisms commonly found in the intestinal tract of humans and animals, and most types do not cause human illness. However one group, VTEC, may cause serious illness or even death. There is more than one strain of VTEC and *E. coli* O157:H7 is the most common. VTEC poses a serious risk to humans as the number of VTEC organisms required to cause illness is very low. It can survive the gastric acids in humans and then pass to the gut where it grows and produces toxins<sup>107</sup>. The Health Protection Surveillance Centre (HPSC) report VTEC as Enterohaemorrhagic *Escherichia coli*.

The utilisation of OA materials and to a lesser extent OMI materials for agricultural purposes is common in many countries, including Ireland. In the case of urban waste water treatment, many of the pathogens present are reduced in number but are not completely removed<sup>108</sup> from the treated water. Those pathogens that are removed are concentrated by sedimentation processes in the removed sewage sludge<sup>108-109</sup>. The type and numbers of pathogens present<sup>110</sup> in sludge used for land-spreading will depend on the source, e.g. urban waste water treatment, meat plant waste water, hospital waste water etc. and constituents originally in the urban waste water being treated<sup>108-109</sup>. The pathogen load in this source material is further influenced by other factors, such as type of processes used in treatment<sup>110</sup>, general health of the local population<sup>57</sup> and weather conditions<sup>108,111</sup>. Certain classes of livestock are liable to shed increased numbers of pathogens, e.g. young bovine calves. Some research has suggested that consideration should be given to separate handling of manures from such stocks so that they are stored for longer periods or composted<sup>63</sup>.

Further details of microbiological hazards are outlined in Appendix 4.

### 5.3 Chemical Hazards

Since Ireland does not have an industrial past, general levels of chemical contaminants in OA and OMI materials and in the Irish environment are lower than in many other countries. However, there may be some regional variations in levels of contaminants in these OA and OMI materials. As such OA and OMI materials spread on agricultural land used for food production may contain hazardous chemical contaminants. With respect to food safety, metal contaminants in OMI materials<sup>112-113</sup> are considered more important than organic contaminants. The latter include lipid-soluble persistent organic chemicals, biocides<sup>114</sup>, pharmaceuticals and their metabolites. As with the pathogen level in sludge used for land-spreading (Chapter 5.2), chemical contamination of sludge could be influenced by other factors such as type of processes used in treatment, general health of the population and weather. However, data gaps exist<sup>6</sup>.

Maximum levels for nitrates are set out in EU legislation in respect of water<sup>17</sup>, lettuce, spinach and infant food<sup>115</sup> and high levels have been found in leafy vegetables both in Ireland and across the EU<sup>116</sup>. The land-spreading of animal manures and commercial fertilisers also can give rise to elevated levels of nitrates in water<sup>117</sup> and vegetables<sup>118</sup> (Appendix 5.10).

Some metals are concentrated in the roots and vegetative parts of crops and are less likely to be present in the generative parts, e.g. wheat grain,<sup>8, 119</sup>. The main uptake of metals by grazing animals is through ingestion of contaminated herbage or soil<sup>6, 8, 119-120</sup>. Total metal content in soil by itself is insufficient as a measure to indicate possible environmental risk. The speciation of metals in the soil and subsoil determines their behaviour and hence the toxicity toward terrestrial biota. However, there is little information in relation to quantities of these substances ingested and absorbed by animals<sup>18</sup> and their subsequent ingestion and absorption by humans via the food chain.

Some risk assessment studies have indicated that the risk to public health through exposure to metals via the food chain is remote for the general population<sup>121</sup>. Most of these substances do not accumulate in the muscle meat of domestic animals but rather in the offal, e.g. liver and kidney,<sup>8, 121</sup>. A European report in 1999 concluded that “sewage sludge can be used beneficially on land as a soil conditioner and fertiliser but, because of contamination with pollutants, the application of sewage sludge requires knowledge of trace element contents in soils”<sup>122</sup>. Consumption of contaminated fruit, vegetables and crops appears to be the main routes of exposure to organic municipal material-borne metals<sup>73</sup>.

It is not viable or cost effective to analyse for all chemicals in the end product of the waste water treatment (i.e. sewage sludge) due to the variability of chemical input source and treatment used at the waste water plant. In turn, the bioavailability of any chemical contaminant applied to the soil alters with the soil type, water content and pH. The vast majority of organic chemicals are rendered harmless by degradation and/or metabolic breakdown in the sewage system or by photodegradation once land-spread on the soil. A problem may arise if the pathway for degradation and/or metabolic breakdown for chemicals is similar, resulting in pathway overload. When this occurs, the parent compound may enter the environment unaltered. The consequent behaviour of these chemicals if land-spread would depend on the variable soil conditions.

The United States Environmental Protection Agency has indicated that biosolids are an important resource that can and should be safely used to condition soils and to provide nutrients for agricultural, horticultural and forest crops and vegetation, and for reclaiming and re-vegetating areas disturbed by mining, construction and waste disposal activities<sup>123</sup>. Nevertheless, special care must be exercised when utilising these materials and a comprehensive set of regulatory requirements<sup>124</sup> have been established based on a scientific risk assessment of this practice<sup>125</sup>. Further details of chemical hazards are outlined in Appendix 5.

## 6. CURRENT AND EMERGING ISSUES

### 6.1 Introduction

In addition to the hazards previously mentioned (Chapter 5), there are hazards to food safety which may arise over time in Ireland, from the land-spreading of organic municipal and industrial (OMI) materials and perhaps organic agricultural (OA) materials. For example, between 1993 and 2003, the WHO indicated that at least one new pathogen per year with the ability to be transmitted through the environment had been recognised as a new threat to public health<sup>119</sup>. A number of factors have contributed to this development. These include<sup>119</sup>:

1. changes in food production methods
2. changes in food transportation and distribution methods
3. changing population demographics
4. advances in technologies designed to isolate and identify pathogens
5. changes in pathogen evolution
6. development and application of microbial risk assessment techniques to quantify risks from pathogens
7. globalisation of food products and markets.

There are gaps in the current scientific knowledge concerning the practice of land-spreading of OA, and in particular, OMI materials and the implications of these practices for food safety. These gaps mainly relate to the pathogen and chemical contaminant content of organic materials, the fate of pathogens and chemical contaminants in soil and the changes in soil characteristics brought about by continued spreading of organic materials on Irish agricultural land used for food production<sup>126</sup>. Much information is lacking, in relation to the survival of human enteric viruses especially for foodstuffs and soils<sup>127</sup>.

### 6.2 Antimicrobial Resistance

The use of antimicrobial substances in livestock has been associated with antimicrobial resistance in *Salmonella* serovars and *Campylobacter* spp. isolated from humans and also likely among *Enterococcus* spp., and *Escherichia coli*<sup>128</sup>. Recognition of this potential relationship between the use of antimicrobial substances in livestock and development of antimicrobial resistance in bacteria isolated from humans, on occasion, was originally proposed in the 1960s<sup>128-129</sup>.

In 2007, EFSA stated that information which had been submitted on antimicrobial resistance of zoonotic bacteria (Chapter 5) across the EU for 2005 had indicated that foods of animal origin might serve as reservoirs for resistant bacteria with the risk of direct or indirect transfer of resistant bacteria to humans<sup>96</sup>. For example, the reporting of antimicrobial resistance in *Campylobacter* from the EU member states and Norway, demonstrated the presence of a reservoir of resistant bacteria in food animals, which implies a potential risk for foodborne transmission to humans<sup>96</sup>.

A Swedish study in 2006 demonstrated that *Salmonella* spp. isolated in sewage treatment plants had

originated from infected humans and had survived such treatment. When treated sludge from these plants was then used as a fertiliser, it was considered that this material could pose a risk of spreading multi-resistant *Salmonella* strains from sludge to the environment, to animals and ultimately to humans<sup>130</sup>. Another study conducted in 2006 indicated that the survival of salmonellae in waste water despite treatment implied the possibility of selection of antimicrobial resistant strains, or the acquisition of resistance through the transference of genetic material<sup>131</sup>. Research on antibiotic resistance in Ireland, funded by the EPA is currently being conducted at NUI, Galway (Chapter 3.3.2).

### 6.3 Influenza

Information on the excretion of influenza viruses such as the avian influenza virus H5N1 in urine or faeces of mammalian species, including humans, is limited<sup>132</sup>. However, the isolation of the H5N1 virus from the faeces of a child presenting with diarrhoea followed by seizures, coma and death<sup>132</sup> suggests that the virus may be excreted by infected humans. The H5N1 virus could potentially enter municipal sewage via urine or faeces excreted by infected humans or in animal materials that are combined with human sewage<sup>132</sup>. DAFF has produced a range of publications in relation to the control and management of avian influenza and disposal of poultry litter in the event of an outbreak<sup>133</sup>.

### 6.4 Composts and Associated Risks

There is some concern regarding the potential food safety risks of compost made from municipal sewage sludge (Appendix 3.2.2) as well as the environmental loading of bacterial spores, e.g. *Clostridium botulinum* (Appendix 4.3.7), from composts<sup>104, 134</sup>. Spores from a range of *Cl. botulinum* have been found in 50% of marketed garden compost<sup>134</sup>.

Composts derived from urban waste water treatment sludges also pose a cause for concern. A review of scientific data in 1995 indicated that there was a risk associated with hand to mouth contact and ingestion by children of composted urban waste water treatment sludges containing the metals mercury, lead, cadmium and chromium<sup>121</sup>. While this scenario is less likely to arise in an agricultural context, and while currently Irish waste water sludges typically have low metal contents, this finding still draws attention to the need for care and caution when composts derived from municipal and industrial waste water sludges are under consideration for approval for spreading on agricultural land used for food production.

Unlike most other EU countries there is currently no Irish legislation relating to the production, marketing and importation of composts intended for use on land (Chapter 4.5.1). Furthermore, no national standards or guidelines in relation to these products are available. Statutory standards are common in other European countries, in which there are established composting industries.

Meanwhile, in Ireland, it is understood that, as part of the National Strategy on Biodegradable Waste<sup>81</sup>, the spreading on land of compost derived from biodegradable municipal solid materials is to be made mandatory under the Landfill Directive<sup>27</sup> (Appendix 3.2.2).

### **6.5 Landfill**

The Sewage Sludge Directive 86/278/EEC<sup>1</sup> seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man<sup>135</sup>. However, while sludge recovery in agriculture and biosolids production have high operational costs, the land-spreading of OA and in particular OMI materials on agricultural land used for food production is likely to increase. These increases are a consequence of environmental policy (i.e. recovery), increased regulation of landfills and a Europe-wide decline in soil quality which has been primarily caused by a loss of soil organic matter<sup>136</sup>. Furthermore, landfill capacity is finite and the costs associated with its use are significant.

In line with Irish Government policy, the disposal of urban waste water treatment sludge to landfill is decreasing<sup>24</sup>. At the same time the production of sludge is increasing from new urban waste water treatment plants and is forecast to further increase with the development and implementation of new treatment plants<sup>24</sup>. Consequently the production of biosolids and their use on agricultural land used for food production is increasing<sup>24</sup> (Appendix 2.2.1). As the treatment requirements for municipal waste water become more stringent, and as additional waste water volumes continue to be treated, proportionally more sludge from these facilities will require management in the future. As risk is proportional to the magnitude of a potential hazard, increases in quantities of biosolids being land-spread on agricultural land used for food production increases the potential risk to food safety.

### **6.6 Exposure to Accidental Contamination**

The cause of a disease or altered physiological state may be difficult to establish<sup>112</sup>. While this report does not consider accidental industrial contamination, it is recognised that even where gross unforeseen contamination occurs a cause/effect relationship may be difficult to establish.

Minamata disease, a neurological syndrome caused by mercury poisoning, was first identified in Japan after a discharge of elemental mercury in waste sludge into Minamata Bay, where it was converted to organomercurials which resulted in the syndrome developing in people eating fish from the bay<sup>137</sup>. The cause-effect relationship between nonylphenols in detergents and environmental oestrogenic chemicals took ten years to be identified. Effective surveillance, monitoring and control programmes of source material remains the essential prerequisite for food safety in the future use of OA and in particular OMI materials, for land-spreading. For example, the contamination of trout with perfluorinated tensides, two orders of magnitude greater than the tolerable limit for fish, was the consequence of fertiliser mismanagement with subsequent water and fish contamination<sup>138</sup>. Due to vigilant surveillance and monitoring, it would seem that none of the contaminated fish in this incident entered the human food chain<sup>138</sup>.

### 6.7 On-site Waste Water Treatment Systems

In 1999, waste water from over one-third of the Irish population was treated by small-scale on-site systems principally associated with those living in dwellings not connected to municipal sewers usually in rural areas<sup>139-141</sup>. However, this figure may have changed since 1999 with increased urban development. On-site waste water treatment systems are designed to treat waste water at or near the location where it is produced (Chapter 3.3.1). These include systems such as private residential septic tanks, private communal septic tanks and secondary treatment systems such as mechanically aerated or filter systems<sup>140</sup>.

The most prevalent small-scale on-site system in use in Ireland is the conventional septic tank system<sup>139-141</sup>. The most recent census results, from 2002, indicated that there are 407,768 individual septic tank systems in the State<sup>142</sup>. However, specific data on the level, number and type of on-site waste water treatment systems serving private, individual, residential houses and communal developments in Ireland remain limited, although at county level some data may be available through sludge management plans. Wastewater treatment systems such as septic tanks and percolations areas should be designed in accordance with planning laws<sup>143</sup> technical documents issued by the DEHLG<sup>144</sup> and the EPA wastewater treatment manual for single houses<sup>105</sup>. However, data on the standard and inspection of existing and new septic tank systems after installation are limited. There is no official or routine monitoring of the efficacy of septic tank systems once installed.

Septic tank systems require regular de-sludging (i.e. typically every one to two years) to operate efficiently. Consequently, given the estimated number of septic tank systems in the State<sup>142</sup> there are practical difficulties in monitoring the use or disposal of this sludge. Sludges including septic tank sludges are regarded as waste under the Waste Management Act (with amendments)<sup>31</sup>. Under Section 34 of the Act<sup>31</sup> there is a general obligation to obtain a waste collection permit on any person who for the purpose of reward collects waste (i.e. the de-sludging of septic tank systems should only be undertaken by permitted collectors). Each LA is also required to keep a list of collection permits under Article 27 of the Waste Management (Collection Permit) Regulations, 2001<sup>145</sup>. The EPA holds a National Register of Collection Permits as required under Article 25 of the aforementioned Act<sup>145</sup> which is currently accessible via the EPA website<sup>9</sup>. Although current Regulations permit spreading of residual sludge from septic tanks on grassland provided that the grassland is not grazed within six months following such use (Chapter 3.3.1)<sup>1</sup>, the extent of this practice is unknown. Consequently, this practice is a matter of concern for now and increasingly for the future as the number of one-off housing increases.

### 6.8 Gaps in Current Knowledge and Legislation

As mentioned earlier, many gaps in current knowledge remain, concerning the transfer of contaminants and pathogens into the receiving environment and the food chain through the practice of land-spreading OA and, in particular, OMI materials. Gaps both in current knowledge and data significantly influence the validity of future risk assessments. This lack of knowledge impinges on the ability to establish scientifically valid management and treatment strategies for the land-spreading of OMI materials, and to a lesser degree OA materials, designed to maximise food safety. The following is a non-exhaustive list of identified gaps in current knowledge and legislation<sup>30, 52-53, 126, 130, 146-152</sup>:

1. currently available data do not permit a comparison between countries, as no common research protocols have been applied
2. while there is a commitment at European level to revise and amend current legislation at present there is an inconsistent and often complex legal framework for the management and control of specific organic materials rather than a consistent legislative framework incorporating relevant codes of practice for all organic materials which are land-spread
3. robust public health monitoring and surveillance systems to determine the efficacy of urban waste water treatment, and on-site waste water treatment systems and the safety of current and future land-spreading practices in Ireland are not in place
4. further improvements in building controls for the future use of on-site waste water treatment systems such as septic tanks

<sup>9</sup> The Waste Management (Collection Permit) Regulations, 2007 (S.I. No. 820 of 2007) shall come into operation on the 31st March 2008.

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5. data on the individual contribution of various sectors particularly industry, the health care sector, e.g. hospitals, and domestic municipal sources to sludge produced by urban waste water treatment are not available
  6. data on the following and the implications for food safety are limited, incomplete or unavailable:
    - the ability of pathogens to survive in organic material and on agricultural land used for food production following land-spreading
    - the ingestion and absorption by animals of organic compounds, metals, pathogens and their toxins
    - the toxicity of some widely-used organic compounds for humans and animals as well as their occurrence in the environment
    - runoff from land and subsequent contaminant and pathogen transfer to water supplies fish and shellfish farms
    - behaviour in soil of specific chemicals constituents from organic municipal and industrial materials such as drugs, pharmaceutical products and household chemicals
    - the contribution of biosolids to pathogen and contaminant transfer in the food chain
    - the use of nanotechnology<sup>r</sup>
    - the effects climate change may bring to the practice of land-spreading in Ireland
    - the development of multi-xenobiotic resistance
    - the effectiveness of current treatment and management options for spreading OA and OMI materials in preventing viral contamination of food and water sources.

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<sup>r</sup> In 2007, a Nanotechnology Working Group was established under the aegis of the Scientific Committee of the FSAI. This working group will report on the issues of nanotechnology and its implications for food safety in 2008.

## 7. HAZARD IDENTIFICATION AND RISK

### 7.1 Introduction

Management, treatment and prevention strategies are available to prevent and/or minimise the migration, contamination and accumulation of chemical substances, pathogens and/or their toxins in foods produced on land on which OMI materials have been land-spread. OA materials such as animal manures can be regarded as suitable for use as fertilisers or soil amendments if used appropriately and in accordance with good agricultural practice.

As previously mentioned (Chapter 4.5), in Ireland and elsewhere in the EU, treatment of OA materials, other than storage, is considered unnecessary for compliance with the accepted and regulated practice of animal manure management. Exceptions to this rule exist such as a mandated treatment of manure following an outbreak of a controlled notifiable disease. However, land-spreading of inadequately managed OA, and in particular inadequately treated and/or managed OMI materials containing potentially harmful chemicals and pathogens on agricultural land used for food production can contaminate field crops, water supplies, grazing animals and aquatic life and thereby compromise food safety.

The conditions affecting the presence and survival of pathogens and the presence of chemical contaminants, the potential for contamination of food products, and the hazards to food safety associated with the practice of spreading organic materials to agricultural land used for food production in Ireland, have been identified. A qualitative risk categorisation has been assigned to each hazard identified, based on currently available data. It is acknowledged here that in doing so, present scientific knowledge is incomplete regarding the survival and growth of pathogens and the persistence of chemical contaminants in organic agricultural, municipal and industrial materials following land-spreading. Accordingly, this categorisation is open to revision in the light of new data<sup>5</sup>.

### 7.2 Definition of Risk in Respect of Hazards

In this report, a hazard is defined as 'a biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect'<sup>16</sup>. Risk is a function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food<sup>16</sup>.

For the purposes of this report it is assumed that exposure to the hazard alone will lead to a health effect, the magnitude and severity of which cannot be estimated. Therefore, risks are categorised only on the basis of the likelihood of exposure to a hazard that is known to cause health effects in the general population. In relation to a specified hazard, this is further qualified as shown in Table 5.

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<sup>5</sup> Consideration of the environmental implications of land-spreading OA and OMI materials on agricultural land used for food production in Ireland, including occupational exposure, is outside the scope of this report.

**Table 5. Category of Food Safety Risk Corresponding to Likelihood of Exposure to a Hazard following the Land-spreading of OA or OMI Materials**

Category of Food Safety Risk	Likelihood of Exposure to Hazard
III	Unlikely, but not excluded
II	Likely, with a low probability
I	Likely, with a high probability

### 7.3 Biological Hazard Identification and Risk

The presence of pathogens in OA and OMI materials which are spread on agricultural land used for food production introduces the risk of soil, crop and animal contamination. There is also risk of their transmission via food including water. Depending on the source of the OA or OMI material it can be assumed that if no treatment and/or management option(s) are applied, the risk of contamination of foods of animal or vegetable origin produced on land so treated will increase.

The range of biological hazards and the categorisation of risks to food safety both depend on the source and source control of the particular organic material that is spread on the agricultural land used for food production. In relation to known biological hazards the likely effectiveness of various treatment and management options was assessed where data was available. Source control of OA and OMI material is important in controlling biological hazards and minimising risks to food safety. Furthermore, not all pathogens are necessarily present in all land-spread organic materials, all the time. Data on specific waste water discharges and components of discharges from hospitals and the health care sector in Ireland are limited or unavailable (Chapter 3.3.2).

With each biological hazard the assignment of a risk category was made on a general basis and was not assigned to any one food product sector, such as RTE foods. However, the category of risk assigned in Table 6 to each of the biological hazards mentioned, when applied to RTE foods, would be higher than for other foods. However, risk categorisation for all foods can be mitigated by appropriate treatment and/or management which have not been accounted for in the current risk categorisation.

### 7.3.1 Organic agricultural materials

Many foodborne pathogens, including VTEC, *Salmonella* spp. *Campylobacter jejuni*, *Listeria monocytogenes* are often carried by livestock<sup>26</sup>. While appropriately treated and managed OA materials such as manure are effective fertilisers<sup>153</sup>, outbreaks of foodborne illness associated with contamination of food and drinking water<sup>154</sup> with pathogens from an agricultural source such as manure have occurred. EFSA in 2005 indicated that “whenever animal manure is placed on the open market, other than for use within the epidemiological geographical area, the risk of spread of pathogenic microorganisms needs to be taken into account<sup>155</sup>. In contrast, the application of untreated animal manure to land, within the same epidemiological geographical area where the manure has been produced and managed in accordance with good agricultural practices, poses little problem to human and animal health<sup>155</sup>.

Provided best practice for managing OA materials has been followed (Chapter 4.5.1), there are clear indications that food safety is not at a particular risk as a result of land-spreading animal manures to arable crops<sup>7</sup>. However, potential threats do exist, particularly in relation to RTE crops, as evidenced by cases of human illness associated with direct or indirect contamination of food<sup>10-13, 73, 159-163</sup> or water supplies<sup>104, 154</sup> by animal manure, largely as a result of poor management practices at farm level.

The risk categorisation for *Salmonella* spp. and VTEC based on current data is Level I (Table 6). Furthermore, from an Irish perspective, there is a correlation between contamination of drinking water supplies with animal slurry and outbreaks of VTEC O157 illness<sup>104, 164</sup>. The risk categorisation for *L. monocytogenes* and *Campylobacter* spp. are Level II (Table 6). However, when OA or OMI materials are land-spread onto RTE crops such as salad leaves which are likely to be consumed without further processing, the risk categorisation for *L. monocytogenes* will be higher. The ability of *L. monocytogenes* to persist in manure-amended soil for several weeks increases the possibility that it can be transmitted through soil to fresh produce, e.g. RTE foods<sup>163</sup>. The risks to food safety from other bacterial pathogens arising from the spreading of OA materials such as animal manure on agricultural land used for food production are regarded in general terms as Level III (Table 6).

**Table 6. A Categorisation of the Relative Risk of Biological Hazards to Food Safety Likely to Arise as a Consequence of the Land-spreading of OA and OMI Materials on Agricultural Land used for Food Production in Ireland<sup>1</sup>**

Biological Hazard <sup>2</sup>	Agriculture	Municipal			Industry			
	Farms etc.,	Urban Waste Water Treatment	On-site Waste Water Treatment	Hospitals <sup>3</sup>	Meat Processing	Dairy Processing	Food Processing	General Industry
Risk Categorisation <sup>4</sup>								
Hepatitis A, Rotavirus, Adenovirus, Astrovirus & Enteroviruses	III	II	II	II	III	III	III	III
Norovirus	III	I	I	I	III	III	III	III
<i>Cryptosporidium</i> <sup>5</sup>	I	II	I	II	II	III	III	III
<i>Toxoplasma gondii</i> <sup>6</sup>	III	II	II	III	III	III	III	III
<i>Taenia saginata</i> <sup>7</sup>	III	II	II	II	III	III	III	III
<i>Brucella abortus</i>	III	III	III	III	III	III	III	III
<i>Campylobacter</i> spp.	II	II	III	III	II	III	III	III
<i>L. monocytogenes</i> <sup>8</sup>	II	III	III	III	III	III	III	III
<i>Mycobacterium bovis</i>	III	III	III	III	III	III	III	III
<i>M. tuberculosis</i>	III	III	III	II	III	III	III	III
<i>Salmonella</i> serovars	I	II	I	I	III	III	III	III
VTEC	I	II	I	II	III	III	III	III

<sup>1</sup> Risk categorisation can be mitigated by appropriate treatment and/or management. However, these factors have not been accounted for in the risk categorisation presented in Table 6

<sup>2</sup> In relation to the parasites *Giardia* spp. and *Ascaris* spp. there are little Irish data available. In the case of *Ascaris lumbricoides*, the status of this agent as a zoonotic agent is unclear. *Toxocara canis* and other *nematodes* (roundworms) of domestic pets are not transmissible to grazing stock (Appendix 4.4.4).

<sup>3</sup> While hospital material will generally have a high risk categorisation very little of this material is land-spread in Ireland (Chapter 3.3.2).

<sup>4</sup> Please note Table 5 (Chapter 7.2) for further information on risk categorisation

<sup>5</sup> Until recently *Cryptosporidium* was thought to be a single species with two distinct genotypes – Type 1 (human) and Type 2 (bovine). Genotype 1 has now been reclassified as a separate species *C. hominis*. It is isolated almost exclusively from humans and associated with human-to-human transmission<sup>156-157</sup>. Genotype 2 (bovine), now known as *C. parvum*, is isolated from human and bovine hosts and other animals such as sheep and goats and is associated with animal-to-human transmission<sup>156-157</sup>. The risk categorisation for *Cryptosporidium* will be significantly influenced by the type/quality of management and/or treatment applied to the organic material which is land-spread. As such this may alter the assigned risk.

<sup>6</sup> The main risk factor to humans for *T. gondii* is contact with infected cats and recreational gardening where cats defecate<sup>158</sup>. Sporulated oocysts *T. gondii* excreted by cats are very resistant to environmental conditions and remain infectious in moist soil or sand for up to 18 months (Appendix 4.4.3).

<sup>7</sup> The ova of *Taenia saginata*, the so-called beef tapeworm of humans (Appendix 4.4.4) have not been a major risk but are likely to be present in ethnic foods and hence may be present in urban effluents

<sup>8</sup> When OA or OMI materials are land-spread on to RTE crops such as salad leaves which are likely to be consumed without further processing the risk categorisation for *L. monocytogenes* will be higher.

The risks to consumers posed by parasites that may enter the food chain as a result of OA materials, such as animal manure, containing the intermediate or infective stages of the parasite onto land, are in most cases, at Level III (Table 6). The exception is *Cryptosporidium* spp. Based on current data, the risk to public health and food safety in this case is at Level I (Table 6), particularly in the case of specific drinking water supplies in various parts of Ireland. The low infective dose of *Cryptosporidium* (as low as ten oocysts) increases this risk. The EPA has indicated that the contamination of water supplies with *Cryptosporidium* presents a significant threat to the safety of drinking water in Ireland<sup>165</sup>. Land-spreading OA materials such as manure and particularly slurry pose a high risk of *Cryptosporidium* contamination of water sources. Although well-kept and managed slurry stores can allow oocysts to die off, there is no way of knowing how effectively they are being operated and therefore a risk should be assumed. Sheep pens and cattle sheds and lambing or calving on the catchment also present a potential risk<sup>165</sup>. The EPA has produced a risk screening methodology to assist LA in prioritising supplies that are at a high risk of contamination with *Cryptosporidium* and to identify high-risk factors, which can be mitigated to reduce the risk associated with the supply<sup>165</sup>.

Viruses are known to be transmissible through food and are a food safety concern<sup>166</sup>. In general the risk of exposure and thus food safety from viruses due to spreading of OA materials such as manure onto agricultural land used for food production is considered to be at Level III (Table 6).

### **7.3.2 Organic municipal materials**

In relation to organic municipal materials, the range of biological hazards and the risks to food safety will depend on the source of municipal material which is spread on agricultural land used for food production. Pathogens may enter urban waste water from a variety of sources including hospitals, domestic dwellings, schools, nursing homes, farms, and industry. The range of biological hazards present in organic municipal materials spread on agricultural land used for food production depends on a number of variables<sup>109, 111, 136, 167-168</sup>. These include the health status of the contributing human population, e.g. incidence of enteric infection within a community<sup>167</sup>, presence and type of hospitals and industry such as meat plants (including poultry meat plants) in the area served by the urban waste water treatment plant<sup>109, 169-170</sup>.

A 2006 EC report<sup>29</sup> (i.e. for the period 2001-2003) indicated that on the whole, the Use of Sewage Sludge in Agriculture Directive 86/278/EEC<sup>1</sup> has been quite effective in preventing any spread of pollution due to use of sewage sludge. However, it was also concluded that the use of sewage sludge as fertiliser on agricultural soils is a good environmental option, if and only if it poses no threat to the environment or to animal and human health<sup>29</sup>. In general, the pathogen and chemical content of sludge used on agricultural land will largely reflect that of the wastewater (i.e. entering an urban waste water treatment plant) from which it originated. Typically, the same pathogens associated with OA materials are associated with organic municipal materials except for enteric viruses, for which humans are the main source<sup>167</sup>. However, while the DEHLG codes of good practice for the use of biosolids in agriculture do include some targets for bacterial levels (Chapter 3.3.1)<sup>2</sup> they don't include standards for viruses or parasites. Consequently, no account is taken in existing regulations of the fact that pathogenic human viruses, along with parasites such as *Cryptosporidium* spp. and tapeworm ova are resistant to some treatment processes and that significant numbers of these pathogens that ultimately are transmissible through food survive such treatments<sup>169, 171-173</sup>.

Based on available data, there is considered to be a Level I and Level II risk to food safety from *Salmonella* serovars and VTEC, respectively, in relation specifically to municipal discharges from hospitals (Table 6). However, this assessment is tempered by the fact that while hospital material will generally have a Level I risk categorisation very little of this material is land-spread in Ireland (Chapter 3.3.2). There is a Level II risk to food safety from *Salmonella* serovars, VTEC and *Campylobacter* spp. in relation to municipal discharges from urban waste water treatment (Table 6).

The risk to food safety from on-site waste water treatment systems such as septic tanks is Level I, particularly with respect to Norovirus, *Cryptosporidium hominis*, *Salmonella* spp. and VTEC (Table 6). Other pathogens present a Level II risk to food safety if these materials are spread on agricultural land used for food production (Table 6). However, the risk categorisations outlined in Table 6 would be significantly higher if untreated material from on-site waste water treatment systems were land-spread on or near RTE food crops.

While water is a primary vector for *Cryptosporidium* spp. other foods may also play a role in the transmission of this parasite to humans<sup>174-175</sup>. *Cryptosporidium* spp. may be present in marine water close to primary sewage outfalls and *Cryptosporidium* oocysts can survive in seawater long enough to be concentrated by filter feeders such as oysters<sup>176</sup>. However, there are no reported incidents of cases of cryptosporidiosis associated with the consumption of shellfish.

Research carried out in 2003 demonstrated a relationship between septic tank density and illness in children in the same geographic area<sup>177</sup>. Septic tank systems have also been directly implicated in disease outbreaks<sup>178</sup>. Although management processes, e.g. restrictions on type of land on which material can be spread, and when it can be spread, may reduce the risk of direct contamination of foods, this does not protect watercourses and marine environments used for fish farming and shellfish cultivation from contamination<sup>179-182</sup>.

While there are few reports on the loadings of parasites such as *Cryptosporidium* in sewage effluent or sewage sludge<sup>73</sup>, on taking account of the limited data currently available, land-spreading of sewage sludge (i.e. untreated) and/or effluent from urban waste water treatment plants, hospitals and untreated manures from slaughter plants contaminated with *Cryptosporidium* spp. of both animal and human origin represents a Level II risk to food safety (Table 6). The EPA has indicated that sewage works and septic tanks may not remove *Cryptosporidium* oocysts if there is cryptosporidiosis in a community. As such, there could be oocysts in the sewage works or septic tank effluent and that effluent could enter a raw water source<sup>165</sup>.

It is estimated that over 100 different viruses excreted by humans may be adsorbed onto sewage sludge from urban waste water treatment<sup>169</sup>. As organic municipal materials are in large part derived from general human activities, the risk to food safety from viruses due to land-spreading of sludge from urban waste water treatment can fluctuate from Level II to Level I depending on the source of the material, and ultimately, of its constituents (Table 6). Consequently, the risk associated with the land-spreading of sludge from urban waste water treatment is determined *inter alia* by the original source of the OMI material, its constituents and the treatment and/or management it receives prior to land-spreading.

Norovirus are the major cause of sporadic and epidemic gastroenteritis in the EU<sup>93, 98-99</sup> and are commonly found in effluent and sewage sludge. Consequently, the risk to food safety, based on high levels of the virus in untreated organic municipal materials, and the highly infectious nature of the virus can present a Level I risk (Table 6). The risk would be particularly high at times when sectors of the population are affected by outbreaks of viral gastroenteritis.

Rotavirus infection is common in children under five years of age and the virus is found in human sewage in high concentrations. The hazard to food safety is ranked as Level II because of the high level of immunity found in the adult population (Table 6)<sup>183</sup>. Astroviruses are found in human sewage<sup>184</sup> but normally only cause infection in children and the elderly where immunity may be reduced<sup>185</sup>. As such, the hazard to food safety is ranked as Level II. Adenoviruses are also commonly found in human sewage and sewage contaminated waters. Adenoviruses may be responsible for up to 10% of gastroenteritis in infants but is not common in adults and as such the hazard is ranked as Level II also.

### 7.3.3 Organic industrial materials

As in the case of organic municipal materials, the range of biological hazards and the risks to food safety from land-spreading of organic industrial materials will depend on the source of the material which is intended to be spread on agricultural land used for food production. The European Commission has indicated that it is extremely unlikely that pathogens of humans and animals would be present in materials discharged from vegetable processing facilities<sup>57</sup>. Sludge from paper processing is inherently composed of poorly biodegradable cellulose and lignin. They can be regarded as free of pathogens and present no risk to food safety<sup>57</sup>. However, because of the highly variable nature of meat and dairy plant materials discharged and the limited data on number and species of pathogens present in these materials, a direct extrapolation of assigned risk to all meat and dairy plants is not appropriate.

Generally, organic materials discharged from meat plants, e.g. abattoirs and dairy plants, can be characterised by their high nutrient content, e.g. protein, fat,<sup>185</sup> in comparison with other organic municipal and OA materials<sup>136</sup>. A considerable range of microbiological pathogens are present in the materials discharged from meat plants (including poultry meat plants)<sup>185-186</sup> and, to a lesser extent, dairy processing facilities. A Food Standards Agency (FSA) report in 2002 acknowledged that data on numbers and types of pathogens in materials from meat plants, e.g. lairage effluent, gut contents and blood as well as liquid wastes from lorry and carcass washing, were limited<sup>150</sup>. The report stated that while the pathogens present in these materials reflect those in the animals slaughtered, their numbers and significance will also be influenced by the storage conditions of the materials<sup>150</sup>.

In 2003, research conducted at British commercial meat plants determined that the materials from meat plants spread on land were comprised of effluent-based and animal-based materials<sup>187</sup>. The study also focused on the waste practices conducted in these plants that affected the spectrum and quantitative levels of pathogens in materials (i.e. lairage, lairage/stomach content, stomach content, blood and effluent) later to be spread on agricultural land used for food production<sup>187</sup>. Relatively low levels of bacterial pathogens were found in the materials when spread on land, while the most commonly isolated pathogen was *Campylobacter*. However, the residual numbers of pathogens that may be present after treatments are subject to fluctuation depending on the throughput of the plant and other factors. When these materials are subsequently spread on agricultural land used for food production there is cause for concern from a food safety viewpoint. Of greater concern are the risks attached to the discharge of untreated materials from these plants, were these to be spread on land used for food production<sup>187</sup>.

Based on available data, there may be a Level II risk to food safety from the presence of *Campylobacter* spp. and *Cryptosporidium* spp.<sup>188</sup> from organic materials which are land-spread on agricultural land used for food production originating from meat processing (Table 6). There is no evidence available that human viruses originating from organic materials from the food or general industries, when spread on agricultural land used for food production, are a cause for concern at this time<sup>126</sup>. Consequently the risk to food safety associated with viral contamination of foods resulting from the land-spreading of organic industrial materials is ranked as Level III (Table 6)<sup>126</sup>.

#### 7.4 Transmissible Spongiform Encephalopathies

There are limited data on the prevalence of Transmissible Spongiform Encephalopathies (TSEs) in OA and OMI materials or on agricultural land used for food production. The occurrence of the Bovine Spongiform Encephalopathy (BSE) agent in effluents from meat plants slaughtering cattle in the UK was assessed in 2001 and it was concluded that in the UK situation, any such contamination, were it to occur in sewage sludge derived from such effluents, would not be such as to sustain the epidemic in that country at the time<sup>189</sup>. This research<sup>189</sup>, and others, also discounted horizontal spread of the BSE agent as a consequence of the land-spreading of such materials.

Meanwhile, an opinion issued by EFSA's scientific panel on biological hazards in 2004 reported that there are no scientific data available defining the fate of prions following spreading to land, pasture or directly into the soil<sup>190-191</sup>. Due to the stringent precautionary measures now in place across the EU, cross contamination of animal manures from meat plants with TSE agents is regarded as unlikely<sup>155, 190</sup>. Furthermore, recent legislative controls on ABP<sup>18</sup> (Chapter 3.4.1), are likely to reduce the risk, if any, of TSEs being transmitted to the food chain *via* the spreading of OA and OMI materials on agricultural land used for food production.

While not related directly to the issue under discussion it is appropriate to mention here that the persistence in soil of prions derived from the cadavers of TSE cases for prolonged periods after burial, creates the potential for contamination of nearby aquifers with TSE agents from these sources<sup>192</sup>. Current legislation addresses this by prohibiting the burial of livestock carcasses except under licence<sup>18</sup>.

## 7.5 Chemical Hazard Identification and Risk

A pragmatic approach has to be taken when describing and assessing the chemical hazards since there may be food safety implications whether by spreading OA or OMI materials on land used for food production, aquatic food species or through water used either during food processing or cultivation of RTE salad vegetables. As with biological hazards, the range of chemical hazards and the categorisation of risks to food safety will depend on the source and source control of the OA or OMI materials, which are spread on agricultural land used for food production. The risk categorisation for all foods can be mitigated by appropriate management and treatment. In relation to identified chemical hazards which may pose a risk to food safety, the effectiveness of various treatment and management options was assessed where data were available. However, more data on specific chemicals<sup>193</sup> that are present in OA and in particular, OMI materials which are spread on agricultural land used for food production, are required. More data concerning the ingestion and absorption levels of organic compounds and metals by animals are also required.

A 2006 EC report (i.e. for the period 2001-2003) indicated that the average concentrations of metals in sludge used in agriculture across the EU were below the threshold limits set in legislation<sup>1</sup> and the general trend was towards a slow but steady decrease in metal concentrations<sup>29</sup>. However, a 2005 review<sup>53</sup> concluded that regulatory frameworks suffer from a lack of data to underpin the risk assessments conducted to assess transfer of toxic metals and persistent organic compounds to the human food chain from animal livestock production and so provide the basis for the published limits which at present are poorly defined<sup>53</sup>. The REACH Regulation<sup>45</sup> which came into force in June 2007 gives greater responsibility to industry to manage the risks from chemicals and to provide safety information on the substances of concern (Chapter 3.4).

Currently, it is not possible to assess the quantities and fates of organic compounds ingested by animals<sup>8, 53</sup>. As the aetiology of a disease or altered physiological state may be difficult to establish<sup>112</sup>, effective surveillance, auditing and control programmes of the source of OA and in particular, OMI materials remain the essential prerequisite for food safety.

Source control of OA and OMI materials is important in controlling chemical hazards and minimising risks to food safety. Furthermore, not all chemical contaminants are necessarily present in all land-spread organic materials, all the time. With each chemical hazard the assignment of a risk category was made on a general basis and was not assigned to any one food product sector, such as RTE foods. However, the category of risk assigned in Table 7 to each of the chemical hazards mentioned, when applied to RTE foods, would be higher than for other foods.

Data on the specific components of discharges from hospitals and the health care sector in Ireland are limited or unavailable. However, as hospitals discharge waste water into public sewers, a residual drug load, particularly antimicrobials, cancer drugs and their metabolites entering the waste water may be present in sludge which is spread on agricultural land used for food production in Ireland. Research on antibiotic resistance in hospital effluents is on going at NUI, Galway<sup>40-42</sup> (Chapter 3.3.2) and the occurrence of pharmaceutical and personal care products in sludge based fertilisers is being studied by researchers at Dublin City University<sup>194</sup>.

**Table 7. A Categorisation of the Relative Risk of Chemical Hazards to Food Safety Likely to Arise as a Consequence of the Land-spreading of OA and OMI Materials on Agricultural Land used for Food Production in Ireland<sup>1</sup>**

Chemical Hazard	Agriculture	Municipal			Industry			
	Farms	Urban Waste Water Treatment	On-site Waste Water Treatment	Hospitals <sup>2</sup>	Meat Processing	Dairy Processing	Food Processing	General Industry
	Risk Categorisation <sup>3</sup>							
<b>Metals:</b> Cadmium, Copper, Nickel, Lead, Zinc, Mercury, Chromium, Arsenic	III	I	III	III	III	III	III	I
<b>Veterinary Drugs</b>	II-III	III	III	III	III	III	III	III
<b>Human Drugs:</b> Antimicrobials, Antibiotics, $\beta$ -blockers, Antiepileptics & Lipid Regulators, Others	III	III	III	II	Not Applicable <sup>4</sup>			
Hormones	III	II	II	II				
Drugs of Addiction	III	II-III	III	II				
<b>Contaminants<sup>5</sup>:</b> PCDD/Fs, PCBs & PAHs	III	III	III	III	III	III	III	III

**Table 7. Continued**

Chemical Hazard	Agriculture	Municipal			Industry			
	Farms	Urban Waste Water Treatment	On-site Waste Water Treatment	Hospitals <sup>2</sup>	Meat Processing	Dairy Processing	Food Processing	General Industry
	Risk Categorisation <sup>3</sup>							
<b>Biocides:</b>								
Group 1 - Disinfectants & General Biocides	I-II	I	II-III	I	II	II	II	III
Group 2 - Preservatives	III	III	III	III	III	III	III	I
Group 3 - Pest control	II-III	III	III	III	III	III	III	III
Group 4 - Other Biocides	III	III	III	III	III	III	III	II
<b>Others:</b>								
Formaldehydes	III	Unknown					III	III
Fuels & Oils	III	III	III	III	III	III	III	III
Endocrine Disruptors	III	III	III	III	III	III	III	III
Nitrates & Phosphates	I	III	III	III	III	III	III	III
Agrochemicals	II	III	III	III	III	III	III	III
Radioactive Materials	III	III	III	II	III	III	III	III

<sup>1</sup> The risk categorisation for all foods can be mitigated by appropriate treatment and/or management. In relation to identified chemical hazards which may pose a risk to food safety the effectiveness of various treatment and management options was assessed where data was available. However, more data on specific chemicals<sup>193</sup> that are present in OA and in particular OMI materials which are spread on agricultural land used for food production are required.

<sup>2</sup> While hospital material will generally have a high risk categorisation very little of this material is land-spread in Ireland.

<sup>3</sup> Please note Table 5 (Chapter 7.2) for further information on risk categorisation.

<sup>4</sup> There is no reason to believe that human drugs are a risk from these sources.

<sup>5</sup> Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs) and Polychlorinated Dibenzo-p-Dioxins and Furans (PCDD/Fs).

### **7.5.1 Organic agricultural materials**

Metal concentrations in animal manure will, in the main, mirror herbage and soil concentrations from the land on which the animals grazed. Consumption of contaminated crops appears to be the main route of exposure to sludge-borne metals<sup>8</sup>. It is assumed that the specific contribution of sludge-borne metals to the human diet is very low, when taking into account the observed level of metals present in soil, and considering the surface area over which land-spreading takes place<sup>8</sup>. Fruit and vegetables for human consumption are monitored for pesticides, fungicides and metals<sup>195</sup>.

National monitoring programmes analyse animal produce for residues of animal remedies, metals and pesticides<sup>195</sup>. None of the organochlorine, organophosphate and pyrethroid groups have been detected<sup>195</sup>. The main exposure route to veterinary medicinal drugs is from OA materials such as manure from the intensive livestock sector<sup>196</sup>. Some antibiotics, e.g. penicillin, are easily hydrolysed but some, sulphonamides, have been found in drinking-well water and groundwater while tetracyclines and fluoroquinolones were found bound to sludge sediment<sup>196</sup>. Unabsorbed antibiotics can be excreted into the environment but the phase II metabolites of chloramphenicol and sulphadimidine maybe are reactivated in liquid manure into their parent compounds<sup>196</sup>.

The impact of detergents, disinfectants and biocides<sup>114</sup> is not deemed significant because of minimal transfer from soil to human consumers (Chapter 7.3.2). However, the use of biocides and antimicrobials (Appendix 5.7.1) may exert selective pressure on bacteria possibly resulting in microbial resistance to these agents which may increase risk. So far, there are no available data to document ready degradability of disinfectants. Based on the insufficient data on degradation, a classification of “not readily biodegradable” by default has been proposed.

### **7.5.2 Organic municipal materials**

The spreading of organic municipal materials on agricultural land used for food production creates the potential of introducing chemical contaminants<sup>197</sup>. These include metals, organic pollutants and endocrine disrupting chemicals (Appendix 5.9). Prior to the 1980s poor management practices in relation to the land-spreading of sewage sludge impacted on soil, crop, water and air quality and in some circumstances caused food safety problems. This contributed to the introduction of legislation<sup>1</sup> designed to protect the environment and in particular soil, when sewage sludge was used in agriculture<sup>197</sup>.

The introduction of legislative limits to control inputs of metals, organic pollutants and endocrine disrupting chemicals is fraught with difficulties<sup>197</sup>. This is demonstrated by the difficulties experienced by the EU in achieving consensus among experts in relation to agreeing new legislative limits for metals and organic pollutants considered necessary to update the current EU Sewage Sludge Directive<sup>1</sup>. DEHLG has also pointed out that administrative problems in the aforementioned process have resulted in delays to the Directives update and revision. To date, consensus has not been achieved almost ten years since the review process was initiated (Chapter 3.4)<sup>197</sup>.

Inputs of metals and organic contaminants to organic municipal materials occur from three generic sources: domestic, commercial and urban runoff. Human faeces contributes 60 to 70% of the load of cadmium, zinc, copper and nickel while organic contaminants, pharmaceutical and personal care products, cleaning products and liquid wastes are the sources of most of the remainder<sup>9</sup>. Some metals will persist in soil for many years. It is possible this may lead to an accumulation of these substances with repeated land-spreading and an increasing risk to human health (Table 7). Nevertheless, runoff is the main contributor to metal accumulation in soil and it would take centuries, if ever, before metals from sludge would approach soil limit values. Plant uptake of sludge-borne metals is a minor part of those acquired from the soil and total plant uptake of metals present in soil always remains below the limit values for foodstuffs<sup>8</sup>.

In a recent United Kingdom report<sup>198</sup>, sewage sludge was applied to agricultural soils at high concentrations to induce stress in the soils microbial community and increase metal concentrations in the soil up to statutory limit concentrations<sup>1</sup>. The study found that at the statutory limit there appears to be an impact on rhizobia numbers (i.e. microorganisms or bacteria belonging to the genus, *Rhizobium*, which are commonly involved in fixing nitrogen) and reduced soil biomass size and that the current soil limit for cadmium of 3mg/kg was not sufficiently protective to produce grain below the EU maximum permissible grain cadmium concentration of 0.235mg/kg dry matter, unless soil pH was maintained above 6.8<sup>198</sup>.

Urban runoff is not generally a major contributor of potentially toxic elements to urban waste water treatment plants. Atmospheric deposition onto paved surfaces and consequential runoff is the main source of persistent organic pollutants of concern such as Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs) and Polychlorinated Dibenzo-p-Dioxins and Furans (PCDD/Fs). Soil is a long-term repository for these organic pollutants and remobilisation by volatilisation from soil is responsible for their recycling and redistribution in the environment<sup>9</sup>. Being strongly hydrophobic, these organic pollutants are efficiently removed during waste water treatment and they bind to sludge. Scientific evidence has not identified a potential harmful environmental impact so concern about their deleterious effects has diminished<sup>121</sup>.

Detergent residues, e.g. Nonylphenol and Nonylphenol Ethoxylates (NPE), surfactants, e.g. Linear Alkyl Benzene Sulphonates (LAS)), plasticizing agents, e.g. Di-2-(Ethylhexyl) Phthalate (DEHP), are the most abundant organic contaminants in sewage sludge<sup>9</sup>. The direct risk of detergents on human health is low (i.e. Level III) because of effective degradation during aerobic waste water treatment and a low transfer from soil to human consumers (Table 7). NPE accumulates during anaerobic digestion (Appendix 3.1.5) – the principal method of stabilising sewage sludge<sup>9</sup>. Since bulk quantities of LAS are discharged into these treatment plants even though it is degraded therein, significant concentrations are found in sludge. Surfactant residues degrade quickly when added to aerobic soil. However, due to their disinfectant attributes, there is a risk in regard to development of concomitant resistance to clinically important antimicrobial agents<sup>9</sup> (Table 7).

The plasticizing agents, phthalates, are mainly degraded under aerobic conditions but not under anaerobic conditions. The oestrogenic activity of NPE and that of trace amounts of natural and synthetic oestrogens – the bulk of oestrogenic activity in these treated effluents – are a concern. Currently little is known about the effects of other endocrine disruptors, e.g. DEHP, in the environment. Subtle changes affecting androgen and thyroid activity due to phthalates have been noted in humans but are equivocal<sup>199</sup>. Little is known of the fate of musks<sup>200</sup> but human health effects are most likely to arise from direct application.

### **7.5.3 Organic industrial materials**

Sources of the industrial materials indicated in Chapter 4.7 and 5.3 and discharges from some of these industries are controlled by the EPA under IPPC licences<sup>70</sup>. The nature of any potential contaminant depends on the type of industry and some examples of contaminants and their sources are detailed in Appendix 5 (i.e. Tables 12-14). These industries, in the main, are the large ones where source control is specific and strictly controlled. Problem areas may arise with small and medium enterprises on industrial estates where tenancies may change without notification to the LA which, therefore, may be unaware of the contents of current discharges. Thus, uncontrolled discharge of effluents directly into the municipal waste water stream may occur. Source control and identification of potential contaminants from such operations would appear to be difficult under current legislation<sup>1</sup>. However, the maximum permissible concentrations set for zinc and copper in sludge<sup>1</sup> and the large quantities of the surfactant LAS in use (Appendix 5.5.4) are likely to be the limiting factors for the land spreading of organic industrial sludge. The concerns associated with detergent, disinfectant and biocide use in industry are similar to those for municipal materials (Chapter 7.5.2).

## 8. DISCUSSION

In Ireland, the land-spreading of appropriately treated and/or managed organic agricultural (OA) materials such as animal manure is recognised not only as a sustainable management option but also as an effective source of nutrients for plants and crops. Appropriately treated and managed organic municipal and industrial (OMI) materials produced to specified minimum standards of good practice, such as biosolids are land-spread in many countries, as not only a source of nutrients for crops but also as a sustainable management option. In Ireland, in 2004, of the estimated 60.75 million tonnes of OA and OMI materials land-spread on agricultural land, over 99% was OA materials.

When land-spreading is inappropriately practiced, there is an increased risk of contamination of food crops, particularly ready-to-eat (RTE) food crops with known hazards, as evidenced by the significant global burden of human enteric illness associated with contaminated fresh produce. Such contamination has occurred by direct means, such as crop contact with contaminated OA or OMI materials, or by indirect means, e.g. irrigation of water contaminated with OA or OMI materials. The principal risk to the safety of RTE food crops is the land-spreading of OA or OMI after drilling or planting of these crops. The risk to the safety of RTE food crops can be minimised by not land-spreading OA or OMI materials to growing crops and maximising the interval between the land-spreading of these materials and the sowing of the crops.

Management and good practice refer to the careful storage, handling and land-spreading practices of OA and OMI materials that minimise the risk of food safety issues arising. Treatment refers to the active processing of OMI materials and to a lesser extent OA materials, by one or more specific actions in order to reduce or eliminate hazards. In some cases treatment, management and good practice options are prescribed under legislation, or are incorporated in codes of good practice pertaining to agriculture. Essentially, the effectiveness of management and treatment protocols depends on their correct implementation at all levels. There are reports about deficiencies in the effective implementation of good practice in Ireland at present and concerns that these issues are not being adequately addressed.

For OA materials particularly, management and good practice entail their spreading on land as a soil amendment, which is a long accepted means of managing OA materials in Ireland and elsewhere. However, management and good practice in land-spreading include consideration of the characteristics of organic material to be land-spread, properties of the soil and interactions with soil biota, rate, timing and method of land-spreading, intended crop or use of land to be land-spread and climatic conditions as well as the degree of vulnerability and susceptibility of groundwater and surface waters to contamination.

The land-spreading of OMI materials and to a lesser extent OA materials poses risks to food safety from pathogenic microorganisms and/or chemical contaminants that they contain. OMI materials such as biosolids are more likely to contain chemical contaminants than OA materials. Both OA and OMI materials may contain pathogenic microorganisms including viruses and parasitic agents of human and animal health concern. Many gaps in current knowledge remain concerning the risk of transfer of pathogenic microorganisms and chemical contaminants into the food chain through the practice of land-spreading of OMI materials in particular, on agricultural land used for food production in Ireland.

The likelihood, concentration and nature of hazards in OA and OMI materials are dependent on the source of the materials. Control and monitoring of the source material is required if OA and OMI materials are to be land-spread on agricultural land used for food production. This requirement is particularly important in the context of OMI materials, as the source of the material is likely to stem from many different industrial and municipal sources including industry, hospitals and the health care sector. The majority of OMI material which is land-spread is a result of urban waste water treatment. Local authorities employ a specific method of treatment or a combination of treatments to render this material suitable for land-spreading on agricultural land. These treatments are based on the characteristics of the influent waste water received at a treatment plant and the current end-use option(s) identified by the local authority in its sewage sludge management plan for that county.

Trends associated with OMI materials in Ireland indicate a significant increase in the use of treated OMI materials such as biosolids in agriculture with a corresponding decrease in disposal to landfill. However, the relative proportion of OMI to OA materials land-spread on agricultural land still remains small. Despite this, the land-spreading of OMI materials where the minimum standards specified in legislation and good practice are not implemented represents a risk for food safety due to chemical contaminants and microbiological pathogens. The nature and extent of such risk, in the context of land-spreading in Ireland is addressed and assessed, in this report, at this, relatively early stage in the practice of land-spreading of OMI materials in Ireland.

An issue of importance is the absence, in Ireland, of statutory controls or uniform standards for the natural biodegradation of OA and in particular OMI materials. Effective composting is a recognised natural biodegradation treatment used to render OMI materials safe for use on agricultural land. The lack of standards is a recognised impediment to the appropriate use of composts in the Government's National Strategy on Biodegradable Waste. The development of such standards, and their enforcement through legislation, is therefore a priority.

The use of treated OMI materials such as biosolids in agriculture must be in compliance with local authority sewage sludge management plans. The Environmental Protection Agency (EPA) has recommended that all local authorities should audit the chain of custody of sewage sludge consignments under their supervision and, further, should ensure that sewage sludge registers are kept up to date and are compliant with the requirements of legislation<sup>1</sup>. In spite of these recommendations, however, the EPA has found that in some local authorities where biosolids are used in agriculture, sampling programmes are either non-existent or in need of improvement, and that there is inadequate maintenance of sludge registers. Where there is a lack of compliance in this matter, there is justifiable cause for concern regarding the safety of food produced on land so treated and, consequently, an immediate need for corrective action. Current good practice for the use of biosolids in agriculture is stipulated in the Department of the Environment, Heritage and Local Government's Code of Good Practice. However, the code of good practice has no statutory basis because the current legislation does not make reference to the code of good practice or define treatment options or associated processing conditions.

Under the current legislation there are specific circumstances where OMI materials such as untreated sludge from certain treatment plants or residual sludge from septic tanks may be used in agriculture<sup>1</sup>. Sludge from septic tanks or from sewage treatment plants with a treatment capacity less than 300kg BOD<sub>5</sub> per day, are not subject to the same legal requirements as sewage treatment plants with a treatment capacity greater than 300kg BOD<sub>5</sub> per day<sup>1</sup>. The most recent census results, from 2002, estimate that there are over 400,000 individual septic tank systems in the State. Septic tank systems require regular active management including de-sludging to operate efficiently. Consequently, given the estimated number of septic tank systems in the State there are practical difficulties in monitoring the use or disposal of residual sludge from septic tanks. Furthermore, there is no official monitoring of the efficacy of individual septic tank systems and the extent to which residual sludge is used on agricultural land.

The provision in the legislation<sup>1</sup> for use of untreated sludge in agriculture and residual sludge from septic tanks on grassland is a matter of concern for food safety because it allows for the re-circulation of human and animal pathogens in the food chain. There is now a need for corrective action at national level to address the risks posed by this practice.

Regulatory enforcement of OA and OMI materials transcends the responsibilities of several Government departments, State agencies and individual local authorities. As such, coordination and transparency between these groups is necessary to ensure a coherent approach to risk assessment in the area of food safety. Provision of adequate resources to allow enforcement, coordination and greater cooperation between stakeholders is required to ensure best practice for management and treatment of OA and in particular OMI materials such as sewage sludge from urban waste water treatment.

Effectively managed land-spreading practices provide a sustainable option for the utilisation of OA and certain OMI materials on agricultural land used for food production. Such use is conditional, however, on the implementation of effective controls and the consistent application of good practice at every level, as described in this report. In the absence of sustained implementation of effective preventive and control measures, the land-spreading of OA and in particular OMI materials on agricultural land used for food production is considered likely to pose both microbiological and chemical risks to food safety. There are minimal risks to food safety when the minimum standards of good practice are applied to OA and OMI materials which are land-spread on land used for non food crops.

## 9. CONCLUSIONS

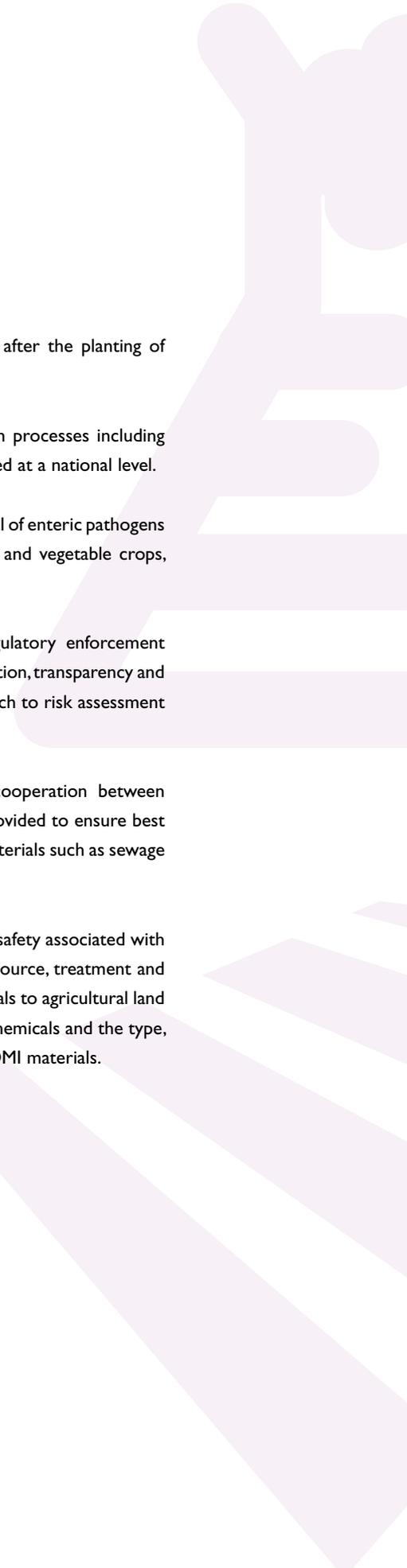
1. Land-spreading of OA materials on agricultural land for food production is beneficial and should continue provided there is adherence to good management and agricultural practices at farm level to prevent or reduce food safety risks. However, there is a limited range of practical, validated and effective treatment options available for OA materials.
2. The persistence chemicals and survival of pathogens in the environment is influenced by many variables, including the characteristics of organic material to be land-spread, properties of the soil and interactions with soil biota, rate, timing and method of land-spreading, intended crop or use of land and climatic conditions.
3. An understanding of the environmental persistence of enteric pathogens and chemical contaminants is required to provide a scientific basis for management practices designed to mitigate the potential risks to health associated with land-spreading OA and OMI materials on agricultural land used for food production. However, current uncertainties and gaps in knowledge impinge on the ability to establish consistent management and treatment strategies designed to maximise food safety.
4. There is potential for the transfer of pathogens and chemical contaminants to food and water as a result of land-spreading of organic agricultural (OA) and organic municipal and industrial (OMI) materials. In most circumstances the risk to food safety is considered to be low where the source of the organic material is known, adequately controlled, the material is treated in the case of OMI materials and best practices are applied at all levels.
5. Contamination of ready-to-eat (RTE) and vegetable food crops represents the principal risk to food safety associated with inappropriate land-spreading of OA and OMI materials. Risks can be minimized by amendment of current practices to take account of additional best practices identified in this report.
6. At the core of an acceptable management system for OA materials is adequately sized storage facilities constructed to an approved standard. In Ireland, treatment of OA materials, other than storage, is considered unnecessary for compliance with the accepted and regulated practice of OA material management. However, uncertainties about the nature and management of OA materials, in particular storage conditions and storage capacity mean that there is a reasonable likelihood that land-spreading of OA on agricultural land used for food production could contaminate field crops, water supplies, grazing animals and aquatic life and thereby compromise food safety.
7. Treatment and management strategies to prevent or minimise contamination of food with chemical contaminants and pathogens and/or their toxins as a result of land-spreading of OMI materials are available. However, the effectiveness of these strategies is dependent on correct and consistent implementation.

8. The permitted uses of untreated sludge in agriculture (provided that it is previously injected or otherwise worked into land) and the use of residual sludge from septic tanks on grassland (provided that the grassland is not grazed within six months following such use) represent potential routes for recycling enteric pathogens through the environment to the food chain. Therefore the provision in legislation for the use of these materials is a matter of concern for food safety given the unknown extent and nature of land-spreading of these OMI materials.
9. Appropriate codes of good practice or standards for sewage sludge, to be later used in agriculture are not referred to or defined in legislation. This omission is identified in this report as a matter of concern.
10. Adequate treatment of OA and OMI materials make significant contributions to the safe use of these materials. However, the absence, in Ireland, of statutory controls or uniform standards for natural biological degradation processes including composting of OA and OMI materials is recognised by this report as a matter of concern.
11. The control and monitoring of source material is critical to ensure the safety of the land-spreading OA and OMI materials to agricultural land used food production. This requirement is particularly important in the context of OMI, as the influent waste water, with chemical contaminants stems from many different industrial and municipal sources some of which may not be readily traceable.
12. The Environmental Protection Agency's (EPA) reports on sewage sludge indicate that sampling programmes at some local authorities where sewage sludge is used in agriculture are either non-existent or in need of improvement, and that there is inadequate maintenance of sludge registers. This report identifies this situation as a matter of concern.
13. Regulatory enforcement of OA and OMI materials transcends responsibilities of several government departments, state agencies and individual local authorities. As such, coordination and transparency between these groups is necessary to ensure a coherent approach to the control of food safety hazards associated with land-spreading identified in this report. Consequently, the provision of adequate resources to allow enforcement, coordination and greater cooperation between government departments, state agencies and local authorities is required to ensure best practice for the management and treatment of OA and in particular OMI materials such as sewage sludge from urban waste water treatment.

## 10. RECOMMENDATIONS

In Irish food law, the primary responsibility for food safety rests with the food business operator. It is necessary to ensure food safety throughout the food chain, starting with primary production, e.g. on the farm<sup>3</sup>. These recommendations relate to the minimum safe standards when land-spreading organic agricultural (OA) and organic municipal and industrial (OMI) materials on agricultural land used for food production. In every case the food producer land-spreading OA or OMI materials should consider if additional measures/precautions are required to ensure the safety of the food they produce.

1. Current legal requirements and codes of good practice for the use of OMI materials such as sewage sludge in agriculture should be revised to address the issues raised in this report. The Department of the Environment, Heritage and Local Government's codes of good practice for the use of biosolids in agriculture should have a statutory basis.
2. The current legislative prohibition on the use of untreated OMI materials on agricultural land and grassland should be extended. Specifically the legal provisions that allow for the use of untreated sludge in agriculture and residual sludge from septic tanks on grassland should be removed so that these practices are no longer permitted.
3. Source control and monitoring of OMI materials are essential to food safety if they are to be land-spread on agricultural land used for food production. Legislative requirements concerning source control and monitoring should be consistently complied with. Specifically, local authorities should audit the chain of custody of sewage sludge consignments under their supervision and, further, should ensure that sewage sludge registers are kept up to date and are compliant with the requirements of legislation.
4. The use of treated sewage sludge on agricultural land should continue to be permitted but only when treatment and/or management strategies are employed that consistently minimise the possibility of chemical or microbial contamination of foods produced on agricultural land to which these materials are land-spread. However, the interval between the land-spreading of treated sewage sludge and harvesting of ready-to-eat (RTE) and vegetable food crops should be maximised and should be no less than 12 months.
5. The current practice of land-spreading untreated OA materials on agricultural land for food production should continue to be permitted with one exception. Untreated OA materials should not be spread on land to be used for ready-to-eat food crops.

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6. Treated or untreated OA and OMI materials should not be land-spread after the planting of ready-to-eat food crops.
  7. Statutory controls or uniform standards for natural biological degradation processes including composting of OA and OMI materials should be developed and implemented at a national level.
  8. The method of land-spreading used should minimise the survival and dispersal of enteric pathogens and chemical contaminants in particular by aerosol drift to adjacent RTE and vegetable crops, grazing land, livestock and waterways.
  9. Government departments, state agencies and local authorities with regulatory enforcement responsibilities for OA and OMI materials, should ensure that good coordination, transparency and communications between all groups is applied to ensure a coherent approach to risk assessment in the area of food safety.
  10. Adequate resources to allow enforcement, coordination and greater cooperation between government departments, local authorities and state agencies should be provided to ensure best practice for the management and treatment of OA and in particular OMI materials such as sewage sludge from urban waste water treatment.
  11. To enable a more comprehensive scientific assessment of the risks to food safety associated with land spreading of OA and OMI materials, greater funding for research on source, treatment and management strategies related to the land-spreading of OA and OMI materials to agricultural land should be provided. This should include research on the concentration of chemicals and the type, numbers, prevalence and survival of pathogens in OA and, in particular, in OMI materials.

## APPENDIX I: LEGISLATION

### 1.1 Food

Within food legislation there are many references to what is required to ensure food safety and the direct and indirect responsibilities of food business operators<sup>†</sup> in providing safe food. However, under Article 14 of Regulation (EC) No 178/2002, it fundamentally states that food shall not be placed on the market if it is unsafe<sup>16</sup>. Further, under Article 17 there is a responsibility on food business operators at all stages of production, processing and distribution within the businesses under their control to ensure that foods satisfy the requirements of food law which are relevant to their activities and verify that such requirements are met<sup>16</sup>.

Regulation (EC) No 852/2004 on the Hygiene of Foodstuffs applies to all stages of production, processing and distribution of food and to exports, and without prejudice to more specific requirements relating to food hygiene<sup>3</sup>. Under Article 1 of Regulation (EC) No 852/2004 the primary responsibility for food safety rests with the food business operator and as such it is necessary to ensure food safety throughout the food chain, starting with primary production, e.g. on the farm<sup>3</sup>.

Under Article 4 of Regulation (EC) No 852/2004, food business operators must also comply with microbiological criteria<sup>3</sup>. Regulation (EC) No 2073/2005 sets down microbiological criteria for a range of foodstuffs including meat and dairy products and fruit and vegetable products, including ready-to-eat fruit and vegetable products<sup>89</sup>. Regulation (EC) No 853/2004 lays down specific hygiene rules for food of animal origin but the primary responsibility for food safety still rests with the food business operator<sup>204</sup>.

#### 1.1.1 Contaminants in food

The basic principles of EU legislation on contaminants in food are in Council Regulation 315/93/EEC which<sup>205</sup> states:

*“Food containing a contaminant to an amount unacceptable from the public health viewpoint and in particular at a toxicological level shall not be placed on the market. Contaminant levels shall be kept as low as can reasonably be achieved following recommended good working practices.”*

Maximum levels must be set for certain contaminants in order to protect public health. Maximum levels are set for nitrate, mycotoxins (i.e. Aflatoxins, Ochratoxin A, Patulin, Fusarium Toxins), heavy metals (i.e. Lead, Cadmium, Mercury), Tin, 3-monochloropropane-1,2-diol (3-MCPD), Polychlorinated Dibenzo-p-Dioxins and Furans (PCDD/Fs), Polychlorinated Biphenyls (PCBs) and Polycyclic Aromatic Hydrocarbons (PAHs) in foodstuffs under Commission Regulation 1881/2006<sup>115</sup>.

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<sup>†</sup> Regulation (EC) No 178/2002 defines a food business operator as the natural or legal persons responsible for ensuring that the requirements of food law are met within the food business under their control<sup>16</sup>.

## 1.2 Drinking Water

The basic standards governing the quality of drinking water (i.e. potable water) intended for human consumption are set out in EU Directive 98/83/EC, which is implemented in Ireland as S.I. No. 278 of 2007<sup>17</sup>. The legislation sets standards in relation to the quality of water intended for human consumption, cooking, food preparation, other domestic purposes and food production. S.I. No. 278 of 2007<sup>17</sup> also gives full effect to Directive 2000/60/EC<sup>206</sup> establishing a framework for Community action in the field of water policy. It prescribes quality standards to be applied and related supervision and enforcement procedures in relation to supplies of drinking water, including requirements as to sampling frequency, methods of analysis, the provision of information to consumers and related matters<sup>17</sup>.

Under EU food law, where there is a reference to drinking water, it is usually defined as water which meets the standards of the drinking water legislation<sup>17</sup>. Where the water quality does not meet the specified standards, remedial measures are outlined in legislation for public and private drinking water supplies<sup>17</sup>. The drinking water legislation lays down maximum levels for a number of chemical parameters in drinking water, namely acrylamide, antimony, arsenic, benzene, benzo(a) pyrene, boron, bromate, cadmium, chromium, copper, cyanide, 1,2-dichloroethane, epichlorohydrin, fluoride, lead, mercury, nickel, nitrate, nitrite, pesticides, polycyclic aromatic hydrocarbons, selenium, tetrachloroethene and trichloroethene, trihalomethanes and vinyl chloride<sup>17</sup>. These substances are stringently regulated because of concerns about their effect on public health. In addition, a number of chemical parameters are monitored in drinking water as so called “indicator” parameters, reflecting water quality. These include odour, aluminium, ammonium, chloride, iron and manganese, and also certain parameters influenced by chemical content including taste, pH, and colour<sup>17</sup>.

Under the Hygiene of Foodstuffs Regulation (EC) No 853/2004<sup>3</sup>, potable water is water meeting the minimum requirements laid down in Council Directive 98/83/EC<sup>17</sup>. Regulation (EC) No 178/2002 on General Food Law indicates that water ingested directly or indirectly like other foods contributes to the overall exposure of consumers to ingested substances, such as chemical and microbiological contaminants<sup>16</sup>. Therefore the definition of food includes water, intentionally incorporated into food during its manufacture, preparation or treatment. However, water is only a food after the point of compliance. The point of compliance is where a drinking water supply must be in compliance with the requirements of legislation for drinking water safety<sup>17</sup>.

### 1.3 Animal By-products

Animal manure is the largest organic by-product arising from Irish agriculture, and is typically used as a fertiliser, along with specific materials from the municipal and industrial sectors such as the meat and dairy industries. In addition to these materials other products of animal origin (i.e. animal by-products (ABP)) after appropriate treatment may also be spread on agricultural land<sup>18</sup>. The health rules concerning ABP including the collection, transport, storage, handling, processing and use or disposal of ABP is governed by Regulation (EC) No 1774/2002 (S.I. Nos. 612 and 615 of 2006)<sup>18</sup>. Articles 4, 5 and 6 the Regulation 1 classifies ABP into three categories, each with approved processing and use/or disposal methods depending on their category<sup>18</sup>. Under the definition of ABP, certain types of manure and digestive tract content are included and can be spread on agricultural land<sup>18</sup>. S.I. No. 615 of 2006 allows the spreading of catering waste, after it has been transformed in an approved composting or biogas plant, on pastureland, with a 21 day grazing ban for ruminant animals, and a 60 day grazing ban for pigs<sup>18</sup>. S.I. No. 615 of 2006 also allows for the spreading of Category 3 materials, which are obtained from an approved Category 3 processing plant and have been transformed in an approved technical plant to be spread on arable land with a three year grazing ban and 12-month ban on production of hay and ensiled crops<sup>18</sup>. The latter also applies to Category 3 fish by-products and former foodstuffs of animal origin, or containing products of animal origin, that have been transformed in an approved biogas or composting plant. As such, the management of these materials is controlled by this Regulation<sup>18</sup>.

Under the ABP Regulations, there are strict processing parameters for food waste in regard to treatment times and process temperatures along with the particle size of the material that is allowed to be treated (i.e. when collecting animal material from treating waste water the equipment used in the pre-treatment process shall consist of drain traps or screen with apertures or a mesh size of no more than 6mm in the downstream end of the process or equivalent systems that ensures that the solid particles in the waste water passing through them are no more than 6mm in size)<sup>18</sup>.

The Regulations<sup>18</sup> also require continuous monitoring and recording of temperature/time parameters during treatment processes and end product monitoring. The regulations also have specific requirements for various microorganisms, e.g. *Salmonella*, Enterobacteriaceae and *E. coli*, in end products such as meat and bone meal, compost/digestate from composting or biogas plants, processed manure and processed manure products which are placed on the market<sup>18</sup>. Spreading of manure, provided it does not pose a risk to either animal or human health, is permitted subject to environmental best practice and other relevant legislation<sup>22</sup>.

Sufficient measures must be in place to exclude animals from accessing land on which the compost or organic fertiliser or soil improver has been spread for the relevant periods.

An opinion issued by the European Food Safety Authority's (EFSA) Scientific Panel on Biological Hazards in 2005 indicated that the criteria in the current ABPs legislation relating to composting does not address adequately the identified hazards and does not realistically reflect the technological situation, e.g. temperature, humidity etc, given in such processes<sup>191</sup>. Furthermore, the use of end-point testing with biogas and composting processes is not appropriate for process monitoring as indicated in the current ABPs legislation<sup>191</sup>.

In the light of the above EFSA opinion<sup>191</sup> and others, Regulation (EC) No 181/2006<sup>18</sup> has recently amended Regulation (EC) No 1774/2002<sup>18</sup>, particularly Article 22, 1(c) to allow land-spreading of certain Category 2 and 3 materials to pasture lands with suitable post spreading restriction on subsequent grazing or harvesting (i.e. 21 days). This is under the proviso that the placing on the market and export of organic fertilisers and soil improvers complies with the requirements of Regulation (EC) No 181/2006<sup>18</sup> as regards organic fertilisers and soil improvers other than manure. S.I. No. 615 of 2006<sup>18</sup> transposes Regulation (EC) No 181/2006<sup>18</sup> into Irish law and prohibits the spreading of any processed Category 2 material on any land except manure and digestive tract contents.

In 2007, EFSA issued an opinion on the safety vis-à-vis biological risk of mesophilic biogas and compost treatments concerning ABPs of Category 3 and manure and digestive tract content<sup>79</sup>. EFSA concluded that mesophilic biogas and compost treatments cannot consistently achieve a reduction of the relevant biological hazards in accordance to Regulation (EC) No 208/2006<sup>18</sup>. ABPs treated with a process not following Regulation (EC) No 1774/2002<sup>18</sup> or not validated according to Regulation (EC) No 208/2006<sup>18</sup> should be considered as untreated ABPs vis à vis biological hazards<sup>79</sup>.

## **1.4 Environmental**

### **1.4.1 Waste management**

The European Unions (EU) general strategy for overall waste management is based on the hierarchy of (in order of preference) prevention, minimisation, reuse, material recycling, energy recovery and safe disposal. The 1975 Directive on Waste (75/442/EEC)<sup>207</sup>, as amended by Council Directives 91/156/EEC<sup>208</sup> and 91/689/EEC<sup>209</sup> gave Member States including Ireland the provision to take actions to encourage the prevention, recycling and processing of waste, and to ensure that any residuals are utilised or disposed off without endangering public health or the environment. They also provide the overall structure for an effective waste management regime within the EU<sup>207-209</sup> Directive 75/442/EEC is often referred to as the Framework Directive on Waste<sup>207</sup>. The EPA has indicated that the provision of waste management infrastructure in Ireland continues to improve<sup>23</sup>.

#### **1.4.2 Sewage sludge**

S.I. No. 148 of 1998 (with amendments) defines and controls the use of sewage sludge in agriculture and gives provision for the protection of the environment, particularly soil when sewage sludge is used in agriculture<sup>1</sup>. The legislation sets out maximum limits for seven metals (i.e. mercury, lead, zinc, nickel, cadmium, copper and chromium) in soil and sludge, and defines the maximum quantities of these metals that can be introduced into soil. The legislation does not set out microbiological levels for sewage sludge used in agriculture<sup>1</sup>. S.I. No. 148 of 1998 also placed a two tonne per/hectare limit on the amount of sewage sludge (i.e. dry matter) that could be spread on the land within one year<sup>1</sup>. The two tonne per/hectare limit has been further amended by S.I. No. 267 of 2001 which sets a limit based on the absolute qualities of all seven metals (i.e. mercury, lead, zinc, nickel, cadmium, copper and chromium) which may be applied to soil, per/hectare, per/year based on a ten year average<sup>1</sup>.

The disposal of sewage sludge to the marine environment is not permitted (Appendix 1.4.5) in accordance with the provisions of the Dumping at Sea Act, 1981 (as amended)<sup>210</sup> and Directive 91/271/EEC<sup>28</sup> which also prohibits sludge been dumped at sea since 31<sup>st</sup> December 1998<sup>28, 210</sup>.

A system for the licensing or certification of waste water discharges from areas served by local authority sewer networks was introduced on a phased basis commencing in December 2007 in accordance with the requirements of the Waste Water Discharge (Authorisation) Regulations, 2007 (S.I. No. 684 of 2007)<sup>359</sup>. The licensing and certification process will give effect to a number of EU Directives by the imposition of strict restrictions or prohibitions on the discharge of dangerous substances and thus prevent or reduce the pollution of waters by waste water discharges. All discharges to the aquatic environment from sewerage systems owned, managed and operated by water service authorities will require a waste water discharge licence or certificate of authorisation from the EPA. The authorities will be required to apply to the agency for a licence by set dates depending on the population equivalent of the area served by the sewer network. The authorisation process provides for the EPA to place stringent conditions on the operation of such discharges to ensure that potential effects on the receiving water bodies are strictly limited and controlled. However, the regulations do not regulate sludge disposal from waste water treatment operations.

#### **1.4.3 Good agricultural practice for protection of waters**

The Good Agricultural Practice for Protection of Waters Regulations, 2006<sup>4</sup> often referred to as the Nitrates Directive, has the objective of reducing water pollution by nitrates from agricultural sources and preventing further such pollution, with the primary emphasis being on the management of manures and other fertilisers<sup>4</sup>. The Regulations address<sup>4</sup>:

- waste storage
- farmyard management
- nutrient management
- land-spreading of slurries.

The Regulations are designed to afford additional protection to waters from agricultural sources and include measures such as:

- set periods when the land spreading of fertilisers are prohibited
- limits on the land application of fertilisers
- set distances from water bodies including boreholes, springs and wells for the abstraction of water used for human consumption
- storage requirements
- record keeping.

The legislation has provisions to limit the land spreading of all nitrogen containing fertilisers, but in particular, to set specific limits for spreading of livestock manure<sup>4</sup>. The specific limit for the spreading of livestock manure has been set at 170kg/hectare with no limits set for other organic wastes. In addition, the legislation also has restrictions on when land spreading is prohibited<sup>4</sup>. These restrictions are applied under the legislation on a geographically based zone and as such, have implications on storage requirements for all organic waste producers<sup>4</sup>.

#### **1.4.4 Spoil from dredging maintenance**

The spreading of spoil from dredging maintenance (Appendix 2.2.2) on agricultural land requires a waste permit from a relevant local authority<sup>31</sup>. The activity can be described as a waste recovery activity as set out in the 4th schedule of the Waste Management Acts, 1996-2003, class ten of which relates to the treatment of any waste on land with a consequential benefit for an agricultural activity or ecological system<sup>31</sup>. To meet the regulatory conditions, the material must have a beneficial effect on the land. Clearly, contaminated material would not meet this criterion and hence would not be suitable for spreading on agricultural land<sup>31</sup>.

#### **1.4.5 Dumping at sea**

Dumping at sea is regulated under the Dumping at Sea Acts, 1996 and 2004<sup>210</sup>. The Dumping at Sea Act, 1996 (as amended) prohibits the dumping at sea from vessels, aircraft or offshore installations of a substance or material, and the dumping at sea of vessels, aircraft or offshore installations, unless permitted by the Minister for Communications, Energy and Natural Resources<sup>210</sup>. The dumping of sewage sludge, animal carcasses, animal parts, animal products and fish waste is also not permitted. However, dumping at sea permits are granted for the disposal of dredging (Appendix 1.4.4) material from ports, harbours and marinas in the absence of suitable alternative reuse and disposal methods<sup>210</sup>. All permit applications for the dumping of dredge spoil at sea are processed by the Department of Communications, Energy and Natural Resources (DCENR) Coastal Zone Management Division. Guidelines for dumping dredge spoil at sea and information on making an application for a permit are available on the DCENR website.

#### **1.4.6 Manure management**

Under the IPPC Directive (96/61/EC)<sup>70</sup>, facilities with 40,000 or more poultry places (Appendix 4.3.7), 2,000 places for pigs over 30kg, and those with more than 750 sow places, must acquire an IPPC Licence from the relevant authority e.g., the EPA in Ireland. However, pig slurry and poultry litter account for less than 5% of total volume of OA materials land spread in Ireland. Under an IPPC licence, a facility must implement best available techniques (BAT) by October 2007 to effect the protection of air, soil and water resources<sup>70</sup>. What constitutes BAT for these producers has been specified by the European IPPC Bureau<sup>211</sup> and excludes manure treatment on-site except in very specific circumstances. These circumstances include<sup>211</sup>:

- a limited availability of land on which to utilise manure in an appropriate manner
- local excesses of nutrient or nutrient demand
- marketing possibilities for green energy
- local regulations
- the presence of abatement techniques.

However, under the IPPC Directive<sup>70</sup> a fundamental BAT that all affected intensive animal producers must implement is good agricultural practice. While some elements of what constitutes good agricultural practice are suggested by the European IPPC Bureau<sup>211</sup>, this term is not prescribed absolutely. One could argue then, that although the IPPC Directive<sup>70</sup> is concerned about environmental protection, it also implies some degree of animal health and food safety protection via the requirement on animal producers to implement good agricultural practice. Through such an interpretation, the IPPC Directive<sup>70</sup> would therefore, indirectly influence the where, when and how of manure management on land vis-à-vis food safety, e.g. exclude spreading to certain crops used for human consumption, and animal health, e.g., exclude spreading to grazing lands for some period of time.

Producers not regulated by the IPPC Directive<sup>70</sup> (i.e. small pig and poultry producers, producers of all other animals) have few requirements for manure management with which they must comply, other than generic environmental regulations, e.g. Nitrates Directive, Water Framework Directive, Section 21A of the Local Government (Water Pollution)(Amendment) Act, 1990 and various water pollution and nuisance laws, and specific government supported environmental programmes, e.g., Rural Environment Protection Scheme. As with the IPPC Directive<sup>70</sup>, these regulatory/voluntary programmes primarily address environmental protection, but it is arguable that food safety and animal health are addressed indirectly. The Commission is currently carrying out a review of the IPPC Directive<sup>70</sup>, and related legislation on industrial emissions, over the period 2006-2007. The review will not affect requirements of the IPPC Directive<sup>70</sup> that Member States and industry had to fulfil before 30 October 2007<sup>212</sup>.

#### **1.4.7 Water Framework Directive**

The Water Framework Directive<sup>206</sup>, implemented in Ireland under S.I. No. 278 of 2007<sup>17</sup> (Appendix 1.2) sets a framework for comprehensive management of water resources in the EU, within a common approach and with common objectives, principles and basic measures. It addresses inland surface waters, estuarine and coastal waters and groundwater and aims at maintaining high-status of waters where it exists, preventing any deterioration in the existing status of waters and achieving at least good-status in relation to all waters by 2015. The Directive rationalises and updates existing water legislation by setting common EU wide objectives for water. It is broad in its scope and relates to water quality in rivers, lakes, canals, groundwater, transitional (estuarine) waters and coastal waters out to a distance of at least one nautical mile<sup>206</sup>. All Member States have to ensure that a coordinated approach is adopted for the achievement of the objectives of the Water Framework Directive and for the implementation of programmes for this purpose. The main activities in the implementation of the Water Framework Directive will take place in the context of River Basin Management Projects led by LAs. DEHLG is promoting the establishment by LAs of projects to address all inland and coastal waters.

## APPENDIX 2: SOURCE, TYPE AND VOLUME OF MATERIALS

### 2.1 Agricultural Materials

#### 2.1.1 Animal manures

Cattle manure accounts for 60.56% of the total volume of material in the national agricultural waste inventory for 2004<sup>10</sup> followed by pig slurry (4.04%), sheep manure (2.22%) and poultry litter (0.29%). Cattle slurry accounts for almost 80% of cattle manure production with farmyard manure (FYM) accounting for the remainder<sup>213</sup>. The animal manures which collectively account for just over 40 million tonnes, are managed exclusively by land spreading to farmland. This is considered to be the most sustainable management option available as the nutrient contained in the manure is recycled<sup>66</sup>. Soils can treat the organic matter additions and safely assimilate the manure nutrients for crop production. It is estimated that the nutrients contained in animal manures are worth approximately €130 million annually to Irish farming<sup>214</sup>. Regulations now direct the land spreading of manure and other organic materials by specifying acceptable spreading in terms of rates and dates of spreading with the objective of reducing the impact of this activity on the water, soil and air resources<sup>4, 74, 215</sup>.

In general, cattle and sheep manure is spread on land which is associated with a specific farm. The pig and poultry manures are generally transported off the farm and spread on farm land managed by other farmers. Approximately, 79% of cattle slurry is spread on conservation or silage areas, 16% is spread to grazing areas with the remainder, 4%, spread on maize and tillage areas (i.e. tillage is land which is ploughed or cultivated and sown with a crop)<sup>214</sup>. Approximately 34% of the cattle slurry is spread in spring, with 45% spread in summer, 14% in autumn and 6% in winter<sup>214</sup>. There is a lower proportion (56.3%) of FYM spread on grassland conservation areas and a higher proportion spread on grazed grassland (26.7%) and tillage areas (13.3%) compared with cattle slurry (Table 8). Solid manure was generally spread later in the year (summer and autumn) compared with cattle slurry. The differences in the timing of the land-spreading and the crop to which they are applied are as would be expected.

**Table 8. Spreading of Solid Cattle Manure<sup>1</sup> to Land and Season of Spreading<sup>214</sup>**

Land Uses	Spring	Summer	Autumn	Winter	Total
Conservation Land	6.47	18.12	27.53	4.16	<b>56.3</b>
Grazing Land	5.70	4.64	12.20	4.18	<b>26.7</b>
Maize <sup>2</sup>	2.09	0.38	0.28	0.96	<b>3.7</b>
Tillage	5.81	1.53	5.61	0.34	<b>13.3</b>
<b>Total</b>	<b>20.07</b>	<b>24.67</b>	<b>45.62</b>	<b>9.64</b>	

<sup>1</sup> Solid cattle manure = farm yard manure (FYM).

<sup>2</sup> Maize is an annual crop which is part of tillage and is generally found on grassland rather than arable farms. Maize is harvested, ensiled like grass and fed to animals.

Over 85% of pig slurry is spread on grassland used for conservation (47.31%) and grazing (38.33%). Most of the remainder is spread on tillage land. Almost 70% of the pig slurry is land spread in the spring and summer. Table 2 outlines the spreading of pig slurry to agricultural land in Ireland.

**Table 9. Spreading of Pig Slurry to Land and Season of Spreading<sup>165</sup>**

Land Uses	Spring	Summer	Autumn	Winter	Total
Conservation Land	18.80	16.40	10.43	1.68	<b>47.31</b>
Grazing Land	12.40	12.60	10.98	2.35	<b>38.33</b>
Maize	4.38	0.00	0.00	0.00	<b>4.38</b>
Tillage	4.75	0.50	4.38	0.38	<b>10.01</b>
<b>Total</b>	<b>40.33</b>	<b>29.5</b>	<b>25.79</b>	<b>4.41</b>	

There are no data available for poultry manure management in terms of the season of spreading or the crop to which it is spread on. It is worth noting that the relatively small quantity of all types of animal manures spread on tillage land reflects the fact that only approximately 9% of farmed land in Ireland is used for tillage<sup>216</sup>. The national location and distribution of animal manure was approximated using data from the Central Statistics Office<sup>216</sup> agricultural census of 2001<sup>216</sup> and published manure production figures<sup>74</sup>. They provide an indication of the distribution of cattle, sheep, pig and poultry manure loads<sup>216</sup>. The highest manure concentrations are broadly associated with the areas of intensive grassland agriculture in the southern part of the country, the midlands and parts of the north east. The lower concentrations are associated with mountainous areas of the country<sup>216</sup>. In general, sheep are associated with the mountainous areas with the exception of parts of Leinster and Connaught<sup>216-217</sup>. Cavan and Monaghan have a relatively high density of pig and poultry. Limited areas within Waterford, Cork, Limerick and smaller areas of some of the midland counties also have high pig and poultry enterprises.

The 2006, Food and Agricultural Policy Research Institute Ireland Partnership<sup>218</sup> provides a view of the Irish agriculture sector over the next ten years. The baseline projections for animal numbers in the cattle, pig and sheep sectors were used to provide an indication of possible trends in animal manure production over the next ten years<sup>218</sup>. The production of pig, cattle and sheep manure will decline by approximately 10%, 18% and 24%, respectively, between 2005 and 2015<sup>218</sup>. There are no reliable data available in relation to the expected trends in poultry numbers for this period.

### **2.1.2 Soiled water**

Soiled water refers to waste water generated by dairy enterprises during milking operations including the runoff of rain water from paved farmyard areas contaminated with animal excreta or other organic materials<sup>23</sup>. As such, it is an underestimate as there will be soiled water produced on cattle and sheep farms during the winter months. Soiled water accounted for 30.54% of the total volume of materials in the national agricultural waste inventory for 2004<sup>23</sup>. Peak production will tend to be associated with peak rainfall periods during the year. The nutrient value of soiled water relative to the volumes produced is low compared with manure. This has resulted in soiled water being managed as a waste rather than a nutrient recycling operation.

Soiled water is generally land spread to the areas adjacent to the farmyard. In absence of specific data, the location and distribution of soiled water production will reflect that of cattle manure production with the highest quantities produced in areas with the highest bovine concentrations. Soiled water production over the next decade will generally reflect the downward trend in cattle and sheep numbers. This trend will be underpinned by regulatory requirements to reduce soiled water losses from farmyards. Soiled water does not include any liquid where such liquid has either a biochemical oxygen demand exceeding 2,500mg per litre, or a dry matter content exceeding 1%. Soiled water which is stored together with slurry or which becomes mixed with slurry is deemed to be slurry<sup>4</sup>.

### **2.1.3 Silage effluent**

Silage effluent is the sugar rich liquor produced following the ensiling of fresh grass and accounted for 1.89% of the total volume in the national agricultural waste inventory for 2004<sup>23</sup>. The volume produced is determined by the dry matter of the grass ensiled. For example, one tonne of grass ensiled at 20% dry matter will produce 137 litres of effluent while grass with a dry matter content of 23% will produce on average 69 litres of effluent. The dry matter of the grass will be determined by cutting date and weather conditions. Peak production period is in the summer months of May to July. The effluent is collected directly from the pit and is land spread generally following dilution with water. The location and distribution of silage effluent production will reflect bovine concentrations with the highest quantities produced in areas with the highest bovine concentrations. Silage effluent production over the next decade will generally decline though year to year variability will continue to exist reflecting the weather during the silage cutting season. The move towards baled silage production will contribute to a reduction in the volume of silage effluent requiring management.

#### **2.1.4 Spent mushroom compost**

Spent mushroom compost is the material that remains following mushroom production<sup>72</sup>. Mushroom compost is manufactured from wheaten straw and poultry manure with the addition of water and gypsum. These undergo composting and pasteurisation processes after which the compost is selective for the mushroom fungus. The compost is then spawned with mushroom mycelium filled into polyethylene bags, each containing 20kg of compost, and delivered to the mushroom farms. A by-product of mushroom production is the spent mushroom compost which remains after the mushroom crop has ceased harvesting. It is generally spread on agricultural land.

In 2004, approximately 274,050 tonnes<sup>23</sup> of mushroom compost was used in the Republic of Ireland for mushroom production<sup>217</sup>. This is very similar to the volume, 280,000 tonnes, reported for 1998<sup>72</sup>. The most common method of applying spent mushroom compost in Ireland is by using a solid manure spreader. The production of spent mushroom compost is widely distributed throughout the country with the greatest volumes in Monaghan (24%) and Cavan (11%)<sup>72</sup>. The Irish mushroom industry is facing increasing competition in its main export markets, e.g. United Kingdom and from the Dutch and Polish mushroom industries. Against this background it is unlikely there will be any major increase in the volumes of spent mushroom compost in the next decade.

## **2.2 Municipal Materials**

### **2.2.1 Biosolids**

Overall, the amount of sewage sludge generated in Ireland has increased significantly over the last ten years with the subsequent use of biosolids on agricultural land also increasing significantly<sup>24</sup>. During 2004-2005, a total of 121,750 tonnes of dried sludge was produced nationally by waste water treatment plants with population equivalent greater than 500 persons<sup>24</sup>. The use of biosolids in agriculture now accounts for 76.1% of the total sludge arisings, compared with 63% in 2002/2003 and 45% in 2001/2002<sup>24</sup>. However, it is important that sludge used or supplied for use in agriculture is managed and treated in accordance with the legislation to minimise the risks to human, animal and plant health<sup>215</sup>.

Over 60% of the total amount of biosolids used on agricultural land in Ireland originates from a single waste water treatment facility in Dublin (i.e. Ringsend waste water treatment plant). At this facility, sludge is dewatered by centrifuge and thermally dried<sup>216</sup> to make it acceptable for use as a soil amendment. The production of biosolids from waste water treatment plants has increased in Ireland from 33,559 tonnes (dry solids) in 2001 to 59,827 tonnes (dry solids) in 2005<sup>24</sup>. As might be expected, the higher volumes of production are associated with the cities and larger towns<sup>24</sup>. In addition, the current investment programme under way in waste water treatment plants at some of the larger population centres will contribute an additional 20,000 tonnes dry solids to the total biosolids generated in Ireland.

### **2.2.2 Spoil from dredging**

Dredging of bodies of water (Appendix I.4.4), including inland waters, estuaries and seaports is necessary to maintain navigation routes, remove sediments from water intakes, structures and basins, carry out engineering works or carry out environmental clean-up works (i.e. removal of contaminated sediments)<sup>219</sup>. The Office of Public Works carries out river dredging in Ireland. River dredging may arise from the implementation of flood defence schemes where river flood conveyance may need to be increased. The OPW also maintains arterial drainage schemes completed under the 1945 Arterial Drainage Act<sup>220</sup> which involves the removal of silt build-up in channels. Other bodies involved in dredging include Waterway's Ireland, Bord na Mona, local authorities and the Department of Communications, Marine and Natural Resources. A number of options exist for disposal of dredged sediments (i.e. dredging spoil) including:

- disposal at sea
- landfill
- spreading on agricultural land
- beach nourishment
- disposal as hazardous waste.

The method of disposal chosen will depend on the physical, chemical and microbiological nature of the spoil from dredging maintenance<sup>219</sup>. The nature and degree of chemical and microbiological contamination will vary widely. For example, the spoil from dredging maintenance of many rivers will be relatively uncontaminated whereas dredgings from a port or estuary into which urban sewage and industrial effluents have been discharging for several years may contain significant contaminant levels<sup>221</sup>. Spoil from the dredging maintenance of rivers, is generally relatively uncontaminated (unless immediately downstream of urban sewage or industrial effluent discharges or abandoned mines)<sup>222</sup> and would commonly be spread on adjoining lands<sup>126</sup>.

In defining the suitability criteria for spoil from dredging maintenance to be spread on agricultural land, it would appear logical that the metal limit values for both land and sludge set out in the legislation<sup>215</sup> would have equal relevance to spoil. A similar comment applies to the criteria set out in the same regulations regarding procedures to obtain representative samples.

The issue of microbiological characterisation is not as straightforward however, as the nature and level of contamination of spoil from dredging maintenance can vary widely. For example, spoil from dredging maintenance of an estuary or seaport into which significant quantities of sludge have been discharged may warrant having the same spreading restrictions as applied to sewage sludge<sup>215</sup>. A microbiological analysis of the spoil for comparison with microbiological characteristics of biosolids, in addition to assessment of contamination sources applying at the site from which the dredged sediments originated, may be of some help in characterising the suitability of the spoil for spreading on agricultural land. It is suggested that if spoil from dredging maintenance is poorly characterised and that proper assessment cannot be made of its potential impacts on public health and the environment, it shall not be dumped<sup>219</sup>.

## APPENDIX 3:TREATMENTS

### 3.1 Agricultural Materials

Treatments for agricultural materials can be broadly divided into two types, passive and active<sup>73</sup>. Passive treatments include the use of storage and buffer zones and rely primarily on the passage of time, in conjunction with physical barriers and environmental factors, such as temperature, moisture fluctuations and ultraviolet irradiation, to reduce pathogens.

An opinion issued by EFSA's Scientific Panel on Biological Hazards in 2005 indicated that the spreading of untreated manure to land, within the same epidemiological geographical area where the manure has been produced and in association with good agricultural practices, poses little problem to public and animal health<sup>155</sup>. However, untreated manure should not be used on horticultural crops, particularly ready-to-eat (RTE) crops. Active treatments include pasteurisation, heat drying, anaerobic digestion, alkali stabilisation, aerobic digestion or combinations of these (Table 10).

Treatment	Potential Pathogen Reduction		
	Viruses	Bacteria	Protozoa Parasites
<b>Pasteurisation</b>	Medium	<b>High<sup>1</sup></b>	<b>High</b>
<b>Irradiation</b>	Low	<b>High</b>	Medium/High
<b>Lime Treatments</b>			
Slaked lime	Medium/High	<b>High</b>	Medium
Quick lime	High	<b>High</b>	<b>High</b>
<b>Anaerobic Digestion</b>			
Mesophilic (30–35°C)	Low	Low	Low
Thermophilic (50–55°C)	Medium/High	Medium/High	Medium
<b>Aerobic Digestion</b>			
Mesophilic (up to 20°C)	Low	Low	Low
Thermophilic (50–55°C)	<b>High</b>	<b>High</b>	<b>High</b>
<b>Composting (50–60°C)</b>	No Data	<b>High</b>	<b>High</b>
<b>Incineration</b>	<b>High</b>	<b>High</b>	<b>High</b>

<sup>1</sup> Poor reduction in bacterial spores

References: 2, 7, 30, 90-91, 108, 111, 131, 151, 155, 167, 171, 223-225, 354-355, 360

A large body of research has confirmed that treatment techniques do exist that can control to acceptable levels the hazards posed by microorganisms found in animal manure. In general such processes include aerobic, e.g. composting, and anaerobic, e.g. anaerobic digestion, biological processes accompanied by elevated temperatures that together create adverse environmental conditions that kill or otherwise inactivate the microorganisms. The design and operation of these processes is well advanced and can be considered more or less routine. However, managerial input is an essential ingredient to the success of all treatment processes. A comprehensive review of manure treatment strategies is available as a consequence of a major EU-funded project involving more than 30 research organisations across Europe<sup>7</sup>. The following information has been condensed from this source, except where noted otherwise.

### **3.1.1 Storage**

Some microbial inactivation occurs as a consequence of the storage of agricultural materials, due to the conditions which develop. The extent to which inactivation occurs depends on the species of pathogens present, the moisture content of the material, temperature and other factors. Nevertheless, as some pathogens can survive for extended periods storage alone is unlikely to reduce numbers of all pathogens occurring in animal manure<sup>7</sup>. Current research<sup>226</sup> has indicated that livestock wastes should be batch stored and not subjected to continuous additions as this reduces the effectiveness of storage as a means to reduce levels of pathogens<sup>7,226</sup>. However, in Ireland it is common practice to routinely top-up storage tanks with fresh material on a continuous basis. Batch storage is not readily practical on most Irish farms. Consequently, storage of manure is not a major mitigation option for the control of pathogens in manure.

### **3.1.2 Buffer zones**

To prevent the contamination of watercourses, buffer zones are established in good agricultural practice for protection of waters<sup>4</sup>. Where the watercourse is not used for drinking supply purposes, the standard specified distance is five metres which may be reduced to three metres under certain circumstances. The effectiveness of these distances for preventing contamination of watercourses is uncertain and under some conditions microbial contamination may transit considerable distances.

### 3.1.3 Composting

Composting is a degradation process commonly used as an active treatment in which organic materials are digested, aerobically or anaerobically, by microbial action<sup>73</sup>. When composting is carefully controlled and managed, and appropriate conditions are achieved, the high temperature generated can kill most pathogens in a number of days<sup>73</sup>. Proper management involves relatively close attention to the composting material, regardless of the type of composting system employed, to assure that<sup>7</sup>:

- aerobic conditions are maintained more or less throughout the material
- a sustained period (>3 days) of high temperature (mid-thermophilic range, 55-60°C) is achieved.

A 2006 study recommended thermophilic composting for treatment of manures destined for pathogen-sensitive environments such as those for vegetable production, residential gardening, or application to rapidly draining fields<sup>354</sup>. A 2007 study indicated that *L. monocytogenes* and *S. Typhimurium* were destroyed most rapidly under thermophilic composting conditions for pig manure<sup>355</sup>. Turning and mixing the material is essential, as is monitoring of temperature and moisture status, in order to achieve these conditions. The variability in managerial input among farms is likely to be high, calling to question the strict reliance on composting as a disinfection process in general. Where specific diseases are of concern, trials should be undertaken first to establish the effectiveness of a composting process/system<sup>7</sup>. In contrast to on-farm systems, centralised compost or anaerobic digestion facilities are likely to be designed and operated to a very high standard and, likely, will be regulated as waste management facilities by the EPA. Residuals from such facilities may, in time, be required to meet quality standards.

Licensed facilities could also have to abide by rigorous environmental management standards meant to ensure, *inter alia*, a minimum degree and uniformity of treatment. For example, in response to EU Regulations on the management of ABP (Appendix 1.3)<sup>18</sup>, statutory instruments were passed in Ireland regulating the use of ABP in composting and bio-gas (i.e. anaerobic digestion) facilities<sup>18</sup>. These Regulations require veterinary input and approval as part of the approval process for the establishment of composting or anaerobic digestion facilities intending to accept ABP<sup>18</sup>. Stringent processing standards and microbiological testing of end product must comply with standards laid out in EU Regulation 1774/2002 as amended, Annex VI<sup>18</sup>.

### **3.1.4 Aerobic treatment**

Composting (Appendix 3.1.3) is a viable aerobic process for the treatment of relatively dry organic wastes. The high temperatures achieved in a compost pile are the result of natural microbial activity. In materials with a higher moisture content (i.e., slurries and liquids) to which an adequate supply of oxygen is provided (through mechanical aeration), microbial processes also produce heat, but this is rapidly dissipated in the liquid unless the wastes are contained in insulated vessels. In such systems, temperatures can reach 70°C, which, together with free ammonia, predation by other microorganisms, and lowered substrate concentrations, is enough to have a very negative effect on the survival of pathogens<sup>7</sup>.

Despite its benefits, however, aerobic treatment of animal manure slurries and liquids (through aeration) also presents risks to public health via the creation of aerosols. Thus, where disease concerns in manure are high, or where notifiable diseases exist, aerobic treatment via aeration would not be recommended<sup>7</sup>.

### **3.1.5 Anaerobic digestion**

Anaerobic digestion of organic wastes has a long track record, and is often associated with production of biogas, the result of organic decomposition in the absence of oxygen. Anaerobic digestion occurs in three distinct phases, which occur simultaneously in the treatment reactor. Each of the three processes has different environmental requirements, making the optimisation of anaerobic digestion difficult.

The extent to which pathogen reduction occurs in anaerobic digestion depends largely on the temperature at which the process is maintained, with digestion in the thermophilic range being most effective<sup>7</sup>. However, the thermophilic digestion process is easily upset and therefore more difficult to manage, such that operating in the mesophilic range is operationally more viable for on-farm application. At the mesophilic range, pathogen reduction can still occur but may take longer (days or weeks) than in thermophilic digestion<sup>7</sup>. As a disinfecting process, anaerobic digestion has a proven effectiveness, especially when operated at thermophilic temperatures and/or long residence times. Where specific microbial hazards are present, thermal pre-treatment (70°C for one hour or more) may be appropriate<sup>7</sup>.

### **3.1.6 Chemical treatments**

Chemical sanitising agents, e.g., formaldehyde, sodium hydroxide, lime, are used to treat manure particularly when an outbreak of a notifiable disease occurs. Chemical treatment of manure involves introducing the sanitising agent into the manure and assuring complete mixing and a long (approximately four days) residence time<sup>7</sup>. Lime treatment, using unslaked (quicklime, calcium oxide) or slaked (calcium hydroxide) forms, is a widely recommended treatment option and specific guidelines exist to effect disinfection of both liquid (including slurry) and solids wastes. However, compared to manures in liquid systems, solid manure is more difficult to disinfect because of the obstacles faced in trying to achieve a uniform and complete mixing of disinfectant with the waste<sup>7</sup>.

### **3.1.7 Heat treatments**

Pasteurisation and sterilisation are well established heat treatments for a variety of materials to render them microbiologically safe. Due to the volume of material involved and the associated energy inputs and costs, heat treatment of animal manure by either pasteurisation or sterilisation, while technically achievable, is practically questionable. In specialised circumstances, heat treatment may be justified<sup>7</sup>.

### **3.1.8 Incineration**

Incineration offers many waste management benefits, e.g. volume reduction with simultaneous heat recovery, not the least of which is the destruction of pathogenic microorganisms<sup>7</sup>. In certain circumstances, the viability of centralised thermal treatment for dry animal wastes can be demonstrated, and this form of treatment may become more widely applicable as concerns ancillary to food safety increase.

### **3.1.9 Dewatering**

Dewatering is a treatment process that separates the liquid and solid portions of waste water sludge which in turn increases the solids content of the sludge. Dewatering is usually performed in a series of steps utilising two or more pieces of equipment, with each subsequent step reducing the percentage of liquid in the sludge. In Ireland, filter belt presses and centrifuges are the most common technologies employed for dewatering processes. Sludges are thickened primarily to decrease the capital and operating costs of further sludge processing steps by reducing the volume of sludge.

Dewatering may be an effective control measure for viruses but its effectiveness depends on the extent to which dewatering is carried out. In one study, viral inactivation was only observed when the solids content reached at least 65%<sup>225</sup>. In addition, the effectiveness of anaerobic digestion and aerobic digestion for inactivating viruses is dependant on the operational temperature of the process with high temperatures being required for inactivation of viruses<sup>171,223</sup>. In trials in which cattle manure was inoculated with bovine enteroviruses and bovine parvovirus, inactivation occurred within 30 minutes during thermophilic anaerobic digestion at 55°C<sup>10</sup>. The enteroviruses survived for up to 13 days under mesophilic conditions (35°C). Neither of these two environmentally resistant viruses survived aerobic composting for 28 days when the temperature reached 60°C on the third day and was maintained at that temperature for the remainder of the fermentation<sup>10</sup>.

## 3.2 Municipal Materials

### 3.2.1 Municipal sludges

Sludge is a by-product of waste water treatment processes. After treatment to an approved standard, sludge may be used as a fertiliser or soil conditioner in agriculture<sup>2</sup>. Approximately 0.13% of the total material land spread in Ireland in 2004 was of municipal origin<sup>22</sup>. Municipal sludge can originate from the treatment of urban waste water consisting of domestic waste water or a mixture of domestic and industrial/agricultural waste waters and/or run-off rain water<sup>8</sup>.

The characteristics of sludge depend on the compositional characteristics of the influent waste water and the treatment applied to the sludge product. A number of treatments are available to produce sludge suitable for land-spreading including thermal drying, dewatering, thickening and various disinfection treatments<sup>8</sup>. In some cases, sludge may undergo a number of treatments to reach the standards necessary to allow its use on agricultural land. In Ireland, sludge is typically dewatered (filter belt or centrifugation) before land filling, or undergoes anaerobic digestion or thermal drying before spreading to land<sup>204</sup>. Alternatively, if sludge is not to be land-spread, it may under specific conditions, be incinerated or sent to landfill<sup>1</sup>. However, in Ireland incineration is as yet not used in the management of sludge (Appendix 3.1.8).

Other technologies for the utilisation of sludge exist, e.g. silviculture, land reclamation and other combustion technologies such as wet oxidation, pyrolysis and gasification, and are employed under regulation in other countries, particularly the USA. In Ireland, entities using sludge in agriculture must ensure that the quality of the soil, surface water and ground water is not impaired and ensure that sludge is not used except in accordance with a nutrient management plan<sup>14</sup>. In studies on the impact of treatments on bacterial populations in municipal sludge, populations of bacteria are generally reduced by treatment<sup>360</sup>. However, in the case of *L. monocytogenes*, French data have indicated that only lime treatments (Table 10) will reduce numbers of this pathogen and other bacteria below detectable limits<sup>224</sup>. It was concluded that land-spreading of treated sludge (i.e. biosolids) onto agricultural land could contribute to an increase in the dissemination of *L. monocytogenes* in the environment<sup>224</sup>.

### **3.2.2 Biodegradable municipal waste (composted source separated organics)**

As a result of the Landfill Directive<sup>174</sup> EU Member States must divert increasing quantities of biodegradable municipal waste (BMW) from landfill. The Government has developed a strategy for the management of biodegradable waste<sup>81</sup>. The biodegradable fraction makes up approximately 75% of the solid waste arising from households and businesses<sup>81</sup>. The principal components of BMW are food wastes, paper, cardboard and garden trimmings; food and garden wastes comprise approximately 40% of BMW<sup>81</sup>. It is estimated that centralised biological treatment (composting and/or anaerobic digestion) will need to treat approximately 240,000 tonnes of BMW by 2010; 320,000 tonnes by 2013, and 330,000 tonnes by 2016<sup>81</sup>. These processes will produce a residual, stabilised product that most likely will need to be land spread. It has been determined that the best use for the greatest amount of compost from BMW would be on agricultural cropland, both conventional and organic.

As a consequence of the Landfill Directive<sup>27</sup>, large quantities of BMW will need to be diverted from landfills in the coming years, and according to the National Strategy on Biodegradable Waste, this will be accomplished by a combination of recycling, recovery, and biological treatment. Composting (Appendix 3.1.3) is the most likely form of treatment for these materials. Depending on the precise process utilised, products of varying qualities (in terms of compost characteristics) can result. Separating BMW materials at their sources of generation, and keeping them separate, is fundamental to producing high quality composts suitable for spreading on agricultural land. As noted previously, both composting (Appendix 3.1.3) and anaerobic digestion (Appendix 3.1.5) are biological processes that, depending on their management, can attain temperatures high enough to provide effective reductions in potential pathogens.

## 3.3 Industrial Materials

### 3.3.1 Industrial sludges

Sludges are also a by-product of industrial waste water treatment processes (Appendix 3.2.1). After further treatment to an approved standard, some industrial sludge may be suitable for use in land-spreading<sup>22</sup> (Appendix 3.2.1). Industrial sludges can originate from<sup>8</sup>:

- treatment of waste water originating from industrial processes, e.g. food processing, abattoirs, dairies, pulp and paper industry, tanneries etc
- treatment of raw water to produce potable or non-potable water also produces sludges, but these are largely inorganic materials generally arising from the application of chemical processes.

The EPA has indicated that the discharge of water treatment sludge to receiving water, where practiced, should cease immediately. The mixing of water treatment sludges for subsequent spreading on land is not permitted under the Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998<sup>1</sup> and therefore such practices, where they exist, should cease immediately<sup>21</sup>. While it has been reported that only 0.82% of the total material land spread in Ireland in 2004 was of industrial origin<sup>22</sup> the EPA has identified uncertainties in relation to aspects of land spreading industrial organic materials in Ireland including<sup>22</sup>:

- quantities and types of materials produced by industry in Ireland
- quantities and types of materials currently spread on agricultural land in Ireland
- the short and long term effects and impact the land spreading of these materials have or may have on food safety, animal health, soils and the environment.

As such, the EPA is currently developing a guidance manual on the practice of land spreading as a management option for industrial organic materials in Ireland<sup>22</sup>.

## APPENDIX 4: DESCRIPTION OF MICROBIOLOGICAL HAZARDS

### 4.1 Introduction

Use of OA materials such as manure<sup>60</sup> and OMI materials such as sewage sludge<sup>360</sup> may introduce pathogens to soil and crops following land-spreading with run-off from the land, possibly contaminating water supplies<sup>357</sup>. Pathogens are excreted by the faecal route<sup>109</sup> and also with other excretions or secretions from the bodies of animals<sup>203</sup> and humans. For example, manure typically consists of animal excreta (i.e. faeces and urine), bedding and dilution water as well as secretions from the nose, throat, blood, vagina, mammary gland, skin and placenta. It has been indicated that manure can potentially harbour over 197 different zoonotic pathogens<sup>101,109</sup>. Some pathogens are also excreted from clinically healthy animals<sup>203,109</sup> and humans. Pathogens may be found in OA and OMI materials in an infectious form such as vegetative bacteria or viruses and also in the form of spores, cysts and eggs which will become pathogenic when inside a human host<sup>203</sup>.

During land-spreading of some organic materials, airborne dispersal of contaminants or pathogens<sup>48-49,211</sup> can arise. Nevertheless research on aerosols derived from land-spreading techniques in the United States has indicated that under current American guidelines and regulations, the risks to the public health are not significant<sup>50,211</sup>. In 2007, further American research indicated that in dry, arid climates the majority of aerosols associated with the land-spreading of biosolids appear to be associated with on-site soil<sup>211</sup>. However, from an Irish context, the same may not be the case.

The type and variety of pathogens in OA and OMI materials depends largely on the source of the organic material<sup>203</sup>. For example, organic materials discharged from hospitals may transfer viral infections such as Norovirus while organic materials from farm operations, e.g. manure, may transfer bacterial pathogens such as *Salmonella* spp. As such, it is important that pathogens are controlled when organic materials are land-spread for the protection of public health. Due to the large variety and nature of pathogens in OA and OMI materials<sup>7,168</sup> the emphasis in this appendix is placed on those of most concern in terms of food safety. These include species of virus, e.g. Norovirus, bacteria, e.g. *Salmonella*, *E. coli*, *Campylobacter* and *Listeria* as well as species of the parasitic organisms, e.g. *Cryptosporidium* and *Giardia*<sup>93,98</sup>.

### 4.2 Viruses

The sources of human viruses are faecal material, urine and sewer-disposed contaminated blood. They can also be excreted with animal faeces. In this case, they usually come from birds, cats and dogs<sup>203</sup>. Due to their host specific nature and inability to multiply outside of living cells it would appear that viruses are unlikely to be present or persist in animal manures<sup>109,150</sup>. However, viruses are the leading cause of infectious gastrointestinal disease in Ireland<sup>98</sup>. Viruses such as the Norovirus have been associated with animal manures including pig manure<sup>101,109,227</sup>. In 2006, the World Health Organization (WHO) indicated that the avian influenza virus H5N1 can survive for at least 35 days in bird faeces at low temperatures<sup>228</sup>.

#### 4.2.1 Norovirus

Norovirus<sup>u</sup> is one of the four genera of Caliciviruses that make up the Caliciviridae<sup>229</sup>. They are small (30-35nm) single stranded RNA viruses. Acute gastroenteritis caused by Norovirus is usually a mild self-limiting infection lasting 12 to 24 hours. Symptoms include diarrhoea, nausea, vomiting and abdominal pain following an incubation period of 24 to 60 hours. The virus is highly infectious and has been identified as the major cause of epidemic gastroenteritis in the community<sup>230</sup>. Person-to-person transmission is common, especially in closed communities and large outbreaks of Norovirus induced gastroenteritis have been reported in hospitals, nursing homes, cruise ships and military settings<sup>151</sup>. Immunity is complex and poorly understood but is believed to be short-term and repeated infections occur. Outbreaks of Norovirus associated gastroenteritis have been linked with sewage contaminated water<sup>231</sup> and food, most notably shellfish<sup>173</sup>. A recent study has also identified the presence of animal enteric Caliciviruses in oysters from coastal regions of the United States of America which have high livestock production<sup>229</sup>.

#### 4.2.2 Hepatitis A

Hepatitis A virus is a member of the Hepatovirus Genus within the family Picornaviridae. It is a small (27-30nm) single stranded RNA virus spread by the faecal-oral route. The virus has an extended incubation period of between two to six weeks (average four). It causes a debilitating disease progressing from general flu-like symptoms (headache, nausea, malaise) to vomiting, diarrhoea and jaundice. The illness is generally self-limiting and without complication. However, illness can persist for several months. Generally, childhood infections are mild or asymptomatic and subsequent long-term immunity develops. Symptoms are more pronounced in adults. Improved sanitary conditions in developed countries have led to reduced exposure in childhood and many adults remain susceptible to infection. Outbreaks of Hepatitis A have been associated with shellfish<sup>82</sup>, sewage contaminated waters and ready-to-eat food crops<sup>232</sup>.

#### 4.2.3 Adenovirus

Enteric adenoviruses are double stranded deoxyribonucleic acid (DNA) viruses, with a diameter of 80nm. Enteric adenoviruses have been reported to cause 10% of gastroenteritis in infants. Clinical symptoms include diarrhoea, vomiting and fever. Infection appears primarily to be associated with infants and is not common in adults. Adenoviruses can be detected in sewage effluents and sewage contaminated water<sup>233</sup> and shellfish<sup>234</sup>.

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<sup>u</sup> Previously described as Norwalk Virus or Small Round Structured viruses (SRSV)

#### **4.2.4 Rotavirus**

Rotaviruses are a genus of the family Reoviridae. They are double stranded RNA viruses, about 72nm in diameter. Group A rotavirus infections in children are ubiquitous with antibodies detectable in virtually all children by the age of five. Such infections have been frequently identified as the most important viral pathogen causing diarrhoeal disease which requires hospitalisation. Group A rotaviruses are rarely associated with adult infections which is due to high levels of immunity probably because of repeat infections<sup>235</sup>. Non-group A infections are not common but may cause sporadic family and community outbreaks in all age groups. Rotavirus is readily found in sewage and sewage-contaminated water<sup>183</sup>.

#### **4.2.5 Astroviruses**

Astroviruses are small (28nm diameter) single stranded RNA viruses. Astroviruses generally cause sporadic individual cases of illness often in infants and the elderly. Symptoms include vomiting, diarrhoea, fever and abdominal pain. Incubation periods are between two and four days whilst illness lasts for two to three days. Complete recovery without complication is the normal course for the illness. Immunity is long-term but may be reduced in the elderly making this group susceptible to infection. Astroviruses have been linked to outbreaks associated with water<sup>171</sup> and shellfish<sup>236</sup>.

#### **4.2.6 Enteroviruses**

Enteroviruses are a genus of the family Picornaviridae. They have a single stranded RNA genome and are about 27nm in size. There are a number of distinct serotypes which are known to cause infections in humans. These include the polioviruses, echoviruses and Coxsackieviruses (Group A and B). Most infections are mild or asymptomatic. However, where infection spreads to sites other than the intestine significant illness can occur. Enteroviruses can cause poliomyelitis, acute myocarditis, aseptic meningitis and non-specific febrile illnesses. Although enteroviruses may be present in sewage and associated with contaminated water and shellfish, they have rarely been linked with illness from these sources in developed countries<sup>166</sup>. However, it has been speculated that enteroviruses illness associated with sewage-contaminated shellfish may be under reported<sup>173</sup>.

### **4.3 Bacteria**

Foodborne bacterial pathogens are intrinsically linked to the farm environment and can enter the food chain or water supply at many points from farm to fork. The following descriptions are largely adapted from a 2006 EFSA opinion<sup>151</sup>.

#### **4.3.1 Brucella**

Brucellosis can be contracted directly by contact with secretions of infected animals most notably at the time of parturition and also at the time of abortion which may then be collected as slurry or FYM. Brucellosis can be transmitted by milk and contracted through the consumption of raw milk from infected cows or goats. It can also be contracted directly by inhalation of infected dry products a mechanism that in some areas is more important than the infection via milk<sup>237</sup>. *Brucella melitensis*, *B. abortus* and *B. suis* can cause infection in humans, while *B. melitensis* is the most virulent. Brucellosis in humans is related to the occurrence of brucellosis in animals. The main vehicles for orally acquired infections are contaminated raw milk and raw milk products, such as some creams, butters and cheeses<sup>151</sup>.

#### **4.3.2 Mycobacterium bovis and Mycobacterium tuberculosis**

Tuberculosis is an infectious disease with distinctive clinical and pathological features. Tuberculosis occurs in humans and many animal species including species of animals used for production of food (milk or meat) for human consumption (cattle, sheep, goats and deer)<sup>361</sup>. In humans, tuberculosis is an infectious and contagious disease often of lifetime duration<sup>238</sup>, caused by *M. tuberculosis* and *M. bovis*<sup>151</sup>. However, the principal microorganism associated with human tuberculosis is *M. tuberculosis*. *M. bovis* is the causative agent of tuberculosis in animals used for production of food and accounts for a relatively small proportion of human cases of tuberculosis reported in Ireland<sup>361</sup>. *M. bovis* can be shed in faeces and, with some reduction in numbers, persists in the excreta and in contaminated slurry and the environment for 330 days and longer<sup>361</sup>. While clinical disease due to *M. bovis* infection is now relatively rare in the Irish population, exposure to such infection can occur as a result of direct contact with affected cattle and through the consumption of contaminated raw milk or raw milk products<sup>239,361</sup>.

#### **4.3.3 Verocytotoxigenic Escherichia coli**

*Escherichia coli* are bacteria naturally found in the gut of humans and animals<sup>107</sup>. Most strains do not cause illness in humans but some have the ability to produce one or both of two verotoxins (i.e. VT1 and VT2) and are called Verocytotoxin producing *E. coli* (VTEC). *E. coli* O157 is the most common VTEC<sup>151</sup>. Healthy bovine animals and other ruminants are the primary source of VTEC. However, VTEC has been detected in the faeces of other ruminant and non ruminant farmed animals, wild animals, domestic pets and birds<sup>94, 100, 107, 136, 240</sup>. In food animals in Ireland the rate of *E. coli* O157:H7 varies from 7.3% (109/1500) on cattle hides, 5.75% (23/400) on sheep fleeces, to 0.5% (3/570) in pig faeces<sup>241-242</sup>.

Verocytotoxigenic *E. coli* can persist in domestic animals such as cattle without causing disease<sup>92</sup>. It is important to note that while contamination of meat products with VTEC during slaughter is the principal route by which these pathogens enter the food chain<sup>100</sup>, other more indirect routes of contamination of foods have occurred via animal manure<sup>161, 243-244</sup>. Research has also indicated the ability of VTEC to survive in soil, the environment and animal faeces for long periods of time<sup>194</sup>. VTEC appear to be well adapted to survive in animal faeces and soil, persisting for extended periods ranging from several weeks to many months.

Studies on the survival of *E. coli* O157:H7 in faeces outdoors on grass under ambient weather conditions in Ireland showed the organism was capable of surviving for 99 days in faeces and in the underlying soil. The pathogen could be recovered directly from faeces on the grass for 50 days. When faeces were no longer visible on the grass, using enrichment techniques, the organism was shown to persist in the underlying soil for a further 49 days<sup>58</sup>. A similar study in the UK reported the survival of *E. coli* O157 in cattle faeces for greater than 50 days but reported much shorter survival times in cattle slurry in which it fell to undetectable levels within ten days<sup>245</sup>. A recent Irish study recovered faecal material from cattle inoculated with *E. coli* O157:H7 and compared the survival of the pathogen in the faecal material and in water. In faeces, the pathogen survived for up to 97 days and up to 109 days in water. Survival of this *E. coli* O157:H7 strain was better following passage through the animal than when inoculated into faeces under laboratory conditions indicating that in low-nutrient conditions survival was enhanced by passage through the animal gastrointestinal tract<sup>246</sup>.

Another Irish study on the survival of *E. coli* O157:H7 in bovine slurry stored at 10°C showed the pathogen was recoverable in the slurry for up to three months<sup>247</sup>. There have been few studies on the persistence of non-*E. coli* O157:H7 serotypes in animal faeces, however, one study which investigated the survival of *E. coli* O26, O11 and O157 in bovine faeces stored at 5, 15 and 25°C demonstrated that at all three pathogens survived for up to eight weeks at 25°C<sup>248</sup>.

Similar persistence has been reported in sheep manure with survival for 100 days at 4°C or 10°C<sup>249</sup>. However, a study on the survival of *E. coli* O157:H7 in poultry manure and slurries reported that the pathogen had a decimal reduction time ranging from half a day at 37°C to one to two weeks at 4°C. The faster destruction of *E. coli* O157:H7 in poultry manure, and slurry as opposed to bovine and ovine manure and slurry may be reflective of the higher levels of free ammonia in poultry manure<sup>250</sup>.

VTEC can survive for periods of 34-36 weeks in the faeces of rats, pigeons<sup>251</sup> and these vermin may have a role in the wide spread dissemination of VTEC in the environment. Because of this persistence, animal waste materials are important as potential vehicles for transmission within herds, farms, the fresh food chain, and the wider environment. The low infectious dose of VTEC poses an important public health risk.

Treatment of manures and slurries can expedite the decline of pathogens including *E. coli* O157:H7 in animal wastes. Active treatment processes currently used include composting, heat drying, and anaerobic digestion. A study on the effect of drying and/or gassing with ammonia on the destruction of *E. coli* O157:H7 in fresh chicken manure reported a 3-4 log<sub>10</sub> decrease of *E. coli* O157:H7 over six days in manure stored at 20°C<sup>252</sup>. This decline in numbers was accompanied by an increase in pH and accumulation of ammonia in the manure. Over the same period of time, the decline in numbers of the pathogen was greatly increased (8 log<sub>10</sub> units) by drying the manure to a moisture content of 10% followed by exposure to ammonia gas to a level of 1% of the manure wet weight<sup>252</sup>.

At present, only a limited amount of manure is composted in Ireland and the process may not always be under strict control. Under controlled conditions of aeration, moisture, particle size and carbon-nitrogen ratio of the combustible material, composting temperatures of 55-65°C can be reached which would be sufficient to inactivate *E. coli* O157:H7 and other pathogens. Studies have shown that *E. coli* O157:H7 inoculated at a level of log<sub>10</sub> 7 colony forming units (CFU) g<sup>-1</sup> was non detectable after 72 hours in composted manure<sup>253</sup>. Other treatments particularly suited to slurries include anaerobic digestion typically at 30-35°C with 12 days retention for pig slurry or 20 days for cattle and poultry slurry. The addition of lime (quick lime or slaked lime to raise the pH to 12 for at least two hours) should also result in significant pathogen reduction<sup>254</sup>.

#### **4.3.4 *Salmonella* spp.**

Salmonellosis is one of the most often reported zoonotic infections in the EU<sup>94</sup>. All mammals and birds may act as carriers of ubiquitous serovars of *Salmonella* spp. in the gastro-intestinal tract, without showing any, or only low or moderate, clinical signs<sup>151</sup>. These infected animals shed *Salmonella* spp. in the faeces, thus enabling the bacteria to spread in the environment<sup>53</sup>. The duration of the shedding depends on the animal species and the serovar involved, though the infection might persist in the animal for the rest of its life<sup>151</sup>. Like VTEC, research has indicated the ability of *Salmonella* spp. to survive in soil, the environment and animal faeces for long periods of time (i.e. months)<sup>255-256</sup>.

#### **4.3.5 *Listeria monocytogenes***

*Listeria monocytogenes* is part of the genus *Listeria* which has six identified species<sup>13</sup>. It may be found in the intestines of animals and humans without causing illness<sup>13</sup>. It is widely distributed in many natural and man-made environments such as soil, water, sewage, vegetation and silage where it can survive for long periods of time<sup>13</sup>. *L. monocytogenes* can also be found on walls, floors, drains, ceilings and equipment in food processing environments. It has been isolated from a wide variety of foods including seafood, vegetables, fruit, dairy products, salads and meat products<sup>13</sup>.

Listeriosis is conventionally considered an uncommon but potentially life threatening invasive infection that primarily affects identifiable “at risk” sections of the population (i.e. pregnant women, newborns, elderly people and people with impaired immune function)<sup>13</sup>. In Ireland between 2000 and 2003 there was an average of 6.5 cases of listeriosis per annum (i.e. 0.17 per 100,000 of the population per annum)<sup>13</sup>.

*Listeria monocytogenes* has a high resistance to heat, salt and acidic pH and can grow at or below refrigeration temperatures and under conditions of low oxygen, including the conditions under which raw milk is transported and stored<sup>13</sup>. Adult carrier animals do not secrete the pathogen in milk, but milk can be contaminated faecally via the udder and teat surface. Intestinal carriage is probably continuous because of constant exposure but faecal shedding of the organism may be intermittent<sup>151</sup>.

Many RTE fruit and vegetable products, e.g. coleslaw, prepared salad mixes, do not receive a listericidal step as part of their processing<sup>13</sup>. Some horticultural producers use animal manure and other OA and OMI materials as fertiliser. Although there have been few reported cases of listeriosis attributed to fresh produce, producers should take steps to control the risks of contamination<sup>13</sup>. Use of OA materials such as animal manure should be carefully managed and monitored. The ability of *L. monocytogenes* to persist in manure amended soil for several weeks increases the possibility that it can be transmitted through soil to fresh produce, or to shoes, clothing and hands of field workers, especially in winter when soil temperatures are low<sup>163</sup>.

#### **4.3.6 *Campylobacter* spp.**

*Campylobacter* spp. is widespread in the intestinal tract of warm-blooded animals used for food production<sup>257</sup>. They may therefore readily contaminate foods of animal origin. Contamination of water may occur through run-off from animal production units. Contamination of vegetables and salads may occur through contact with animal faeces during growing, through contact with contaminated water during harvesting or preparation, or as a result of cross contamination from raw meat in commercial or domestic kitchens<sup>257</sup>.

During intestinal carriage in adult bovine animals, the pathogen is not transmitted directly into milk. Contamination of milk occurs via faecal contamination of udder and teat surfaces, and of milking appliances. Contaminated raw milk has caused *Campylobacter* infections<sup>151</sup>. However, although many foods may be contaminated, it is considered by many authorities that poultry and poultry products are of particular importance as a source of human infection. *Campylobacter* spp. does not multiply very effectively in most foods however, it may survive through the food distribution system and because consumption of a small number of organisms (500 or less) may be associated with illness, proliferation in food is not a prerequisite for infection<sup>257</sup>.

#### 4.3.7 *Clostridium botulinum*

*Clostridium botulinum* is the species name for all organisms producing botulinum neurotoxin, which currently comprises seven serologically distinct toxin types (A-G). Occasionally one organism produces more than one toxin type. The most important groups associated with foodborne botulism in humans are Group I (proteolytic, mesophilic), commonly types A and B, and Group II (non-proteolytic/saccharolytic, psychrotrophic), commonly type E, and occasionally types B and F. In animals, botulism is most commonly due to type C or type D. Four different forms of botulism are recognised<sup>151</sup>. If *C. botulinum* multiplies in a food, and that food is subsequently ingested without appropriate heating, the person consuming it suffers botulism via intoxication from preformed toxin. Under certain circumstances, *C. botulinum* multiplies in the human gut, producing neurotoxin<sup>151</sup>. Infants are particularly susceptible to toxic infectious botulism (i.e. infant botulism), the most common reported type of botulism in the United States since 1980<sup>258</sup>.

The majority of outbreaks in cattle<sup>v</sup> have been associated with direct or indirect contact with poultry deep litter (turkey and broiler). Poultry litter is a mixture of bedding material (i.e. most commonly chopped straw) and faeces of commercially reared poultry. Type C and D *C. botulinum* are obligate parasites requiring decomposing carcasses for multiplication and toxin production. Therefore, where litter contains decomposing poultry carcasses, the risk of botulism to bovine animals which has access to this litter or its effluent, increases significantly.

In the past and to a lesser extent, more recently, poultry litter has been topically spread to land as an inexpensive fertiliser. Litter stacks in adjacent fields to grazing animals and wash water from poultry houses have also been associated with outbreaks. The poultry producer is obliged under the ABP Regulations<sup>18</sup> to ensure that litter is free of carrion. This is regulated by the Department of Agriculture, Fisheries and Food (DAFF) and guidance notes on good practice with regard to the handling of litter have been circulated to the farming industry. Where the Regulations<sup>3</sup> are being fully complied with, e.g. removal of carcasses etc, potential risk of disease is considerably reduced but a residual risk may remain. The level of residual risk is very much dependant on the level of good practice applied. Good waste water and litter management in the poultry unit reduces risk of bovine botulism. While large poultry units (i.e. > 40,000 birds) are required to have an IPPC licence<sup>70</sup>, this does not apply to smaller units (Appendix I.4.6). It would seem appropriate that new smaller poultry units not requiring an IPPC licence should be required to have a waste management system that can be regulated and inspected by the local authority.

<sup>v</sup> In cattle affected by botulism, toxin delivered from a food source is rapidly and irreversibly bound to the motor end plates in muscles in a form that is unlikely to be able to cause re-intoxication following consumption of meat or milk from affected cattle<sup>362</sup>

## 4.4 Parasites

### 4.4.1 *Cryptosporidium*

*Cryptosporidium* is one genus of the protozoan phylum Apicomplexa, class Sporozoa, subclass Coccidiasina referred to as coccidians. Although up to 23 *Cryptosporidium* species have been named, only eight are regarded as individual species based on biological characteristics<sup>157</sup>. Cryptosporidiosis came to prominence in the 1980s as a cause of severe diarrhoeal illness in patients with Acquired Immunity Deficiency Syndrome (AIDS), but it has increasingly become recognised as a major cause of diarrhoeal illness in otherwise healthy individuals. Cryptosporidiosis may be asymptomatic but can also occur as a self-limiting disease characterised by watery diarrhoea that may be accompanied by dehydration, weight loss, abdominal pain, fever, nausea and vomiting<sup>95, 363</sup>. Gastrointestinal symptoms tend to last between one to two weeks<sup>363</sup>, which is longer than commonly seen with most bacterial gastrointestinal infections. In immunocompromised individuals, symptoms are more severe and the organism can invade other organ systems such as the lungs and bile duct and become life-threatening<sup>156</sup>. The low infective dose of *Cryptosporidium* (as low as ten oocysts with *C. parvum*) increases the risk of *Cryptosporidiosis*<sup>10</sup>.

The two main species associated with human infection are *C. parvum* and *C. hominis*. The primary reservoirs of these zoonotic agents are humans for *C. hominis*, and humans and livestock (particularly calves and lambs) for *C. parvum*<sup>156</sup>. Cryptosporidiosis may be contracted through consumption of food or water contaminated with faecal matter from an infected person or animal, recreational bathing or direct contact with contaminated faeces<sup>95</sup>. However, the transmission route for sporadic cases remains unconfirmed. It is likely that transmission from animal reservoirs is of primary importance for sporadic cases, with perhaps animal contact and water source contamination by livestock being central<sup>104</sup>. *C. parvum* produces environmentally resistant oocysts which enables it to remain viable in the environment for at least a year<sup>10</sup>. Research has also indicated that manure enhances the attachment of oocysts to soil particles and that oocyst attachment to soil is substantially affected by bovine manure in a complex manner and should have implications for how oocysts may be transported through or over soils<sup>259</sup>.

Consumption of contaminated water is of particular concern as *C. parvum* is relatively resistant to treatment with chlorine. Public and private water supplies rely on coagulation and filtration mechanisms or natural purification by geological processes to form a barrier to *C. parvum* contamination. However, these systems can become overwhelmed when the numbers of organisms in the environment increase, e.g. during heavy rainfall, meaning that numbers sufficient to cause illness can enter the water supply<sup>95</sup>. An extensive waterborne outbreak of cryptosporidiosis in the United States in 1993 resulted in over 400,000 cases of cryptosporidiosis illness<sup>10</sup>. Interestingly, although manure runoff from dairy farms and effluent from beef slaughter plants were suspected to be likely sources for the outbreak, *Cryptosporidium* oocysts recovered from outbreak associated cases were of the human genotype<sup>318</sup>. Later, effluent from an urban waste water treatment plant was considered a more likely source<sup>92</sup>.

The broad host range of *C. parvum*, together with the high output of oocysts, ensures a high level of contamination in the environment and both infected human beings and livestock can contribute to the numbers of waterborne oocysts both through sewage effluent discharges, including those containing contributions from abattoirs, and the disposal of sewage sludge to land<sup>188</sup>.

On January 1<sup>st</sup> 2004, human Cryptosporidiosis became a notifiable disease in Ireland<sup>262</sup>. Over 605 cases of cryptosporidiosis were notified in 2007, making cryptosporidiosis the most common protozoan gastrointestinal pathogen notified in Ireland. The current drinking water legislation (Appendix 1.2) has no numerical standard for *Cryptosporidium*<sup>17</sup>. *C. parvum* may be difficult to control in drinking water supplies as it is not affected by chlorination at levels that are considered safe for water treatment and human consumption and because it can infect a wide variety of mammals<sup>10</sup>.

#### **4.4.2 Giardia**

*Giardia* is a protozoan parasite that causes Giardiasis and is the most commonly isolated parasite worldwide<sup>151</sup>. The *Giardia* species infecting humans and causing giardiasis is *Giardia duodenalis*, sometimes referred to as *Giardia lamblia* or *Giardia intestinalis*<sup>151</sup>. *Giardia* is known to be common in faeces of pets, livestock and wild animals, but it is not generally considered to cause significant animal disease. *Giardia* cysts, as with *C. parvum* oocysts, are commonly found in sewage effluent and surface waters<sup>151</sup>. In some countries, the use of human faecal material as a fertiliser is an important source of infection. Many cases of traveller's diarrhoea are caused by *Giardia*. Even in developed countries, drinking water can be contaminated with small amounts of sewage, especially when septic systems are built too close to wells. Foods and drink, particularly raw fruits and vegetables, tap water or ice made from tap water, unpasteurised milk or dairy products, may be contaminated with *Giardia*<sup>151</sup>.

On January 1st 2004, human Giardiasis became a notifiable disease in Ireland<sup>262</sup>. Like *C. parvum*, *Giardia* poses a significant risk to drinking water supplies due to its resistance to chlorine. Although *Giardia* is more susceptible than *Cryptosporidium*, both have a greater resistance to chlorine than bacteria and survive levels routinely used for water treatment<sup>151</sup>. However, *Giardia* can more readily be removed by filtration than *Cryptosporidium* because of its larger size<sup>151</sup>. Like *C. parvum*, *Giardia* produces an environmentally resistant cyst which enables it to remain viable in the environment for at least a year<sup>10</sup>.

#### **4.4.3 *Toxoplasma gondii***

Toxoplasmosis is caused by an obligate intracellular protozoan parasite *Toxoplasma gondii*<sup>95</sup>. *T. gondii* is a ubiquitous parasite that occurs in most parts of the world. Its definitive hosts are members of the cat family (Family Felidae) while its intermediate hosts include humans and most livestock. The parasite is commonly isolated from cat faeces, raw meat, raw vegetables, and the soil. While the parasite generally replicates in its definitive host, the cat, it is an opportunistic parasite of many other hosts including humans. It is a common cause of abortion in sheep in Ireland with over 70% of ewes in affected flocks showing evidence of infection. Latent infections are also common in cats throughout Europe<sup>260</sup>. The oocysts are highly resistant to disinfectants and are distributed in the environment through wind, surface water, manure and harvested feed, the latter being a source of infection for livestock.

There are a number of factors such as age and immunocompetence that determine whether an infected host will express the disease symptoms of *T. gondii*. In general, humans infected with *T. gondii* are asymptomatic carriers as evident in the high proportion of the Western European population<sup>95</sup>. However, infection of a pregnant woman can result in abortion or congenital malformation of the foetus while newborns are also particularly vulnerable. Infection in humans takes place through the consumption of undercooked meat that contains parasitic tissue cysts, which are also excreted in the milk of infected cattle, sheep and goats<sup>151</sup>. Otherwise, consumption of sporulated oocysts following direct contact with cat faeces, contaminated soil or vegetables and fruits contaminated with oocysts of the parasites excreted in feline faeces<sup>151, 156</sup> or less commonly, with other manures containing such oocysts has been implicated as a source of infection with this parasite. In 1995, an outbreak of acute toxoplasmosis affecting<sup>147</sup> individuals in Vancouver, Canada was attributed to the consumption of municipal drinking water contaminated with oocysts from cats and wild felines<sup>261</sup>.

Toxoplasmosis became a notifiable disease in Ireland in 2004<sup>262</sup> and so the figure of 33 human cases notified in 2004 represents the first reliable data on this human disease in Ireland<sup>95</sup>. There were more female cases (64%) than male and the majority of them (58%) were in the 25 - 44 years age group<sup>95</sup>.

The main risk factor to humans for *T. gondii* is contact with infected cats and recreational gardening where cats defecate. Sporulated oocysts *T. gondii* excreted by cats are very resistant to environmental conditions and remain infectious in moist soil or sand for up to 18 months. Soil contamination, resulting from land-spreading of manures and treated urban effluents, can be a source of infection for grazing livestock, the result of which may be infestation of meat, notably sheep meat and pig meat, with tacyzoites, a meatborne stage of the same parasite that is highly infectious for humans<sup>158</sup>.

#### **4.4.4 *Taenia saginata* and *Taenia solium***

*Taenia saginata* is a cestode parasite, or tapeworm, for which the human is the definitive host. It is found in the small intestine and is from four to ten metres in length and in the absence of treatment can reside in this location for 25 years or longer. Usually the infection is asymptomatic, the person becoming aware when segments are passed in the stool or emerge from the anus. Symptoms, if present, are usually mild abdominal discomfort and may include nausea, and loss of weight. Infective ova contained in tapeworm segments are passed in the faeces and when ingested by grazing cattle, the intermediate hosts, the ova develop and migrate from the small intestine to the muscles and other tissues of the infected animal, where they develop into cysts, *Cysticercus bovis*, which after ten to 12 weeks, are infectious for humans when consumed. *T. saginata* is not transmitted from person-to-person. There are few data available on the prevalence of *C. bovis* in cattle at slaughter in Irish meat plants. One study, conducted under commercial conditions on 376,116 cattle in 1977-1980, showed a prevalence of 0.62% over the period<sup>263</sup>.

The ova of *T. saginata*, the so-called beef tapeworm of humans (Appendix 4.4.5) have not been a major risk but may be present in urban effluents. They are highly resistant to adverse reagents including chlorination at levels up to 20 parts per million and treatment with copper sulphate and lime. In waste water treatment, using flocculating agents, up to 95% of ova settle out in settling tanks in two to three hours. However, these ova can pass through sewage systems that do not use prolonged settling systems; thus, if sewage is inadequately treated, human effluent can be a source of infection for cattle. This occurs particularly with overload of the sewage system and from the increased use of detergents which interferes with sedimentation and oxidation. The detergents also create large masses of foam that can be blown about and that may act as a means of dispersal for the still viable ova. Sludge requires heat treatment or drying for three months or longer, to be rendered non-infectious from *T. saginata*. Furthermore, flies as well as gulls and other birds feeding on sludge can transfer infection, mechanically or otherwise, to cattle. Carcasses of infected cattle carrying cysticerci, the infectious stage of this tapeworm, are a high risk to the consumer unless meat is cooked properly.

*Taenia solium*, a tapeworm of humans, has the pig as its intermediate host. The infective stage, *Cytcercus cellulosae* has not been reported in Irish pigs and data on the prevalence of the infection in the Irish population are not available.

#### 4.4.5 Helminth eggs

Helminths are roundworms, flatworms and tapeworms, a number of which are of public health concern. Some helminth ova are among the most resistant forms of parasite contamination typically found in sludge<sup>264-265</sup>. These include the ova of the large roundworm of the dog, *Toxocara canis*, and *Ascaris lumbricoides*, the human roundworm; agricultural sludge may carry the ova of *Ascaris suum*, the pig roundworm. The eggs are very resistant to physical conditions and the environment and can survive for up to one year<sup>264, 266</sup>. Human infection involving these species is usually the result of direct contact with the infective stages of the ova and grazing animals thus exposed are rarely involved as accidental hosts in this context.

#### 4.5 Transmissible Spongiform Encephalopathies

Transmissible spongiform encephalopathies (TSEs) are a family of neurodegenerative disorders of the central nervous system that include scrapie in sheep, BSE in cattle and Creutzfeldt-Jakob disease (CJD) and variant CJD (vCJD) in humans<sup>95</sup>. These diseases display common characteristics including long incubation periods, a range of clinical symptoms and a similar pathology. It is now generally accepted by the scientific community that these diseases are caused by and spread via a protein (prion) rather than bacteria or viruses, a relatively unusual mode of transmission<sup>95</sup>. This prion protein, normally found on the nerve membranes in the brain, changes conformation and becomes a disruptive factor to neighbouring prion proteins and associated nerve cells. The first member of this family of diseases identified was scrapie, which has been endemic in sheep (and goats) in certain parts of Europe for over two centuries<sup>95</sup>.

Among animals, cattle contract BSE as a result of the ingestion of feed containing the causal agent. The agent is not known to be excreted in urine or faeces although in rare cases where the dam is affected, the detritus of abortion or parturition may contain the agent. Otherwise, the BSE agent is present in high numbers in the nervous and other tissues of affected cattle; as the disposal of such materials derived from slaughtered cattle for land use represents a risk of exposure for grazing stock such use is prohibited in accordance with current legislation<sup>18</sup> (Appendix 1.3).

## 4.6 Pathogen Survival

### 4.6.1 Introduction

Whilst an extensive list of pathogens has been outlined in Appendices 4.2 to 4.5, in practice only a limited number of pathogens are regularly encountered and many are eliminated by treatments such as composting or present in numbers which are unlikely to cause disease. Most pathogens, with some notable exceptions, are adapted to growth within the warm environment (i.e. typically > 30°C) of a human or animal host. When outside the host, unless protected from the environment, numbers of pathogens will usually remain constant or decline quickly.

The public health risks associated with microbiological contamination of foods are dependent on the ability of pathogens to adapt and survive in OA and OMI materials prior to land spreading<sup>100</sup>, within or on the soil after spreading<sup>267</sup>, within or on vegetation after spreading, e.g. crops, grass etc<sup>268</sup>, within or on animals after spreading, e.g. cattle<sup>100</sup> or other surfaces, e.g. farm equipment<sup>269</sup>, after application<sup>136</sup>.

The survival of pathogens in OA and OMI materials, within or on the soil and on or within crops and animals depends on many factors including temperature, total solids content, moisture, pH and microbial competition<sup>147, 249, 265, 270</sup>. However, scientific knowledge in relation to survival of pathogens in OA and OMI materials is limited<sup>150</sup>. For example, little is known about how the viability of *C. parvum* is affected by the soil environment<sup>271</sup>. But it is known that *Cryptosporidium* oocysts decline rapidly in four weeks at 20°C in stacked manure heaps<sup>271</sup>. *E. coli* from livestock faeces can survive on grass for at least five to six months, affording opportunity for the organism to contaminate animals, plants or water<sup>240</sup>. While it is dangerous to extrapolate data and predict survival of pathogens such as *E. coli* O157 after land-spreading, higher pathogen numbers remaining in organic material at the time of application would pose an increased risk of the organisms surviving in sufficient numbers to cause infection<sup>102</sup>. The long-term survival of pathogens such as *E. coli* O157 in organic materials has implications for the subsequent transmission to crops and adjacent watercourses and also to direct infection of humans and animals in contact with contaminated lands. *L. monocytogenes* has been isolated in organic materials from farms, abattoirs, cattle markets, and poultry packing plants<sup>13, 272</sup>. Viruses have been isolated from a range of human and animal organic materials<sup>150, 180</sup>. However, data on their survival are limited<sup>273</sup>. Table 11 outlines the estimated persistence of pathogens in the environment.

**Table II. Estimated Persistence of Pathogens in the Environment**

Pathogenic Group <sup>1</sup>	Fresh Water and Sewage		Soil <sup>2</sup>		Crops <sup>3</sup>	
	Typical (Days)	Maximum (Days)	Typical (Days)	Maximum (Days)	Typical (Days)	Maximum (Days)
<b>Bacteria</b> <sup>4-5</sup>	<30	≥60	<20	≥70	<30	≥70
<b>Viruses</b> <sup>6</sup>	<50	≥120	<20 <sup>7</sup>	≥100	<30	≥60
<b>Protozoa</b> <sup>8-9</sup>	<70	≥180	<75	≥60	<3	≥5
<b>Helminths</b> <sup>9</sup>	<365	≥365	≥365	≥365	<30	≥60

<sup>1</sup> Survival time will vary among all species of pathogen<sup>148</sup>. Some bacterial pathogens like *C. jejuni* will only grow within an animal host and viruses, most protozoa and parasites all require human or animal tissue in which to replicate. However, this does not negate the potential risk to public health posed by these pathogens<sup>163,167,64,265</sup>. Pathogen die-off usually follows a logarithmic curve, with higher concentrations give longer ultimate survival times. In relation to the application rate in land-spreading, penetration of ultraviolet irradiation, heat, moisture and predators from soil are reduced as the thickness of land-spread sludge or other organic material increases, as is the loss of moisture by evaporation.

<sup>2</sup> Many studies describe the impact of temperatures, physicochemical (i.e. pH, moisture and organic matter content) and the textural properties of soil on the survival of *E. coli* O157:H7 in soil<sup>198</sup>. The survival of pathogens in soil is influenced by both soil and environmental variables, including sunlight, pH, temperature, moisture content, soil texture and organic matter content<sup>207,218,228</sup>. All organisms are sensitive to ultraviolet irradiation. Sunlight reduces the survival of bacteria and viruses in soil directly through the effect of ultraviolet light and as a result of drying<sup>136</sup>. Bacteria can survive longer in cold and fine textured soils<sup>136,358</sup>. However, differences in soils affect pathogen survival in different ways<sup>136</sup>. Survival times are longer at cooler, (but above freezing) temperatures. Enteric bacteria may multiply at summer temperatures. Most organisms are not resistant to desiccation. Rainfall may reduce concentrations through runoff or leaching. Survival times are generally shorter at low (< 5) or high (> 10) pH values<sup>136,228</sup>. Disparities in survival data may be explained by differences in experimental, soil and agronomic conditions, nevertheless, the quantitative relationships between these factors and die-off rates in soil remain undetermined<sup>228</sup>.

<sup>3</sup> Survival on crops is shorter than in soil, due to the effects of desiccation and sunlight.

<sup>4</sup> Relates to *Salmonella* and VTEC predominately. In one study VTEC, *Salmonella*, *Campylobacter* and *Listeria* survived in stored slurries and dirty water for up to three months<sup>64</sup>. The length of survival of *M. bovis* in the environment appears to vary considerably according to environmental conditions, ranging from only a few weeks to a year or more. However, there is scant understanding of how *M. bovis* survives in an environment to which it is ill adapted<sup>274</sup>. Spore forming bacteria, e.g. *Clostridium* spp are more resistant to effects of environmental pressures than vegetative bacteria, e.g. *Salmonella* spp<sup>228</sup>.

<sup>5</sup> *Salmonella* and VTEC may survive for longer periods in faeces. In one study VTEC, *Salmonella*, *Campylobacter* generally survived in the soil for up to one month after application to both sandy arable and clay loam grassland soils, whereas *Listeria* commonly survived for more than one month<sup>64</sup>. In another study from 2006 it was reported that *E. coli* O157:H7 could survive for more than two months on manure-amended soil<sup>249</sup>

<sup>6</sup> Relates to Enteroviruses. Non-enveloped viruses, e.g. enteroviruses, are more resistant to pH change and dehydration than enveloped viruses<sup>228</sup>.

<sup>7</sup> In warm climates, inactivation of viruses near the surface of soil can be rapid with a median 90% reduction (i.e. T90) of three days, while comparable inactivation at low temperatures can require approximately 30 days<sup>356</sup>. In the United Kingdom it has been suggested that, mean soil temperatures will seldom exceed 15°C at 10cm depth in summer, and 5°C in winter. Viral decay rates will be slow under such conditions, with decimal reduction times from 24 days to over 100 days, but the cultivation of soil after sludge application will encourage viral decay by encouraging evaporation<sup>237</sup>.

<sup>8</sup> Relates to *Cryptosporidium* oocysts.

<sup>9</sup> Most helminths and parasitic protozoa have developed a lifecycle stage, (ova or cyst), that is resistant to environmental pressures<sup>228</sup>.

#### 4.6.2 Agricultural materials

The transfer of pathogens to food through the spreading of agricultural materials such as animal manures to agricultural land is well described<sup>240, 357</sup>. Research has indicated that manure typically contains in excess of  $10^{10}$  bacteria per/g and that the numbers and types of pathogens in manures will be determined by the animal species, disease status, storage conditions, age and chemical composition of the manure<sup>10, 109, 150, 275</sup>. Also, apparently healthy animals may be excreting large numbers of pathogens in their waste<sup>10, 103, 109</sup>. Pathogens in run-off from livestock yards etc will reflect those in the pure livestock wastes, albeit at lower concentrations.

The Food Standards Agency (FSA) UK has compiled tables relating the prevalence and numbers of the most relevant organisms in manures from the main farmed land animals in the UK<sup>150</sup>. Due to similarity of climate and farming systems, it would be reasonable to expect similar prevalence in Irish livestock and limited data available do seem to corroborate this observation<sup>63</sup>. However, the FSA<sup>150</sup> and others<sup>63, 109</sup> do refer to the lack of quantification of pathogens in studies thus making quantitative risk assessment difficult<sup>63, 109, 150</sup>.

The rate of decline in animal manures is related to storage conditions, temperature, dry matter content and chemical composition. Several studies also refer to the effectiveness of the composting process for pathogen decline associated with the storage of solid livestock materials<sup>10, 109, 150, 275</sup>. From an Irish context, cattle manure comprises the vast bulk of the materials addressed in this report and most of this is stored as slurry, not as FYM (Appendix 2.1).

In 2001, it was reported that there was a marked increase in *Salmonella Typhimurium* DT 104 isolates from humans in the Netherlands<sup>276</sup>. One cause of this increase in *S. Typhimurium* DT 104 isolates from humans was considered to be the increase of the pathogens in cattle and pigs. The Dutch Veterinary Health Service indicated that the risk of infection with *S. Typhimurium* DT 104 in farms that had bought pig manure was over 20 times higher than on farms that had not done so<sup>276</sup>. The rise in the national dispersal of manure was said to be an important risk factor for the spread of *S. Typhimurium* DT 104 and possibly other pathogens. In Canada, there have been some connections drawn between human VTEC infection and the ratio of beef cattle numbers to the human population and the spreading of manure to the surface of agricultural land by solid and liquid spreaders<sup>277</sup>.

In Scottish studies, it was reported that *E. coli* O157 survived for up to six months in soil<sup>62</sup>. Following manure spreading to land, *E. coli* O157, *Salmonella* and *Campylobacter* generally survived in the soil for up to one month after application to both the sandy arable and clay loam grassland soils, although these pathogens often could not be detected after four days. In many cases, *Listeria* survived in the soil for more than one month after manure spreading, particularly on the clay loam grassland soil. There was some indication that the pathogens survived longer in the clay loam grassland soil than in the sandy arable soil, although differences in cultivation and meteorological conditions meant that this could not be confirmed<sup>64</sup>.

In a recent British study, *E. coli* O157, *Salmonella* and *Campylobacter* survived in stored slurries and dirty water for up to three months, with *Listeria* surviving for up to six months<sup>64</sup>. In contrast, pathogens survived for less than one month in solid manure heaps where temperatures > 55°C were obtained, and most could not be detected after one week. These results provide strong evidence that managing solid manure heaps to promote composting and elevated heap temperatures is a very effective way of reducing pathogen numbers<sup>64</sup>.

The long-term storage of slurry and FYM for periods >12 months will give risk minimisation of *Brucella* organisms<sup>364</sup>. Treatment of slurry with quick lime milk or hydrated lime powder so that the pH of the slurry reaches a minimum of pH 12 will inactivate *Brucella* organisms provided this pH is maintained for 24 hours or more before land-spreading. This lime treatment is not suitable for dungstead manure due to the high dry matter level in the product<sup>w</sup>.

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<sup>w</sup> Since 2000, a scheme has been in place whereby slurry on all infected holdings is treated with liquid lime to “sterilise” the slurry and prevent the spread of infection via contaminated slurry. This treatment is arranged and paid for by DAFF. Where treatment is not possible, manure/slurry is subjected to long term storage (12 months)<sup>364</sup>.

As previously stated, many studies note that due to the anaerobic conditions in slurry stores, regular topping up with fresh material and low storage temperatures, there is ineffective destruction and decline of pathogens. The fact that poultry manure usually contains low numbers of pathogens is testament to the destructive efficiency of the composting process as poultry manure tends to be a solid or semi-solid material which remains aerobic and therefore easily composted<sup>109</sup>. The FSA has concluded that in the case of slurry storage in animal housing there is little destruction and decline of pathogens<sup>150</sup>. Research has been reported that VTEC can remain viable in bovine faeces for up to 70 days, depending on inoculum levels and temperature<sup>278</sup>. Several other studies have reported survival times for the various pathogens including<sup>7, 10, 60, 63, 109, 270, 275</sup>:

- *Campylobacter*, two to 20 days
- *Escherichia coli* O157:H7, one week to one year
- *Cryptosporidium* oocysts, 28 days to months
- *Listeria monocytogenes*, days to years
- *Mycobacterium*, up to six months
- Clostridia and other spore forming organisms are likely to be long-term survivors even withstanding composting.

However, survival rates are less important than the rate at which the numbers decline during manure storage. Many studies refer to *D*-values or T90 values (i.e. the time taken to achieve a 90% reduction in numbers) which are more relevant for risk assessment<sup>150, 275</sup>. The FSA has outlined some *D*-values for the major pathogens which are considered in this report<sup>150</sup>.

There is no evidence to suggest that viruses, e.g. hepatitis A, enteroviruses, present anymore than a low risk to food safety from agricultural sources. Bovine strains of Norovirus exist but there is no evidence that they cause infection in humans. Although animal strains of rotaviruses that share a high degree of homology with human strains have been identified, animal to human transmission is considered to be rare<sup>183</sup>.

#### 4.6.3 Municipal materials

The occurrence and survival of pathogens in sewage sludge and the subsequent occurrence, survival and virulence of pathogens when municipal materials are land-spread has been extensively reviewed<sup>82, 111, 121, 126, 132, 148, 203, 279</sup>. Typically, the type and numbers of pathogens found in municipal materials such as sewage sludge will reflect the general health of the population in addition to the nature and concentration of industry, e.g. abattoirs, food processing, pharmaceuticals etc. and the presence of hospitals in a specific local authority area.

Sewage sludge may contain a large variety of pathogens including *Salmonella* spp., *L. monocytogenes*, VTEC, viruses such as Norovirus as well as the eggs and cysts of parasites such as *Cryptosporidium* and *T. saginata*. However, while modern treatment of sewage sludge typically results in a high level of pathogen removal not all pathogens are removed and those which remain while present in low concentrations are often viable<sup>272, 359</sup>. Examination of municipal sewage samples at two month intervals in 1991 to 1992 found that 84% to 100% contained *L. monocytogenes* or *L. innocua*<sup>13, 272, 280</sup>. More recent research in 2006 demonstrated that *Salmonella* spp. isolated in sewage treatment plants originated from infected humans and survived treatments at these sewage treatment plants<sup>130</sup>. Viruses such as hepatitis A can be found in human sewage which enters waste water treatments plants. Currently, the prevalence of hepatitis A infections in Ireland is low<sup>98</sup> but a decreasing immunity in the general population means that the potential for large outbreaks exists. Enteroviruses including echoviruses and Coxsackieviruses are commonly found in human sewage. Rarely, enteroviruses can spread to the sites outside the intestine and illness can be severe.

#### 4.6.4 Industrial materials

Abattoirs, dairy plants, food processing and pharmaceutical facilities produce a range of by-product materials which are unfit for human consumption but can in some incidences after suitable treatment and/or storage be land-spread. These materials can be divided into unfit meat and meat by-products, e.g. specified risk material, blood, gut contents etc., and other materials, e.g. lairage materials, washings etc.<sup>187</sup>.

As previously mentioned, (Appendix 1.3) under the definition of ABP, the spreading of ABP other than manure to pasture land as organic fertilisers or soil improvers is prohibited<sup>18</sup>. However, permitted materials do have the potential to contain zoonotic pathogens. The list of abattoir associated zoonoses is very extensive<sup>11</sup>. The type and numbers of pathogens in these materials will vary according to a number of factors and as such their subsequent transfer to soil, crops, grazing animals and the human food chain. These factors include:

- the health of animals to be slaughtered at an abattoir
- the numbers of animals to be slaughtered at an abattoir
- standards of hygiene and training at different facilities
- how materials are managed and stored at different facilities etc.

Research from 2005 reported that there was little decline in the numbers of VTEC present in materials discharged from creameries over a 64 day period<sup>136</sup>. In the same study, VTEC was also found to survive for more than 60 days in four out of five untreated meat plant discharges examined<sup>136</sup>.

Research in 2003 on 28 commercial abattoirs in the United Kingdom for practices related to, and quantitative levels of pathogens in materials to be applied on agricultural land, found that materials applied on agricultural land comprise two main groups, effluent-based wastes and animal-based wastes<sup>187</sup>. The effluent-based wastes include three main types: separated solids, sludge and water<sup>187</sup>. Mixing of sludge and blood was also found to be a regular practice at poultry meat plants. Animal-based materials included digestive tract content and blood<sup>187</sup>. All red meat plants examined spread some of these materials to land. In the materials tested, the most commonly isolated pathogen was *Campylobacter*. The pathogen was found in effluent and blood from poultry meat plants and in lairage and blood from red meat plants. *L. monocytogenes* was found in only 1.1% of all samples (4.2% in lairage waste), and not in any sample from poultry meat plants. *Salmonella* and VTEC O157 were not isolated from any of the meat plant (including poultry meat plant) samples<sup>187</sup>.

In the same research, the overall incidence of the protozoan pathogens *Giardia* and *Cryptosporidium* (viability not assessed) in red meat abattoir materials was 52.5% and 40%, respectively<sup>187</sup>. The material most frequently contaminated with protozoan pathogens was lairage waste, followed by effluent<sup>187</sup>. In lairage wastes from single-species abattoirs, the incidence of *Giardia* and *Cryptosporidium* was higher at sheep and pig abattoirs than at cattle abattoirs<sup>187</sup>.

#### 4.6.5 Soil

An important consideration in assessing the hazards posed by pathogens in OA and OMI materials is their persistence in the material itself, the rate and extent of decline in these materials over time and, after land-spreading on the soil (Table 11). However, it appears that while many studies have indicated growth of pathogens in OA and OMI materials, there is insufficient evidence to show that any growth is sustained, particularly after land-spreading<sup>150</sup>. It seems apparent also that there are difficulties in developing valid models to assess the survival of pathogens, e.g. VTEC, in OA and OMI materials, e.g. manure, and soils<sup>281</sup>. Often the characteristics of the soil, e.g. temperature, pH, water activity, aeration of soil, competing microflora, chemical composition of soil, etc. maybe poorly defined and show great variation. In some cases, the data from laboratory research may not be valid under field conditions<sup>281</sup>. The activity of sunlight and other bacteria, protozoa and fungi, which normally contribute to the breakdown of faeces, appear to destroy some pathogens such as *M. bovis* (Appendix 4.3.2).

Research has indicated that the land-spreading of sludge from municipal sources containing *L. monocytogenes* and *Salmonella* spp. to soil may result in a longer survival time for *L. monocytogenes*<sup>272</sup>. Populations of *L. monocytogenes* in soil remained essentially unchanged seven weeks after application<sup>272</sup>. VTEC and other pathogens can by different routes of transmission, circulate in the farm environment through foraging from pastures on which manure is spread or where animals graze, and via contaminated water<sup>281</sup>. There is evidence that VTEC can survive in soil and manure for extended periods, indicating a potential for contamination of fresh produce, surface, drinking or irrigation water.

The survival of *E. coli* in two types of soil (i.e. loamy clay and silty sands) indicated that *E. coli* survived for 19 weeks and that  $\leq 1 \log_{10}$  reduction was observed during the first three months<sup>282</sup>. Under field and laboratory conditions VTEC has been found to survive on land for several months, with a 3 to 6  $\log_{10}$  reduction in six months<sup>283</sup>. Other research has found that a non-toxigenic strain of *E. coli* O157:H7 inoculated in bovine faeces and stored on grassland, could survive for several months, although an 8  $\log_{10}$  reduction was expected in six months<sup>58</sup>. A similar reduction in numbers after six months was also confirmed by other research<sup>284</sup>. Moreover, it appears that the soil type influences the survival time of VTEC at least and VTEC may have the potential to survive on pastures for several months<sup>281</sup>. There is also a possibility of contamination and survival of VTEC in rivers and lakes downstream from pastures or fields where manure is spread<sup>281</sup>.

#### 4.6.6 Food

The survival and growth of pathogens in food is directly or indirectly influenced by the intrinsic and extrinsic properties of the food<sup>285</sup>. Minimum and maximum growth conditions for foodborne pathogens are limited by the intrinsic and extrinsic properties of the food product. Typically, the growth rate of pathogens will decrease as the upper or lower limits of growth are approached. However, it is important to note that pathogens may grow outside these limits. Data in relation to the intrinsic and extrinsic properties of food and some of the minimum and maximum growth conditions for foodborne pathogens have been published by the FSAI<sup>285</sup>.

The number of documented outbreaks of human infections associated with the consumption of root, e.g. carrots, salad, RTE, e.g. lettuce, and other raw fruits, vegetables, and unpasteurised fruit juices has increased in recent years<sup>159</sup>. According to the Centres for Disease Control and Prevention (CDC) in the United States, the number of reported produce-related outbreaks per year doubled between the period 1973-1987 and 1988-1992. During both time periods, the etiologic agent was unknown in more than 50% of outbreaks. However, outbreaks with identified etiology were predominantly of bacterial origin<sup>160</sup>.

Many fruit and vegetable related outbreaks of foodborne illness have been associated with cross contamination via other foods. However, in some outbreaks there is evidence that either direct or indirect contact with OA and/or OMI materials has resulted in human illness<sup>100, 286-287</sup>. For example, it has been concluded that contact or probable contact with organic material such as animal faeces is a strong risk factor for VTEC infection in humans<sup>288</sup>.

The use of untreated animal manure rather than chemical fertilisers, as well as untreated sewage or contaminated irrigation water may contribute to increasing risk for human illness<sup>100</sup>. The use of untreated waste water and other waste materials such as sewage for irrigation and fertilisation has been implicated as one of the major sources of pathogenic microorganisms contaminating fruit and vegetable products<sup>286-294</sup>. The spreading of municipal sludge and irrigation water contaminated with *Ascaris ova* onto tomatoes and lettuce indicated that the parasite could remain viable for up to one month after spreading on the produce<sup>272</sup>. The WHO has recommended that crops to be eaten raw should be only irrigated with biologically treated effluent that has been disinfected to achieve a coliform level of not greater than 100 coliform per/100ml in 80% of samples taken<sup>295</sup>.

The potential for widespread outbreaks of foodborne human infection due to consumption of raw produce was dramatically illustrated in Japan in 1996. More than 6,000 cases of *E.coli* O157:H7 infection were reported<sup>296</sup>. The outbreak resulted in four deaths and affected more than 4,000 school children. Raw radish sprouts that had been prepared in central kitchens appear to have transmitted the pathogen, although the mechanism of sprout contamination was not determined<sup>160</sup>. Root crops such as radishes will typically contain a high level of soil at the point of harvest<sup>290</sup> which increases the risk of contamination.

Fruits and vegetables can become contaminated with VTEC whilst growing in fields, or during harvest, handling, washing/cleaning, processing, distribution, retail, preparation, and final use<sup>101, 272, 297-298</sup>. Contamination may be due to the use of improperly treated manure as fertiliser; exposure to faecal contaminated irrigation or washing water or contacts with animals, birds or insects, pre and post harvest. The extent and the impact of this kind of contamination on consumer health are unclear, since limited data are available<sup>281</sup>. However, as it appears that risk factors for human exposure to VTEC are linked to either direct or indirect exposure to ruminants and ingestion of food commodities contaminated by faecal contents from ruminants or humans, this exposure could be very low given that the infectious dose for VTEC could be as low as ten bacterial cells<sup>281</sup>.

Factors contributing to increases in outbreaks of food poisoning implicated through consumption of fruit and vegetable products may include the emergence of previously unrecognised pathogens<sup>289,299</sup>, changes in production practices and consumption patterns, improvements in epidemiological surveillance and microbiological techniques<sup>297</sup> and increased international trade and distribution<sup>100</sup>.

The spreading of OA and OMI materials directly or indirectly onto agricultural land has significant consequences for the safety of fruit and vegetable crops, particularly prepared RTE fruit and vegetable products, e.g. prepared salads. Apples can be contaminated with pathogens when dropped on soil which has been fertilised with animal manure leading to contamination of unpasteurised juices made with the apples<sup>298</sup>. Sprout seeds, e.g. alfalfa sprouts, bean sprouts, are often contaminated with pathogens through the use of OA and OMI materials as fertilisers at a farm level. This can lead to increases in pathogen numbers within the seed lot during the subsequent sprouting process<sup>159</sup>.

Despite widespread international recognition of the hazards, the production and consumption of RTE fruit and vegetable products has developed considerably in Ireland over the last ten years due to changes in technology, practices, and consumer demands. Typically, RTE crops will include salad leaves, e.g. lettuce, watercress etc., some vegetables, e.g. bean sprouts, carrots, cabbage etc., and fruits, e.g. apples, strawberries etc. Crops in or near the ground are most vulnerable to pathogenic microorganisms which may survive in soil after OA or OMI materials are land spread<sup>73</sup>. Low growing crops that may be splashed with soil during irrigation or heavy rainfall are also at risk<sup>73</sup>.

Other factors that influence the potential for contamination include the condition and type of crop, the amount of time between potential contamination and harvest, and post-harvest handling practices<sup>300</sup>. Produce that has a large surface area, e.g. leafy vegetables, and those with topographical features, e.g. rough surfaces, that foster attachment or entrapment may be at greater risk from contamination, especially if contact occurs close to harvest or during post-harvest handling<sup>300</sup>.

Freshly prepared RTE salads, in addition to freshly cut fruit and vegetables, are now commonly served and sold in restaurants and retail outlets across Ireland. However, changes in technologies and practices associated with the production of fruit and vegetable products may have introduced an increased risk for human illness associated with pathogenic microorganisms. The microbiological contamination of these RTE products may pose a significant risk to public health. This is set against a backdrop of fruit and vegetable products been increasingly implicated in outbreaks of food poisoning worldwide<sup>301-302</sup>. However, routine washing of fruit and vegetable crops in potable water prior to consumption will reduce the risks of foodborne illness<sup>73</sup>.

Human infection may arise from contamination of fruit and vegetable crops grown in soil to which OA and OMI material has been spread. This is particularly the case if these crops are to be minimally processed and sold as an RTE food, e.g. prepared salad leaves. There is also the added risk that pathogens such as VTEC present in the soil due to OA and OMI material spreading, may be spread throughout the environment via water run-off<sup>303</sup> and in some cases, birds<sup>304</sup> and other wildlife, e.g. deer,<sup>301, 305</sup>. Wild rabbits were implicated in an outbreak of VTEC infection in visitors to a wildlife centre in the United Kingdom following contamination of picnic areas with rabbit faeces<sup>305</sup>. It's also apparent that some pathogens such as VTEC may be able to survive and multiply on the surface of stored fruits and vegetables<sup>100, 268, 306</sup>.

Molluscan shellfish such as oysters and mussels are filter feeders. During the feeding process they can accumulate microorganisms, including human pathogens, when grown in waters impacted by human sewage and other OA or OMI materials. Such shellfish can present a significant public health risk when consumed raw or lightly cooked<sup>173</sup>. In recognition of the risks posed by bivalve shellfish, controls are in place across the EU. Shellfish harvesting areas are classified on their sanitary quality based on *E. coli* monitoring<sup>3, 89, 204, 247-248</sup>. The classification awarded prescribes the level of treatment required by shellfish before they can be placed on the market including relaying in clean seawater and cooking. An end product standard of <230 *E. coli* 100g<sup>-1</sup> also exists which all shellfish placed on the market must meet<sup>308</sup>. Using *E. coli* to monitor for the sanitary quality of shellfish it is not possible to distinguish whether contamination is from human or animal source.

Despite these controls the risks associated with shellfish directly contaminated with sewage are well documented and such shellfish have been associated with numerous outbreaks of viral illness even when compliant with the legislative controls<sup>180-182</sup>. The principal viral illnesses associated with sewage contaminated shellfish are gastroenteritis caused by Norovirus and infectious hepatitis caused by hepatitis A virus<sup>173</sup>. Other viral illnesses have also on occasions been linked with illness and shellfish consumption<sup>173</sup>.

As previously mentioned, the spreading of OA and OMI materials to agricultural land has the potential to contaminate watercourses with pathogens. Where those watercourses impact marine waters, these too can subsequently become contaminated. Marine waters can also become contaminated directly by land runoff. Where shellfish are grown in such waters they will also become contaminated. Contamination of marine waters from agricultural practices has been associated with periods of high rainfall<sup>309</sup>. While evidence of outbreaks of illness directly associated with the spreading of OA and OMI materials to land has been demonstrated, the public health consequences of such contamination have not been established. However, shellfish have been reported to be contaminated with *Cryptosporidium* and *Giardia*<sup>310</sup> indicating an agricultural source of contamination. But it is not possible to say whether the contamination was a result of the spreading of OA materials to agricultural land or contamination of watercourses by grazing animals<sup>310</sup>.

While the direct public health consequences of the spreading of OA and OMI materials to land with regard to shellfisheries is unclear there are other consequences. For example, contamination of shellfisheries through the spreading of ABP to land will affect the classification ascribed to shellfish harvesting areas. This can impose further treatment processes for the shellfish with a resultant economic impact on the industry.

The risk of viral illness associated with shellfish consumption is well established. Generally viral contamination occurs through the direct discharge of sewage effluent from the sewage treatment plants. No direct link has been made with the spreading of sewage sludge to land and illness associated with shellfish consumption, unlike in the case of *Salmonella*<sup>311</sup>. However, such a link would be hard to establish as it is difficult to track the source of contamination in shellfisheries. The possibility that some viral illness could be attributable to viral contamination from the spreading of sewage sludge to land cannot be ignored. Studies have been undertaken to determine the transit characteristics of viruses through soil. Results are variable depending on soil type and conditions but suggest greater transit distances than observed for bacteria<sup>312</sup>. Given the extended survival time of human viruses in the environmental setting<sup>122</sup>, this calls into question the suitability of the use of buffer zones (Appendix 3.1.2) of five metres or less to protect watercourses.

#### 4.6.7 Water

General food law<sup>16</sup> indicates that water ingested directly or indirectly like other foods contributes to the overall exposure of consumers to ingested substances, such as chemical and microbiological contaminants. Therefore, the definition of food includes water, intentionally incorporated into food during its manufacture, preparation or treatment<sup>16</sup>. The basic standards governing the quality of drinking water intended for human consumption are set out in EU Directive 98/83/EC<sup>17</sup>. Under EU food law<sup>3,16</sup> where there is a reference to drinking water, it is usually defined as water which meets the standards of the drinking water legislation<sup>17</sup>.

In principle, irrigation water used on agricultural land should not be contaminated with faeces<sup>272</sup>. However, this can not be guaranteed for all irrigation water. The use of contaminated water on agricultural land can spread pathogenic contamination<sup>313</sup>. The origin and type of water used for irrigation and practices related to its use in agriculture are therefore risk factors which have to be considered<sup>313</sup>. Water is extensively used in the production of food products such as fruit and vegetable products, e.g. irrigation, pesticide/fertiliser spreading, washing, particularly during post-harvest handling often involving a lot of water contact with the produce. However, although water is useful in reducing contaminants such as pathogens, it may also serve as a source of contamination or cross contamination.

In the United States in 1990 and 1993, two outbreaks, attributed to *Salmonella* species were linked to consumption of fresh tomatoes and affected over 300 people<sup>300,314,315</sup>. Tomatoes from both outbreaks were traced back to a single packing facility where a water-bath appeared to be the likely source of contamination<sup>300,314,315</sup>. The quality of water<sup>17</sup>, how and when it is used, and the characteristics of the fruit and vegetable crop influence the potential for water to contaminate produce. Water used in Irish agriculture can vary in quality<sup>44,104</sup>, particularly surface waters that may become contaminated due to the agricultural activities such as land spreading of OA and OMI, run-off from livestock operations and leaking slurry tanks etc. Ground water sources of drinking water may be affected by surface water and also may be vulnerable to contamination from land spreading of OA and OMI materials.

In the United States in 1999, an outbreak of VTEC and *Campylobacter* was associated with contaminated well water used at a county fair. It was thought that the well involved had become contaminated with manure as a result of heavy rains<sup>316</sup>. In 2000, contamination of a public drinking water supply in Walkerton, Ontario, Canada resulted in an outbreak of VTEC and *Campylobacter* infection that affected more than 2,300 people, of whom seven died<sup>154,317</sup>. A report on the incident in 2002 concluded that the primary source of contamination was manure that had been spread on a farm near to a shallow well that supplied the public drinking water system<sup>154,317-318</sup>. In Ireland in 2004, two outbreaks, one general and one family, were linked epidemiologically and/or microbiologically with drinking water from private wells, demonstrating the potential of this type of water supply in the transmission of VTEC infection<sup>319</sup>.

There is some concern that foods of animal origin or those that are treated with water during processing may provide vehicles for the transmission of *C. parvum*<sup>174</sup>. The CDC estimate *C. parvum* to be the etiological agent in 0.2% of foodborne illness outbreaks. To date, only a few food types, including raw sausage and chicken salad, have been implicated in cryptosporidiosis outbreaks<sup>174</sup>. However, this figure may be underestimated as there is a lack of routine methodology to isolate and detect *C. parvum* in foodstuffs<sup>174</sup>.

In the United States in 2006, an outbreak of VTEC due to *E. coli* O157:H7 contamination of spinach resulted in 204 cases of *E. coli* O157:H7 infection with 138 hospitalisations, 30 cases of kidney failure (i.e. Haemolytic Uraemic Syndrome (HUS)) and three deaths<sup>161</sup>. In this VTEC outbreak, the fact that illnesses were so dispersed (i.e. over 26 States) suggested that contamination likely happened early in the distribution chain, possibly at the farm level. Investigation identified the outbreak strain of *E. coli* O157:H7 in cattle faeces (i.e. matching genetic fingerprints for the same strain of *E. coli* O157:H7 that resulted in 204 cases of *E. coli* O157:H7 infection) from fields on farms in California where the spinach was grown<sup>161</sup>. This suggests that the contamination of the spinach with cattle faeces at the farms may have resulted in the outbreak of *E. coli* O157:H7 infection. Further investigation into the outbreak concluded that the water the farms used to irrigate the spinach was contaminated with the outbreak strain of *E. coli* O157:H7. In the United States since 1995, there have been 19 outbreaks of foodborne illness caused by *E. coli* O157:H7 for which lettuce or leafy greens were implicated as the outbreak vehicle<sup>161</sup>.

The spreading of OA and OMI materials on agricultural land has the potential to contaminate watercourses adjacent to the land<sup>309</sup>. This, in turn, can cause microbiological contamination of shellfisheries (Appendix 4.6.6). The health risk associated with this contamination is unclear. However, given the uncertainty of treatment processes for reducing virus levels in sewage sludge and the extended transit distances reported for viruses the most significant public health threat would appear to come from the use of sewage sludge (either treated or untreated) in close proximity to watercourses.

## APPENDIX 5: DESCRIPTION OF CHEMICAL HAZARDS

### 5.1 Introduction

Organic agricultural, municipal and industrial materials used on agricultural land may contain a wide range of chemical contaminants and present a potential risk through the food chain. The EC has issued a proposal<sup>320</sup> setting environmental quality standards for priority substances and other pollutants for surface waters. This updated list includes 41 dangerous chemical substances or groups of substances in two lists composed of 33 priority substances and eight other pollutants<sup>320</sup>. OA and OMI materials may contain substances or groups of substances which are on the list of priority substances.

To assess the potential risk from those substances on the EU priority list including metals and the various other metals and classes of organic chemicals in sludge, one has to consider probable routes of human exposure, the physicochemical and toxicological characteristics together with the levels present in treated waste and, if and where, the source is controlled. These risks have been assessed by many groups<sup>9, 112-113</sup> and all have reached similar conclusions.

Surveys in the United States revealed that both the occurrence and the concentration of potentially toxic pollutants in municipal waste water and sewage sludge were extremely variable and the outcomes were influenced by waste pre-treatment<sup>112</sup>. Where the sources of sludge and pre-treatment are not adequately controlled, a risk from metals and their compounds and organic chemicals may exist. In areas where rigorous and persistent enforcement of industrial waste pre-treatment standards have been applied, e.g. United States and Europe, the chemical pollutant concentrations of municipal sludge decreased substantially<sup>112</sup>. Of the 400 chemical constituents investigated, more than half were not detected and only 56 were detected above a 10% frequency<sup>112</sup>. In addition, while metals and organic compounds are detected in sludge, very low concentrations are generally present<sup>113, 321</sup>.

Metals and the lipid-soluble persistent organic chemicals that are contained in waste water, concentrate in sludge. Recommendations made in 2001<sup>112-113</sup> suggest that metal contamination of sludges is more important than organic contaminants with respect to routes of exposure to chemical pollutants in sludge. However, the bioavailability to plants of metals and organic compounds may also be a key factor of concern for public health<sup>112-113</sup>. Recycling of sludge arising from waste water treatment is advocated in the Urban Waste Water Treatment Directive<sup>28</sup>.

### 5.2 Exposure and Sources of Chemical Contaminants

The routes of exposure to chemical pollutants considered in this report are through soil and water. Exposure is only one part of the equation. Bioavailability is the other; this is dependent on the physicochemical properties of the substance and the contact period (short or prolonged). Chemical pollutants may be released by land-spreading of OA and OMI materials. Table 12 indicates some of the sources of OA and OMI materials and the possible chemical contaminants.

**Table 12. Potential Sources of OA and OMI Materials and Possible Chemical Contaminants**

Source	Type	Possible Contaminants
Agricultural Material (farm, dairy and meat plants)	Waste water, run-off, sludge	Metals, disinfectants, detergents, antibiotics, anthelmintics and metabolites
Municipal and Small Medium Enterprises (SME)	Human body waste	Prescribed and illegal drugs and their metabolites. Metals, oestrogen's - natural and synthetic
	Household effluent	Surfactants, detergents and disinfectants from personal care products, household cleaners and laundry agents. Garden care and hobby products
	Pre-treatment of sludge	Variable contaminants depending on industry and (any) controlled point source
	Run-off	PAHs, PCCD/Fs
Industry	Waste water and sludge	Metals, solvents, paints, wood residue and treatments, surfactants, detergents, pesticides, waste from drug synthesis processes
Hospitals	Waste water and sludge	Prescribed pharmacoactive drugs and their metabolites. Surfactants, detergents and disinfectants, diagnostic agents at higher concentration
Drinking Water	Waste water and sludge	Trihalomethanes, metals
River Dredgings	Sludge	Site dependent, many variables: soil, pH, sorption

The potential pathways of human exposure to pollutants include:

- drinking contaminated water
- eating contaminated fish
- eating contaminated meat from animals grazing on sludge-amended soil or who may have eaten feeds grown on sludge-amended land
- eating contaminated foods, e.g. RTE foods, affected by sludge treated soil.

One of the major routes for environmental contaminants to enter the human food chain is by uptake into the edible parts of crop plants. However, there is little or no evidence for soil-crop transfer despite the increasing scientific investigation into the potential environmental consequences of organic contaminants applied to farmland in sludge. This is because those compounds exhibiting some solubility and potential for plant uptake are also susceptible to rapid degradation processes in soil or are lost through volatilisation, whereas other more persistent compounds usually have very low solubility and are strongly adsorbed by the soil matrix in non-bioavailable forms<sup>9</sup>. There is however, potential for bioaccumulation of chemicals with repeated land-spreading of sludge. Surface spreading of liquid organic materials on pastures grazed by livestock is a theoretical source of organic contaminants to the human food chain because lipophilic compounds in this material could accumulate in meat, fat and milk<sup>9</sup>.

### **5.2.1 Agricultural materials**

Metal concentrations in OA materials will, in the main, mirror herbage and soil concentrations from the land on which the animals grazed. National monitoring programmes analyse animal produce for residues of animal remedies, metals and pesticides. Animal offal complies with the legislative limits<sup>115</sup> except on infrequent occasions from areas of metal anomalies, e.g. disused mines. Pesticides of the organochlorine, organophosphate and pyrethroid groups are monitored but none have been detected at any significant concentration in Ireland<sup>195</sup>. Fruit and vegetables for human consumption are also monitored for pesticides and fungicides.

### **5.2.2 Municipal and industrial materials**

Metals and hydrophobic organic contaminants sometimes found in sewage sludge following waste water treatment may have potential implications for the use of this sludge in agriculture. Municipal waste water can contain a mixture of discharges from households, small and medium enterprises, some larger industries and hospitals. Small and medium enterprises and larger industries often have rudimentary pre-treatment before discharge into the municipal supply. In the past, the dilution factors were considered adequate to reduce the toxicity of effluent water discharge and sludge. The main difference between agricultural and municipal/industrial organic materials is an increase in the concentration and number of pollutants in the latter. Despite the fact that over 6,000 organic compounds (due to human activities) have been detected in raw water sources, most are easily biodegradable in municipal waste water treatment works. The pollutants found in municipal (including hospitals) and industrial waste water and sludge can be divided into three main groups<sup>322</sup>:

- metals such as cadmium, chromium, copper, mercury, nickel, lead, silver, arsenic and zinc
- organic pollutants including PAHs, PCBs, Di-2-(Ethylhexyl) Phthalate (DEHP), Linear Alkyl Benzene Sulphonates (LAS), Nonylphenol and Nonylphenol Ethoxylates (NPE) and PCDD/Fs<sup>322</sup>
- biocides and pharmaceuticals.

### 5.3 Metals

Although the use of sewage sludge on agricultural land is largely dictated by nutrient content (i.e. nitrogen and phosphorus), the accumulation of potentially toxic metals in the sludge is an important aspect of sludge quality. This accumulation of potentially toxic metals should be considered in terms of the long-term sustainable use of sludge on agricultural land. Metal contamination of sludges is much more important than organic contaminants with respect to public health<sup>112-113</sup>. Metals are naturally present in soil at varying levels, and may originate from several anthropogenic sources such as fertilisers, animal manure, sludge, or atmospheric deposition. Apparent differences of soil metal concentrations in some cases may be due to variations in analytical techniques and not just regional variations. Sources of metals and their effects are well described in the literature<sup>323</sup>. The potential risks of some metals to humans, including maximum allowable daily intakes have been comprehensively detailed<sup>324</sup>. It is also important to note some metals such as zinc and copper are essential trace elements to plants and animals in low concentrations. Some of the metals which may be encountered in sludge and examples of their potential sources are outlined in Table 13.

<b>Metal</b>	<b>Source</b>
<b>Cadmium<sup>1</sup></b>	Predominantly found in rechargeable batteries for domestic use, paints and photography. The main sources in urban waste water are from diffuse sources such as detergents, body care products and cigarettes <sup>9</sup>
<b>Copper</b>	Predominantly from corrosion and leaching of plumbing, fungicides, pigments, wood preservatives, larvicides and antifouling paints
<b>Mercury<sup>1</sup></b>	Many mercury compounds are now banned. However, mercury can still be found in dental amalgams, germicidal soaps and antibacterial products and as an additive in old paints for water proofing and marine antifouling, as mercuric chloride in old pesticides, fungicides, insecticides, wood preservatives, embalming fluids and as mercury-silver-tin alloys and for silver mirrors
<b>Nickel<sup>1</sup></b>	Predominantly from alloys used in food processing, sanitary installations, rechargeable batteries and protective coatings
<b>Lead<sup>1</sup></b>	Predominantly from old lead piping in the water distribution systems. It can be found in old paint pigments (as oxides, carbonates), solder, pool cue chalk (as carbonate), in certain cosmetics, glazes on ceramic dishes and porcelain (banned now for uses in glazes), and lead crystal glass. Lead has also been found in wines, possibly from the lead-tin capsules used on bottles and from old wine processing installations
<b>Zinc</b>	Predominantly as salts (oxide, chloride carbonate, sulphide, formate, and arsenate) in medicines, ointments, antiseptics, UV absorbent agent, medicinal shampoo, health supplements, deodorants, cosmetics, inks, paints, pigments, water-proofing products, wood preservatives, anti-pest products, and from corrosion and leaching of plumbing
<b>Silver</b>	Predominantly from small scale photography, household products such as polishes, from odour-resistant clothing and domestic water treatment devices <sup>9</sup>
<b>Arsenic and Selenium</b>	Arsenic inputs come from natural background sources and from household products such as washing products, medicines, garden products, wood preservatives, old paints and pigments. Arsenic is present mainly as dimethylarsinic acid and Arsenic (III) (arsenite) in urban effluents and sewage sludge <sup>9</sup> . Selenium comes from food products and food supplements, shampoos and other cosmetics, old paints and pigments
<b>Organotins<sup>1</sup></b>	No longer permitted as antifouling paints, due to their endocrine effects, but may still be found in some wood preservatives. Photo and biodegradation may diminish organotin residues transfer to agricultural land. Tri Butyl Tin residues found in sludge-amended soils are low. Dumping of sludge and transfer to soil are of ecotoxicological relevance, since these transfer paths give rise to organotin pollution of both aquatic and terrestrial systems <sup>9</sup>

<sup>1</sup> EU Priority list<sup>320</sup>

Potentially toxic metal contamination of urban waste water and sewage sludge is usually attributed to discharges from major commercial premises. Although the sludge metal content from commercial sources may still contribute significantly to the total metal load entering waste water treatment plants, significant progress has been made in eliminating these sources. This is reflected in the significant reductions in metal concentrations in sewage sludge and surface waters reported in all European countries where data on sludge and water quality have been collected<sup>9</sup>.

Sixty to seventy percent of the cadmium, zinc, copper and nickel in domestic waste water and greater than 20% of the input of these metals in mixed waste water from domestic and industrial premises is derived from human faeces. Other principal sources of metals in domestic waste water include body care products, pharmaceuticals, and cleaning products. The majority of metals transfer to sewage sludge, but 20% may remain in the treated effluent, depending on the solubility. For nickel, the most soluble metal, this may be as high as 40% to 60%. Potentially toxic metals are conserved and retained in the sludge during microbial digestion processes at sewage works<sup>9</sup>.

While some risk assessments<sup>110</sup> appear to show only a minimal risk to public health from exposure to metals, some metals will persist in soil for many years. This may lead to an accumulation of these substances with repeated land-spreading and an increasing risk to public health. Runoff is the main influence of metal accumulation in soil, but it would take centuries, if ever, before metals added in sludge would approach soil limit values. Again, plant uptake of sludge-borne metals is a minor part of those acquired from the soil and total plant uptake of metals present in soil always remains below the limit values for foodstuffs<sup>8</sup>.

The pH of the soil appears to be the most important factor influencing metal uptake by plants<sup>8</sup>. Lowering the pH value of soil (i.e. from pH 7 to pH 4) causes an increase in the uptake of cadmium, nickel and zinc. Hence, it is suggested<sup>8</sup> that sludge spreading should be avoided on soil with pH values below five. Acidification of soil only induces a slight increase in copper uptake. A low pH value in soil has no observed effect on lead or chromium uptake<sup>8</sup>.

Uptake of metals by animals occurs through contaminated plant consumption or soil ingestion. Little information is available concerning metal quantities ingested and absorbed or of their subsequent toxicity to animals<sup>8</sup>. There is some concern in the environments of old mining areas that the transfer of lead and cadmium to offal might breach acceptable limits in foodstuffs. Lead and cadmium transfer across the placenta and into milk was observed during indoor feeding trials, but there are likely to be few practical consequences for finished animals<sup>8</sup>. Concentration of copper in the milk was not influenced by the ingestion of sludge-amended soil<sup>8</sup>.

Human exposure to metals may be attributed to several sources and depends on many factors such as diet, actual absorption, and food processing, e.g. formerly the solder in tinned foods was a source of lead in the human diet. Consumption of contaminated crops appears to be the main means of exposure to sludgeborne metals. It is assumed that the specific contribution of sludgeborne metals to the human diet is very low, when taking into account the observed level of metals present in soil, and considering the surface area over which sludge spreading takes place<sup>8</sup>. However, there are sub-populations with sensitivities to metals such as nickel. Initial sensitisation is dermal, but once sensitised they are particularly sensitive to oral challenge with nickel and potentially at risk from exposure to nickel in food and water.

#### **5.4 Organic Pollutants**

The bioavailability of organic compounds to plants is the key concern for public health<sup>113</sup>. A large number of organic pollutants from a wide range of sources may enter municipal waste water and sludge as outlined in Table 14.

**Table 14. Potential Organic Pollutants and Their Sources**

Organic Pollutants	Source
<b>Halogenated Organic Compounds</b>	In drinking-water disinfection, treatments such as chlorination and ozone result in the formation of Halogenated Organic Compounds (AOX). Trihalomethanes (THM) or their bromine derivatives (formed in the presence of small amounts of bromine) are the most common forms in water.
<b>Phthalates</b>	Phthalates are used as additives to increase the flexibility of polyvinyl chloride plastic and also in construction materials, clothing and furnishings. Some phthalates are used as solvents and in adhesives, waxes, inks, cosmetics, insecticides and pharmaceuticals.
<b>Surfactants</b>	Predominately from detergents, but also plastics, textiles, agricultural chemicals and paper products. Surfactants are the most abundant synthetic organic substances found in sludge.
<b>PAHs</b>	PAHs are widely dispersed throughout the natural environment and their persistence is due to their high lipid solubility. PAHs are generally found in complex mixtures in fossil fuels and as incomplete combustion products. While collectively vehicles and home heating are a significant source of many PAHs, PAHs in the environment also arise from the discharge of petroleum products, waste incineration and some industrial processes. PAHs concentrate in sewage sludge.
<b>PCDD/Fs</b>	In the environment, dioxins mainly arise as combustion products from the co-incineration or burning of organic materials and chlorine compounds, chemical production and chlorine bleaching in paper mills. In Ireland it has been estimated that more than half of all air emissions of dioxin arise from the domestic burning of waste. Backyard fires, household heating, cooking with fossil fuels and iron and steel production were the main sources of dioxin production in Ireland in 2000 <sup>325</sup> .
<b>PCBs</b>	PCBs are used commercially for their physical properties of low electrical conductivity and fire resistance as dielectrics in transformers and capacitors, in the formulation of lubricants and as plasticizers. Low-level non-dietary exposure may occur from open-ended applications such as their usage as plasticizers in poly-vinyl chloride (PVC) and neoprene, and their use in furnishings, adhesives and putties.
<b>Brominated Flame Retardants</b>	Used to delay, inhibit or suppress combustion processes in manufactured items. Frequently added into plastic, electronics, paint and textile materials to reduce the risk of ignition. Due to their high fat solubility, some PBDEs are bio-accumulative and persistent in nature. They appear to have an environmental dispersion similar to that of PCBs and dichlorodiphenyltrichloroethane (DDT).

Organic environmental pollutants, like dioxins and PCBs present in agricultural crops, are more the result of atmospheric deposition than direct absorption from contaminated soil. PCDD/Fs are ubiquitous and tend to be concentrated in sludge<sup>112-113</sup> but their concentrations in sludge are quite low<sup>321</sup>. Nevertheless, due to its stability, land spreading of sludge will continue to be a source of soil contamination<sup>113</sup>; the half-life in soil is approximately ten years<sup>326</sup>. Due to restrictive measures on chlorinated compounds, a remarkable decline in sludge dioxin loads has been observed over the last decade<sup>327</sup>. Therefore, the agricultural use of sludge where applied at agronomic rates and with sufficient withholding times will only contribute to a limited extent to the PAH and PCDD/F concentrations in soil<sup>327</sup> and are unlikely to contribute in any significant way to increased exposure to humans via the food chain<sup>113</sup>.

As PCBs are not produced or utilised today, their concentration in the environment, especially in sewage sludge and soils, reflects less the present input by emissions from still existing sources but rather a background pollution caused by recycled material with residual PCB concentrations.

### 5.5 Disinfectants and Detergents

Disinfectants (i.e. sanitisers) and detergents are used by the agricultural, municipal and industrial sectors but predominately by the food industry and agricultural sectors. They are also found in many pharmaceutical and personal care products and used widely in hospitals and medical practices. Their impact on public health is low because many of these substances are biodegradable and there is a low transfer from soil to humans. The environmental impact, however, could be significant. Many are toxic and harmful to aquatic organisms and they have been indicated as responsible for changes in aquatic populations. Many chemicals classified as detergents are dual purpose; primarily they are detergent, with cleaning/degreasing properties and some may also be biocidal. Common detergents contain additional components such as emulsifiers, e.g. polyphosphates, surfactants, e.g. ionic and non-ionic, and sequestrants, e.g. EDTA, to aid cleaning and counteract the effects of hard water. Again these additional components may have biocidal properties. Any detergent or surfactant that is dual purpose is covered by both the Biocidal Directive<sup>114</sup> and Detergent Regulation<sup>330</sup>.

### 5.5.1 Disinfectants

Disinfectants are regulated in the EU by the Biocides Directive<sup>114</sup> the full implementation of which will result in positive lists of approved actives for use within the EU. Biocidal products include disinfectants, preservatives, pest control products and anti-fouling products for use in industry and the home, as well as taxidermist and embalming fluids etc<sup>328</sup>. The Biocide Regulations concerning existing active substances in biocidal products are being re-evaluated. The present status of this process to produce positive lists of approved actives for use within the EU is that products for which approval is being sought have been notified via national authorities and Rapporteur Member States have been appointed for the review of each active. Thus, lists published on the DG Environment website on biocides provide the most comprehensive database of the products available for use<sup>114</sup>.

When transposing the Biocides Directive<sup>114</sup>, Ireland also provided in its legislation (S.I. No. 624 of 2001 and S.I. No. 625 of 2001) that biocidal products on the Irish market on or before 1<sup>st</sup> February 2002 must be notified to the Pesticide Control Service (PCS), the reporting agency for biocides in Ireland. Biocidal products not on the Irish market before 1<sup>st</sup> February, 2002 must be notified to PCS and get prior approval before being placed on the market and used. Each notification must include documentation and information to identify the nature and composition of each biocidal product as well as the manufacturer of each such product and each component thereof. The PCS is compiling an electronic database<sup>328</sup>. However, whilst these databases<sup>114, 328</sup> provide lists of actives available and/or permitted for use, they do not indicate the most commonly used substances. The EC has produced a study on the impact of the implementation of the Biocides Directive<sup>5</sup>, the purpose of which is to provide the Commission with key findings and lessons learned from the implementation of the Directive<sup>x</sup>.

The most commonly used active substances found in disinfectants in Ireland include sodium hydroxide, chlorine and iodine, sulphamic, phosphoric, nitric and peracetic acids, phenolic compounds and quaternary ammonium compounds otherwise known as Quats. These are mainly high-use industrial and agricultural disinfectants. Concern is raised by the rapid increase in use of halogenated disinfectants found in pharmaceuticals and personal care products such as triclosan, triclocarban, Kathon (Methylchloroisothiazolinone/Methylisothiazolinone) and 2-Bromo-2-Nitropropane-1,3-Diol (i.e. Bronopol). These are classed as Biocides: Group 1 - Disinfectants and general biocidal products and Group 2 - Preservatives<sup>114</sup>.

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<sup>x</sup> Further information on this study is available at: <http://ec.europa.eu/environment/biocides/study.htm>

Triclosan is among the most widely used and studied disinfectant. However, similar concerns are raised about other halogenated disinfectants. Triclosan [5-chloro-2-(2,4-dichlorophenoxy)phenol] is used at high concentrations in hospitals for its bactericidal, antifungal and antiviral properties and to control Methicillin-resistant *Staphylococcus aureus* (MRSA). At lower concentrations, it is bacteriostatic but does not appear to be sporicidal. At these low concentrations, it is found in many toothpastes, household and industrial products.

As a result of the widespread application of triclosan at low concentrations, large quantities are washed down household drains into sewage systems. Though some may be degraded in waste water treatment plants, the volume is such that much is released unaltered into the environment. It readily reacts with free chlorine and other trihalomethanes (THM) under drinking water treatment conditions to produce chloroform, an International Agency for Research on Cancer (IARC) class I carcinogen<sup>329</sup>. In recent Irish research, levels of the triclosan were found to exceed  $20\mu\text{g.g}^{-1}$  in digested sludge and  $5\mu\text{g.g}^{-1}$  in thermally dried sludge cake (i.e. biosolids). Triclosan residues were also present in biosolid enriched soils after a three to four month settling period<sup>194</sup>. In addition, significant traces of carbamazepine and warfarin were also detected in this research<sup>194</sup>.

The use of biocides and antibiotics (Appendix 5.7.1) exerts selective pressure on bacteria to acquire biocide or antibiotic resistance<sup>194</sup>. Such use represents a public health risk in regard to development of concomitant resistance to clinically important antimicrobial agents. The more microbial populations are exposed to biocides and antibiotics, the greater the possibility of resistance developing to one or more biocides and/or cross related antibiotic resistance developing. This is further exacerbated where biocidal disinfectants are used at non-biocidal concentrations. Because of the antibacterial effect of disinfectants, degradation tests are not usually relevant. So far, there are no available data to document ready degradability of disinfectants. Based on the insufficient data on degradation, a classification of “not readily biodegradable” by default has been proposed. Further information on biocides is available from the European Commission at: <http://ec.europa.eu/environment/biocides/index.htm>

### 5.5.2 Detergents

Regulation (EC) No 648/2004<sup>330</sup> establishes rules designed to achieve the free movement of detergents and surfactants in the internal market while, at the same time, ensuring a high degree of protection of the environment and public health. Regulation (EC) No 907/2006<sup>330</sup> amended Regulation (EC) No 648/2004 for the specified test methods for determining biodegradability of surfactants in detergents. Surfactants, arising mainly from detergents, are the most abundant synthetic organic substances in sewage biosolids and concentrations from 200 to 20,000mg/kg dry weight has been reported<sup>331</sup>. There are three types of surfactant compounds:

- non-ionic, e.g. alcohol ethoxylates, alkylphenols, including alkylphenol polyethoxylates, NPE, and alkylphenol polyethoxycarboxylates, known endocrine disruptors
- anionic, e.g. LAS, alkane ethoxy sulphonates, secondary alkanesulphonates
- cationic, e.g. di-2-hydroxyethyl dimethyl ammonium chloride, quaternary esters. As a result of the quaternary moiety, these will also have biocidal properties.

Further information on detergents is available from the European Commission at: [http://ec.europa.eu/enterprise/chemicals/legislation/detergents/index\\_en.htm](http://ec.europa.eu/enterprise/chemicals/legislation/detergents/index_en.htm)

### 5.5.3 Non-ionic surfactants

Nonylphenol and Nonylphenol Ethoxylates (NPE) are the commonest non-ionic alkylphenols surfactants with oestrogenic effects. The main degradation products from these are the metabolites 4-nonylphenol and octylphenol which may be more persistent and biologically active than their parent surfactant compounds. They are incorporated into plastics, textiles, agricultural chemicals, paper products and detergents. NPE are also present in sewage effluent and receiving waters and have a tendency to persist and bioaccumulate in the environment<sup>332</sup>. Concentrations in sewage sludge amended soils were found to range from trace levels to 2.72mg/kg dry weight. In 2000 it was reported that there had been a decline in concentrations in sewage in Denmark and Sweden during the 1990s probably as a result of pressure on industry to phase out these compounds in detergents and paints<sup>321</sup>.

Nonylphenols are reported to be endocrine disruptors (Appendix 5.9) in a variety of aquatic organisms (i.e. daphnids and fish). The oestrogenic activity of NPE is the principal concern and measures are proposed to eliminate the discharge of this substance to waste water<sup>9,113</sup>. Research in 1999 examined the fate of the primary degradation products of alkylphenol ethoxylate surfactants in paper sludge<sup>333</sup>. It was found that microbial degradation in soil could significantly reduce the risk of environmental contamination by these surfactants<sup>333</sup>. A 1999 review concluded that based on the limited available data, nonylphenol ethoxylates are persistent in landfills under anaerobic conditions but not persistent in sewage sludge amended soils under aerobic conditions<sup>334</sup>.

There are major data gaps on the toxic effects of NPE to the soil biota. The EU has derived a predicted no effects concentration (PNEC) of 0.069 mg/kg for 4-nonylphenol in soil<sup>335</sup> based on the assumption that soil dwelling organisms are similar to water column organisms in their sensitivity to 4-nonylphenol<sup>331,335-336</sup>. This PNEC is below the detection limit for 4-nonylphenol (0.19mg/kg). Alkylphenols uptake by plants appears to be minimal, they do not leach into groundwater and there is no transfer via the food chain to animals and thus presents a minimal risk through the food chain<sup>331</sup>.

#### **5.5.4 Anionic surfactants**

Linear Alkylbenzene Sulphonates (LAS) are the most common laundry surfactants. They are both hydrophilic and hydrophobic and are rapidly degraded during biological treatment and sorption to solids. They degrade very slowly or not at all under anaerobic conditions<sup>9</sup>. LAS or their degradation products can occur in high concentrations, particularly in anaerobically stabilised sewage sludge and will enter the soil during land spreading, but are not persistent in aerobic soils<sup>9</sup>. An EC report in 2001<sup>9</sup> concluded that the combination of relatively rapid aerobic degradation and reduced bioavailability when applied in biosolids would most likely prevent LAS from posing a threat to terrestrial ecosystems on a long-term basis<sup>337</sup>. However, this is not in agreement with a Canadian report in 2001<sup>331</sup> which stated that the complete loss of LAS from sewage sludge amended soil could take from 98 to 336 days. Despite significant amount of LAS undergoing biodegradation, high residues of LAS remain because of the initial high concentrations present in raw sludge.

The inability to degrade detergent residues anaerobically and the large concentrations present in sludge and waste water have prompted eco labelling initiatives in a number of European countries to influence consumer choice away from detergents containing these surfactants. In 2006, the EC Joint Research Centre<sup>327</sup> concluded that, if sewage sludges are applied to agricultural land with reference to the nutrient demand (i.e. nitrogen and phosphorous) of the respective crops and sufficient withholding periods, stringent restrictions of LAS concentrations in sludges are not necessary.

#### **5.6 Musk Compounds**

These substances include nitrobenzene compounds, musk xylene, musk ketone and the synthetic polycyclic musks that are widely used as fragrances in consumer products. They all are lipophilic, persistent and accumulate in the food chain. They have been detected in human tissue and in aquatic organisms such as fish and molluscs. Although musks' persistence and potential to bioaccumulate are of concern, the toxicity and environmental risks of these chemicals were generally regarded as low<sup>113</sup>. However, two new studies show that this may not be the case for the synthetic musks<sup>338-339</sup>. They have been found in fish products, but so far have not been in other food products<sup>200</sup>.

## 5.7 Medicines and Illicit Drugs

The Irish Medicines Board (IMB) authorises the use of veterinary and human medicinal products in Ireland and monitors the quality of medicines<sup>340</sup>. Over 7,000 human medicinal products and 1,000 veterinary medicinal products are presently authorised by the IMB for use in Ireland. The IMB regulation of the manufacture, marketing and distribution of medicinal products plays a very significant role in ensuring that appropriate standards are maintained in this sector<sup>340</sup>. The IMB also carries out environmental risk assessments<sup>340-341</sup> on most new applications for medicinal products. Data obtained from environmental risk assessments on veterinary products form the basis for any warnings on the labels related to disposal of manure from animals which have been treated with these medicines. However, for older medicines there are frequently data gaps on environmental effects. The possible occurrence of veterinary medicines in sewage sludge would be from the intensive livestock sector.

In contrast with any random, spontaneous or unanticipated effects of organic pollutants, medicines or illicit drugs are purposefully designed to interact at low concentrations with cellular receptors to elicit specific biological effects. Many drugs at therapeutic doses are known to have possible adverse reactions. Medicines range from simple over-the-counter medicines, to highly reactive antineoplastic drugs. Medicines, contraceptive hormones, over-the-counter or prescription, and their metabolites can enter the sewage system. In addition, disposal of unused or out-of-date medicines and illicit drugs is frequently through the sewage system. The behaviour of only a small selection of the most prescribed medicines and their metabolites has been examined in wastewater treatment plants and there are limited data for their fate and that of illicit drugs in these plants. These compounds (unlike conventional industrial/agrochemical pollutants) are generally much less volatile, accumulating in aquatic environments at low concentrations (parts per million or less). Once within the sewage system, the drug behaviour depends on whether it is a parent compound or metabolite. Another factor is the great variation in the excretion of the parent compound (between 10-90%) even within the same class of drugs, e.g.  $\beta$ -blockers, antiepileptics and lipid regulators. Drug concentrations found in sewage plants will also depend on the season, population health and proximity of a hospital discharge.

In 2005, two anti-inflammatory (i.e. ibuprofen and naproxen), two natural oestrogens (i.e. oestrone, oestradiol), one antibiotic (i.e. sulfamethoxazole) and the X-ray contrast media iopromide, together with two musk's (i.e. galaxolide and tonalide) were found in the sewage treatment plants of a Spanish town (i.e. approx population 100,000)<sup>342</sup>. Aerobic treatment removed between 35 and 90% of the compounds<sup>342</sup>. Human re-exposure would come mainly from drinking water, which is usually further treated to remove pollutants after it is taken from surface or ground water.

During primary and secondary wastewater treatment, sorption of any drug with a high affinity for particles will be removed in the sludge mainly by hydrophobic interactions. For this, the octanol/water partition coefficient is a good predictor of the affinity of the compound. Under the conditions encountered in conventional wastewater treatment plants, only those compounds with octanol/water partition coefficients greater than approximately 100 will be removed to an appreciable degree<sup>343</sup>. Few drugs meet this criterion with the exception of the steroid hormones, which have octanol/water partition coefficients of approximately 10,000. However, some antibiotics appear to undergo sorption via ion exchange reactions.

Removal of drugs also can occur via biotransformation/biodegradation by microorganisms. Predicting the relative importance of biotransformation from chemical structure is notoriously difficult. This is further complicated if they are only found at low concentrations. Available data suggest that certain compounds, such as the analgesic, ibuprofen, are readily degraded while others, such as the antiepileptic, carbamazepine are not easily degraded. This highlights concern for the potential fate of drugs in the environment, particularly if there are known adverse human response effects at therapeutic doses. However, since the therapeutic dose is reduced by the combined results/effects of dilution in the wastewater treatment plant and source control, this potential risk is minimised.

Due to analytical costs, the quantities in sewage sludge have not been adequately investigated. Tests that detect subtle end-points (neurobehavioral effects and inhibition of efflux pumps being two examples) are being considered by the EPA. Subtle effects that accumulate unnoticed may be significant. Multi-drug transporters (efflux pumps) are common defensive strategies for aquatic biota with possible significance of efflux pump inhibitors (EPIs) in compromising both the health of the aquatic biota and humans. Effects that have been already noticed are the antidepressant selective serotonin reuptake inhibitors (SSRIs) affecting spawning in shellfish; calcium-channel blockers inhibition of sperm activity in certain aquatic organisms; and antiepileptic drugs triggering extensive apoptosis in the developing brain, leading to neurodegeneration.

### 5.7.1 Antibiotics

Antibiotics are widely used as medicines for human and animal treatment, and previously as growth promoters for animals. The consequences of over use of antibiotics in people, animals, and agriculture exposes both terrestrial and aquatic environments to the potential for accelerated development of resistance among naturally occurring pathogens and also change the community structure/diversity of environmental bacteria. According to the Swiss Environmental Research Institute 54,000 tonnes of antibiotics were used in human medicine in the EU in 1997<sup>344</sup>. Veterinary use amounted to 3,500 tonnes as medicines and 1,600 tonnes as growth promoters. The quantity of the latter is in decline, due to bans on their use<sup>344</sup>. On the other hand, usage in humans is expected to increase with increasing average age of the population<sup>9</sup>. The main entry routes of pharmaceutical substances into the environment are through disposal of waste water treatment end products, sewage effluent and sludge, and manure spreading onto agricultural land or even from the excreta of grazing animals. It has been confirmed that antibiotics used in human medicine were present in the Swedish hospital effluent and five sewage treatment plants<sup>345</sup>. In the United States, antibiotics have been identified in groundwater<sup>346</sup>.

Some antibiotics, e.g. penicillin, are easily hydrolysed, others, sulphonamides, have been found in drinking-well water and groundwater while tetracyclines and fluoroquinolones were found bound to sludge sediment. Unabsorbed antibiotics can be excreted into the environment but the phase II metabolites of chloramphenicol and sulphadimidine are reactivated in liquid manure into their parent compounds<sup>196</sup>. However, most antibiotics are not very persistent in the environment, particularly in soils, and the most widely used growth promoters have been shown to have no effect on invertebrates, even at relatively high concentrations. Soil bacteria, however, may be more sensitive to antibiotics.

Veterinary drugs tend to end up in manure and would have the potential to contaminate soils where manure or slurry is spread. In one study, antibiotic concentrations in soil around a pig farm reached up to 1400mg/kg, due to presence of antibiotics in the animals' feed. Increased use of antibiotics can lead to an increase in drug resistant micro flora. This resistance is actually favoured by low concentrations of antibiotics<sup>347</sup>. Therefore, the presence of antibiotics in the environment may be an issue.

Bacteria containing antibiotic resistance genes can enter the environment via human and animal excreta. Most of the studies in animals to date, have concentrated on pathogenic bacteria but studies have identified widespread resistance in commensal enteric *E. coli* and other Gram-negative enteric bacteria in lactating cattle<sup>348</sup>. The antibiotic resistant genotypes found on one farm were rarely found on other farms as each harboured a unique reservoir of *E. coli* genotypes<sup>348</sup>. The presence of antibiotic resistance in commensal bacteria is a concern as antibiotic resistance genes and accessory genetic elements can be horizontally transmitted to pathogenic bacteria. A pan European study in 2005, concluded that the presence of animal-associated vancomycin resistant enterococci probably reflect the former use of avoparcin in animal production, whereas vancomycin resistant enterococci in human-associated samples may be a result of antibiotic use in hospitals<sup>349</sup>. Bioactive drug residues and antibiotic-resistant bacteria present in farm and hospital wastes when spread on land can run into water bodies and thus may pose a potential risk through the food chain.

### 5.8 Bacterial Endotoxins

Municipal sewage may contain endotoxin<sup>350</sup>. The presence of endotoxin in potable water is known to be a potential problem under some circumstances<sup>351</sup>. The importance of endotoxin in sewage sludge and the water supplies has not been fully assessed<sup>352</sup>. However, endotoxin absorption through damaged and inflamed epithelia has been shown. Once absorbed, endotoxin may produce endotoxic or anaphylactic shock either alone or in combination with specific antibodies or complement. The absorption of ingested endotoxin by the intact epithelium in the gut is open to question. In pigs absorption of *E. coli* endotoxin from the small intestine has been demonstrated.

There are areas where endotoxin can be problematic (inhalation) but most concern is about the absorption of *Cyanobacteria* endotoxin from drinking water<sup>351-352</sup>. Other studies mention the presence of disease processes. Extrapolating from these studies, the absorption of endotoxin from sewage-amended soils seems very unlikely.

## 5.9 Endocrine Disrupting Substances

There is increasing concern about compounds that interfere with any of the hormonal systems<sup>343</sup>. Endocrine disrupting substances block or trigger their effects by binding to receptors. Receptor-specific responses are particularly problematic as they can affect people for which they are not intended<sup>9</sup>. An endocrine-disruptor may have an 'agonistic effect' where it binds to the receptor instead of the natural hormone and causes a response, or it may have an 'antagonistic effect' where the binding of the compound prevents the natural one from binding and producing the required response<sup>9</sup>. Other effects may also occur, since these mechanisms are very complex and may affect many systems in the body. Of particular concern are effects on the reproductive system and the hypothalamic-pituitary-thyroid axis of endocrine disrupting substances. Endocrine-disrupting substances include phthalates, some PCBs, surfactants such as NPE, synthetic musk fragrances and some pharmaceutical compounds, such as synthetic oestrogens. Many of these may persist in sewage sludge and could enter the food chain as they are potentially taken up by plants and animals.

The effects of oestrogen-disruptors were discovered about twenty-five years ago and may occur at concentrations of a few nanograms per litre<sup>9</sup>. Human oestrogen uses are predominately for treatment of disease, contraception and hormonal replacement therapy. Oestrogens, natural and synthetic, are excreted in an inactive form but are found to be reactivated in sewage effluent. Oestrogen receptors are located in the cell nucleus, so oestrogen-like molecules could enter the cell and potentially interact with DNA, causing damage which may lead to tumour formation<sup>9</sup>. Prolonged exposure to these compounds may induce female characteristics in males. There is increasing speculation that these compounds may be linked to reduction in male fertility and reproductive complications<sup>9</sup>.

## 5.10 Nitrates

Maximum levels for nitrates in water<sup>17</sup>, lettuce, spinach and infant food<sup>115</sup> have been established in the EU. The WHO has stated that the primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, a particular problem in children<sup>117</sup>. The WHO has also acknowledged that whilst there is also some evidence of a cancer risk associated with the ingestion of nitrate, the overall weight of evidence is strongly against there being any link<sup>117</sup>.

In 2005 the EPA<sup>106</sup> indicated that since 1995 there has been a general increase in the percentage of water samples with nitrate concentrations between 25-40 mg/l NO<sub>3</sub>. In a Teagasc report in 2005<sup>116</sup>, it is stated that nitrate at excessive levels in leafy vegetables is a particular problem in many European countries including Ireland. High application rates of animal manures may result in higher plant nitrate levels<sup>118</sup>. The nitrate concentration of both ground and surface waters can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal materials<sup>117</sup>.

An EU Opinion in 1997<sup>353</sup> stated that across the EU vegetables have been found to contribute about 70 to 90% of total nitrate intakes whilst noting that in some areas drinking water may make a major contribution. It was recommended that efforts be maintained to reduce exposure to nitrates via food and water<sup>353</sup>.

Under 2006 legislation<sup>4</sup>, in Ireland the protection of waters against pollution caused by nitrates from agriculture is enforced. The legislation requires that stringent legally-binding measures are taken in respect of farm practices to reduce nitrate losses to waters<sup>9</sup>. Further detail on this legislation is given in Appendix 1.4.3.

## GLOSSARY

**Abattoir Materials/Waste** is blood and gut contents together with manure from livestock awaiting slaughter<sup>18,201</sup>.

**Agriculture** is the growing of all types of commercial food crops, including for stock-rearing purposes<sup>1</sup>.

**Agglomeration** means an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point<sup>28</sup>.

**Animal Manures** are the excreta produced by farmed livestock. When animals are housed indoors, these wastes are collected and stored for subsequent spreading on land.

**Animal By-products (ABPs)** are the entire bodies or parts of animals or products of animal origin (i.e. as referred to in Articles 4, 5 and 6 of current legislation) not intended for human consumption, including ova, embryos and semen<sup>18</sup>. Typically, ABPs are the parts of slaughtered animals that are not directly consumed by humans, dead-on-farm animals, manure, digestive tract content, and catering waste that contains or has been in contact with meat products, whether cooked or uncooked.

**Appropriate or Adequate Treatment** is the treatment of organic material(s) by a process(s) in compliance with approved standards, code(s) of good practice or where applicable legislation, which after treatment permits the land-spreading of that organic material on agricultural land.

**Biocides** are active substances and preparations containing one or more active substances, intended to destroy, deter, render harmless, prevent the action of, or otherwise exert a controlling effect on any harmful organism by chemical or biological means<sup>202</sup>.

**Biosolids** (see Pasteurisation, Sludge or Sewage Sludge, Treated Sludge or Sewage Sludge) is the organic by-product of urban waste water treatment which, when treated to an approved standard, can be used beneficially as a fertiliser/soil conditioner in agriculture<sup>2</sup>.

**Biogas Plant** means a plant in which biological degradation of products of animal origin is undertaken under anaerobic conditions for the production and collection of biogas<sup>18</sup>.

**Contamination** (see Hazard) is the presence or introduction of a hazard<sup>3</sup>.

**Compost** is the product of composting biodegradable organic matter.

**Composting** is a biological process in which soil-inhabiting microorganisms<sup>73</sup> decompose biodegradable organic matter, e.g. animal manure, plants, typically in the presence of free oxygen (i.e. under aerobic conditions) to form compost.

**Composting Plant** means a plant in which biological degradation of products of animal origin is undertaken under aerobic conditions<sup>18</sup>.

**Digestive Tract Content** is the content of the digestive tract of mammals and ratites (i.e. emus or ostriches) whether or not separated from the digestive tract<sup>18</sup>.

**Domestic Waste Water** (see Industrial Waste Water, Urban Waste Water) is waste water from residential settlements and services which originate predominantly from human metabolism and household activities<sup>28</sup>.

**Dredgings** are the consequence of sediment removal from surface waters as a management practice to counter the effects of erosion and siltation on these resources. Dredged material is essentially inorganic solids (i.e. soil particles), however, to these is attached or entrained a variety of contaminants, e.g. metals, toxic organics, etc.

**Farmyard Manure** means a mixture of bedding material and animal excreta in solid form arising from the housing of cattle, sheep and other livestock excluding poultry<sup>1-2,4</sup>.

**Fertiliser** (see Organic Fertiliser and Soil Improvers) is any substance containing phosphorus or a nitrogen compound utilised on land to enhance growth of vegetation and may include livestock manure, residues from fish farms and sewage sludge<sup>4</sup>.

**Food or Foodstuff** is any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans. Food includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment. It includes water after the point of compliance as defined in Article 6 of Directive 98/83/EC and without prejudice to the requirements of Directives 80/778/EEC and 98/83/EC<sup>16</sup>.

**Food Processing** refers to the production of food on an industrial scale.

**Grassland** (see Pasture Land)

**Hazard(s)** (see Contamination) is a biological, chemical or physical agent in, or condition of, food or feed with the potential to cause an adverse health effect<sup>16</sup>.

**Hazard Analysis and Critical Control Point (HACCP)** is a system that identifies, evaluates and controls hazards which impact or are significant to food safety.

**Industrial Waste Water** (see Domestic Waste Water, Urban Waste Water) is any waste water which is discharged from premises used for carrying on any trade or industry, other than domestic waste water and run-off rain water<sup>28</sup>.

**Land-Spreading**, is the addition of fertiliser including organic fertiliser to land whether by spreading on the surface of the land, injection into the land, placing below the surface of the land or mixing with the surface layers of the land but does not include the direct deposition of manure to land by animals<sup>Adapted 4</sup>.

**Livestock Manure** (see Manure)

**Manure** is the excrement and/or urine of farmed animals, with or without litter, or guano, that may be either unprocessed or processed in accordance with Chapter III of Annex VII of the Animal-by-Products legislation or otherwise transformed in biogas or composting plants<sup>18</sup>.

**Monitoring** is a procedure of conducting a planned sequence of measurements or observations.

**Municipal waste** is solid waste from households, e.g., rubbish, green wastes, and businesses, e.g. office waste.

**Municipal Compost** is compost made from composting biodegradable organic matter from a municipal source.

**Organic Fertiliser and Soil Improvers** (see Organic Fertiliser, Organic Agricultural, Municipal and Industrial Materials) are any fertiliser other than that manufactured by an industrial process and includes livestock manure, dungstead manure, farmyard manure, slurry, soiled water, non-farm organic substances such as sewage sludge, industrial by-products and sludges and residues from fish farms<sup>4</sup>.

**Organic Materials** are materials originating from an organic source, e.g. livestock manure, sewage sludge etc<sup>Adapted 201</sup>.

**Organic Agricultural, Municipal and Industrial Materials** are materials derived from agricultural enterprises, e.g. animal slurry and manure, municipal, e.g. sludge and sewage sludge from urban waste water treatment, and industrial sources, e.g. sludge from industrial waste water treatment) which after appropriate treatment and management may be suitable for land-spreading as organic fertilisers.

**Pasteurisation** (see Biosolids) is a heat treatment which destroys vegetative pathogenic microorganisms and reduces numbers of other microorganisms. Under the DEHLG COP<sup>2</sup> biosolids can be classified as a pasteurised product following treatment by at least one of six approved processes (Chapter 3.3.1) to attain a prescribed microbiological standard.

**Pasture Land** (see Grassland) is land covered with grass or other herbage and grazed by farmed animals<sup>18</sup>.

**Population Equivalent** is a measurement of the organic biodegradable load. A population equivalent of one means the organic biodegradable load having a five-day biochemical oxygen demand of 60grams of oxygen per day. The load is calculated on the basis of the maximum average weekly load entering a treatment plant during the year, excluding unusual situations such as those due to heavy rain<sup>28</sup>.

**Potable Water** is water meeting the minimum requirements laid down in Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption and S.I. No. 278 of 2007<sup>17</sup>.

**Primary Treatment** (see Secondary Treatment, Urban Waste Water) is treatment of urban waste water by a physical and/or chemical process involving settlement of suspended solids, or other processes in which the BOD<sub>5</sub> of the incoming waste water is reduced by at least 20% before discharge and the total suspended solids of the incoming waste water are reduced by at least 50%<sup>28</sup>.

**Ready-to-Eat Food** is food intended by the producer or the manufacturer for direct human consumption without the need for further cooking or processing to eliminate or reduce to acceptable level microorganisms of concern<sup>89</sup>.

**Risk** is a function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s)<sup>16</sup>.

**Risk Analysis** means a process consisting of three interconnected components: risk assessment, risk management and risk communication<sup>16</sup>.

**Risk Assessment** means a scientifically based process consisting of four steps: hazard identification, hazard characterisation, exposure assessment and risk characterisation<sup>16</sup>.

**Sludge or Sewage Sludge** is (i) residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters (ii) residual sludge from septic tanks and other similar installations for the treatment of sewage (iii) residual sludge from sewage plants other than those referred to in paragraphs (i) and (ii)<sup>1</sup>.

**Slurry** means the excreta (i.e. faeces and urine) produced by farmed livestock and collected from the animals while they are in a building or yard and to which rainwater, soiled water, washings or other extraneous material, e.g. silage effluent, is typically added, creating a material of a consistency that allows it to be pumped or discharged by gravity at any stage in the handling process<sup>Adapted 4</sup>.

**Soil Amendment** is organic material added to soil to improve its physical properties, such as water retention, permeability, water infiltration, drainage, aeration and structure.

**Soil Improver** (see Fertiliser and Organic Fertiliser)

**Soiled Water** is water from concreted areas, hard standing areas, holding areas for livestock and other farmyard areas where such water is contaminated by contact with livestock faeces or urine or silage effluent, chemical fertilisers, washings such as vegetable washings, milking parlour washings or washings from mushroom houses and water used in washing farm equipment<sup>4</sup>.

**Secondary Treatment** (See Primary Treatment, Urban Waste Water) is treatment of urban waste water by a process generally involving biological treatment with a secondary settlement or other process in which the requirements established in Table I of Annex I of Council Directive 91/271/EEC concerning urban waste-water treatment are respected<sup>28</sup>.

**Source Separated Organics** in the context of municipal solid waste typically refers to the organic fraction of household wastes, e.g. food scraps, garden trimmings, that are separated from the other fractions (i.e. dry recyclables, mixed wastes) at their source of generation (i.e. by the householder).

**Spent Mushroom Compost** is residual compost material produced by the mushroom industry.

**Treated Sludge or Sewage Sludge** means sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use<sup>18</sup>.

**Untreated Sludge or Sewage Sludge** (see Sludge or Sewage Sludge)

**Urban Waste Water** (see Domestic Waste Water, Industrial Waste Water) is domestic waste water or a mixture of domestic waste water with industrial waste water and/or run-off rain water<sup>24,28</sup>.

**Xenobiotic** is a chemical which is found in an organism but which is not normally produced or expected to be present in that organism, e.g. antibiotics are human xenobiotics because the human body does not produce them itself nor would they be expected to be present as part of a normal diet. The term xenobiotic can also cover chemicals which are present in much higher concentrations than are usual in an organism.

## BIBLIOGRAPHY

1. **European Union (1986)** Council Directive 86/278/EEC of 12 June 1986 on the Protection of the Environment, and in Particular of the Soil, when Sewage Sludge is used in Agriculture as amended by Council Directive 91/692/EEC (further amended by Council Regulation 1882/2003/EC), and Council Regulation 807/2003/EC. Irish Government, (1991). European Communities (Use of Sewage Sludge in Agriculture) Regulations, 1991. S.I. No. 183 of 1991 as amended by S.I. No. 148 of 1998 and further amended by S.I. No. 267 of 2001.
2. **Department of the Environment Heritage and Local Government (2008)** Codes of Good Practice for the Use of Biosolids in Agriculture - Guidelines for Local Authorities & Wastewater Treatment Plant Operators and Guidelines for Farmers<sup>7</sup> <http://www.environ.ie/en/Environment/Water/WaterServices/PublicationsDocuments/FileDownload,17228,en.pdf>
3. **European Union (2004)** Corrigendum to Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the Hygiene of Foodstuffs. Official Journal, L 139 of 30<sup>th</sup> April 2004. Irish Government, (2006). European Communities (Hygiene of Foodstuffs) Regulations, 2006. S.I. No. 369 of 2006
4. **Irish Government (2006)** The European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006, S.I. No. 378 of 2006 as amended by S.I. No. 526 of 2007<sup>2</sup>
5. **Department of Agriculture and Food, Economics & Planning Division (2005)** Compendium of Irish Agricultural Statistics, 2005
6. **Laternus, F., von Arnold, K. & Grøn, C. (2007)** Organic Contaminants from Sewage Sludge Applied to Agricultural Soils. *Environ. Sci. Pollut. Res.*, **14** Special Issue (1), 53-60
7. **Burton, C. & Turner, C. (2003)** Strategies to Reduce the Disease Risk from Livestock Manure. In: *Manure Management: Treatment Strategies for Sustainable Agriculture*, 2nd Ed., Silsoe Research Institute, Silsoe, UK. pp. 159-222
8. **European Commission Environment Directorate General (2001)** Disposal and Recycling Routes for Sewage Sludge. Part 3 – Scientific and Technical Report. Office for Official Publications of the European Communities

<sup>7</sup> These two guidelines, published on April 30th 2008 by DEHLG, replace the 1999 Codes of Good Practice for the Use of Biosolids in Agriculture - Guidelines for Local Authorities & Wastewater Treatment Plant Operators

<sup>2</sup> Also See: European Commission (2007). Commission Decision (2007/697/EC) granting a derogation requested by Ireland pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources

9. **European Commission (2001)** Pollutants in Urban Waste Water and Sewage Sludge. Final Report, 2001
10. **Pell, A.N. (1997)** Manure and Microbes: Public and Animal Health Problem? *J. Dairy Sci.*, **80**, 2673-2681
11. **Collins, J.D. (1995)** Hazards for Animals and Man Associated with Solid and Liquid Manures from Animals Affected with Notifiable Diseases. *Irish Vet. Journal*, **48**, 187-190
12. **Kelly, W.R. (1980)** A Study of the Effects of Animal Effluents Utilisation for Grassland Production on the Levels of Certain Pathogenic Bacteria in Farm Animals and Their Carcasses. In: Effluents from Livestock, pp. 637-652. Applied Science Publishers Ltd, Ripple Road, Barking, Essex, England
13. **Food Safety Authority of Ireland (2005)** The Control and Management of *Listeria monocytogenes* Contamination of Food
14. **Chapman, P.A., Siddons, C.A., Manning, J. & Cheetham, C. (1997)** An Outbreak of Infection Due to Verocytotoxin-Producing *Escherichia coli* O157 in Four Families: The Influence of Laboratory Methods on the Outcome of the Investigation. *Epi. & Inf.*, **119**, 113-119
15. **O'Connor, D.R. (2002)** Part One: A Summary Report of the Walkerton Inquiry: The Events of May 2000 and Related Issues. Ontario Ministry of the Attorney General
16. **European Commission (2002)** Regulation No 178/2002 Laying Down the General Principles and Requirements of Food Law, Establishing the European Food Safety Authority and Laying Down Procedures in Matters of Food Safety. Official Journal, L Series 031, p1, 01/02/2002, Brussels. Irish Government, (2007). European Communities (General Food Law), Regulations, 2007. S.I. No. 747 of 2007
17. **European Union (1998)** Council Directive 98/83/EC on the quality of water intended for human consumption. Irish Government, (2007). European Communities (Drinking Water) (No. 2), Regulations, 2007. S.I. No. 278 of 2007

18. **European Commission (2002)** Regulation (EC) No 1774/2002 laying down Health Rules Concerning Animal-by-Products not intended for Human Consumption as amended by Commission Regulations (EC) 808/2003, 668/2004, 416/2005, 181/2006, 197/2006 and 208/2006. Irish Government, (2006). European Communities (Transmissible Spongiform Encephalopathies and Animal By-Products) Regulations, 2006 (S.I. No. 612 of 2006); S.I. No. 615 of 2006 Diseases of Animals Act, 1966 (Transmissible Spongiform Encephalopathies) (Fertilisers & Soil Improvers) Order 2006
19. **Department of Agriculture and Food (2006)** Explanatory Handbook for Good Agricultural Practice Regulations  
[http://www.agriculture.gov.ie/publicat/publications2006/good\\_ag\\_practice\\_handbook.pdf](http://www.agriculture.gov.ie/publicat/publications2006/good_ag_practice_handbook.pdf)
20. **Department of Agriculture, Fisheries and Food (2008)** Animal By-products  
[http://www.agriculture.gov.ie/index.jsp?file=animal\\_products/AnimalByProducts.xml](http://www.agriculture.gov.ie/index.jsp?file=animal_products/AnimalByProducts.xml)
21. **Environmental Protection Agency (2007)** The Provision and Quality of Drinking Water in Ireland - A Report for the Years 2006-2007
22. **Environmental Protection Agency (2006)** Investigation into the Application and Long Term Impacts of Landspreading Industrial Organic Wastes in Ireland. Workshop Discussion Document (OEE 04-04). June 8<sup>th</sup> 2006. Report prepared for the EPA by the RPS Group
23. **Collins, C., Le Bolloch, O. & Meaney, B. (2005)** National Waste Report. Office of Environmental Enforcement- Environmental Protection Agency
24. **Smith, D., O'Neill, N., Wall, B. & Crowe, M. (2007)** Urban Waste Water Discharges in Ireland with Population Equivalents Greater Than 500 Persons - A Report for the Years 2004 and 2005. Office of Environmental Enforcement - Environmental Protection Agency
25. **Department of Agriculture and Food, Economics & Planning Division (2006)** Good Farming Practice with Regard to Spreading of Poultry Litter on Land
26. **European Court Judgements (2005)** Commission of the European Communities v Kingdom of Spain 8 September 2005 (C-121/03) and Commission of the European Communities v Kingdom of Spain 8 September 2005 (C-416/02). Available at [www.curia.eu.int](http://www.curia.eu.int)

27. **European Union (1999)** Directive 1999/31/EC on the Landfill of Waste
28. **European Union (1991)** Council Directive 91/271/EEC concerning urban waste water treatment. Irish Government, (2001). Urban Waste Water Treatment Regulations, 2001. S.I. No. 254 of 2001
29. **European Commission (2006)** Report from the Commission to the Council and the European Parliament on Implementation of the Community Waste Legislation for the Period-2001-2003. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0406:FIN:EN:PDF>
30. **Department of the Environment Heritage and Local Government (1993)** Strategy Study on Options for the Treatment and Disposal of Sewage Sludge in Ireland
31. **Irish Government (2003)** Waste Management Acts, 1996-2003
32. **British Retail Consortium, Water UK & ADAS (2001)** The Safe Sludge Matrix - Guidelines for the Application of Sewage Sludge to Agricultural Land, 3rd. Edition
33. **Gale, P. (2003)** Using Event Trees to Quantify Pathogen Levels on Root Crops from Land Application of Treated Sewage Sludge. *J. Appl. Microbiol.*, **94**(1), 35–47
34. **Gale, P. (2005)** Land Application of Treated Sewage Sludge: Quantifying Pathogen Risks from Consumption of Crops. *J. Appl. Microbiol.*, **98**(2), 380–396
35. **Lang, N.L., Bellett-Travers, M.D. & Smith, S.R. (2007)** Field Investigations on the Survival of *Escherichia coli* and Presence of other Enteric Microorganisms in Biosolids-Amended Agricultural Soil. *J. Appl. Microbiol.*, **103**, 1868-1882
36. **Carrington, E.G., Davis, R.D., Hall, J.E., Pike, E.B., Smith, S.R. & Unwin, R.J. (1998)** Review of the Scientific Evidence Relating to the Agricultural use of Sewage Sludge. Report DETR 4415/3 [Part 1] and Report DETR 4454/4 [Part 2] WRc plc, Medmenham

37. **Department of the Environment Heritage and Local Government, Water Services Policy Section (2006)** Cross Compliance Inspections in Respect of the EU Use of Sewage Sludge in Agriculture Directive and Other Matters. Circular WSPI/06
38. **Prüss, A., Giroult, E. & Rushbrook, P. (1999)** Safe Management of Wastes from Healthcare Activities. World Health Organization (WHO), Geneva
39. **Fijan, S., Poljsak-Prijatelj, M., Steyer, A., Koren, S., Cencic, A. & Sostar-Turk, S. (2006)** Rotaviral RNA found in Wastewaters from Hospital Laundry. *Int. J. Hyg. Environ. Health*, **209**, 97-102
40. **Galvin, S., Boyle, F., Morris, D., & Cormican, M. (2007)** Occurrence of Antimicrobial Residues and Antimicrobial Resistant Organisms in Waters and Effluent from a Number of Sites. In: European Scientific Conference on Applied Infectious Disease Epidemiology (ESCAIDE), Stockholm, 18<sup>th</sup> to 20<sup>th</sup> October 2007
41. **Galvin, S., Morris, D., Dorai-Raj, S. & Cormican, M. (2007)** Detection of Antimicrobial Resistant Organisms in Hospital Effluent in Ireland. In: Abstracts of the 107<sup>th</sup> General Meeting of the American Society of Microbiology, Toronto, May 21<sup>st</sup> to 25<sup>th</sup> 2007
42. **Morris, D., Boyle, F., Galvin, S. & Cormican, M. (2007)** Detection of Vancomycin Resistant *Enterococci* in Hospital Effluent in Ireland. In: Abstracts of the Interscience Conference of Antimicrobial Agents and Chemotherapy (ICAAC), Chicago, U.S.A., September 17<sup>th</sup> – 20<sup>th</sup> 2007
43. **Galvin, S., Morris, D. & Cormican, M. (2007)** Detection of Antimicrobial Residues in Hospital Effluent and Rural Piped Water Supplies. In: Abstracts of the 107<sup>th</sup> General Meeting of the American Society of Microbiology, Toronto, May 21<sup>st</sup> - 25<sup>th</sup> 2007
44. **Page, D., Wall, B. & Crowe, M. (2006)** The Quality of Drinking Water in Ireland - A Report for the Year 2005. Environmental Protection Agency
45. **European Union (2006)** Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

46. **Department of Agriculture and Food (2003)** Report of Inter Departmental/Agency Committee on Disposal Options for Meat and Bone Meal
47. **Goss, M. & Richards, C. (2008)** Development of a Risk-Based Index for Source Water Protection Planning, which Supports the Reduction of Pathogens from Agricultural Activity Entering Water Resources. *J. Environ. Management*, (In-Press)
48. **Dowd, S.E., Gerba, C.P., Pepper, I.L. & Pillai, S.D. (2000)** Bioaerosol Transport Modeling and Risk Assessment in Relation to Biosolid Placement. *J. Environ. Qual.*, **29**, 343–348
49. **Lewis, D.L. & Gattie, D.K. (2002)** Pathogen Risks from Applying Sewage Sludge to Land. *Environ. Sci. Technol.*, **36**, 286A-293A
50. **Brooks, J.P., Gerba, C.P. & Pepper, I.L. (2004)** Biological Aerosol Emission, Fate and Transport from Municipal and Animal Wastes. *J. Residuals Sci. Technol.*, **1**, 15-18
51. **Brooks, J.P., Gerba, C.P. & Pepper, I.L. (2007)** Diversity of Aerosolised Bacteria during Land Application of Biosolids. *J. Appl. Microbiol.*, **103**, 1779–1790
52. **European Commission-Health and Consumer Protection Directorate General (2002)** Risk Profile on the Microbiological Contamination of Fruits and Vegetables Eaten Raw: Report of the Scientific Committee on Food
53. **Hill, J. (2005)** Recycling Biosolids to Pasture Based Animal Production Systems in Australia: A Review of Evidence on the Control of Potentially Toxic Metals and Persistent Organic Compounds Recycled to Agricultural land used for food production. *Australian J. Agri. Res.*, **56**, 753-773
54. **Environmental Protection Agency (2004)** Landspreading of Organic Waste - Guidance on Groundwater Vulnerability Assessment of Land
55. **Gleeson, T. (1996)** Runoff Risk Categories for Soils. In: *Agroclimatic Atlas of Ireland* (ed. Collins, J.F. & Cummins, T.F.), Agmet, Dublin, 97

56. **Lang, N.L. & Smith, S.R. (2007)** Influence of Soil Type, Moisture Content and Biosolids Application on the Fate of *Escherichia coli* in Agricultural Soil under Controlled Laboratory Conditions. *J. Appl. Microbiol.*, **103**, 2122-2131
57. **European Commission-Environment Directorate General (2001)** Evaluation of Sludge Treatments for Pathogen Reduction – Final Report. Office for Official Publications of the European Communities [http://ec.europa.eu/environment/waste/sludge/pdf/sludge\\_eval.pdf](http://ec.europa.eu/environment/waste/sludge/pdf/sludge_eval.pdf)
58. **Bolton, D.J., Byrne, C.M., Sheridan, J.J., McDowell, D.A. and Blair, I.S. (1999)** The Survival Characteristics of a Non-Toxicogenic Strain of *Escherichia coli* O157:H7. *J. Appl. Microbiol.*, **86**, 407–411
59. **Hutchison, M.L., Walters, L.D., Moore, A., Crooks, K.M. & Avery, S.M. (2004)** Effect of Length of Time Before Incorporation on Survival of Pathogenic Bacteria in Livestock Wastes Applied to Agricultural Soil. *Appl. Environ. Microbiol.*, **70**, 5111–5118
60. **Nicholson, F.A., Chambers, B.J., Moore, A., Nicholson, R.J. & Hickman, G. (2004)** Assessing and Managing the Risks of Pathogen Transfer from Livestock Manures into the Food Chain. *Water and Environment Journal*, **18**(3), 155-160
61. **Mukherjee, A., Cho, S., Scheftel, J., Jawahir, S., Smith, K. and Diez-Gonzalez, F. (2006)** Soil Survival of *Escherichia coli* O157:H7 Acquired by a Child from Garden Soil Recently Fertilised with Cattle Manure. *J. Appl. Microbiol.*, **101**, 429-436
62. **Fenlon, D.R., Ogden, I.D., Vinten, A. and Svoboda, I. (2000)** The Fate of *Escherichia coli* and *E. coli* O157 in Cattle Slurry after Application to Land. *J. Appl. Microbiol. Symp. Suppl.*, **88**, 149S–156S
63. **Nicholson, F.A., Hutchison, M.L., Smith, K.A., Keevil, C.W., Chambers, B.J. & Moore, A. (2000)** A Study on Farm Manure Applications to Agricultural Land and an Assessment of the Risks of Pathogen Transfer into the Food Chain. A Report to the Ministry of Agriculture, Fisheries and Food, United Kingdom
64. **Nicholson, F.A., Groves, S.J. & Chambers, B.J. (2005)** Pathogen Survival during Livestock Manure Storage and Following Land Application. *Bioresour. Technol.*, **96**, 135-143

65. **Avery, L.M., Hill, P., Killham, K. & Jones, D.L. (2004)** *Escherichia coli* O157 Survival Following the Surface and Sub-Surface Application of Human Pathogen Contaminated Organic Waste to Soil. *Soil Biology & Biochemistry*, **36**, 2101–2103
66. **Carton, O.T. & Magette, W. L. (1999)** Land Spreading of Animal manures, Farm Wastes and Non-Agricultural Organic Wastes. Part I. Manure (and other organic wastes) Management Guidelines for Intensive Agricultural Enterprises. Rural Environment Series No. 19. ARMIS 4026. Teagasc, Johnstown Castle, Wexford. 50 pp
67. **Lehane, J.J. (1991)** Machinery Developments for Safe Application of Wastes to Land. In: Proceedings of Environmental Impact Conference Management, Treatment and Land Spreading of Manures and Wastes, September 11 -12 1991, Johnstown Castle, Wexford. IEI, 22 Clyde Road, Dublin 4
68. **Westerman, P.W. & Bicudo, J.R. (2005)** Management Considerations for Organic Waste Use in Agriculture. *Bioresource Technol.*, **96**, 215-221
69. **Heinonen-Tanski, H., Mohaibes, M., Karinen, P. & Koivunen, J. (2006)** Methods to Reduce Pathogen Microorganisms in Manure. *Livestock Science*, **102**, 248–255
70. **European Union, (1996)** Council Directive 96/61/EC concerning Integrated Pollution Prevention and Control as amended by Directive 2003/35/EC, and Directive 2003/87/EC
71. **Department of Agriculture, Food and Rural Development (2001)** Good Farming Practice - Information Leaflet, 11 pp
72. **Maher, M.J., Magette, W.L., Smyth, S., Duggan, J., Dodd, V.J., Hennerty, M. J. & McCabe, T. (2000)** Managing Spent Mushroom Compost <http://www.teagasc.ie/research/reports/horticulture/4444/eopr4444.htm>
73. **Food Safety Authority of Ireland (2001)** Code of Practice for Food Safety in the Fresh Produce Supply Chain in Ireland - Code of Practice No. 4
74. **Department of the Environment & Department of Agriculture, Food and Forestry (1996)** Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates. 57 pp

75. **Department of Agriculture and Food (2004)** Minimum Specifications for Manure Pits and Dunsteads - Standard SI08, 15 pp
76. **Bassett, J. & McClure, P. (2008)** A Risk Assessment Approach for Fresh Fruits. *J. Appl. Microbiol.*, **104**(4), 925-943
77. **Doyle, M.P. & Erickson, M.C. (2008)** Summer Meeting 2007 – The Problems with Fresh Produce: An Overview. *J. Appl. Microbiol.*, **105**(2), 317-330
78. **Mukherjee, A., Speh, D. & Diez-Gonzalez, F. (2007)** Association of Farm Management Practices with Risk of *Escherichia coli* Contamination in Pre-Harvest Produce Grown in Minnesota and Wisconsin. *Int. J. Food Microbiol.*, **120**, 296–302
79. **European Food Safety Authority (2007)** Opinion of the Scientific Panel BIOHAZ on the Safety Vis-à-Vis Biological Risk of the Mesophilic Process of Biogas and Compost Treatment of Animal By-Products (ABPs). *The EFSA Journal*, **465**, 1-16
80. **Chilled Food Association (2002)** Microbiological Guidance for Produce Suppliers to Chilled Food Manufacturers
81. **Department of the Environment, Heritage and Local Government (2006)** National Strategy on Biodegradable Waste
82. **Hillman, J.P., Hill, J., Morgan, J.E., & Wilkinson, J.M. (2005)** Recycling of Sewage Sludge to Grassland: A Review of the Legislation to Control of the Localization and Accumulation of Potential Toxic Metals in Grazing Systems. *Grass & Forage Sci.*, **58**, 101-111
83. **Chang, A.C., Pan, G., Page, A.L. & Asano, T. (2002)** Developing Human Health-related Chemical Guidelines for Reclaimed Water and Sewage Sludge Applications in Agriculture. Prepared for the World Health Organisation
84. **Kowal, N.E. (1985)** Health Effects of Land Application of Municipal Sludge. EPA/600/1-85/015. 1985. United States Environmental Protection Agency - Toxicology and Microbiology Division Health Effects Research Laboratory Cincinnati, Ohio 45268

85. **Clenaghan, C., O'Neill, N. & Page, D. (2006)** Dangerous Substances Regulations National Implementation Report, 2005 - Under the Water Quality (Dangerous Substances) Regulations, 2001 (S.I. No. 12 of 2001). Environmental Protection Agency, Ireland
86. **Lazzari, L., Sperti, L., Bertin, P. & Povoni, B. (2000)** Correlation between Inorganic (heavy metals) and Organic (PCB'S and PAH's) Micropollutants during Sewage Sludge Composting Process. *Chemosphere*, **41**, 427-435
87. **Amlinger, F., Pollak, M. & Favoino, E. (2004)** Heavy Metals and Organic Compounds from Wastes Used as Organic Fertilisers [http://ec.europa.eu/environment/waste/compost/pdf/hm\\_finalreport.pdf](http://ec.europa.eu/environment/waste/compost/pdf/hm_finalreport.pdf)
88. **Hoyos, S.E., Juarez, J.V., Ramonet, C.A., Lopez, J.C., Rios, A.A. & Uribe, E.G. (2002)** Aerobic Thermophilic Composting of Waste Sludge from Gelatin-Grenetine Industry. *Resources, Conservation & Recycling*, **34**, 161-173
89. **European Commission (2005)** Regulation (EC) No 2073/2005 on Microbiological Criteria for Foodstuffs
90. **Food Standards Agency (2005)** Managing Farm Manures for Food Safety (Final Draft) - Guidelines for Growers to Reduce the Risks of Microbiological Contamination of Ready to Eat Crops <http://www.food.gov.uk/multimedia/pdfs/manguidfinaldraft.pdf>
91. **Department of the Environment (2001)** Code of Practice for Agricultural Use of Sewage Sludge <http://www.defra.gov.uk/environment/water/quality/sewage/sludge-report.pdf>
92. **Institute of Food Technologists (2002)** Expert Report on Emerging Microbiological Food Safety Issues-Implications for Control in the 21<sup>st</sup> Century
93. **Food Safety Authority of Ireland (2005)** Report on Zoonoses in Ireland – 2002 & 2003
94. **European Food Safety Authority (2006)** Trends and Sources of Zoonoses, Zoonotic Agents and Antimicrobial Resistance in the European Union in 2004
95. **Food Safety Authority of Ireland (2006)** Report on Zoonoses in Ireland – 2004

96. **European Food Safety Authority (2007)** The Community Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents, Antimicrobial Resistance and Foodborne Outbreaks in the European Union in 2005
97. **Health Service Executive (2007)** Weekly Infectious Disease Report - Week 38, (Notification Period: 16/09/2007 - 22/09/2007). A Report by the Health Protection Surveillance Centre <http://www.ndsc.ie/hpsc/NotifiableDiseases/WeeklyIDReport/File,1425,en.pdf>
98. **Health Protection Surveillance Centre (2005)** Annual Report, 2004
99. **Centers for Disease Control and Prevention (2001)** Norwalk-like Viruses: Public Health Consequences and Outbreak Management. *Morbidity and Mortality Weekly Report*, **50**(RR-9), 1-17
100. **Duffy, G. (2003)** Verocytotoxicogenic *Escherichia coli* in animal faeces, manures and slurries. *J. Appl. Microbiol.*, **94**(S1), 94-103
101. **Beuchat, L.R. (2002)** Ecological Factors Influencing Survival and Growth of Human Pathogens on Raw Fruit and Vegetables. *Microbes & Infection*, **4**, 413-423
102. **Park, S.W., Worobo, R.W. & Durst, R.A (1999)** *Escherichia coli* O157: H7 as an Emerging Foodborne Pathogen: A Literature Review. *Crit. Rev Food Sci. Nut.*, **39**, 481-502
103. **Collins, J.D. & Wall, P.G. (2004)** Food Safety and Animal Production Systems: Controlling Zoonoses at Farm Level. *Rev. Sci. Tech. Off. Int. Epiz.*, **23**(2), 685-700
104. **Food Safety Authority of Ireland (2006)** Safety of Potable Water in Ireland
105. **Health Service Executive (2005)** Cryptosporidiosis Outbreak in Carlow Town and Environs 2005. Health Service Executive, South Eastern Area
106. **Lucey, J. (2006)** Water Quality in Ireland 2005 - Key Indicators of the Aquatic Environment. Environmental Protection Agency

107. **Food Safety Authority of Ireland (1999)** The Prevention of *Escherichia coli* O157:H7 Infection: A Shared Responsibility
108. **Mara, D. & Cairncross, S. (1989)** Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture. World Health Organization
109. **Strauch D. (1991)** Survival of pathogenic micro-organisms and parasites in excreta, manure and sewage sludge. *Rev. Sci. Tech. Off. Int. Epiz.*, **10**(3), 813 – 846
110. **Deportes, I., Benoit-Guyod, J.L., Zmirou, D. & Bouvier, M.C. (1998)** Microbial Disinfection Capacity of Municipal Solid Waste Composting. *J. Appl. Microbiol.*, **85**, 238-246
111. **Dumontet, S., Dinel, H. & Baloda, S.B. (1999)** Pathogen Reduction by Composting and other Biological Treatments - A Review. *Biol. Agri. & Hort.*, **16**(4), 409-430
112. **Chang A.C., Pan G., Page A.L., & Asano T. (2001)** Guidelines for Reclaimed Water and Sewage Sludge Applications in Agriculture. World Health Organization
113. **European Commission, Joint Research Centre (2001)** Organic contaminants in sewage sludge for agricultural use. Project Coordinators: European Commission, Joint Research Centre, Institute for Environment and Sustainability Soil and Waste Unit, H. Langenkamp and P. Part
114. **European Commission-Directorate-General for the Environment (2006)** Biocidal Products Directive (98/8/EC) <http://ec.europa.eu/environment/biocides/index.htm>
115. **European Commission (2006)** Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs
116. **O’Keeffe, M. & Coen, K. (2006)** National Food Residue Database Report 2005. Food Safety Department, The National Food Centre, Teagasc, Dunsinea, Ashtown, Dublin 15
117. **World Health Organization (2004)** Guidelines for Drinking Water Quality, (3rd Edition), Volume I – Recommendations

118. **Greenwood, D.J. & Hunt, J. (1986)** Effect of nitrogen fertilizer on the nitrate contents of field vegetables grown in Britain. *J. Sci. Food Agr.*, **37**, 373-383
119. **World Health Organization (2003)** Emerging Issues in Water and Infectious Diseases
120. **Beck, A.J., Johnson, D.L. & Jones, K.C. (1996)** The Form and Bioavailability of Non-Ionic Chemicals in Sewage Sludge-Amended Agricultural Soils. *Sci. Total Environ.*, **185**, 125-149
121. **Deportes, I., Benoitguyod, J.L. & Zmirou, D. (1995)** Hazard to Man and the Environment Posed by the Use of Urban Waste Compost: A Review. *Sci. Total Environ.*, **172**, 197-222
122. **European Soil Bureau-Scientific Committee (1999)** Heavy Metals (Trace Elements) and Organic Matter Content of European Soils - A Feasibility Study
123. **Walker, J., Knight, L. & Stein, L. (1994)** A Plain English Guide to the EPA Part 503 Biosolids Rule. EPA/832/R-93/003
124. **United States Code of Federal Regulations (2004)** Title 40: Protection of Environment, Chapter 1: Environmental Protection Agency, Part 503: Standards for the Use or Disposal of Sewage Sludge
125. **Walker, J. & Stein, L. (1995)** A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule. EPA/832-B-93-005. US Environmental Protection Agency, Washington, DC
126. **Environment Protection Agency-Scotland (1998)** Strategic Review of Organic Waste Spread on Land
127. **Rzezutka, A. & Cook, N. (2004)** Survival of Human Enteric Viruses in the Environment and Food. *FEMS Microbiol. Revs.*, **28**, 441-453
128. **Angulo, F.J., Nargund, V.N. & Chiller, T.C. (2004)** Evidence of an Association Between Use of Anti-microbial Agents in Food Animals and Anti-microbial Resistance Among Bacteria Isolated from Humans and the Human Health Consequences of Such Resistance. *J. Vet. Med.*, **B51**, 374-379

129. **Swann, M. M., Blaxter, K. L., Field, H. I., Howie, J. W., Lucas, A. M., Millar, E. L. M., Murdoch, J. C., Parsons, J. H., & White, E. G., (1968)** Joint Committee on the Use of Antibiotics in Animal Husbandry and Veterinary Medicine. Her Majesty's Stationery Office, London
130. **Sahlstrom, L., de Jong, B. & Aspan, A. (2006)** *Salmonella* Isolated in Sewage Sludge Traced Back to Human Cases of Salmonellosis. *L. Appl. Microbiol.*, **43**, 46-52
131. **Espigares, E., Bueno, A., Espigares, M. & Galvez, R. (2006)** Isolation of *Salmonella* Serotypes in Wastewater and Effluent: Effect of Treatment and Potential Risk. *Int. J. Hyg. Environ. Health*, **209**, 103-107
132. **World Health Organization (2006)** Review of Latest Available Evidence on Risks to Human Health through Potential Transmission of Avian Influenza (H5N1) Through Water and Sewage (Last Updated 30/05/2006)
133. **Department of Agriculture and Food (2006)** Information Booklet for Registered Poultry Flockowners
134. **Bohnel, H. and Lube, K. (2000)** *Clostridium botulinum* and Bio-compost. A Contribution to the Analysis of Potential Health Hazards Caused by Bio-Waste Recycling. *J. Vet. Med. B.*, **47** (10), 785-796
135. **DG Environment (2008)** Sewage Sludge  
<http://ec.europa.eu/environment/waste/sludge/index.htm>
136. **Avery, L.M., Killham, K. & Jones D.L. (2005)** Survival of *Escherichia coli* O157:H7 in organic wastes destined for land application. *J. Appl. Microbiol.*, **98**(4), 814-822
137. **Ministry of the Environment, Japan (2002)** Minamata Disease The History and Measures.  
<http://www.env.go.jp/en/chemi/hs/minamata2002/>
138. **Swedish Chemicals Inspectorate & Environmental Protection Agency (2004)** Perfluorooctane Sulfonate (PFOS). Dossier Prepared in Support for a Nomination of PFOS to the UN-ECE LRTAP Protocol and the Stockholm Convention

139. **Environmental Protection Agency (2000)** Wastewater Treatment Manuals -Treatment Systems for Single Houses. Currently being revised as Wastewater as Treatment System for Single Houses with a PE less 10 - Consultation Draft 2007
140. **Gill, L., Ó Súilleabháin, C., Johnston, P. & Misstear, B. (2005)** An Investigation into the Performance of Subsoils and Stratified Sand Filters for the Treatment of Wastewater from On-site Systems (2001-MS-15-M1) Synthesis Report. Prepared for the Environmental Protection Agency by the Environmental Engineering Group, Trinity College Dublin
141. **Department of the Environment and Local Government, Environmental Protection Agency & Geological Survey of Ireland (1999)** Groundwater Protection Schemes. DoELG/ EPA/GSI Joint Publication, 24 pp
142. **Central Statistics Office (2002)** Census 2002, Volume 13 – Housing. [http://www.cso.ie/census/documents/vol13\\_entire.pdf](http://www.cso.ie/census/documents/vol13_entire.pdf)
143. **Irish Government (2006)** Planning and Development Regulations, 2001 to 2006 - S.I. No. 685 of 2006
144. **Department of the Environment Heritage and Local Government (2005)** Building Regulations 1997, Technical Guidance Document H – Drainage and Waste Water Disposal
145. **Irish Government (2001)** Waste Management (Collection Permit) Regulations, 2001 - S.I. No. 402/2001
146. **Oberdörster, G., Stone, V. & Donaldson, K. (2007)** Toxicology of Nanoparticles: A Historical Perspective. *Nanotoxicology*, 1(1), 2-25
147. **Kelly, W.R. & Collins J.D. (1978)** The Potential Health Significance of Antibiotic-Resistant *Escherichia coli* and other Infectious Agents Present in Animal Effluents. Animal and Human Health Hazards Associated with the Utilisation of Animal Effluents. A Workshop in the EEC Programme of Coordination of Research on Effluents - Sponsored by the European Communities Directorate General for Agriculture Coordination of Agricultural Research, 172-188

148. **Jones, P.A & Martin, M (2003)** A Review of the Literature on the Occurrence and Survival of Pathogens of Animals and Humans in Green Compost. The Waste and Resources Action Programme (WRAP)
149. **Gerba, C.P., Pepper, I.L. & Whitehead, L.F. (2002)** A Risk Assessment of Emerging Pathogens of Concern in the Land Application of Biosolids. *Water Sci & Technol.*, **46**(10), 225-230
150. **Stanfield, G. & Gale, P. (2002)** Assessment of the Risks to Food Safety Associated with the Spreading of Animal Manure and Abattoir Waste on Agricultural land used for food production - Final Report (B17002) to the Food Standards Agency
151. **European Food Safety Authority (2006)** Opinion of the Scientific Panel on Biological Hazards on the Request from the Commission Related to the Public Health Risks of Feeding Farmed Animals With Ready-to-Use Dairy Products Without Further Treatment. *The EFSA Journal*, **340**, 1-58
152. **Guzman, C., Jofre, J., Montemayor, M. & Lucena, F. (2007)** Occurrence and Levels of Indicators and Selected Pathogens in Different Sludges and Biosolids. *J. Appl. Microbiol.*, **103**(6), 2420-2429
153. **Gerba, C.P. & Smith, J.E. (2005)** Sources of Pathogenic Microorganisms and their Fate During Land Application of Wastes. *J. Environ. Qual.*, **34**, 42-48
154. **Holme, R. (2003)** Drinking Water Contamination in Walkerton, Ontario: Positive Resolutions from a Tragic Event. *Water Sci. Technol.*, **47**, 1-6
155. **European Food Safety Authority (2005)** Opinion of the Scientific Panel on Biological Hazards of the European Food Safety Authority on the Biological Safety of Heat Treatment of Manure. *The EFSA Journal*, **265**, 1-16
156. **Dawson, D. (2005)** Foodborne Protozoan Parasites. *Int. J. Food Microbiol.*, **103**, 207-227
157. **National Disease Surveillance Centre (2004)** Report of Waterborne Cryptosporidiosis Subcommittee of the Scientific Advisory Committee

158. **Cook, J.C., Gilbert, R.E., Buffolano, W., Zufferey, J., Petersen, E., Jenum, P.A. Foulon, W., Semprini, A.E. & Dunn, D.T. (2000)** Sources of Toxoplasma Infection in Pregnant Women: European Multicentre Case- Control Study. *British Medical Journal*, **321**(7254), 142-147
159. **Taormina, P.J., Beuchat, L.R. & Slutsker, L. (1999)** Infections Associated with Eating Seed Sprouts: An International Concern. *Emerging Infectious Diseases* **5**, 626-634
160. **Buck, J.W., Walcott, R. & Beuchat, L.R. (2003)** Recent Trends in Microbiological Safety of Fruits and Vegetables. *Plant Health Progress*
161. **United States Food and Drug Administration (2006)** Nationwide *E. coli* O157:H7 Outbreak: Questions & Answers <http://www.cfsan.fda.gov/~dms/spinacqa.html>
162. **Hjertqvist, M., Johansson, A., Svensson, N., Åbom, P.E., Magnusson, C., Olsson, M., Hedlund, K.O. & Andersson, Y. (2006)** Four Outbreaks of Norovirus Gastroenteritis after Consuming Raspberries, Sweden, June- August 2006. *Eurosurveillance Weekly*, **11**(9)
163. **Beuchat, L.R. (2006)** Vectors and Conditions for Pre-Harvest Contamination of Fruits and Vegetables with Pathogens Capable of Causing Enteric Diseases. *The British Food Journal*, **108**(1), 38-53
164. **Garvey, P., McKeown, P., Carroll, A. & McNamara, E. (2006)** Epidemiology of Verotoxigenic *E. coli* in Ireland, 2005. *EPI-Insight*, **7**(9), 2-3
165. **Environmental Protection Agency (2008)** Drinking Water Regulations Guidance Booklet No. 4 - Risk Screening Methodology for *Cryptosporidium*
166. **Sair, A.I., D' Souza, D.H. and Jaykus, L.A. (2002)** Human Enteric Viruses as Causes of Foodborne Disease. *Comp. Revs. Food Sci & Food Safety*, **1**, 73-89
167. **Cole, D.J., Hill, V.R., Humenik, F.J., Sobsey, M.D. (1999)** Health, Safety, and Environmental Concerns of Farm Animal Waste. *Occup Med.*, **14**(2), 423-48

168. **Armon, R., Gold, D., Brodsky, M. & Oron, G. (2002)** Surface and Subsurface Irrigation with Effluents of Different Qualities and Presence of *Cryptosporidium* Oocysts in Soil and on Crops. *Water Sci. Technol.*, **46**(3), 115-22
169. **Dumontet, S., Scopa, A., Kerje, S. & Krovacek, K. (2001)** The Importance of Pathogenic Organisms in Sewage and Sewage Sludge. *J. Air & Waste Manage. Assoc.* **51**, 848-860
170. **Tyrrel, S.F. & Quinton, J.N. (2003)** Overland Flow Transport of Pathogens from Agricultural land used for food production Receiving Faecal Wastes. *J. Appl. Microbiol.*, **94**(S1), 87-93
171. **Moce-Llivina, L., Muniesa, M., Pimenta-Vale, H., Lucena, F. & Jofre, J. (2003)** Survival of Bacterial Indicator Species and Bacteriophages after Thermal Treatment of Sludge and Sewage. *Appl. Environ. Microbiol.*, **69**(3), 1452-1456
172. **Griffin, D.W., Donaldson, K.A., Paul, J.H. & Rose, J.B. (2003)** Pathogenic Human Viruses in Coastal Waters. *Clin. Microbiol. Revs.*, **16**(1), 129-143
173. **Lees, D. (2000)** Viruses and Bivalve Shellfish. *Int. J. Food. Microbiol.*, **59**(1-2), 81-116
174. **McEvoy, J.M., Moriarty, E.M., Duffy, G. & Sheridan, J.J. (2003)** The Role of Beef in the Transmission of *Cryptosporidium parvum*. Teagasc, The National Food Centre
175. **Duffy, G., & Moriarty, E.M. (2003)** *Cryptosporidium* and its Potential as a Foodborne Pathogen. *Anim. Health Res. Rev.*, **4**(2), 95-107
176. **Schets, F.M., H.H.J.L. van den Berg, Engels, G.B., Lodder, W.J. de Roda, Husman, A.M. (2007)** *Cryptosporidium* and *Giardia* in Commercial and Non-Commercial Oysters (*Crassostrea gigas*) and Water from the Oosterschelde, the Netherlands. *Int. J Food Micrbiol.*, **113**, 189-194
177. **Borchardt, M.A., Chyou, P.H., De Vires, E.O. & Belongia, E.A. (2003)** Septic system density and infectious diarrhea in a defined population of children. *Environ. Health Perspect.*, **111**(5), 742-748

178. **Beller, M., Ellis, A., Lee, S.H., Drebot, M.A., Jenkerson, S.A., Funk, E., Sobsey, M.D., Simmons, O.D., Monroe, S.S., Ando, T., Noel, J., Petric, M., Middaugh, J.P. & Spika, J.S. (1997)** Outbreak of Viral Gastroenteritis due to a Contaminated Well- International consequences. *J. Am. Med. Assoc.*, **278**, 563-568
179. **Food Safety Authority of Ireland (2003)** Annual Report, 2002
180. **Bosch, A., Sánchez, G., Leguyader, F., Vanaclocha, H., Haugarreau, L. and Pintó, R. M. (2001)** Human Enteric Viruses in Coquina Clams Associated with a Large Hepatitis A Outbreak. *Water Sci. & Technol.*, **43**, 61-65
181. **Christensen, B.F., Lees, D., Henshilwood, K., Bjergskov, T. & Green, J. (1998)** Human Enteric Viruses in Oysters Causing a Large Outbreak of Human Food Borne Infection in 1996/97. *J Shellfish Research*, **17**, 1633- 1635
182. **Perrett, K. & Kudesia, G. (1995)** Gastroenteritis Associated with Oysters. *Communicable Disease Report*, **5**, 141-156
183. **Dubois, E., Leguyader, F., Haugarreau, L., Kopecka, H., Cormier, M., Pommepuy, M. (1997)** Molecular Epidemiological Survey of Rotavirus in Sewage by Reverse Transcriptase Seminested PCR and Restriction Length Polymorphism Assay. *Appl. Environ. Microbiol.* **63**, 1794-1800
184. **Meleg, E., Jakab, F., Kocsis, B., Banyai, K., Meleg, B. and Szucs, G. (2006)** Human Astroviruses in Raw Sewage Samples in Hungary. *J. Appl. Microbiol.*, **101**, 1123-1129
185. **Fransen, N.G., van den Elzen, A.M.G., Urlings, B.A.P. & Bijker, P.G.H. (1996)** Pathogenic Microorganisms in Slaughterhouse Sludge – A Survey. *Int. J. Food Microbiol.*, **33**, 245–256
186. **Linklater, K.A., Graham, M.M. & Sharp, J.C. (1985)** Salmonellae in Sewage Sludge and Abattoir Effluent in South-East Scotland. *J. of Hygiene*, **94**(3), 301–307
187. **Pepperell, R., Massanet-Nicolau, J., Allen, M. & Buncic, S. (2003)** Potential for Spread of Some Bacterial and Protozoan Pathogens via Abattoir Waste Applied on Agricultural land used for food production. *Food Protection Trends*, **23**, 315-325

188. **Reinoso, R., Becares, E. & Smith, H.V. (2008)** Effect of Various Environmental Factors on the Viability of *Cryptosporidium parvum* Oocysts. *J. Appl. Microbiol.*, **104**(4), 980-986
189. **Gale, P. & Stanfield, G. (2001)** Towards a Quantitative Risk Assessment for BSE in Sewage Sludge. *J. Appl. Microbiol.*, **91**(3), 563–569
190. **European Food Safety Authority (2004)** Opinion of the Scientific Panel on Biological Hazards of the European Food Safety Authority on the Safety vis-à-vis Biological Risk Including TSEs of the Application on Pastureland of Organic Fertilisers and Soil Improvers. *The EFSA Journal*, **40**, 1-10
191. **European Food Safety Authority (2005)** Opinion of the Scientific Panel on Biological Hazards of the European Food Safety Authority on the Safety vis-à-vis Biological Risks of Biogas and Compost Treatment Standards of Animal by-Products (ABP). *The EFSA Journal*, **264**, 1-21
192. **Gale, P. (2007)** The Prion/Lipid Hypothesis – Further Evidence to Support the Molecular Basis for Transmissible Spongiform Encephalopathy Risk Assessment. *J. Appl. Microbiol.*, **103**(6), 2033-2045
193. **Harrison, E.Z., Oakes, S.R., Hysell, M. & Hay, A. (2006)** Organic Chemicals in Sewage Sludges. *Sci Total Environ.*, **367**, 481–497
194. **Barron, L., Tobin, J. & Paull, B. (2008)** Multi-Residue Determination of Pharmaceuticals in Sludge and Sludge Enriched Soils using Pressurised Liquid Extraction, Solid Phase Extraction and Liquid Chromatography with Tandem Mass Spectrometry. *J. Environ. Monitoring*, **10**, 353-361
195. **Department of Agriculture and Food (2004)** Pesticide Residues in Food. Dublin Stationary Office, ISBN 0-7557-7380-2
196. **Hallig-Sorensen B., Nors Nielsen S., Lanzky P. F., Ingerslev F., Holten Lutzhoft H. C., & Jorgensen S.E., (1998)** Occurrence, Fate and Effects of Pharmaceutical Substances in the Environment – A Review. *Chemosphere*, **36**(2), 357 – 93
197. **Carton, O.T., Culleton, N., Coulter, B., Schulte, R., Lalar, S., Plunkett, M. & Brennan, F. (2007)** Discussion Note Prepared for the Teagasc Research Leadership Team on the Application of Biosolids and Industrial Organic Materials (BIOMS) to Agricultural land used for food production (Draft 3) Teagasc

198. **United Kingdom Water Industry Research Limited (2007)** Effects of Sewage Sludge Applications to Agricultural Soils on Soil Microbial Activity and the Implications for Agricultural Productivity and Long-Term Soil Fertility: Phase III [http://randd.defra.gov.uk/Document.aspx?Document=SP0130\\_6505\\_FRP.pdf](http://randd.defra.gov.uk/Document.aspx?Document=SP0130_6505_FRP.pdf)
199. **European Chemicals Bureau (2005)** Risk Assessment: bis(2-ethylhexyl) phthalate (DEHP) - CAS#: 117-81-7, EINECS#: 204-211-0. [http://ecb.jrc.it/DOCUMENTS/Existing-Chemicals/RISK\\_ASSESSMENT/DRAFT/R042\\_0310\\_env\\_hh\\_combined.pdf](http://ecb.jrc.it/DOCUMENTS/Existing-Chemicals/RISK_ASSESSMENT/DRAFT/R042_0310_env_hh_combined.pdf)
200. **Peters, R.J.B. (2006)** Man-Made Chemicals in Food Products. TNO Report 2006-A-R0095/B Version 2 [http://assets.panda.org/downloads/tno\\_report.pdf](http://assets.panda.org/downloads/tno_report.pdf)
201. **Pain, B. & Menzi, H. (2003)** Glossary of Terms on Livestock Manure Management. Recycling Agricultural, Municipal and Industrial Residues in Agriculture Network (RAMIRAN)
202. **European Union (1998)** Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998, Concerning the Placing of Biocidal Products on the Market
203. **Lepeuple, A.S., Gaval, G., Jovic, M. and de Roubin, M.R. (2004)** Literature Review on Levels of Pathogens and Their Abatement in Sludge's, Soil and Treated Biowaste. HORIZONTAL – 6, WP3: Hygienic Parameters
204. **European Union (2004)** Corrigendum to Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. Official Journal of the European Union L 139 of 30 April 2004
205. **European Commission (1993)** Regulation (EEC) No 315/93/EEC laying down Community procedures for contaminants in food
206. **European Union (2000)** Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, establishing a framework for the Community action in the field of water policy
207. **European Union (1975)** Directive 75/442/EEC of 15 July 1975 on Waste

208. **European Union (1991)** Directive 91/156/EEC of 18 March 1991 amending Directive 75/442/EEC on Waste
209. **European Union (1991)** Directive 91/689/EEC of 12 December 1991 on Hazardous Waste
210. **Irish Government (1981)** Dumping at Sea Act, 1981. S.I. No. 268 of 1981 amended by Dumping at Sea Act, 1996. S.I. No. 14 of 1996 and further amended by Dumping at Sea (Amendment) Act 2004. S.I. No. 35 of 2004
211. **European Integrated Pollution Prevention and Control (IPPC) Bureau (2003)** <http://eippcb.jrc.es/>
212. **European Commission-Environment Directorate General (2006)** Summary of Directive 96/61/EC Concerning Integrated Pollution Prevention and Control. <http://ec.europa.eu/environment/ippc/index.htm>
213. **Hyde, B.P., Carton, O.T., Murphy, W.E. & Lenehan, J.J. (2006)** Manure Management Practices on Irish Livestock Farms. *Proceedings of the Agricultural Research Forum*, 67
214. **Hyde, B. P. & Carton O.T. (2006)** Manure Management Facilities on Farms and their Relevance to Efficient Nutrient Use. *Fertilizer Association of Ireland Proceedings*, 42, (in press)
215. **Issue Tracker-Food Safety (2007)** Eamonn Bates Europe, January 2007, Page 12
216. **Central Statistics Office (2002)** Census of Agriculture Main Results, June 2000
217. **Teagasc (2004)** National Advisory Programmes, 2004 <http://www.teagasc.ie/publications/2004/20040303/index.htm>
218. **Teagasc (2006)** World Agricultural Trade Reform and the WTO Doha Development Round: Analysis of the Impact on EU and Irish Agriculture. Teagasc Economy Research Centre, Athenry, Galway, Ireland. 79 pp
219. **International Maritime Organization (2000)** Specific Guidelines for Assessment of Dredged Material <http://www.eugris.info/displayresource.asp?ResourceID=5545&Cat=document>

220. **Irish Government (1945)** The Arterial Drainage Act, 1945. S.I. No. 3 of 1945
221. **Environmental Protection Agency (2000)** Management of Contaminated Harbour Sediments in Guam [http://www.guamepa.govguam.net/programs/epr/sediment\\_report.pdf](http://www.guamepa.govguam.net/programs/epr/sediment_report.pdf)
222. **Department of Agriculture, Food and Rural Development (2000)** Report of the Investigation into the Presence and Influence of Lead in the Silvermines Area of County Tipperary
223. **Spillman, S.K., Traub F., Schyzer M., & Wyler, R. (1987)** Inactivation of Animal Viruses during sewage Sludge Treatment. *Appl. Environ. Microbiol.*, **53**, 2077-2081
224. **Garrec, N., Picard-Bonnaud, F. & Pourcher, A.M. (2003)** Occurrence of *Listeria* spp. and *L. monocytogenes* in Sewage Sludge Used for Land Application - Effect of Dewatering, Liming and Storage in Tank on Survival of *Listeria* species. *FEMS Immunology & Medical Microbiol.*, **35**(3), 275-283
225. **Ward R. L. & Ashley, C.S. (1977)** Inactivation of Enteric Viruses in Wastewater sludge through Dewatering by Evaporation. *Appl. Environ. Microbiol.*, **34**, 564-570
226. **Hutchison, M.L., Walters, L.D., Moore, A. & Avery, S.M. (2005)** Declines of Zoonotic Agents in Liquid Livestock Wastes Stored in Batches On-Farm. *J. Appl. Microbiol.*, **99**, 58-65
227. **European Commission DG Health and Consumer Protection (2002)** Opinion of the Scientific Committee on Veterinary Measures Relating to Public Health on Norwalk like Viruses
228. **World Health Organization (2006)** Avian Influenza (Bird Flu) - Fact Sheet. [http://www.who.int/mediacentre/factsheets/avian\\_influenza/en/print.html](http://www.who.int/mediacentre/factsheets/avian_influenza/en/print.html)
229. **Costantini, V., Loisy, F., Joens, L., Le Guyader, F.S. & Saif, L.J. (2006)** Human and Animal Enteric Caliciviruses in Oysters from Different Coastal Regions of the United States. *Appl. Environ. Microbiol.*, **72**(3), 1800-1809
230. **Fankhauser, R.L., Noel, J.S., Monroe, S. S., Ando & Glass, R.I. (1998)** Molecular Epidemiology of "Norwalk-Like Virus" in Outbreaks of Gastroenteritis in the United States. *J. Infect. Dis.*, **178**, 1571-1578

231. **Schaub, S.A. & Oshiro, R.K. (2000)** Public Health Concerns about Caliciviruses as Waterborne Contaminants. *J. Infect. Dis.*, **181**, S374-S380
232. **Tsai, Y. L., Tran, B., Sangermano, L.R. & Palmer C.J. (1994)** Detection of Poliovirus, Hepatitis A Virus, and Rotavirus from Sewage and Ocean Water by Triplex Reverse Transcription-PCR. *Appl. Environ. Microbiol.*, **60**, 2400-2407
233. **Girones, R., Puig, M. Allard, A., Lucena, F., Wadell, G. & Jofre, J. (1995)** Detection of Adenovirus and Enterovirus by PCR Amplification in Polluted Waters. *Water Sci. Technol.*, **31**, 351-357
234. **Pina, S., Puig, M., Lucena, F., Jofre, J. & Girones, R. (1998)** Viral Pollution in the Environment and in Shellfish – Human Adenovirus Detection in the Environment and Shellfish as an Index of Human Viruses. *Appl. Environ. Microbiol.*, **64**, 3376-3382
235. **Bishop, R.F. (1996)** Natural History of Human Rotavirus infection. *Arch. Virol.*, **12**, 119-128
236. **Anon (1998)** Outbreaks of Gastroenteritis in England and Wales Associated with Shellfish: 1996 and 1997. *Comm. Dis. Rep CDR Wkly.*, **8**(3), 21-24
237. **Magariños, H. (2000)** Producción Higiénica de la Leche. Producción y Servicios Incorporados S.A. , Calzada Mateo Flores 5-55, Zona 3 de Mixto, Guatemala
238. **Abolos, P. & Retamal, P. (2004)** Tuberculosis: a Re-Emerging Disease? *O.I.E. Scientific and Technical Review*, **23**, 583-594
239. **O'Reilly, L.M. & Daborn, C.J. (1995)** The Epidemiology of *Mycobacterium bovis* Infections in Animals and Man: A Review. *Tubercle and Lung Disease*, **76**(Suppl 1), 1-46
240. **Avery, S.M., Moore, A., & Hutchison, M.L. (2004)** Fate of *Escherichia coli* originating from livestock faeces deposited directly onto pasture. *Let. Appl. Microbiol.*, **38**, 355-359
241. **O'Brien, S. B., Duffy, G., Carney, E., Sheridan, J. J., McDowell, D. A. & Blair, I. S. (2005)** Prevalence and Numbers of *Escherichia coli* O157 on Bovine Hide at a Beef Slaughter Plant. *J. Food Prot.*, **68**, 660-665

242. **Lenehan, M., O'Brien, S., Crowley, H., Kinsella, K., Sweeney, T., Byrne, C., Sheridan, J.J. & Duffy, G. (2006)** The Prevalence and Virulence Profile of *Escherichia coli* O157:H7 in Sheep and Pigs Presented for Slaughter in the Republic of Ireland. Conference Proceedings, VTEC 2006 Melbourne, Australia, October 30<sup>th</sup> to November 3<sup>rd</sup> (in press)
243. **Hilborn, E.D., Mshar, P.A., Fiorentino, T.R., Dembek, Z.F., Barrett, T.J., Howard, R.T. & Cartter, M.L., (2000)** An Outbreak of *Escherichia coli* O157: H7 Infections and Haemolytic Uraemic Syndrome Associated with Consumption of Unpasteurised Apple Cider. *Epidemiol. Infect.*, **124**, 31–36
244. **Rangel, J.M., Sparling, P.H., Crowe, C., Griffin, P.M. & Swerdlow, D.L., (2005)** Epidemiology of *Escherichia coli* O157:H7 outbreaks, United States, 1982–2002. *Emerg. Infect. Dis.*, **11**, 603–609
245. **Maule, A. (2000)** Survival of Verocytotoxigenic *Escherichia coli* O157 in Soil, Water and on Surfaces. *Symposium Series for Society of Applied Microbiology*, **29**, 71S-78S
246. **Scott, L., McGee, P., Sheridan, J.J., Earley, B. & Leonard, N. (2006)** A Comparison of the Survival in Faeces and Water of *Escherichia coli* O157:H7 Grown Under Laboratory Conditions or Obtained from Cattle Faeces. *J. Food Prot.*, **69**(1), 6-11
247. **McGee, P., Bolton D.J., Sheridan J.J., Earley, B. & Leonard, N. (2001)** The survival of *Escherichia coli* O157:H7 in slurry from cattle fed different diets. *Let. Appl. Microbiol.*, **32**(3), 152-155
248. **Fukushima, H., Hoshina, K. & Gomyoda, M. (1999)** Long-term survival of shiga toxin-producing *Escherichia coli* O26, O111, and O157 in bovine faeces. *Appl. Environ. Microbiol.*, **65**(11), 5177-5181
249. **Kudva, IT, Blanch, K. & Hovde, C.J. (1998)** Analysis of *Escherichia coli* O157:H7 survival in ovine or bovine manure and manure slurry. *Appl. Environ. Microbiol.*, **64**(9), 3166-3174
250. **Himathongkham, S., Riemann, H., Bahari, S., Nuanualsuwan, S., Kass, P. & Cliver, D.O. (2000)** Survival of *Salmonella typhimurium* and *Escherichia coli* O157:H7 in Poultry Manure and Manure Slurry at Sublethal Temperatures. *Avian Disease*, **44**(4), 853-860

251. **Cizek, A., Literak, I. & Scheer, P. (2000)** Survival of *Escherichia coli* O157 in Faeces of Experimentally Infected Rats and Domestic Pigeons. *Let. Appl. Microbiol.*, **31**(5), 349-352
252. **Himathongkham, S. & Riemann, H. (1999)** Destruction of *Salmonella typhimurium*, *Escherichia coli* O157:H7 and *Listeria monocytogenes* in chicken manure by drying and/or gassing with ammonia. *FEMS Microbiol. Let.*, **171**, 179-182
253. **Lung, A.J., Lin, C.M., Kim, J.M., Marshall, M.R., Norstedt, R., Thompson, P. & Wei, C.I. (2001)** Destruction of *Escherichia coli* O157:H7 and *Salmonella enteritidis* in cow manure composting. *J. Food Prot.*, **64**(9), 1309-1314
254. **Bujoczek, G, Reiners, R.S, & Olaszkiwicz, J.A. (2001)** Abiotic factors affecting inactivation of pathogens in sludge. *Water Sci. Technol.*, **44**(10), 79-84
255. **Himathongkham, S., Bahari, S., Riemann, H. & Cliver, D. (1999)** Survival of *Escherichia coli* O157:H7 and *Salmonella typhimurium* in cow manure and cow manure slurry. *FEMS Letters Microbiol.*, **178**, 251-257
256. **Islam, M., Morgan, J., Doyle, M.P., Phatak, S.C., Millner, P. & Jiang, X. (2004)** Fate of *Salmonella enterica* Serovar Typhimurium on Carrots and Radishes Grown in Fields Treated with Contaminated Manure Composts or Irrigation Water. *Appl. Environ. Microbiol.*, **70**(4), 2497-2502
257. **Food Safety Authority of Ireland (2002)** Control of *Campylobacter* Species in the Food Chain
258. **Centres for Disease Control & Prevention (1998)** Botulism in the United States, 1899-1996. Handbook for Epidemiologists, Clinicians, and Laboratory Workers. Unites States Department of Health and Human Services
259. **Kuczynska, E., Shelton, D.R. & Pachepsky, Y. (2005)** Effect of Bovine Manure on *Cryptosporidium parvum* Oocyst Attachment to Soil. *Appl. Environ. Microbiol.*, **71**(10), 6394-6397
260. **Tenter, A.M., Heckeroth, A.R., Weiss, L.W. (2000)** *Toxoplasma gondii* from Animals to Humans. *Int. J. Parasitol.*, **30**, 1121-1258

261. **Bowie, W. R., King, A.S., Werker, D.H., Isaac-Renton, J., Bell, A.A., Eng, S.B. & Marion, S. (1997)** Outbreak of Toxoplasmosis Associated with Municipal Drinking Water. *Lancet*, **350**, 173–177
262. **Irish Government (2003)** Infectious Diseases (Amendment) (No. 3) Regulations 2003. S.I. No. 707 of 2003
263. **Sheridan, M.K. (1982)** Masters Applied Science (Food Science) Thesis, University College Dublin
264. **Gaspard, P.G. & Schwartzbrod, J. (2003)** Parasite Contamination (Helminth Eggs) in Sludge Treatment Plants: Definition of a Sampling Strategy. *Int. J. Hyg. Environ. Health*, **206**, 117-122
265. **World Health Organization (2006)** WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. *Volume II - Wastewater Use in Agriculture; Volume III – Wastewater and Excreta Use in Aquaculture; Volume IV – Excreta and Greywater use in Agriculture*
266. **Schwartzbrod, J., Gaspard, P. & Thiriat, L. (1998)** Pathogenic Microorganisms in Sludge and Effect of Various Treatment Processes for their Removal. *Europ. Wat. Manage.*, **1**, 64-69
267. **Diaz, C. & Hotchkiss, J.H. (1996)** Comparative Growth of *Escherichia coli* O157:H7, Spoilage Organisms and Shelf-Life of Shredded Iceberg Lettuce Stored Under Modified Atmospheres. *J. Sci. Food Agri.*, **70**, 433-438
268. **Fisher, T.L. & Golden, D.A. (1998)** Fate of *Escherichia coli* O157:H7 in Ground Apples Used in Cider Production. *J. Food Prot.*, **61**, 1372-1374
269. **Williams, A.P., Avery, L.M., Killham, K., & Jones, D.L. (2005)** Persistence of *Escherichia coli* O157 on farm surfaces under different environmental conditions. *J. Appl. Microbiol.*, **98**, 1075-1083
270. **Guan, T.Y. & Holley, R.A. (2003)** Pathogen Survival in Swine Manure Environments and Transmission of Human Enteric Illness – A Review. *J. Environ. Quality*, **32**, 383-392
271. **Warnes, S. & Keevil, C.W. (2003)** Survival of *Cryptosporidium parvum* in Faecal Wastes and Salad Crops. *Cryptosporidium parvum* in Food and Water: Teagasc, The National Food Centre

272. **Beuchat, L.R. & Ryu, J.H. (1997)** Produce Handling and Processing Practices. *Emerging Infectious Diseases*, **3**, 459-465
273. **Turner, C., Williams, S.M., Burton, C.H., Cumby, T.R., Wilkinson, P.J. & Farrent, J.W. (1999)** Pilot Scale Thermal Treatment of Pig Slurry for the Inactivation of Animal Virus Pathogens. *J. Environ. Sci. Health B*, **34**(6), 989-1007
274. **Taylor, S.J., Ahonen, L.J., de Leij, F.A.A.M & Dale, J.W. (2003)** Infection of *Acanthamoeba castellanii* with *Mycobacterium bovis* and *M. bovis* BCG and Survival of *M. bovis* within the Amoebae. *Appl. Environ. Microbiol.*, **69**(7), 4316-4319
275. **Hutchison, M.L., Walters, L.D. Avery, S.M. & Moore, A. (2005)** Decline of zoonotic agents in livestock waste and bedding heaps. *J. Appl. Microbiol.*, **99**(2), 354
276. **Van Pelt, W. (2001)** Explosive increase of Multi-Resistant *Salmonella typhimurium* DT 104 in 2001 in The Netherlands. *Eurosurveillance Weekly*, **5**(50)
277. **Valcour, J.E., Michel, P., McEwen, S.A. & Wilson, J.B. (2002)** Association between Indicators of Livestock Farming Intensity and Incidence of Human Shiga Toxin-Forming *Escherichia coli* Infection. *Emerging Infectious Diseases*, **8**, 252-257
278. **Wang, G., Zhao, T. & Doyle, M.P. (1996)** Fate of Enterohemorrhagic *Escherichia coli* O157:H7 in Bovine Faeces. *Appl. Environ. Microbiol.*, **62**, 2567-2570
279. **Strauch, D. (1996)** Occurrence of Microorganisms Pathogenic for Man and Animals in Source Separated Biowaste and Compost Importance, Controls, Limits, Epidemiology. In: *The Science of Composting*, (Eds.) de Bertoldi, M., Sequi, P., Lemmes, B. and Tizano Papi. C. Blackie Academic and Professional, London, 224-232
280. **MacGowan, A.P., Bowker, K., McLauchlin, J., Bennett, P.M. & Reeves, D.S. (1994)** The Occurrence and Seasonal Changes in the Isolation of *Listeria* spp. in Shop Bought Food Stuffs, Human Faeces, Sewage and Soil from Urban Sources. *Int. J. Food Microbiol.*, **21**, 325-334
281. **European Commission - Health and Consumer Protection Directorate General (2003)** Opinion of the Scientific Committee on Veterinary measures Relating to Verotoxigenic *Escherichia coli* (VTEC) in Foodstuffs.

282. **Lau, M.M., & Ingham, S.C., (2001)** Survival of faecal indicator bacteria in bovine manure incorporated into soil. *L. Appl. Microbiol.*, **33**, 131-136
283. **Ogden, I.D., Fenlon, D.R., Vinten, A.J.A. & Lewis, D., (2001)** The fate of *Escherichia coli* O157 in soil and its potential to contaminate drinking water. *Int. J Food Microbiol.*, **66**, 111-117
284. **Gagliardi, J.V., & Karns, J.S., (2000)** Leaching of *Escherichia coli* O157:H7 in diverse soils under various agricultural management practices. *Appl. Environ. Microbiol.*, **66**, 877-883
285. **Food Safety Authority of Ireland (2006)** Guidance Note No. 18 - Determination of Product Shelf-Life
286. **Cody, S.H., Glynn, M.K., Farrar, J.A., Cairns, K.L., Griffin, P.M., Kobayask, J., Fyfe, M. & Hoffman, R. (1999)** An Outbreak of *Escherichia coli* O157: H7 Infection from Unpasteurised Commercial Apple Juice. *Annals Int. Med.*, **130**, 202-209
287. **Morgan, G.M., Newman, C., Palmer, S.R., Allen, J.B., Shepherd, W., Rampling, A.M., Warren, R.E. & Gross, R.J. (1988)** First Recognised Community Outbreak of Haemorrhagic Colitis Due to Verotoxin-Producing *Escherichia coli* O157 in the UK. *Epidemiology and Infection*, **101**, 83-91
288. **Locking, M.E., O'Brien, S.J., Reilly, W.J., Wright, E.M., Campbell, D.M., Coia, J.E., Browning, L.M. & Ramsay, C.N. (2001)** Risk Factors for Sporadic Cases of *Escherichia coli* O157 Infection: The Importance of Contact with Animal Excreta. *Epidemiology and Infection*, **127**, 215-220
289. **Altekruse, S.F. & Swerdlow, D.L. (1996)** The Changing Epidemiology of Foodborne Illness. *Amer. J. Med. Sci.*, **311**, 23-29
290. **Gale, P. (2003)** Pathogens in Biosolids - Microbiological Risk Assessment. UKWIR. UK Water Industry Research Limited

291. **Doyle, M.P. (1990)** Foodborne Illness: Pathogenic *E. coli*, *Y. enterocolitica* and *Y. parahaemolyticus*. *Lancet*, **336**, 1111-1115
292. **Islam, M.S., Draser, B.S. & Bradley, D.J. (1990)** Attachment of Toxigenic *Vibrio Cholerae* O1 on the Mucilaginous Sheet of Blue-Green Algae. *J. Trop. Med. Hyg.*, **93**, 133-139
293. **Mead, P.S. & Griffin, P.M. (1998)** *Escherichia coli* O157: H7. *Lancet*, **352**, 1207-1212
294. **Wei, C.I., Huang, T.S., Kim, J.M., Lin, W.F., Tamplin, M.L. & Bartz, J.A. (1995)** Growth and Survival of *Salmonella montevideo* on tomatoes and disinfection with chlorinated water. *J. Food Prot.*, **58**, 829-836
295. **World Health Organization (1975)** Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards. WHO Technical Report Series No. 517. WHO, Geneva, Switzerland
296. **World Health Organization (1996)** Enterohaemorrhagic *Escherichia coli* infection. *Weekly Epidemiological Record*, **35**, 267-268
297. **De Roever, C. (1998)** Microbiological Safety Evaluations and Recommendations on Fresh Produce. *Food Control*, **9**, 321-347
298. **Millard, P.G., Gensheimer, K.F., Addiss, D.G., Sosin, D.M., Beckett, G.A., Houck-Janoski, A & Hudson, A. (1994)** An outbreak of cryptosporidiosis from fresh-pressed apple juice. *J. Amer. Med. Ass.*, **272**, 1592-1596
299. **Schlundt, J., Toyofuku, H., Jansen, J. & Herbst, S.A. (2004)** Emerging Food-Borne Zoonoses. *Rev. Sci. Tech. Off. Int. Epiz.*, **23**, 513-533
300. **United States Department of Health and Human Services, Food and Drug Administration, & Centre for Food Safety and Applied Nutrition (1998)** Guide to Minimise Microbial Food Safety Hazards from Fresh Fruit and Vegetables

301. **National Advisory Committee on Microbiological Criteria for Foods (1999)** Microbiological Safety Evaluations and Recommendations on Sprouting Seeds. *Int. J. Food Microbiol.*, **52**, 123-153
302. **Lin, C.M., Fernando, S.Y. & Wei, C.I. (1996)** Occurrence of *Listeria monocytogenes*, *Salmonella* spp., *Escherichia coli* and *E. coli* O157:H7 in Vegetable salads. *Food Control*, **7**, 135-140
303. **Ogden, I.D., Hepburn, N.F., MacRae, M., Strachan, N.J.C., Fenlon, D.R., Rusbridge, S.M. & Pennington, T.H. (2002)** Long Term Survival of *Escherichia coli* O157 on Pasture Following an Outbreak Associated with Sheep at a Scout Camp. *Let. Appl. Microbiol.*, **34**, 100-104
304. **Wallace, J.S., Cheasty, T. & Jones, K. (1997)** Isolation of Verocytotoxin-Producing *Escherichia coli* O157 from Wild Birds. *J. Appl. Microbiol.*, **82**, 399-404
305. **Chapman, P.A. (2000)** Sources of *Escherichia coli* O157 and Experiences over the Last 15 Years in Sheffield. *J. Appl. Microbiol.*, **88**, 51S-60S
306. **Pritchard, G.C., Williamson, S., Conson, T., Bailey, Warne, L., Willshaw, G & Cheasty, T. (2001)** Wild Rabbits – A Novel Vector for Verotoxigenic *Escherichia coli* O157. *Veterinary Record*, **149**, 567
307. **Behrsing, J., Jaeger, J., Horlock, F., Kita, N., Franz, P. & Premier, R. (2003)** Survival of *Listeria innocua*, *Salmonella* Salford and *Escherichia coli* on the Surface of fruit and inedible skins. *Post Harvest Biology Technol.*, **29**, 249-256
308. **Marine Institute (2006)** Classification of Shellfish Harvesting Areas  
<http://www.marine.ie/home/services/operational/seafood/Classification.htm>
309. **Crowther, J., Kay, D. Wyer, M.D. (2002)** Faecal-indicator concentrations in waters draining lowland pastoral catchments in the UK: Relationships with landuse and farm practices. *Water Res.*, **36**(7), 1725-1734
310. **Gomez-Couso, H., Freire-Santos, F., Amar C.F., Grant, K.A, Williamson, K., Ares-Mazas, M.E. & McLauchlin, J. (2004)** Detection of *Cryptosporidium* and *Giardia* in Molluscan Shellfish by Multiplexed Nested PCR. *Int. J. Food. Microbiol.*, **91** 279-288

311. **Halliday, M.L., Kang, L.-Y., Zhou, T.-K., Hu, M.-D. Pan, Q.-C., Fu, T.-Y., Huang, Y.-S. and Hu, S.-L. (1991)** An Epidemic of Hepatitis A Attributable to the Ingestion of Raw Clams in Ahanghai China. *J. Infect. Dis.*, **164**, 852-859
312. **Quanrud, D.M, Carroll, S.M., Gerba, C.P., & Arnold, R.G. (2003)** Virus removal during simulated soil-aquifer treatment. *Water Res.*, **37**, 753-762
313. **Hoorstra, E. & Hartog, B. (2003)** A Quantitative Risk Assessment on *Cryptosporidium* in Food and Water. Teagasc, The National Food Centre
314. **Centers for Disease Control and Prevention (1993)** Multistate Outbreak of *Salmonella* serotype Montevideo Infections. *EPI-AID*93-97
315. **Guo, X., Chen, J., Brackett, R.E. & Beuchat, L.R. (2001)** Survival of *Salmonellae* on and in Tomato Plants from the Time of Inoculation at Flowering and Early Stages of Fruit Development through Fruit Ripening. *Appl. Environ. Microbiol.*, **67**, 4760-4764
316. **Centers for Disease Control and Prevention (1999)** Outbreak of *Escherichia coli* and *Campylobacter* Among Attendees of the Washington County Fair - New York, 1999. *Morbidity & Mortality Weekly Report*, **48**, 803-804.
317. **Clark, C.G., Price, L., Ahmed, R., Woodward, D.L., Melito, P.L., Rodgers, F.G., Jamieson, F., Ciebin, B., Li, A. & Ellis, A. (2003)** Characterization of Waterborne Outbreak-Associated *Campylobacter jejuni*, Walkerton, Ontario. *Emerging Inf. Diseases*, **9**, 1232-1241
318. **Jones, K. (2001)** *Campylobacter's* in Water, Sewage, and the Environment. *J. Appl. Microbiol.*, **90**, 68S-79S
319. **Garvey, P., Mc Keown, P., Carroll, A. & McNamara, E. (2005)** Epidemiology of Verotoxigenic *E. coli* O157 in Ireland, 2004. *EPI-Insight*, **6**, 2-3
320. **European Commission (2006)** Proposal for a Directive of the European Parliament and of the Council on environmental quality standards in the field of water policy and amending Directive 2000/60/EC. COM/2006/397 Final

321. **Paulsrud, B., Wien, A. & Nedland, K.T. (1998)** A Survey of Toxic Organics in Norwegian Sewage Sludge, Compost and Manure. Paper presented at 8<sup>th</sup> International Conference of the FAO Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture, Rennes, France, 26-29<sup>th</sup> May 1998
322. **Petersen, L.S. (2003)** Organic Contaminants in Sewage Sludge. Swedish Environmental Protection Agency
323. **Thornton, I., Rautiu, R. & Brush, S. (2001)** Lead the Facts. Ian Allan Printing Ltd, United Kingdom. ISBN: 0-9542496-0-7
324. **Baars, A.J., Theelen, R.M.C., Janssen, P.J.C.M., Hesse, J.M., Van Apeldoorn, Meijerink, M.C.M., Verdam, L., & Zeilmaker, M.J., (2001)** Re-evaluation of human maximum permissible risk levels. RIVM Report 711 701 025
325. **Concannon, C. (2005)** Dioxin Levels in the Irish Environment - Third Assessment (Summer 2004) Based on Levels in Cows' Milk. Environmental Protection Agency, Wexford, Ireland. ISBN: 1-84095-172-9
326. **Rideout, K. & Teschke, K., (2004)** Potential for Increased Human Foodborne Exposure to PCDD/F when Recycling Sewage Sludge on Agricultural Land. *Environmental Health Perspectives*, **112**(9), 959-969
327. **European Commission, Joint Research Centre (2006)** Background Values in European Soils and Swage Sduges: Results of a JRC-coordinated study on background values, Gawlik, B.M. & Bidoglio, G. (eds.). Part I: Evaluation of the Relevance of Organic Micro-Pollutants in Sewage Sludge
328. **Pesticides Control Service of the Department of Agriculture and Food (2006)** <http://www.pcs.agriculture.gov.ie/>
329. **Rule, K.L., Ebbett, V.R., Vikesland, P.J. (2005)** Formation of Chloroform and Chlorinated Organics by Free-Chlorine-Mediated Oxidation of Triclosan. *Environ Sci Technol.*, **39**(9), 3176-3185

330. **European Commission (2004)** Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents. Amended by Commission Regulation (EC) 907/2006 of 20 June 2006 amending Regulation (EC) No 648/2004 on detergents, in order to adapt Annexes III and VII thereto
331. **Water Environment Association of Ontario (2001)** Fate and Significance of Contaminants in Sewage Biosolids Applied to Agricultural Land through Literature Review and Consultation with Stakeholder Groups. Prepared by R.V.Anderson Associates Limited, M.D.Webber Environmental Consultant and SENES Consultants Limited
332. **Yamamoto, J.T., Donohoe, R.M., Fry, D.M., Golub, M.S. & McDonald, J.M. (1996)** Environmental Estrogens: Implications for Reproduction in Wildlife. In: Fairbrother, A., Locke, L.N. & Hoff, G.L. (eds.) Non-infectious Diseases of Wildlife, 2<sup>nd</sup> Edition, pp. 31-52
333. **Hawrelak, M., Bennet, E. & Metcalfe, C. (1999)** The Environmental Fate of the Primary Degradation Products of Alkylphenol Ethoxylate Surfactants in Recycled Paper Sludge. *Chemosphere*, **39**(5), 745-752
334. **Maguire, R.J. (1999)** Review of the Persistence of Nonylphenol and Nonylphenol Ethoxylates in Aquatic Environments. *Water Qual. Res. J. Can.*, **34**(1), 37 – 78
335. **Environment Agency (1997)** SIDS Initial Assessment Report for Phenol, 4-Nonyl-, Branched Nonylphenol. National Center for Ecotoxicity and Hazardous Substances, London
336. **Bennie, D.T. (1999)** Review of the Environmental Occurrence of Alkylphenols and Alkylphenol Ethoxylates. *Water Qual. Res. J. Can.*, **34**(1), 79 – 122
337. **Larsen, J.R. & Andersen, T.T. (2006)** Survey of Liquid Hand Soaps, Including Health and Environmental Assessments - Survey of Chemical Substances in Consumer Products No. 69, 2006. Danish Ministry of the Environment, Environmental Protection Agency
338. **Schreurs, R. H., Legler, J., Artola-Garicano, E., Sinnige, T. L., Lanser, P. H., Seinen, W. & Van der Burg, B. (2004)** In vitro and in vivo antiestrogenic effects of polycyclic musks in zebrafish. *Environ. Sci. Technol.*, **38**, 997-1002

339. **Luckenbach, T. & Epel, D. (2005)** Nitromusk and Polycyclic Musk Compounds as Long-Term Inhibitors of Cellular Xenobiotic Defense Systems Mediated by Multidrug Transporters. *Environ. Health Perspectives*, **113**(1), 17–24
340. **Irish Medicines Board (2007)** Annual Report, 2006  
<http://www.imb.ie/images/uploaded/documents/IMB%20Annual%20Report%20final.pdf>
341. **European Medicines Agency (2004)** Guideline on Environmental Impact Assessment from Veterinary Medicinal Products Phase II <http://www.emea.eu.int/pdfs/vet/vich/079003en.pdf>
342. **Carballa, M., Omil, F., Lema, J.M., Llompert, M., Garcia, C., Rodriguez, I., Gomez, M. & Ternes, T. (2005)** Behaviour of Pharmaceuticals and Personal Care Products in a Sewage Treatment Plant of Northwest Spain. *Water Sci Technol.*, **52**(8), 29-35
343. **Sedlak, D.L. & Pinkston, K.E. (2001)** Factors Affecting the Concentrations of Pharmaceuticals Released to the Aquatic Environment. The 2<sup>nd</sup> International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, pp. 56-64. October 9-11, 2001. Minneapolis, MN, United States
344. **Graves, K., Jensen, V.B., Odensvik, K., Wierup, M. & Bangen, M. (2006)** Usage of veterinary antimicrobials in Denmark, Norway and Sweden following termination of antimicrobial growth promoter use. *Preventive Veterinary Medicine*, **75**, 123–132
345. **Lindberg, R. (2006)** Determination of Antibiotics in the Swedish Environment with Emphasis on Sewage Treatment Plants. UMEÅ University, Sweden. ISBN 91-7264-045-6
346. **Karthikeyan, K.G., Bleam, W.F. & Gu, C. (2003)** Occurrence of antibiotics in wastewater effluents and their mobility in soils: A case study for Wisconsin. DNR Project #169 <http://dnr.wi.gov/org/water/dwg/gw/research/reports/169.pdf>
347. **Jorgensen, J. H., Weigel, L. M., Swenson, J. M., Whitney, C. G.; Ferraro, M. J. & Tenover, F. C. (2000)** Activities of Clinafloxacin, Gatifloxacin, Gemifloxacin, and Trovafloxacin against Recent Clinical Isolates of Levofloxacin-Resistant *Streptococcus pneumoniae*. *Antimicrobial Agents and Chemotherapy Journal*, **44**(11), 2962-2968

348. **Sawant, A. A. (2005)** Descriptive and Molecular Epidemiology of Antibiotic Resistant Gram-Negative Enteric Bacteria from Dairy Cattle. PhD Thesis, Department of Veterinary Science Pennsylvania State University
349. **Kuhn I., Iversen A., Finn M., Greko C., Burman L.G., Blanch A.R., Vilanova X., Manero A., Taylor H., Caplin J., Dominguez L., Herrero I.A., Moreno M.A. & Mollby R. (2005)** Occurrence and relatedness of Vancomycin-Resistant Enterococci in Animals, Humans, and the Environment in Different European regions. *Appl. Environ. Microbiol.*, **71**(9), 5383 – 5390
350. **Anderson, W. B., Mayfield, C.I., Dixon, D.G. & Huck, P.M. (2003)** Endotoxin inactivation by selected drinking water treatment oxidants. *Water Res.*, **37**, 4553-4560
351. **Stewart, I., Schluter, P.J. & Shaw, G.R. (2006)** Cyanobacterial lipopolysaccharides and human health – a review. *Environ. Health*: **5**(7), 1-23
352. **Codd, G.A., Morrison, L.F. & Metcalf, J.S. (2005)** Cyanobacterial toxins: risk management for health protection. *Toxicology Appl. Pharmacology*, **203**(3), 264-272
353. **European Commission (1997)** Food Science and Techniques - Reports of the Scientific Committee for Food (Thirty Eighth Series). Opinions of the Scientific Committee for Food on Nitrates and Nitrite
354. **Grewal, S.K., Rajeev, S., Sreevatsan, S. & Michel, Jr. F.C. (2006)** Persistence of *Mycobacterium avium* subsp. *paratuberculosis* and other Zoonotic Pathogens during Simulated Composting, Manure Packing, and Liquid Storage of Dairy Manure. *Appl. Environ. Microbiol.*, **72**(1), 565-574
355. **Grewal, S., Sreevatsan, S. & Michel Jr. F.C. (2007)** Persistence of *Listeria* and *Salmonella* during Swine Manure Treatment. *Compost Sci. & Utilization*, **15**(1), 53-62
356. **Sorber, C. & Moore, B. (1987)** Survival and Transport of Pathogens in Sludge-Amended Soil: A Critical literature Review. United States Environmental Protection Agency, Washington, D.C., EPA/600/2-87/028

357. **Heaton, J.C. & Jones, K. (2008)** Microbial Contamination of Fruit and Vegetables and the Behaviour of Enteropathogens in the Phyllosphere: A Review. *J. Appl. Microbiol.*, **104**(3), 613-626
358. **Cools, D., Merckx, R., Vlassak, K., Verhaegen, J., (2001)** Survival of *E.coli* and Enterococcus spp. derived from pig slurry in soils of different texture. *Appl. Soil Ecol.* **17**, 53-62
359. **Irish Government (2007)** Waste Water Discharge (Authorisation) Regulations, 2007 (S.I. No. 684 of 2007)
360. **Graczyk, T.K., Lucy, F.E., Tamang, L. & Miraflor, A. (2007)** Human Enteropathogen Load in Activated Sewage Sludge and Corresponding Sewage Sludge End Products. *Appl. Environ. Microbiol.*, **73**(6), 2013-2015
361. **Food Safety Authority of Ireland (2008)** Zoonotic Tuberculosis and Food Safety (2<sup>nd</sup> Edition)
362. **Advisory Committee on the Microbiological Safety of Food - Ad Hoc Group on Botulism in Cattle (2005)** Report on Botulism in Cattle. <http://www.food.gov.uk/multimedia/pdfs/acmsf2006botulismcattle.pdf>
363. **Food Safety Authority of Ireland (2008)** *Cryptosporidium* - Protecting Your Food Business
364. **Food Safety Authority of Ireland and Department of Agriculture, Fisheries and Food (2007)** The National Control Plan for Ireland - For the Period from 1st January 2007 to 31st December, 2011 | [http://www.fsai.ie/service\\_contracts/national\\_control\\_plan\\_2007\\_2011.pdf](http://www.fsai.ie/service_contracts/national_control_plan_2007_2011.pdf)

## NOTES





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