Development and Preliminary Testing of Sustainable Development Indicators for Biosolids Management at Regional / Local Level in Ireland

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DECLARATION

"I hereby certify this material which I now submit for assessment of the programme of study leading to the award of PhD is entirely my own work, except where such works have been cited and acknowledged within the text of this study".

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ABSTRACT

Management of biosolids (treated sewage sludge) is becoming a significant issue for Local Authorities throughout Ireland, especially with the progressive implementation of the EU Urban Wastewater Treatment Directive 91/271/EEC of 1991. The future of biosolids management will depend on what direction Local Authorities take in the immediate future. This direction will be determined by quantity and quality of treated sewage sludge, types of sludge treatment available/selected and recycling/disposal outlets that will be acceptable to most stakeholders and most importantly, pose no danger to human health.

The aim of this thesis is to develop and conduct a preliminary test of sustainable development indicators (SDIs) for managing biosolids at the regional/local level. Accordingly, a set of 22 SDIs (comprising five headline, seven core and ten complementary indicators) has been developed using a stakeholder-based approach. These indicators are arranged according to the Driving force-Pressure-State-Impact-Response framework and address all domains of biosolids management namely, production, quality, cost, legislation/regulation, training/research and recycling/disposal. A preliminary test of the indicators was carried out in County Sligo to verify their suitability and usefulness. A key finding of the study is that the SDIs are relatively effective and can make significant contributions to the sustainable management of biosolids.

The stakeholder participatory approach adopted in the study meant that the indicator development process involved participants from varied background, knowledge, experience and perspective. Such a 'mix' is necessary in order to capture the multi-faceted criteria of sustainable biosolids management. The methodology and analysis of the survey results were designed to ensure an unbiased, critical, and fair input by the participating stakeholders.

The thesis concludes by synthesising the findings and making a number of recommendations and suggestions for further research. These propositions, if implemented, could lead to the refinement of the SDIs and generation of new ones.

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"To the Glory of Almighty God and to the benefit of all human kind"

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ATAD	Autothermal thermophilic aerobic digestion
BAT	Best available technology
BESI	Biomass Energy Solution Incorporated
BOD	Biochemical Oxygen Demand
CBOs	Community Based Organisations
CEN	European Standard Commission
CFR	Code of Federal Regulations
COMHAR	The National Sustainable Development Partnership
CSO	Central Statistics Office
CV	Calorific value
DEHP	Di-2-ethylhexy phthalate
DFID	Department for International Development
DM	Dry matter
DoE	Department of the Environment
DOEHLG	Department of Environment, Heritage and Local Government
DPCSD	Department for Policy Co-ordination and Sustainable Development
DPCSD	United Nations Department of Policy Coordination and Sustainable Development
DPSIR	Driving force-pressure-state-impact-response
DSR	Driving force-state-response
EC	European Commission
EEA	European Environment Agency
EEC	European Economic Community
ENFO	Environmental information service
EPA	Environmental Protection Agency (Ireland)
ESRC	Economic and Social Research Council
EU	European Union
EUROPTA	European Participatory Technology Assessment Agency
FAO	Food and Agriculture Organisation
FWR	Foundation for Water Research
GDP	Gross Domestic Product
GRI	Global Reporting Initiative

IDRC	International Development Research Centre of Canada
IISD	International Institute of Sustainable Development
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
ISO	International Standard Organisation
IUCN	The World Conservation Union
JOCSD	Joint Oireachtas Committee on Sustainable Development
LAS	Linear alkyl benzene sulphonates
MAFF	Ministry of Agriculture, Fisheries and Food
MDT	Metric dry tonnes
MPN	Most probable number
MWN	Measuring the wealth of nations
NGOs	Non governmental organisations
	NGSMI National Guide to Sustainable Municipal Infrastructure
NIOSH	National Institute of Safety and Health
NMP	Nutrient management plan
NSDS	National sustainable development strategies
NVZ	Nitrate vulnerable zones
ODA	Overseas Development Administration (United Kingdom)
OECD	Organisation for Economic Cooperation and Development
OJ	Official Journal
PAME	Participatory assessment, monitoring and evaluation
PAR	Participatory action research
PCBs	Polychlorinated biphenyls
PE	Population equivalent
PIP	Participatory and integrated policy
POPs	Persistent organic pollutants
PR	Participatory research
PRA	Participatory rural appraisal
PSR	Pressure-state-response
PTEs	Potentially toxic elements
REPS	Rural Environment Protection Scheme

RRA	Rapid rural appraisal
SCWO	Supercritical water oxidation
SDIs	Sustainable development indicators
SFT	Sludge to fuel
SI	Statutory Instrument
SMP	Sludge management plans
SRT	Solids Residence Time
TDS	Tonnes of dry solid
Teagasc	The Agriculture and Food Development Authority
TNS	The Natural Step
UK	United Kingdom
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nation Commission on Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nation Environmental Programme
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
VAR	Vector attraction reduction
VDOH	Virginia Department of Health
VOC	Volatile organic compounds
VS	Volatile solids
WCED	World Commission on Environment and Development
WSSD	World Summit on Sustainable Development
WWTPs	Wastewater treatment plants

CHAPTER ONE
INTRODUCTION

This study explores the development and preliminary application of sustainable development indicators (SDIs) as a tool for the management of biosolids at the regional and local levels in Ireland using a stakeholder-based participatory approach. Sustainable development indicators have emerged as tool to measure progress towards sustainable development for a number of fields. The study is geared towards providing (through the SDIs) reliable and timely information fundamental to effective decision-making in relation to sustainable management of biosolids. Presenting this information as sustainable development indicators is designed to help policy makers assess progress towards agreed biosolids policy objectives, as well as providing a basis for communicating with other stakeholders and the general public.

1.1 Context

Biosolids are stabilised by-products arising from the treatment of sewage, or from septic tanks or similar installations, and also known as treated sewage sludge (Everard et al 2002). Biosolids are, therefore, no more optional to an urbanised society than sewage treatment itself, since they are inevitable by-products collected at different stages of the wastewater treatment process. In the European Union (EU) where tough clean water directives are taking effect, biosolids production is growing significantly, as more local communities build and improve wastewater treatment plants (EEA 2002).

In Ireland, there are thirty-six proposed hub centres selected (by the Department of Environment, Heritage and Local Government) in accordance with Ireland's National Sludge Strategy Plan. A hub centre is a regional sludge treatment centre chosen on the basis of its geography and infrastructure, while also taking cognisance of Local Authorities' administrative boundaries (Lehany and Bartlett 2002). The management of biosolids will, therefore, become a significant issue for Local Authorities, especially with the progressive implementation of the EU

Urban Wastewater Treatment Directive 91/271/EEC of 1991. Its sustainability will depend on what direction Local Authorities take in the immediate future. This direction will be determined by quantity and quality of biosolids, types of sludge treatment available/selected and recycling/disposal outlets that will be acceptable to most stakeholders and most importantly, pose no danger to human health.

This research study is an attempt at qualifying and quantifying the issues arising from the increasing production of biosolids with a view to developing and applying (for the first time) sustainability indicators at local/regional level, to show trend measurements that describe improving or degrading conditions. The indicators will also define risk levels and inherently act as mechanisms to demonstrate the effectiveness of biosolids management policies and programmes of Local Authorities.

The study is an integral part of the larger biosolids research programme at the Institute of Technology, Sligo. The larger research programme takes a life cycle approach to biosolids management. The entire biosolids research programme is designed to address substantial shortcomings in the prevailing knowledge about the nature of sewage sludge, about their treatment, about the reuse/disposal of biosolids, and about systems for overall sustainable management. Altogether the individual projects complement each other allowing for integration of expertise and results.

1.2 Background to Study

With the EU Landfill Directive 2000/53/EC of 2000 requiring the diversion of increasing amounts of organic and putrescible wastes from landfills, coupled with an urgent deficit in landfill capacity in most of Local Authorities areas, the sustainable management of biosolids is currently imperative. Local Authorities face some contentious issues in this circumstance including, regulatory, technical, social, environmental and economic. These issues present challenges to the sustainable management of biosolids. To secure its continued 'social licence' to operate, Local Authorities must respond to these challenges by engaging its many different stakeholders and addressing their concerns. They must also be able to measure and assess the sustainability of their biosolids management programmes and demonstrate continuous improvements over time.

In Ireland, there is significant increase in biosolids production resulting from many new wastewater treatment plants being installed by Local Authorities. The practice before now was to discharge untreated wastewater to estuaries and coastal waters. However, there is currently an obligation to meet the requirements of the EU (Urban Waste Water Treatment) Directive 91/271/EEC of 1991. Annual Irish sewage sludge is expected to increase to 120,000 tonnes of dry solids (from the current level of 42,000 tonnes of dry solids in 2003) by 2013 as a consequence of changes in European and State water legislations (EEA 2002, EPA 2005). In addition, approximately 30 million tonnes of animal manure require land spreading annually in Ireland (Anon. 1993). These millions of tonnes of biosolids and animal manure generated each year will need to be sustainably managed.

Once treated, biosolids can be recycled or disposed of using three main routes; recycling to agriculture, incineration or landfilling. Other developing outlets include silviculture, vermiculture, land reclamation, and combustion technologies namely; wet oxidation, pyrolysis and gasification. Each recycling or disposal route has specific inputs, outputs, impacts, and (possibly) public concerns. Despite over three decades of research on the safety and benefits of the reuse of biosolids, including the recycling of nutrients and reduction in inorganic fertiliser use, stakeholder and public concerns remain in relation to:

- *Environment* – air, soil and ground/surface water contamination from trace elements, toxic chemicals and potentially harmful pathogens;
- *Economic* – liability and uncertainty of long-term effects of biosolids application on land value;

- *Social* – public perception of quality and safety of biosolids, food safety and nuisance issues such as odour;
- *Institutional* – quality assurance, monitoring and enforcement of regulations.

Much of the emphasis in addressing these stakeholder and public concerns has been on legislation, regulations, and codes rather than participatory approaches. A sustainable biosolids management programme will require a significant degree of interaction (and partnership) among all stakeholders, although unanimous support for any system is unlikely ever to be achieved. This is because of the sometimes, mutually exclusive demands of the various stakeholders.

There are many stakeholders with interest in biosolids management. Andersen (2001) identified six categories namely; the farming community, industries, water and waste industry, Local Authorities, national authorities and citizens. Although identifying the main positions, attitudes and constraints of all stakeholders on various biosolids reuse and disposal options is difficult, continued public opposition to beneficial reuse and disposal of biosolids, resulting from a lack of public confidence and trust, can have several adverse consequences including;

- Possible shortage of disposal capacity;
- Choice of a sub-optimal disposal option;
- Litigations resulting from dereliction of international and national obligations;
- Greater environmental and health risks to the local public due to short-term disposal methods may result in;
- Higher disposal costs due to delayed programme initiation.

Therefore, the role and importance of stakeholder involvement in the decision-making process and sustainable management of biosolids cannot be emphasised enough. Sustainable development recognises that everyone has a role to play in protecting themselves and the environment.

For the purpose of this study, sustainable development is defined as development or practices that provide, for this and future generations, equal consideration and accommodation for social, environmental and economic satisfaction within the carrying capacity of available natural stocks.

Current thinking on policy performance evaluation recognises that to accurately evaluate the performance of a policy, evaluation tools must be capable of measuring the policy objectives including the qualitative and quantitative features of sustainable development and meeting the environmental, economic, and social components of the policy for current and future generations (van Pelt 1993, Gilmour and Fisher 1991, WCED 1987). Sustainability indicators have risen to prominence as an effective tool to measure the economic, environmental and social outcomes of policies, programmes and projects. These indicators can describe the current state of a system, detect changes, show cause-effect relationships, and even highlight emerging issues (Gahin and Paterson 2001, Parkins et al 2001, Fraser Basin Council 2000, Meadows 1998). Thus, in this study sustainable development indicators (SDIs) are proposed as tools to manage biosolids at the local and regional levels. Furthermore, appropriate SDIs are currently being used to address the problem of communicating environmental information (UNCSD 1996).

The development of SDIs can be achieved in two ways – conventional and participatory (Hubbard 2002).

The conventional approach involves, for example, an external consultant who develops the indicators so that performance could be assessed against the initial policy objectives. The organisation and content of the 'conventional' indicator set is at the discretion of the external evaluator, and may have little or no consultation with stakeholders. Bell and Morse (2001) insist that such SDIs may lack relevance unless local stakeholders are involved.

The participatory approach works by having local stakeholders develop their own SDIs to manage a given activity, normally with facilitation by experts. Hubbard (2002) maintains that indicators developed based on local objectives may not, necessarily, be the same as the policy or programme objectives (depending on the level of consultation in defining the policy or programme objectives). In theory, the accuracy of the indicators should be strengthened by the broad range of perspectives brought to bear by the diverse participants, especially if a participatory approach is consistently used and the local participants are already familiar and comfortable with a wide range of participatory tools (Nazarea et 1998, IUCN/IDRC 1999). Again, the 'local' indicators are more likely to reflect the unique conditions of the policy or programme in relation to their community. There is an increased likelihood that such SDIs will be used directly by the stakeholders to manage, monitor and improve the policy or programme (Bell and Morse 2001).

1.3 Research Objectives

This study seeks to address three weaknesses in the sustainable management of biosolids in Ireland. The first weakness is the seeming lack of meaningful stakeholder participation in formulating biosolids management policies and programmes. The second is the lack of suitable tools to assess and communicate the sustainability of such policies and programmes. The third is the paucity of readily available information to policy makers and the public to aid effective decision-making in relation to biosolids management.

Therefore, the overall objective of this research study is to provide a framework for proactive and sustainable management of biosolids, through the provision of readily understandable information. It is proposed to provide this information by developing and testing a set of SDIs for biosolids management suitable for use at a local/regional level.

1.3.1 Specific objectives: To achieve the overall goal of this research study, five principal specific objectives are outlined below:

- Identification of all major stakeholders in the biosolids issue and their main concerns;
- Identification of the data/information requirements to address stakeholder concerns;
- Assessment of the overall data requirements and a rationalisation of these requirements based on availability and reliability of data, technical and economic criteria;
- Generation of a draft set of sustainability indicators for a Local Authority in Ireland;
- Critically review and assess the methodology employed for the generation of the SDIs with recommendations on the application of the methodology to other regions of Ireland.

1.4 Methodology

The research objectives were pursued in various ways. Desk studies were carried out, considering issues such as; current activities in the management of biosolids, evaluation of sustainable development indicators, developing a methodology for deriving biosolids related indicators in collaboration with major stakeholders, and conducting a pilot study of the developed indicators.

A stakeholder survey provided material for the development of a candidate set of indicators. The candidate set was disseminated in June 2005 to the stakeholders to evaluate and select the headline, core and complementary set of indicators. The selected indicators were tested in a pilot study in Sligo County Council to determine their usefulness and applicability.

1.5 Significance of Study

Despite a proliferation of literature on SDIs (Rigby et al 2000) there is presently no comprehensive set of indicators (at international, regional and local levels) for biosolids management. This study is an attempt to close that gap by developing SDIs for the management of biosolids at the local and regional levels.

A great deal of literature has also emerged in support of participatory methods of SDI development (Hira and Parfitt 2003, Hagmann et al 2002, Parkins et al 2001, Johnson 1999, Nazarea et 1998, Cummings 1997, Tacconi 1997). Overall, however, there are presently no studies where participatory methods have been used to develop SDIs for the sustainable management of biosolids. The stakeholder-based participatory methodology adopted in this study strives to close this gap in international and local indicator development initiatives.

1.6 Scope and Limitations of the Study

This research study does not attempt to describe the detailed technical issues associated with establishing a biosolids management programme, such as selection of measurement methods, sampling strategies and data analysis. This is beyond the scope of this study and is well documented in several recent literature (Spinosa and Vesilind 2001, Timoney 1998a, Oleszkiewicz and Mavinic 2002, Starr 2000).

The study does not attempt to thoroughly review the broader wastewater and sewage sludge management status in Ireland, as this has been the subject of another study. The research focuses on constructing indicators (economic, social, environmental and institutional) for managing biosolids, with ample review of literature on the wider aspects of sustainability. It also focuses on testing out the indicators (in a Local Authority) with a view to assessing their applicability and usefulness.

There are certain factors that may have weakened the research results. The awareness of these limitations influenced the research design. First, there are always difficulties in conducting participatory research, particularly in a situation where the participants have different backgrounds and varied levels of knowledge and experience. To ensure the highest possible accuracy, research methods were carefully selected and used to validate and verify the accuracy of the information collected. A range of tools was also used to ensure transparency and accuracy of the stakeholder participatory process (see Chapter 6).

Time was the second constraint. The testing of the indicators was limited to the headline and core sets only. There was neither time for the testing of the complementary set of indicators, nor for additional review of the tested indicators by the participating stakeholders. The third constraint is the verification of the integrity of data collected for testing the indicators. Most of the data collected from the Local Authority could not be verified from other sources, particularly in situations where discrepancies occurred. These weaknesses are acknowledged in Section 10.1.5 and Section 10.2 of Chapter 10.

1.7 Structure of the Thesis

The research study involved intensive research over a four-year period. To provide an understanding of the key issues that underpin the need for this study, the thesis firstly provides an introduction in Chapter 1. It comprises a context and background to the study, the study objectives, significance, scope and limitations.

Chapter 2 then reviews the key issues that need to be considered in developing a set of SDIs for managing biosolids using a stakeholder based participatory approach. The chapter looks at the origin, theory and practice of stakeholder participatory approaches, their advantages and challenges. The role of stakeholder participation in research and sustainable development is specifically reviewed.

Existing guidelines and approaches to sustainability indicators development, their framework and typology are reviewed in Chapter 3. The chapter explores the concept of sustainable development and sustainable development indicators, their origin, theory and practice. The Irish experience in indicator development and use is also examined.

Social, economic and environmental risks associated with biosolids reuse and approaches for minimising these risks are presented in Chapter 4. It includes a comprehensive review of biosolids production processes, classification and management options. Particular focus is placed on the sustainability of various biosolids management options, and public perception of biosolids recycling.

An overview of relevant legislation, regulations and codes of good practice both at European, national and Local Authority levels, is presented in Chapter 5. The framework of applicable laws, regulations and guidelines in the Local Authority, regional or national jurisdiction is reviewed, since it is an important consideration in the development and implementation of a biosolids management programme.

Chapter 6 details the methodology employed in the study. The chapter commences with the research design, followed by a full description of the instrument for data collection (including its validation and reliability), and procedure for data treatment and analyses. The chapter concludes by detailing the techniques adopted for indicator development, selection and testing.

Chapter 7 presents the results and findings from the stakeholder survey. Included in this chapter are the response rate and presentation of responses using various chart formats. The summary of stakeholder concerns and suggested actions or information needed to address them is presented using a tabular format.

The indicator development and selection process is outlined in Chapter 8. It describes various stages in the development of the set of indicators for managing biosolids. It also describes in detail the indicator selection process and concludes by presenting the selected set of indicators organised as headline, core and complementary indicators.

Chapter 9 presents results of the preliminary testing of the SDIs carried out in County Sligo. The chapter describes the field application of the set of headline and core indicators, availability of data and overall usefulness of the individual indicators. It concludes by presenting the indicators that are successfully tested.

A discussion, analysing the application of the indicators and highlighting key findings of the study, is presented in Chapter 10. The chapter examines the robustness of the applied SDIs and the data used to test them. It also evaluates the suitability, value and ease of determination of the headline and core sets of indicators. Finally, it outlines the strengths and weaknesses of the techniques used in the study, and the problems encountered.

Chapter 11 presents the synthesis, conclusion and recommendations arising from the study. It commences by summarising the major findings of the research. A table outlining data availability for testing the indicators in Sligo County is presented. The chapter concludes with a set of recommendations and suggestions for future research.

The 'References' section lists all literature cited and consulted in the course of this study. A significant amount of literature was obtained through the internet. The date of accessing these materials, and the universal resource locations (URL) or websites is given.

The 'Appendices' contain other necessary information and documents not accommodated in the main body of this thesis. These include survey questionnaires, cover letters, list of contacts and other materials used for the study.

CHAPTER TWO

STAKEHOLDER PARTICIPATORY APPROACHES

Participatory approaches aim to provide people with an opportunity to investigate and analyse their own situation, evaluate capabilities and constraints and play a greater role in determining and enacting responses and solutions to their own problems (UNDP 1998). This chapter looks at the origin, theory and practice of stakeholder participatory approaches, their advantages and challenges. The role of stakeholder participation in research and sustainable development is specifically reviewed.

2.1 Who is a Stakeholder?

The United Kingdom Overseas Development Administration (ODA) define a stakeholder as any person, group or institution that has an interest in any activity, project or programme (ODA 1995). The ODA include in this definition both intended beneficiaries and intermediaries, winners and losers, and those involved or excluded from decision making processes. Karl (2000) identifies stakeholders as those who are affected by the outcome, negatively or positively, or those who can affect the outcomes of a proposed intervention.

According to ODA (1995), stakeholders are groups of people who share a common interest, for example 'the consultancy', 'the project management team', 'the villagers', 'the Local Authorities'. But, within any of these, there are sub-categories of stakeholders with differing interests which they may or may not be prepared to subsume in the general collective interest. Analysis might conclude that the concept of 'villager' as a collective stakeholder is quite meaningless because the various groups of people living in the village have so little in common; some villagers might consider that they have more shared interest with the representatives of the Local Authorities than with their next door neighbours. Similar issues arise in formal institutions, such as government ministries. Competition between departments or individuals may be stronger than commitments to the institutions as a whole. There may also be cross-cutting interests, such as ethnic bias, both within the institution and affecting outside relationships. The ODA emphasise that care is therefore needed to recognise the variety of interests involved.

2.2 Stakeholder Categories

Harrison and St. John (1998) categorise stakeholders into primary and secondary stakeholders. Primary stakeholders are those people and groups ultimately affected by an activity. Secondary stakeholders are those within the operating environment such as the broader local communities, activist groups and government agencies. Both primary and secondary stakeholders operate within the broader environment subject to sociocultural, economic and political/legal forces and technological change. In addition to primary and secondary stakeholders, there may be external stakeholders. This will include people and groups not formally involved in a project, but who may be impacted by the activity such as politicians and senior civil servants (DFID 1995a, Clayton et al 1998).

Stakeholders are sometimes also categorised according to their relative importance or influence. Importance refers to the extent that the needs and interests of stakeholders are prioritised by an activity. Influence refers to the power stakeholders have over the activity (Grimble and Wellard 1997). Among primary and secondary stakeholders, some will be key stakeholders, that is those who can significantly influence the activity, or are most important for meeting the objectives of the activity or project (DFID 1995b)

2.3 Stakeholder Participation

Stakeholder participation can be defined as a process whereby stakeholders (those with rights, and therefore responsibilities, and/or interests) play an active role in decision making and in the consequent activities which affect them (ODA 1995). This is based on the precepts according to Dalal-Clayton and Bass (2002) that:

- Stakeholders know a great deal and their knowledge can drive innovations;

- Stakeholder participation in assessment, planning and evaluation is fundamental;
- Working with strengths and capacity of stakeholders is vital to success;
- If stakeholders cannot manage and control responses, ultimately they will not be sustainable.

There has been a growing emphasis on empowerment of people, a concept that has been widely promoted by NGOs (Oakely and Marsden 1984, Rudqvist and Woodford-Berger 1996). The concept of participation as empowerment is seen basically as access to and control over resources, or as a way of releasing human energies and enlarging talents and potential (FAO 1990, Uphoff 1992). Stakeholder participatory approaches can be traced to a number of antecedents (Grimble and Wellard 1997) and has been linked to democratisation, good governance, equality, and human rights (FAO 1990, Rudqvist and Woodford-Berger 1996).

In recent years, the roles of the three 'sustainable development triad' sectors (government, civil society and private sector; see Figure 2.1) have begun to change significantly.

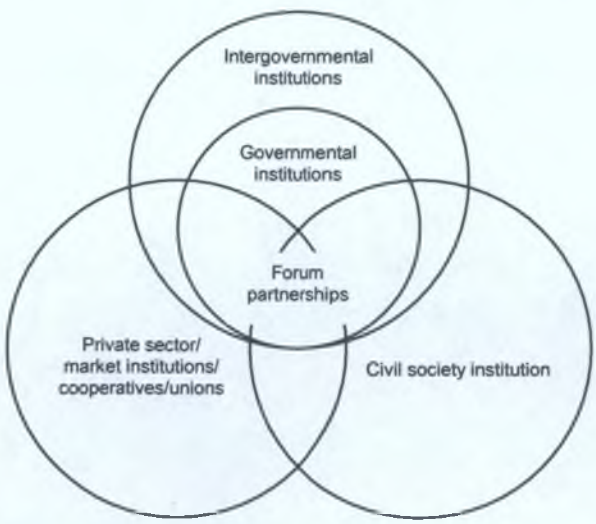


Figure 2.1 Stakeholders and sustainable development 'triad'
(Source: Bass et al (1998) in Dalal-Clayton and Bass (2002) p186).

For example (Tennnyson and Wilde 2000) recount that:

- Civil society-led popular movements more or less peacefully overthrowing undemocratic governments in South Africa, the former Soviet Union and central Europe, with many of the civil society activists forming the new governments; and with a subsequent lack of faith placed in centralised government planning systems;
- The South-East Asian so-called 'economic miracle' having come and gone within a decade, reminding governments and international organisations that business investment alone will not bring the needed development they (perhaps naively) hoped it would;
- Many international businesses, previously entirely focused on maximising shareholder value, are rethinking their responsibilities to the societies in which they operate. As the gulf between rich and poor widens, so do the threats to social stability and economic growth.

These and more events have opened up new possibilities for a greater interdependence between sectors and have led to innovation and creative collaboration. So world events have, in a sense, encouraged sectors to work together more closely, bringing to the collaboration different but potentially complementary skills, experiences and attributes (Dalal-Clayton and Bass 2002).

Participation is often used to mean a number of different kinds of activity (Rudqvist and Woodford-Berger 1996). Within the research and development context, participation describes both an act and an umbrella term for a supposedly new style of research and development intervention. It can also be viewed as a desired end-point related to the degree of involvement in decision making, a concept of considerable importance in current governance debate (Campbell and Salagrama 1999). Oakley and Mardsen (1984) describe it as a continuum of participation which spreads from collaboration to empowerment. Oakley (1991) elaborated on the description of this continuum for use when considering participation in projects. He identifies stages of participation moving from cooperation by people in activities defined and controlled externally, to greater involvement of the people in the decision making process, increased control over resources, greater levels of influence over the direction and control of the whole process, and the distribution of benefits from it.

2.4 Approaches to Stakeholder Participation

There are a considerable number of approaches to stakeholder participation, each reflecting the circumstances of its development, the motives driving them and what part of the development process they aim to address. Some of the key approaches summarised by Campbell and Salagrama (1999) are discussed following.

2.4.1 Participatory action research (PAR): In PAR, a social group is helped to formulate a critical analysis of its own situation; its problems, weaknesses, needs, strengths, and resources. By identifying and consolidating the knowledge and skills which they already possess, the social group can use these as tools for their own empowerment. Historically, PAR reflected a much more stand-alone approach to participation, building on the capacities of the disempowered to make their own changes. Other approaches have tended to start from a more collaborative base.

2.4.2 Rapid rural appraisal (RRA): Whilst RRA is not a participatory method, it did provide the foundation for many of the methods used in participatory approaches. RRA enables outsiders to understand rural conditions quickly by combining methods from various disciplines to yield relevant data. The key principles in RRA are that it is a progressive and rapid learning process where triangulation (cross-checking data by multiple methods) is often used to quickly validate or refute findings; and it is a multidisciplinary learning process where a range of disciplines, local informants and knowledge are brought together.

2.4.3 Participatory rural appraisal (PRA): PRA grew out of RRA but the community members are much more actively involved in the generation and analysis of information. PRA is generally a continuing participatory process, unlike RRA which is more a one-off process. PRA supports the direct participation of communities, with rural people themselves becoming the main investigators and analysts. Rural people set the priorities; determine needs; select and train community workers; collect, document, and analyse data; and plan and implement solutions based on their findings. Actions stemming from this research tend to serve the local community. Outsiders are there to facilitate the process but do not direct it.

2.4.4 Participatory assessment, monitoring and evaluation (PAME): PAME is an approach which is based on the premise that beneficiaries of interventions monitor and evaluate these interventions *de facto* either by adopting changes or discontinuing them as soon as external inputs are withdrawn. This is people-led and gender is explicitly incorporated as a perspective on development.

2.4.5 Participatory research (PR): PR is an approach to research which aims to involve community members in the research process to varying degrees. In many instances, the community act as an agent of the external researcher or may collaborate in some aspects of the research such as data collection or analysis. A more developed view of PR is where the community has control of the research process. There are close links between PR and indigenous knowledge.

2.4.6 Participatory and integrated policy (PIP): PIP developed within the fisheries sector from a recognition that different policy objectives can conflict and that taking a sectoral approach to policy formulation and implementation has the inherent flaw of increasing this potential for conflict. It also acknowledged that those whose lives are going to be affected by policy processes should be involved in those processes and be linked to national policy frameworks. PIP aims to involve all stakeholders in the policy process and to integrate these processes across sector and between administrative levels from the community, through local and national, to international policies.

Campbell and Salagrama (1999) suggest that the growing convergence of these different approaches is a recognition that each has a complementary role to play with the others. PAME provides a basis for monitoring the effectiveness and impact of PAR and PRA approaches used within communities. PR can provide data, which utilises indigenous knowledge, into the policy process of PIP. PIP can in turn help to create the structures and processes needed to support the effectiveness of PRA and PAR. The relationship between some of the approaches and research and development cycles is shown in Figure 2.2. Each approach draws upon approach-specific methods for its implementation. They also draw upon a growing number of participatory methods that can be called upon and adapted to the specific needs of each approach.

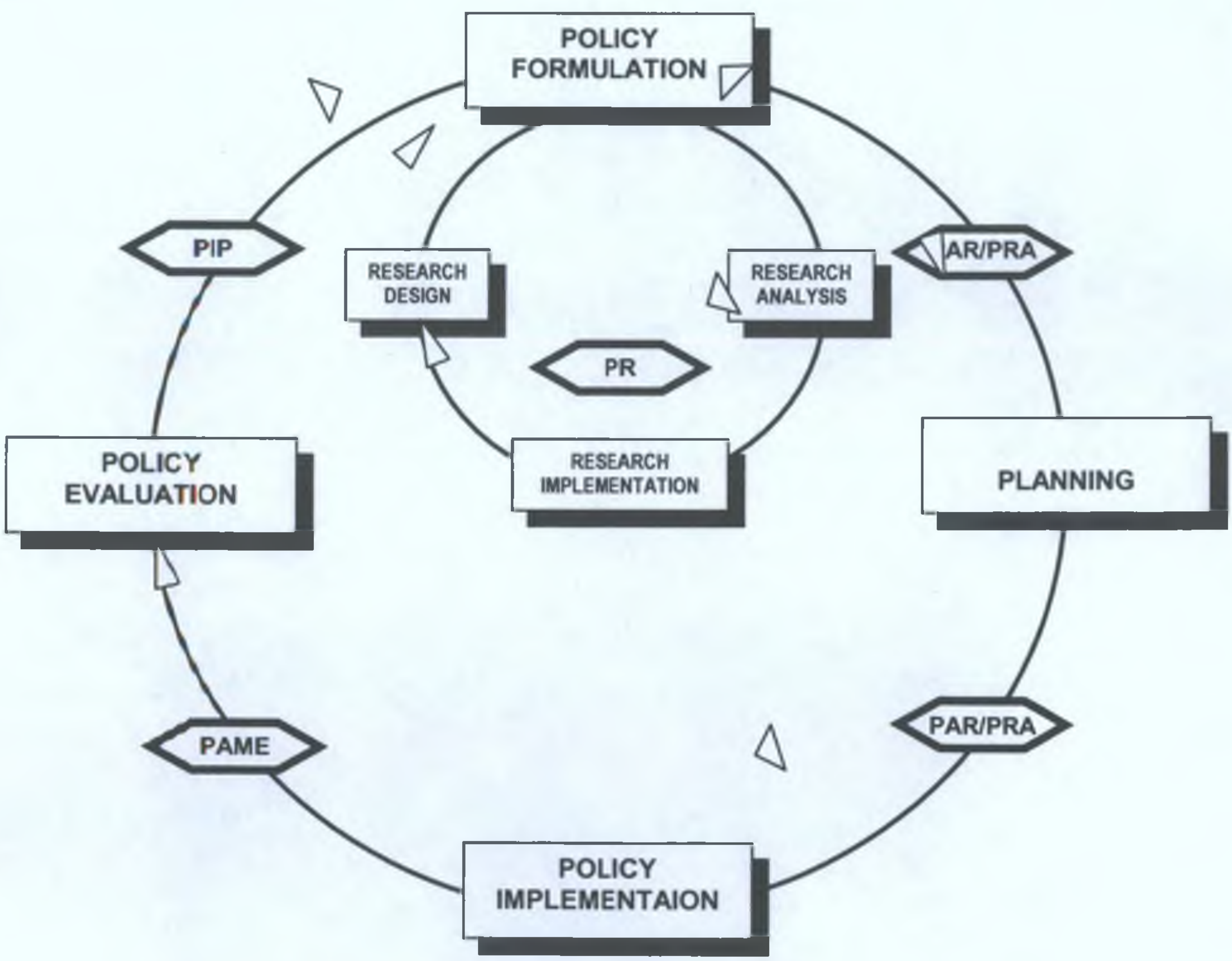


Figure 2.2 Application of the different participatory approaches
(*Source: Campbell and Salagrama 1999*)

The research cycle is shown as a smaller circle linked to the development cycle. The different participatory approaches are shown in hexagonal boxes on the part of the development cycle where they are mainly used. PR applies to all parts of the research cycle. PAR and PRA operate mainly in the planning and implementation parts of the development cycle. PAME operate during and after implementation. PIP processes operate at the policy level. In assessing the quality of participatory approaches, Adnan et al (1992) in Campbell and Salagrama (1999) identifies six critical features as shown in Table 2.1.

Table 2.1: Criteria for assessing the quality of participatory processes

1. Transparency	Whether all stages of project activities are publicly visible, including decision making processes?
2. Access to Information	Whether there is adequate and timely access to project information for all?
3. Accountability	Whether the agencies involved in project management and implementation are procedurally and periodically answerable to the people in the impact areas, as well as the citizens of the country in general?
4. Meaningful choice	Whether people can participate in a voluntary manner without being compelled, constrained or otherwise left with no other choice?
5. Comprehensiveness	Whether people have been consulted from the very outset in defining the nature of the problem prior to any project being decided upon, as contrasted to consultation during subsequent stages of the project cycle?
6. Non-Alienation	Whether people have participated in a way that they do not feel distanced and alienated from the project management, the implementation process and the eventual outcomes?

(Source: Adnan (1992) in Campbell and Salagrama (1999) p9.)

They emphasise that evaluation of stakeholder participation is concerned with processes, which are qualitative, and not results that are quantitative. In its more developed forms, stakeholder participation in research is with and for people and not on them (Lammerink and Wolffers 1994). According to Oakely and Marsden (1984), it is even more concerned with description and interpretation than with measurement and prediction. Because participation is a dynamic process that must be evaluated over time, conventional 'ex post' assessments are inadequate. It should be participatory involving the people affected by the policy or project (Oakely 1991).

Siocum (2003) has made distinctions between levels of participation depending upon the set objectives. These include; transmitting information (unidirectional) in which the stakeholder is being informed by authorities who are planning or have planned what is to happen. Sometimes it is called 'non-participation'. The second level is consultation (bi-directional, but the consulted party frames the issue), for example, responding to surveys or being consulted. Nevertheless, this does not automatically give stakeholders the opportunity to influence the planning process, so the level of participation may be quite minimal. Active participation is the third level of participation based on a partnership in which citizens, stakeholders, experts and/or politicians actively engage in the debate. In active participation, all parties involved can frame the issue to a greater or lesser extent. However, Siocum (2003) emphasises that participation is a continuum and methods vary in the degree to which they engage participants in framing the questions and issues and in designing the procedures.

2.5 Benefits of Stakeholder Participation

The European Participatory Technology Assessment (EUROPTA) declare that demands for increased stakeholder participation in policy making have been founded upon both pragmatic and normative lines of argumentation (EUROPTA 2000). The organisation reports that from a pragmatic perspective, participation is considered to improve the quality of decisions, while from a normative point of view participation is necessary to render the decision making process more democratic. Each of these lines of thought, it continues, is based upon two perceived insufficiencies: uncertainty and inequality. From the pragmatic point of view, it is better to have as much knowledge, experience and expertise as possible in addressing the complex (and thus uncertain) nature of social issues and problems. This means that institutionalised and/or informal influence on decision making processes are unequally distributed among members of society. Therefore, access must be created for all relevant persons to contribute to solutions and planning for the future. From a normative perspective, EUROPTA (2000) maintains that new problems and issues in society often pose questions for which existing social norms are inadequate or non-existent, creating uncertainty and anxiety in the society. In addition, Siocum (2003) posits that the plurality of (often conflicting) norms in a society is often mixed up with interests (financial or otherwise), which are unequally represented in society. It is thus normatively desirable to enable a process that is as democratic as possible in order to ensure that all values and opinions can be represented in a policy debate.

2.5.1 Towards sustainability: It has long been recognised that greater participation by those who are to be affected by a policy, research or development can improve the efficiency, effectiveness and sustainability of those processes and their outputs (Campbell and Salagrama 1999). Where this occurs, the reasons can be broadly described as functional. There are several functional reasons for the growing interest in greater participation:

- The imposition of standard 'top-down' interventions on to diverse local realities have failed to address local needs;
- The greater involvement of local people may have positive cost implications; and
- The more local people are involved in development initiatives, the more likely they are to shoulder the ongoing cost of maintaining such initiatives (Chambers 1995).

Participation for functional reasons is generally passive and seen as a manageable input to an externally defined process of research or development (Campbell and Salagrama 1999, Chambers 1995). However, whilst functional participation may have started in this way, it has progressively informed and influenced a more fundamental shift towards people-led development, and this includes a parallel shift in research (Campbell and Salagrama 1999). Chambers (1995) notes that arguably, the big shift of the past two decades has been from a professional paradigm centred on things to one centred on people.

2.5.2 Compliance with the law: Participation is seen also as an important mechanism for gaining compliance with laws and policies. It may be said that whilst the threat of punishment may act as a deterrent to some, for compliance by the majority of people, the law must be built upon a basis of morality and self interest (Honore 1995).

2.5.3 Capacity building: Involvement in participatory processes also builds capacity among the public. It does so by educating the public as well as creating networks of relevant persons who can continue to address policy issues as they develop (Siocum 2003). However, not only the public needs to learn. All decision makers can best learn how to improve their services and products by receiving direct feedback from the 'users'. Rather than first making and fixing, it is most efficient to involve the end-users in the initial design and planning (Siocum 2003).

2.5.4 Research and development: The reasons for supporting greater participation in research and development are broadly related to empowerment, in that they deal with access, power, decision making, prioritisation, agenda setting, and distribution of benefits (Campbell and Salagrama 1999). Central to empowerment-level reasoning on participation is a reaction against centralisation, bureaucratisation, rigidity and remoteness of the state (Midgley 1986). Furthermore, participation is seen as a way of building social cohesion. It is a useful process to achieve consensus when differences in opinion and even conflicts need to be resolved (Siocum 2003). When this approach is taken up early in the process, stakeholders can share their perspectives, values and reasoning on an emerging issue as these develop and mature. When opinions have already been polarised, some methods are particularly useful at mediating between interest groups to achieve consensus or at least arrive at a common decision after all perspectives have been expressed. At a minimum, these processes achieve mutual understanding and all voices can be heard (Siocum 2003).

There are also reasons for supporting greater participation in research and development which relate to the philosophy underpinning the way we describe, understand and explain the world we live in (Campbell and Salagrama 1999). The evolution of participatory processes has led some researchers to the belief that there are multiple realities and that professional realities are constructed differently from those of local people (Chambers 1998). This belief is shared by a small but growing group, the predominant view, however, remains that there is one 'correct' knowledge system and the success or failure of research to generate knowledge is measured in its adherence in approach to that system (Campbell and Salagrama 1999).

Redclift (1992) contends that sustainable development is usually discussed without reference to epistemological issues. It is assumed that the system of acquiring knowledge through the application of scientific principles is a universal epistemology, and anything less than the 'scientific knowledge' hardly deserves attention. Redclift (1992) further argues that such a view, rooted as it is in ignorance of the way we think of other cultures' epistemology, is less than fruitful. An important, if rather patronising step towards greater participation of traditional communities and their knowledge systems has been that indigenous knowledge which has been 'extracted' using social research methods and placed in a scientific framework, has a value-added quality (Campbell and Salagrama 1999).

2.5.5 Governance: Siocum (2003) asserts that effective and meaningful stakeholder involvement is essential to enable high quality and democratic governance and to strengthen civil capacity. Other benefits include developing and delivering programmes effectively and efficiently; building public confidence and trust in decisions; and generating a greater understanding of public issues, concerns, priorities and solutions. It increases mutual learning through the sharing of information, data and experience. In doing this, stakeholder involvement ensures that decisions and policies incorporate knowledge and expertise that otherwise might be overlooked. Siocum (2003) concludes that stakeholder involvement could lead to a rapid identification of possible controversial aspects of an issue and help bring together different points of view to achieve consensus in a collaborative manner.

2.6 Applying Stakeholder Participation to Indicator Development

Pahl-Wostl (2002) contends that the general shift towards a polycentric understanding of policy making requires the involvement of stakeholders as active participants into the policy process at different levels of societal organisation. Again, one of the messages that emerged from the Brudtland Report (1987) and the Rio Declaration (1992) was that active public participation is a prerequisite for achieving sustainable development (WCED 1987, UNCED 1992). Sustainable development is derived from people's capacities to exercise choice, and to access opportunities and resources, and use them for their livelihoods in ways that do not foreclose options for others to make their living, either now, or in the future (UNDP 1998). Cartwright (2000) further emphasises that the viability of sustainable development depended on the full support and participation of the people it affects. As with all aspects of SDI construction, the choice of indicators, especially those reflecting human values, needs to emerge from a process that allows wide participation and achieves broad consensus (Bell and Morse 2000). SDIs could therefore, be employed as social constructions through which policy problems may be identified and defined, policy targets set, and progress measured (Bossel 1999).

It will be evinced in Section 2.7 of this Chapter that sustainable biosolids management involves many stakeholders, often with conflicting interests. Biosolids management deals with complex technical and system issues (Andersen 2001). Systems theory can provide a systematic framework for guiding the search for indicators and assessing viability and sustainability of a given system (Anderson and Johnson 1997). It cannot however, determine the final choice of indicators. This task remains to be completed by the investigators and in collaboration with the stakeholders. The resulting indicators will obviously be influenced by background, knowledge and experience of the investigators and stakeholders. The use of stakeholder processes will facilitate a convergence through discussions and by defining indicator selection criteria. To be effective, the views and opinions of all major stakeholders will be taken into context within which those stakeholders operate, within their system boundary (Bossel 1999, Azapagic 2003, Anderson and Johnson 1997). The goal is to reach consensus or compromise in the form of a decision on the 'best' set of indicators (Cartwright 2000).

One of the main requirements for indicator design, arising from their consideration as a technical policy tool, is that indicators should be scientifically valid or analytically sound, and be responsive to changes that are occurring (Pastille 2002). Science can help significantly in assuring that the process of indicator search, selection and aggregation are as objective and circumspect as possible. However, science cannot provide an objective method for finding the one-and-only true indicator set for a complex system. The reason is simple: the number of potential indicators in such systems is very large, while the set of indicators must be relatively compact if it is to be of any value. Hence, the compelling need for selection and aggregation (Bossel 1999, Bell and Morse 2000, Adriaanse 1993). Table 2.2 contrasts science with stakeholder participation showing the major shortcomings of scientific methods.

Table 2.2 Participatory methods contrasted with 'scientific' methods

Scientific Research	Participatory Research
Only recognises the 'scientific method'.	Recognises that no research method has absolute validity.
Emphasises statistical analysis. Values precision more than trustworthiness.	Recognises the biases and inherent limitations of different methods.
Applies methods with much rigour. Adapts reality to methods.	Is creative, recognises the value of qualitative data, and the information of local people.
Produces a lot of descriptive data that contributes little to understanding.	Puts emphasis on process, not just results.
Extracts data for analysis and planning by experts and policy makers.	Promotes analysis by local people and motivates their own planning for research and development.

(Source: Chambers 1998)

Bell and Morse (2000) further contend that it is obviously wrong to let a group of experts make a selection of indicators in an area as complex as sustainable development. It is their thinking that the experts are likely to focus on issues and items of their professional expertise while neglecting others that may have a significant effect in the real system. A search for indicators can only be as complete and comprehensive as the imagination, knowledge and experience of the researchers allow (Bosch 1999). But the best knowledge of systems and problems, including their long-term perspective, can usually be found with those who have to cope with them daily: citizens, businesses, unemployed persons, managers and administrators, farmers, media practitioners, doctors, social workers, police and educators (Anderson and Johnson 1997). The principle is that people should be fully involved in issues concerning themselves and the society in which they live. Effectiveness of indicators and sustainability of a system depend practically, in part, on the commitment of interested parties or stakeholders (ODA 1995).

It is therefore, imperative that this pool of intimate system and problem knowledge must be systematically included in the process of indicator search and selection. To be coupled with the available knowledge is the full spectrum of value perspectives of a community in a participatory indicator search and selection process (Cartwright 2000).

According to Mayoux (undated), stakeholder participatory approaches used in indicator development also face a number of inherent challenges. Some of these are common to all participatory methodologies; some are due to the visual tools and some to the participatory process. Table 2.3 depicts the advantages and challenges of stakeholder participation in indicator development. Mayoux (undated) notes that participatory approaches are not a fixed set of mechanistic tools but a diverse range of possible techniques which need to be flexibly adapted to particular situations and needs. The degree to which participatory methods realise their potential contribution depends critically on how carefully they are used and in what context.

Table 2.3 Stakeholder participation: Advantages, challenges and way forward

	Advantages	Challenges	Ways Forward
Relevance of issues and indicators	▪ rapidly identifying the range of potential issues ▪ participatory prioritisation of different goals ▪ identification of locally relevant indicators	▪ standardisation of goals and indicators to allow comparative assessment ▪ ensuring that sensitive issues are aired	▪ using the same goals, weighting locally-specific indicators ▪ role play and/or triangulation with qualitative methods
Representation of different stakeholders	▪ identifying relevant stakeholder categories for assessment, control and analysis ▪ involving different stakeholders in a participatory process, including the most vulnerable	▪ the focus on consensus may mask differences ▪ ensuring that the most vulnerable are present and their voices heard ▪ resolving differences between stakeholders	▪ paying attention to participatory process: location, timing, composition of discussion groups and discussion agenda ▪ triangulation with quantitative survey or informal qualitative targeted interviews
Reliability of findings	▪ rapidly obtaining issues and other information for whole communities or groups ▪ exploring processes and hypotheses ▪ rapidly investigating underlying or side issues	▪ scale and representation beyond physically identifiable communities ▪ focus on diagram outputs may detract from analysis of processes	▪ using quantitative methods including mapping and voting ▪ careful documentation of context and the assessment process ▪ triangulation with other methods
Credibility of practical inference	▪ increases communication between researchers, policy makers and stakeholders ▪ makes information immediately accessible to different stakeholders	▪ may raise unrealistic expectations ▪ may create tensions which cannot be resolved	▪ attention to identifying and clarifying the limitations of the programmes and policies ▪ careful attention to the participatory process
(Source: Mayoux 'undated')			

2.7 Stakeholders Involved in Biosolids Management

Andersen (2001) identifies six major categories of stakeholders (Figure 2.3) involved in the production, treatment, disposal and recycling of biosolids. These include the farming community, industry, water and waste industry, Local Authorities, national authorities and citizens.

Within each category, Andersen (2001) has identified several groups according to the nature of their activity and shared interests regarding biosolids management. The category defined as the 'farming community' essentially regroups landowners and their representative organisations, the farmers' professional representatives, as well as individual farmers who may have different motivations and constraints than their representative organisations. The industries category contain industries mostly involved in biosolids management including food companies which purchase and process all food products, and the retail companies which sell these food products to the consumer.

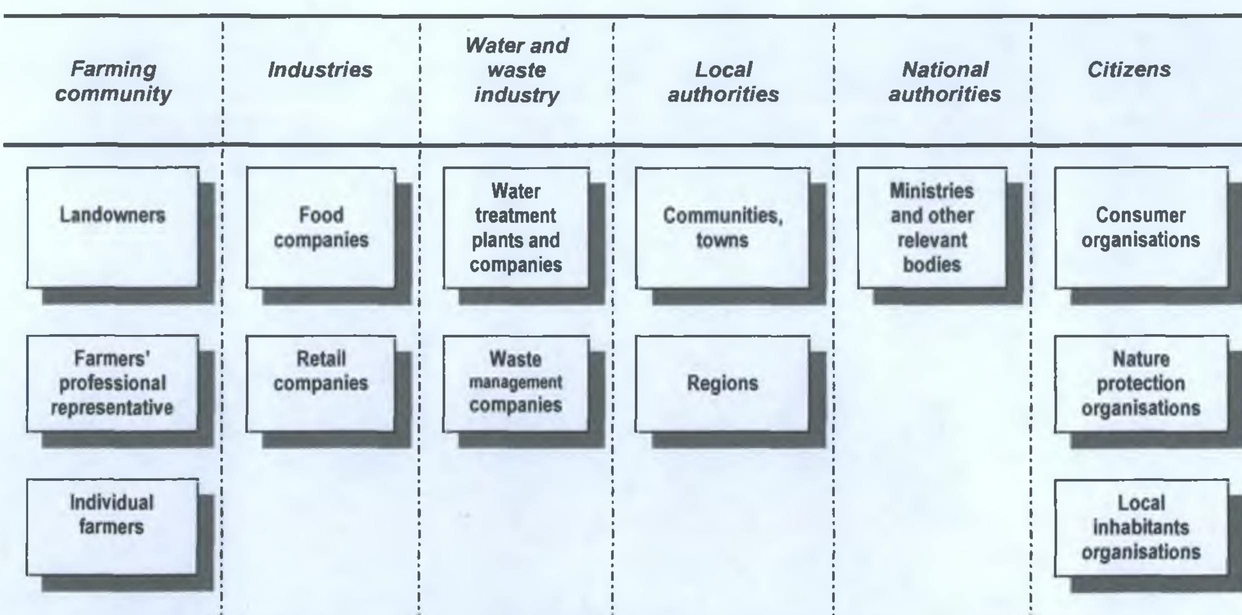


Figure 2.3 Categories of stakeholders involved in biosolids management
(*Source: Andersen 2001*)

The water and waste industry is also an important stakeholder in the biosolids system, as water companies can be in charge of collection and treatment of wastewater, sewage sludge production and treatment, while waste management companies recycle (land spreading companies in particular) or dispose of sewage sludge. The Local Authorities involved in biosolids management can be local communities, towns and cities which usually have the responsibility for wastewater collection and treatment, or regions which can have specific competencies in the field of environmental monitoring and control. In some cases, these local communities have delegated the wastewater treatment service to private operators; however in other cases, the Local Authorities are directly in charge of wastewater and sewage sludge treatment.

The other major categories identified by Andersen (2001) are the national authorities and citizens. The national authorities have essentially the role of defining the official policy concerning biosolids management, including the relevant ministries and agencies charged with environmental, food and public health responsibilities. The citizens or civil society category includes mostly consumer organisations, nature protection organisations, as well as associations of local inhabitants.

CHAPTER THREE
SUSTAINABLE DEVELOPMENT INDICATORS

Sustainable development indicators (SDIs) have emerged as excellent communication tools aimed at making the concept of sustainable development measurable by quantifying and qualifying trends in society (Pastille 2002). This chapter explores the concept of sustainable development and sustainable development indicators, their origin, theory and practice. Various indicator frameworks and typologies are reviewed. The Irish experience in sustainable development and indicator development is also examined.

3.1 Sustainable Development

The publication in 1987 of *Our Common Future,* by the World Commission on Environment and Development (WCED 1987) formally drew worldwide attention to the (un)sustainable nature of human development and its effect on Earth's resources. The Commission defines sustainable development as a process of change in which exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations; sustainable development meets the needs of the present generation without compromising the ability of future generations to meet their own needs. In order to choose the direction or orientation of the change that will lead us towards sustainable development in society, several aspects of many different activities have to be studied (Svanström et al 2003).

Sustainable development implies processes that secure long-term prosperity, welfare and well being without irreversibly affecting nature and the social resource base on which they depend (Mehra 1997). It offers a renewed normative standard in societal decision-making and a guiding principle for deciding about future developments (Dalal-Clayton et al 1994). The principle of sustainability highlights the need to reintegrate the anthropocentric and ecocentric perspectives in human and social development, especially interactions that link economy and ecology (Hens 1999).

Sustainability by definition is a composite, and thus, an ambitious policy target (Neuman 1999). It comprises environmental, economic and social criteria with equal importance. Neither environmental degradation nor violating human dignity by poverty, disease or other threats, nor public or private bankruptcy can be acceptable elements of a sustainable society (Spangenberg et al 1998). The picture that emerges is an holistic and operational view of sustainability that does require global interdependence, environmental stewardship, social responsibility and economic viability (Hens 1999).

Sustainable development will entail integration of objectives where possible, and making trade-offs between objectives where integration is not possible (Dalal-Clayton et al 1994). This approach adduces the 'win-win-win' idea of finding a common ground for economic, social and ecological goals (Spangenberg et al 1998). Figure 3.1 shows the dimensions of sustainable development. The darkened area represents the 'win' or area of full integration or optimum sustainability.

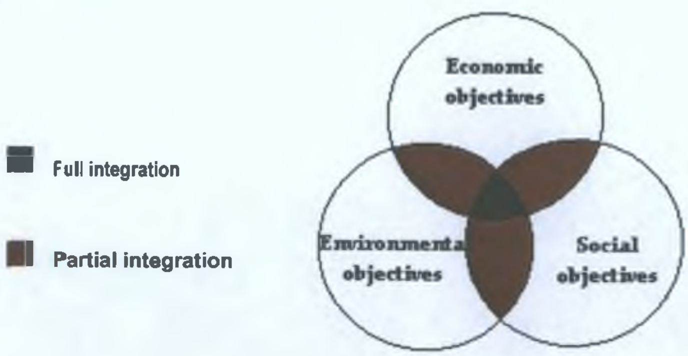


Figure 3.1 Dimensions of sustainable development
(Source: Dalal – Clayton et al. 1994)

Most human activities involve flows of both energy and materials (Svanström et al 2003). They observe that the proper way to address energy and materials management in society would be to focus on the functions we need in sustainable society and then study the most efficient way to use available energy and material sources or flows to fulfil these functions. They further maintain that the three dimensions of sustainable development, social, economic and environmental aspects, are considered to be each equally important for successful implementation of truly sustainable activities.

If the concept of sustainable development were to be broken down in ideological terms, it could be essentially divided into a *weak* and a *strong* definition (Elliot 1998). The weak (Brundtland) definition is the idea that economic goals (or increasing economic growth) which result in natural capital (stock) depletion is compatible with protecting the environment so long as it is converted into manufactured capital of equal value, often referred to as 'ecological modernisation' (Connelly and Smith 1999). In weak sustainability, the principles of the free market and private enterprise are undisturbed, and in fact are strengthened by environmental protection (Connelly and Smith 1999; Elliot 1998). They maintain that the problem with weak sustainability is that, while monetary value can be assigned to manufactured goods and capital, it can be very difficult to assign a monetary value to natural materials and services. Manufactured goods and services cannot replace some of these natural materials and services. For example, they ask; what will be the monetary value of the ozone layer?

Strong sustainability on the other hand, is the idea that certain functions performed by the environment are unique and cannot be duplicated by humans (Mega 1996; Pepper 1996). Again, the ozone layer is an example of an ecosystem that is difficult to duplicate by humans (Pepper 1996). Strong sustainability takes the view that economic and environmental goals are incompatible as they currently stand (Beatley and Manning 1998). It implies living within certain limits, such as consuming resources proportionate to their capacity to regenerate, rather than consuming them until they are depleted and then try to substitute them with something else (Campbell 1996). Connelly and Smith (1999) maintain that strong sustainability further implies a reform of the world economy and decision-making processes, as this will allow the commencement of the long process of trying to reverse the adverse global trends that we are now experiencing.

3.1.1 Agenda 21: The United Nations Conference on Environment and Development (UNCED), the Earth Summit, in Rio de Janeiro, Brazil in 1992 adopted Agenda 21, a comprehensive plan of action to be implemented globally, nationally and locally by organisations, governments, and major groups in every area in which humans have an impact on the environment. Everyone, including governments, business people, trade unions, teachers, indigenous people, men, women and children have their roles, individually and collectively.

Agenda 21 became the frame of reference for sustainable development focussing on humans and their rights to healthy and productive lives in harmony with nature. In other words, it became a framework for reconciling the twin requirements of a high quality environment with a healthy economy for all the peoples of the world (Hens 1999). Agenda 21 provides options for:

- Combating degradation of land, air and water;
- Conserving forests and preserving the diversity of living species;
- Dealing with poverty and excessive consumption, health and education, cities and rural communities;
- Roles for everyone; governments, business people, trade unions, teachers, indigenous people, men, women and children.

Chapter 8 of Agenda 21 recommends that governments draw up national sustainable development strategies (NSDS). The 1997 Special Session of the UN General Assembly set a target date of 2002 for their elaboration. In 2002, the World Summit on Sustainable Development (WSSD) reiterated this recommendation; the Johannesburg Plan of Implementation urged countries to make progress in the formulation and elaboration of NSDSs and begin their implementation by 2005.

Across the globe, states, regions, municipalities and communities are responding to the challenges of making the sustainability transition (Mehra 1997). The Irish experience is presented in Section 3.3.

3.2 Systems Thinking and Sustainable Development

A system is defined as a group of interacting, interrelated or interdependent components that form a complex and unified whole. This configuration of system components allows it to perform specific system functions in its system environment (Anderson and Johnson 1997). Bell and Morse (1999) list six major features of a system:

- Identification of a boundary: this defines the system as distinct from its environment;
- Interaction with the environment: the environment is not the system itself, since it is outside, but it does affect it;
- Closed or open: concerns the interrelation of the system with what lies beyond its boundary;
- Goal seeking: a system is capable of changing its behaviour to produce an outcome;
- Purposeful: systems select goals;
- Exerting control: a system retains its identity under changing circumstances.

There is a vigorous and developing discussion on systems and sustainable development (Stowell et al 1997). One view of the systems approach is the primacy of the whole: the primacy of the whole suggests that relationships are, in a genuine sense, more fundamental than things, and that wholes are primordial to parts. We do not have to create interrelatedness (Stowell et al 1997). They contend that the whole world is already interrelated, and the total system of which human society is a part, and on which it depends for support, is made up of a large number of component systems. However, Bell and Morse (1999) aver that the whole cannot function properly and is not viable and sustainable if individual component systems cannot function properly, that is, if they are not viable and sustainable.

The earth is made up of systems – ecological systems, social systems and economic systems – which represent, overall, an astounding array of complexity, both within and also between them (Stowell et al 1997). The most fundamental of these are the natural (ecological) systems, as without these, there would probably be no other life and no other systems (Senge et al 1994). Bell and Morse (1999) insist that recognising the interrelated nature of all systems provides us with a base from which to start thinking about sustainable development. They further maintain that as part of the overall 'web of life', humanity is intimately connected to natural systems (water, the atmosphere, the biosphere) and our actions will impact upon them. As our influence in natural systems increases, we then feel the effects of our own actions through the dynamics of feedback that exists in all systems (Jones 2001). Sustainable development is possible only if the component systems as well as the total system are viable, and is a property of viable systems: if a system is viable in its environment, then it might be expected to seek its own continuance and therefore sustainability (Senge et al 1994).

3.3 Sustainable Development in Ireland

Enormous changes have occurred in Ireland over the past decade which have transformed the country from being a marginal region of Europe to a position where in 2001, it had a per capita level of income well above the EU average (Walsh 2002). Annual economic growth rates in excess of 7% have been experienced since the mid 1990s, reaching a peak of over 11% in 2000. The total number of people at work increased by 40% between 1991 and 1999, while the number unemployed declined by 52%, giving an unemployment rate of under

4%. Per capita GDP (Gross Domestic Product) levels had risen to the EU average by 1998. In 2000, the per capita GDP for Ireland was the second highest, after Luxemburg, in the EU. Net emigration has been replaced by high levels of net in-migration, including large numbers of return migrants and also many others from diverse ethnic backgrounds (CSO 2001).

In 1992, at the time of the UNCED, Ireland had only just embarked on a programme approach to environmental protection with the publication of the *Environment Action Programme* in 1990; the policy and legislative frameworks for environmental protection and, more broadly, sustainable development were not fully developed; plans for the creation of a specialised agency for environmental protection had not yet reached the implementation stage; industry with significant polluting potential was not subject to an integrated regulatory regime; and finally, in terms of the economic sectors, there was a view that high standards of environmental protection could impact on competitiveness and reduce Ireland's ability to attract Foreign Direct Investment (DOELG 2002). The application of a sustainability-based approach to development in Ireland was first published in a report of the Joint Oireachtas Committee on Sustainable Development (JOCSD) in March 1997 (JOCSD 1997). The report concluded that sustainable development policies would, in the case of Ireland, lead to sustainable competitive advantage in industries, such as food production and tourism, where a green image may enhance job creation.

In April 1997, the Government published *Sustainable Development – A Strategy for Ireland* (Government of Ireland 1997). It examined and addressed the concept of sustainability; and was framed to direct the growth of the Irish economy and national consumption and lifestyle patterns towards a more sustainable course. The overall aim of the strategy is to ensure that economy and society in Ireland develop to their full potential within a well protected environment, without compromising the quality of the environment, and with responsibility towards present and future generations and the wider international community.

In reviewing and assessing the progress so far, the Department of the Environment and Local Government (2002) note that there have been a number of major policy developments. For example, institutions for environmental protection and sustainable development have been strengthened. The assessment records that the concept of environmental integration is now more fully accepted as a feature of legislation, government policy and national development programmes. There is also greater appreciation of the importance of shared responsibility for the environment on the part of all sectors of society. Public access to information in relation to the environment, according to the review, has been extended. The environmental information service (ENFO), has established itself as a model of best practice with an international reputation. In terms of environmental outcomes, the long-standing trend of deterioration in river water quality has been halted.

The 1997 Strategy's aim of achieving more sustainable production and consumption recognises the challenges inherent in a consumer society, fuelled by the economic boom of recent years. The review insists that while there has been progress towards greater eco-efficiency, there is still a considerable way to go in terms of sustainable production. The increase in consumption, whether in terms of transport or energy or individual consumer good, is associated with adverse impacts such as waste generation, congestion and urban sprawl, the review asserts. In terms of future perspectives, the review set out policy priorities in relation to sustainable development for the new decade. In doing this, the review recognises that there will be a need for continuing analysis and adaptation of policies and actions in respect of these issues and in other areas of sustainable development policy concern and action.

The Department of the Environment and Local Government issued guidelines to Local Authorities in 1995 and updated in 2001 to assist the implementation of Agenda 21 at local level in recognition of the fact that local government has a crucial role to play in relation to sustainable development. To promote the preparation of appropriate actions plans, it provided for the appointment of Local Agenda 21 Officers in all Local Authorities (Department of the Environment and Local Government 2002).

Some other administrative structures are in place to review and support progress towards sustainability in Ireland. These include the Joint Oireachtas subcommittee on sustainable development which is monitoring the implementation of the National Strategy, and the Green Network of Government Departments which promotes policy coordination and a consistent approach to environmental management across government departments. COMHAR, the national sustainable development partnership, is established to extend public consultation and participation on the sustainable development agenda. A modern legislative framework for the protection of all the environmental media has been put in place culminating in the Waste Management Act 1996, the Dumping at Sea Act 1996, the European Communities (Natural Habitats) Regulations 1997, and the Litter Pollution Act 1997 and the Wildlife (Amendment) Act 2000. There is a strong and widely respected Environmental Protection Agency; an integrated pollution control licensing system has been put in place in respect of EU Integrated Pollution Prevention Control (IPPC) requirements (DOELG 2002).

However, in critiquing the National Sustainable Development Strategy, O'Sullivan (2001) observes that nearly all strategies proposed are taken either from existing Government or EU policies, and they present a very conservative approach to what is perceived to be a problem which may come to affect this country at some unspecified time in the future. He maintains that Ireland's poor performance in this policy area is a consequence of the uncritical embracing of the principles of free trade and various forms of economic determinism which place monetary values at the centre of development thinking and planning. O'Sullivan specifically questions the rationale behind the Strategy's prediction of increasing unsustainability in the energy field; alternative energy sources are predicted to contribute only 10% of electricity needs by 1999 (while remaining 90% dependent on fossil fuels), despite Ireland having one of the best locations for wave power, wind power and biomass energy; and probably importing 93% of its total energy requirements by 2010.

3.4 Measuring Sustainable Development

The European Commission's Fifth Environmental Action Programme, entitled "Towards Sustainability" published in 1993 (93/C 138, Official Journal of the EC, 17.5.93, p.42ff), recognises as a priority the strengthening of the information systems needed to formulate a sustainable way of development. It demands that decision-makers and the public must have ready access to accurate information on the benefits and hazards associated with development (EC 1993).

Heinen (1994) maintains that sustainability must be made operational in each specific context (for example forestry, agriculture), at scales relevant for its achievement, and appropriate methods must be designed for its long-term measurement. There is little consensus on how sustainable development should be measured (Hens 1999).

3.4.1 Measuring the wealth of nations (MWN): The World Bank's analysis of the wealth of nations was first published in 1995. It generated great interest in the use of indicators to measure the pace and direction of change in environmentally sustainable development (Hamilton and Lutz 1996). In particular, the attempts to redefine what it means to be "wealthy" or "poor" by recognising that a country's wealth is the combination of various forms of capital, produced, natural, and human resources, led to new thinking on what constitutes wealth and how it could be measured (Cropper and Simon 1996). The emphasis on stocks of wealth supports a new paradigm for sustainable development, as a process of managing a portfolio of assets to preserve and enhance the opportunities people face (World Bank 1997).

The MWN offers a structured approach with aggregated monetarised results which allow international comparisons. These include new estimates of national wealth and genuine saving (the true rate of saving in a nation after due account is taken of the depletion of natural resources and the damage caused by pollution), a detailed analysis of changes in subsidies with environmental consequences, and progress on the conceptual foundations of social capital (Hamilton 1996). They are based on easy to acquire data sets and use existing knowledge in indicators development. Moreover, the need for clear policy targets to relate to measurements, and for complementary work to be done, is recognised (Cropper and Simon 1996). The new estimates reinforce the importance of the natural resource base of all economies as well as the fundamental role of human resources (including both human capital and the more difficult to define but important concept of social capital) in determining a nation's wealth and, in turn, the opportunities for welfare gains for a nation's population (World Bank 1997). The focus of MWN is on economic growth placed in a context of sustainability while social capital is defined and examined in terms of how it affects economic growth (Hamilton 1996). Economic growth may be an important aspect, especially in developing countries, which is the main target area of the World Bank. However, the distinctions between growth and development as well as the identification of economic sustainability as one of the components that constitute sustainable development have long been recognised (Farsari and Prastacos 2001). The policy implications of measuring genuine saving are quite direct: persistently negative rates of genuine saving must lead, eventually, to declining wellbeing. For policy makers, the linkage of sustainable development to genuine rates of saving means that there are many possible interventions to increase sustainability, from the macroeconomic to the purely environmental (Hamilton 1996).

However, MWN has some inherent problems in its concept and methodology (OECD 1998). What OECD referred to as 'substitution' appears in MWN under the concept of 'investment' and 'saving'. Consumption of natural resources can be regarded as investment if genuine saving is positive. Although critical limits on depletion are recognized, MWN is silent on the use of the saving, for example, part of saving being invested on research and technology development on more sustainable options. This adds some limitations in its use as a measure of sustainable development (Farsari and Prastacos 2001). Moreover the conversion of environmental function to monetary terms places the focus on the instrumental or use values of natural resources. The World Bank in its estimations is presently ignoring critically important ecological and life support functions provided by natural systems as well as their aesthetic value because the calculations needed are too complex to undertake (Hardi and Barg 1997).

3.4.2 Barometer of sustainability: The Barometer of sustainability is one of the individual contributions towards making sustainable development measurable. It was developed by Robert Prescot-Allen in 1997 and has three special features.

The first feature of the barometer is the equal treatment of people and the ecosystem. The Barometer treats people and the environment together and as equally important. The scale has two axes, one for human wellbeing and the other for ecosystem wellbeing. This ensures that an improvement in human wellbeing does not mask a decline in ecosystem wellbeing, or vice versa. Each conclusion about the conditions of people is expressed as a point on the human axis; an index of human wellbeing. Conclusions about the condition of the ecosystem are expressed as points on the ecosystem wellbeing axis; an index of ecosystem wellbeing. The intersection of the two points provides a reading of overall wellbeing and progress towards sustainability (Prescot-Allen 1997). A lower score on one axis overrides a higher score on the other; the reading of overall wellbeing and sustainability is based on whichever subsystem (the society or the ecosystem) is in worse condition. This is to prevent an improvement in ecosystem wellbeing being read as compensating for a drop in human wellbeing, or vice versa. It reflects the view that people and the ecosystem are equally important and that sustainability is a combination of human wellbeing and ecosystem wellbeing (Prescot-Allen 1997).

The second feature of the Barometer is the five-sector scale. The user can control the scale by defining the range of performance appropriate for each sector. This feature gives users an unusual degree of flexibility; in other performance scales, only the end points are defined. Defining the sectors of the scale extends a series of judgements that starts with definitions of sustainable development, ecosystem wellbeing and human wellbeing, and continues through the choice of issues to be assessed and the selection and interpretation of indicators. This process of value-based judgements is not peculiar to the Barometer. It is common to all decision making and assessment, but perhaps not sufficiently acknowledged (Prescot-Allen 1997).

The third feature of the barometer is the ease of use. Converting indicator results to the Barometer scale involves simple calculations. Formulae accessible only to people trained in statistics or indices have been deliberately avoided. Ease of use by a wide range of users is preferred to mathematical sophistication. Moreover, it allows the interested parties to define their own criteria for sustainability and thus the overall process to be participative. One of the most important points which should be self evident in all sustainable development measurement frameworks is that there is no substitution between ecosystem and human wellbeing as they are both prerequisites for sustainable development (Prescot-Allen 1997).

Hardi and Barg (1997) have highlighted the Barometer's limitations concerning subjectivity of the procedure employed. There is especially the question of what constitutes sustainable development and whether there exists a unique set of clearly defined criteria to assess sustainability by the Barometer (Farsari and Prastacos 2001).

3.4.3 Ecological footprint: Wackernagel and Rees, in their contribution towards making sustainable development measurable, formulated the ecological footprint analysis. It measures how much land is required to supply a particular population (country, region, city, business or individual) with its living and lifestyle needs, food, housing, energy/fuel, transport, and consumer goods and services. The ecological footprint analysis is made on the assumption that each human activity requires resources and produces waste flows which need to be dissipated to a biologically productive area necessary to provide these functions (Wackernagel and Rees 1996). Performing this exercise shows how divergent lifestyles in different regions of the world result in highly variable footprints; poorer developing countries show footprints of less than one hectare per capita while those of wealthy countries approach nine to ten hectares (Wackernagel *et al* 1997). These figures should be viewed within the perspective that there are only 1.5 hectares of ecologically productive land and about 0.5 hectares of truly productive ocean per person on the Earth, the 'fair Earth-share'.

According to Farsari and Prastacos (2001) eco-footprint analysis is rather an indirect way of measuring sustainability. They maintain that it actually measures consumption of goods and translates them into productive land units. Given the fact that consumption patterns are a major issue for sustainability, it manages to capture this basic element and relate it to the other very basic element, which is resources depletion (Hamilton and Lutz 1996). However, socio-cultural aspects are indirectly reflected in the results, while there are environmental issues such as contamination which are not included to provide a full picture of the state of the environment. Therefore, it offers a good tool for global and national monitoring of aggregated crude results, but when detailed information is needed to proceed to national and sectoral policies, more rigorous and specific data may be necessary (Farsari and Prastacos 2001).

Ecological footprinting remains a very useful accounting tool to monitor and compare changes in a global scale or between nations in their consumption patterns and gives a picture of the state and trends over time. Its contribution to developing sustainability is that it highlights the issue of equity between nations, and between developing and developed societies (Wackernagel et al 1997).

3.4.4 Sustainability indicators: Chapter 40 of Agenda 21 (UNCED 1992) calls for countries, international organisations and non governmental organisations (NGOs) to develop indicators of sustainable development and use them to develop policy. These indicators must be conveyed in a readily comprehensible way, but compiled with due regard for inherent complexities and uncertainties in the data. This will then provide better and more systematic information about the factors affecting sustainable development which can be drawn on when making decisions (OECD 1999). Indicators are used to simplify information about complex phenomena, such as sustainable development, in order to make quantification possible and communication easier (Pastille 2002). They act as signs or signals of complex events and systems. They are pieces of information pointing to characteristics of systems or highlighting what is happening (IISD 1997).

Building upon the systems approach, authors such as Rotmans (1997) stress the importance of including both flow and stock indicators, in response to the dominance of flow indicators in most studies. Stock indicators represent the state of a system at a particular moment in time, while flows refer to the rate of change and are thus measured over a period of time. Usually stock levels change only slowly, so that they can often be assumed to remain constant in the short term. However, in the long run, stocks can change drastically, both in a quantitative and in a qualitative sense. In turn, this can have an important effect on the performance of the system and on the volume of flows. For issues that have long-term scope, a thorough understanding of developments of both stocks and flows is necessary, because each contains unique information: flow indicators highlight short-term changes, while stock indicators do so for long-term changes.

Indicators vary depending on the audience, and the geographic, political or social context (Pinter et al 2000). To be meaningful at local levels, the selected indicator must reflect community values, concerns and hopes for the future. Providing members of the community with information that they are not prepared to utilise is not productive (Pastille 2002). Indicators therefore must be tailored to the needs of the users: policy makers and the public. The public, on the other hand, must be able to provide their own contributions to addressing the problems to which they ultimately contribute (Filho 1999).

The Bellagio Principles for sustainable development were developed in November 1996 at Bellagio, Italy (Hodge and Hardi 1997). According to Bell and Morse (1999), the Bellagio Principles deal with four aspects of assessing progress towards sustainable development:

- *Principle 1* deals with the starting point of any assessment – establishing a vision of sustainable development and clear goals that provide a practical definition of that vision, in terms that are meaningful for the decision-making unit in question;
- *Principles 2 through 5* deal with the content of any assessment and the need to merge a sense of the overall system with a practical focus on current priority issues. *Principle 5* particularly emphasises the use of a limited number of SDIs;
- *Principles 6 through 8* deal with key issues of the process of assessment;
- *Principles 9 and 10* deal with the necessity for establishing a continuing capacity for assessment, and broadly layout how the SDIs should be developed and employed.

The ten principles are presented in full in Appendix A.

One of the major criticisms regarding SDIs is that they attempt to encapsulate complex and diverse processes in a relatively few simple measures (IISD 1997). Another is the unavoidable issue of subjectivity in the selection and evaluation of representative indicators (Filho 1999). Stakeholders (including researchers and experts) involved in the construction of SDIs have certain scientific and social backgrounds and therefore a degree of subjectivity is inevitable (Bossel 1999). Other problems include lack of appropriate data and over aggregation of data. Lack of appropriate data may result to the omission of vital information. This will invariably lead to measuring what is measurable rather than what is important. Over aggregation could also lead to misinterpretation, bad communication and analysis incapability (Meadows 1998). However it is generally accepted that indicators as measures of sustainability can be valuable aids to planning, forecasting and awareness building when chosen carefully and as systematically as possible (IISD 1997).

3.5 Definition and Purpose of SDIs

The need for an integral systematic approach to indicators' definition, framework and measurement has been widely recognized (Bossel 1999). The emphasis is to develop well-structured methodologies, easy to reproduce and to ensure that all aspects of sustainable development are included in the measurement (Farsari and Prastacos 2001).

In general, it may be said that an indicator is a synthetic and representative reflection of a greater, more complex sum of phenomena, preferably made measurable on a quantitative scale (OECD 2001). Sustainability indicators are key mechanisms to measure progress of a system or society towards or away from sustainability (Pastille 2002). By providing information relevant to sustainability in comprehensive and quantitative form, sustainable development indicators have become powerful aids for decision-making (IISD 1997). They comprise a characteristic or condition which can be described in a way which provides information about some other characteristics or condition which is, itself, not amenable to direct observation or measurement (Passachier 2002).

Measuring progress towards or away from sustainability is important to:

(a) Provide feedback on system behaviour and policy performance;

(b) Improve chances of successful adaptation;

(c) Ensure movement toward common goals;

(d) Improve implementation; and

(e) Increase accountability.

Indicators help support sustainability assessment and are essential in policy formulation (Pinter et al 2000). Other important purposes of indicator use are summarised in Figure 3.2.

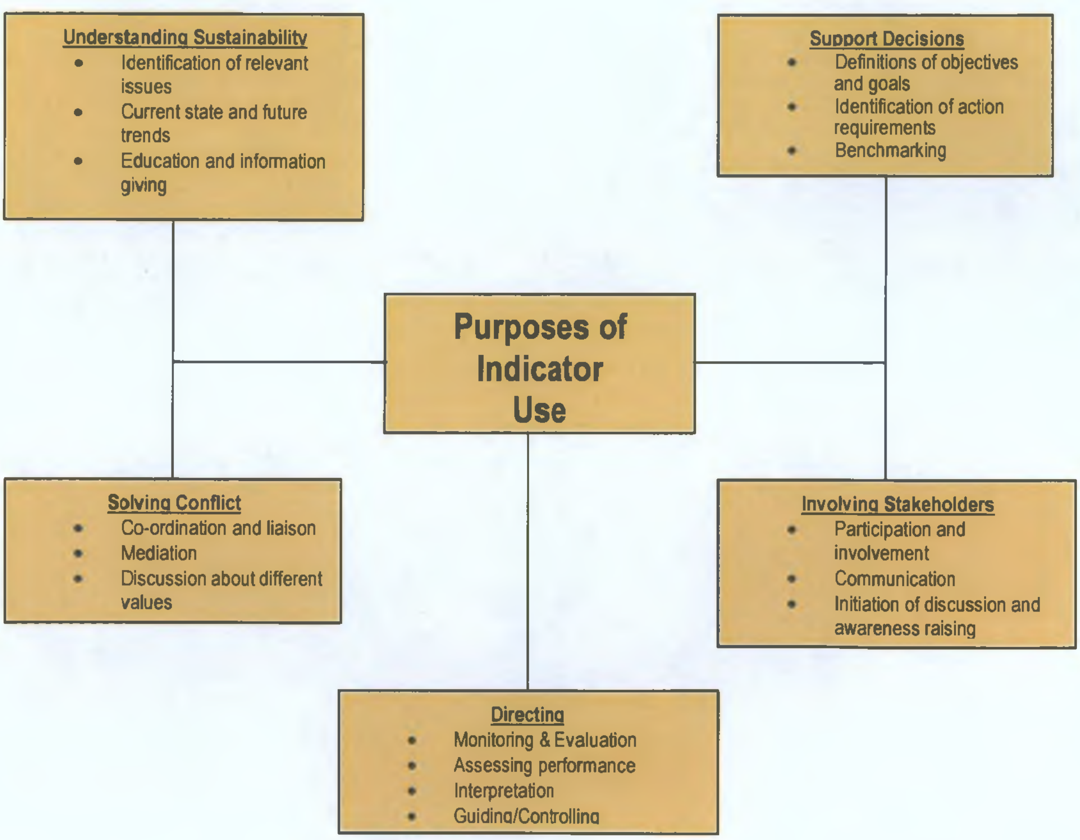


Figure 3.2 Purposes of indicator use (*Source: Pastille* Consortium *2002)*

The search for suitable SDIs has resulted in intense research and demonstration initiatives worldwide (OECD 2001). This is to address the increasing importance of environmental policy issues, particularly in the context of sustainable development (Lehane 1999). Bossel (1999) lists a number of requirements for identifying indicators of sustainable development:

- Indicators of sustainable development are needed to guide policies and decisions at all levels of society: village, town, city, county, state, region, nation, continent and world;
- These indicators must represent all important concerns: an *ad hoc* collection of indicators that just seem relevant is not adequate. A more systematic approach must look at the interaction of systems and their environment;
- The number of indicators should be as small as possible, but not smaller than necessary. That is, the indicator set must be comprehensive and compact, covering all relevant aspects;
- The process of finding an indicator set must be participatory, to ensure that the set encompasses the visions and values of the community or region for which it is developed;
- Indicators must be clearly defined, reproducible, unambiguous, understandable and practical. They must reflect the interests and views of different stakeholders;
- Through analysis of trends shown by these indicators, it must be possible to deduce the vitality and sustainability of current developments, and to compare with alternative development paths;
- A framework, a process and criteria for selecting an adequate set of indicators of sustainable development are needed.

SDIs are developed based on available data, the information needs of decision makers and key policy priorities (OECD 2001). They are potentially powerful tools for creating change because they go to the heart of decision-making (Hens 1999; Lehane 1999). Although lack of data makes indicator development more difficult, it does not make it impossible. If no data directly related to an important issue are available, a number of techniques may need to be adopted to fill the gap (OECD 1999).

3.6 Selecting Indicators

The selection and design of good indicators is a daunting task. Therefore, it is useful to identify a set of clear criteria for indicator selection and design (Azapagic 2004). The OECD (2001) has developed a set of criteria for selecting operational indicators based upon three simple ideas:

- Policy relevance and utility for users;
- Analytical soundness, and;
- Measurability.

Another criterion is the level of aggregation (Cartwright 2000; Jesinghaus 2000)

3.6.1 Policy relevance: An indicator should be relevant to the objectives of the policy or issue which it intends to address (Braun et al 1999). It is intended to improve the outcome of decision-making on levels ranging from individuals to the entire biosphere (Pastille 2002). Defining the issue to be addressed is therefore the first essential step in selecting indicators. This, however, poses its own problems, for issues are themselves multidimensional, and the definition of any issue is likely to vary, depending on the perspective of the user (Cartwright 2000). Each of these may then be traced either backwards (towards their source) or forwards (towards the effects and consequences). Because of the many-to-many relationships involved, each will thus follow a different network of links, and result in a different definition of the issue of concern (Innes and Booher 2000).

3.6.2 Analytical soundness: A good indicator is one that stakeholders can understand and depend on (Pastille Consortium 2002). It must be evidenced either by research, or evident from logic and first principles (OECD 2001). Variations or changes in the indicator must also reflect changes or variations in the target. The association must therefore be consistent across the range of conditions that the indicator describes. Association between indicators and the target conditions they refer to can take several forms (Innes and Booher 2000). They list four main types of association that can usefully be recognised:

- Causal indicator and target are linked because one causes the other;
- Contingent indicator and target are linked because one is a necessary precondition for the other;
- A statistical association links statistical indicator and target. In this case, one does not cause or act as a precondition for the other, but the two tend to vary in broad harmony, often because both are related to some other common factor, or because they are part of a complex web of association or coexistence;
- Component indicator and target are linked because one represents a subcomponent of the other.

Whatever the association, stakeholders should be able to relate it to some common knowledge or experience (Pastille 2002).

3.6.3 Measurability: An indicator should be easy to collect, measure and record (OECD 2001). Effective indicators should be based on data that are easy to access (IISD 1997). This is a principle that many proposed indicators fail to satisfy, primarily because the data needed to construct them are not available, or the methods or models for applying them are not well established (Cartwright 2000). Simple availability of data is not enough. The data must also be accurate enough to enable changes in the target condition to be detected. In order words, the indicator must be sensitive to real variations in the target condition, and must not be blurred by errors, uncertainties, inconsistencies or gaps in the data (Passachier 2002).

3.6.4 Level of aggregation: A fourth criterion is the level of aggregation. This criterion seeks to determine at which level (sectoral, regional, national) the indicator should be applied. This is to establish meaningful information for policy monitoring (Jesinghaus 1999). This criterion encapsulates the spatial and temporal diversity of the measured phenomena and the geographic scale of different issues ranging from the local level to the global scale (Terres and Al-Khudhairy 2000).

Cartwright (2000) recognises that some indicators are more sensitive and/or relevant to regional/local situations. Hence, a consistent way to construct and measure some indicators at national level is to define regions and to establish a representative sample set of monitoring sites in the regions (Terres and Al-Khudhairy 2000).

3.6.5 Other criteria: Authors such as (Bosch 2001, Kreisel 1984, Adriaanse 1993, Pastides 1995) have also attempted to define criteria for good indicators in the areas of environment and sustainable development. They suggest a number of core criteria for effective indicator selection and design (see Table 3.1). It needs to be noted that the criteria are not all necessarily achievable in every case and that they apply not just to individual indicators, but also to the indicator set as a whole (Bosch 2001). Ideally, indicators developed at local level should feed into regional-scale indicators, and hence into those developed at national and international level (Terres and Al-Khudhairy 2000). This provides a seamless cascade of information between the different levels – and a means of ready communication and consensus. In practice, this is difficult to achieve, since local users are likely to be concerned about different problems, and want them expressed in different ways (Cartwright 2000). Passachier (2002) warns that different users may read different messages from an indicator. Some potential users may simply gain nothing from a particular indicator, because it does not convey anything of obvious relevance. This is not to say that both vertical and horizontal linkage of indicators is not possible. Rather, the issue is that these means of translation need to be developed if indicators are to have meaning for all those concerned.

Table 3.1 Criteria for effective indicator set *(Source: Passachier 2002)*

Precept	Criterion
Interpretability	*Scientifically credible* – based on known or strongly suspected relationships between what is being measured (indicators) and what they are intended to represent (target conditions) *Sensitive* – responsive to changes in the target conditions (and thus specific to those target conditions and reasonably unconfounded) *Consistent* – providing a coherent message (different indicators are not contradictory) *Transparent* – computed using a clear and explicit methodology (which can thus be repeated if necessary) *Understandable* – expressed in a way that can be easily and consistently understood by the user
Measurability	*Available:* - based on data that are already available or obtainable within an acceptable timeframe and cost *Timely:* - available soon after the event or period to which it relates *Spatially accurate* – at a sufficiently high resolution to show geographic variations in the target condition *Robust* – unaffected by minor variations in the data source or method of computation
Utility	*Relevant and Pertinent* – related to an issue of current or future concern to the user *Exclusive* – without unnecessary duplication *Comprehensive* – covering the whole area, time period and issue of concern *Cost Effective* – providing information that merits the costs of implementation.

3.7 Indicator Frameworks

Putting indicators in an appropriate context or framework can increase their usefulness (IISD 1997). A conceptual indicator framework provides a convenient way to organise indicators in relation to system components and ensure they correspond to different purposes within the system. A well-defined conceptual indicator framework is essential for describing the process relationships between the origin and consequences of environmental problems and benefits (Hammond et al. 1995).

Given the virtually unlimited number of potential indicators, a well-defined conceptual indicator framework should have a coherent, solid methodological and scientific basis for indicator selection. This will make for a structured selection process that permits 'comparisons' from country to country and from organisation to organisation (Jesinghaus 1999).

The following is an overview of some of the best known international efforts on the development of conceptual frameworks for sustainable development indicators. They use different typologies to categorise indicators, based on the driving force – pressure – state – impact – response (DPSIR) chain of cause-effect relationships, on capital forms and on stocks and flows respectively. The frameworks examined in this study include the:

- OECD's Pressure-State-Response (PSR) framework
- UNCSD's Driving Force-State-Response (DSR) framework
- Driving Force-Pressure-State-Impact- Response (DPSIR) framework
- World Bank's Measuring the Wealth of Nations (MWN)
- Barometer of Sustainability
- Ecological Footprint

The first four frameworks are developed by international organisations while the last two are experimental frameworks developed by individuals.

3.7.1 Pressure-State-Response (PSR) Model: The PSR model developed by the OECD (1995) has played a dominant role in the indicator framework debate. Figure 3.3 presents the conceptual framework for the model. The PSR framework for indicator development is based on the concept of causality (Hens 1999). Human activities, processes and patterns (driving forces) influence the environment and, in many cases, exert pressure on it. Use of natural resources, emission of pollutants and the production of waste are the classical parameters of these pressures. They can result in effects on the environment, such as global climatic changes, ozone depletion, soil erosion and eutrophication. Often such changes have direct, delayed or potential impacts on the functioning of ecosystems (Hammond et al. 1995). They also impact on societies for example, through shortage of clean water, collapse of fisheries from over exploitation, and ailments and death due to atmospheric pollution. Society responds to these changes by policy, for example, energy taxes. Sometimes nature has the capacity to respond to the altered environmental state spontaneously (Jesinghaus 1999). The model has the big advantage that it interlinks through policy actions the interrelation between the human subsystem and the environmental subsystem (Hens 1999).

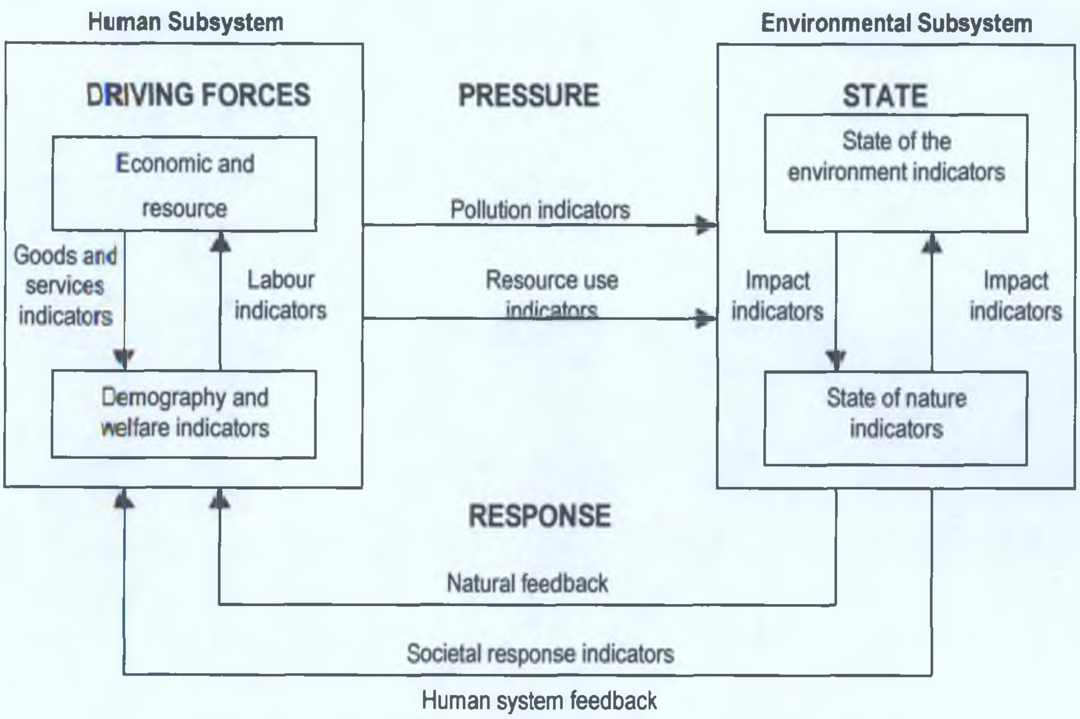


Figure 3.3 Conceptual framework of Pressure-State-Response model for indicators.
(Source: UNEP and DPCSD 1995)

The PSR framework has limitations. One of these, according to the OECD (1998), is that in practice, the distinction between environmental conditions and the pressures may be ambiguous and the measurement of environmental pressures is often used as a substitute for the measurement of environmental conditions.

Another disadvantage is the linear relationships in the human activity and environment interactions which is incapable of capturing the more complex and dynamic nature of the processes (OECD 1993, Bossel 1999). Finally, the crucial role of target groups and sectors is inadequately reflected in the model (Hens 1999).

3.7.2 Driving Force-State-Response (DSR) Model: The United Nations Department of Policy Co-ordination and Sustainable Development (DPCSD or CSD for short) has its own programme for the development of sustainability indicators (CSD 1995). Using the PSR model of the OECD as a base, the CSD broadened the model's scope to include non-environmental dimensions of sustainability. The CSD model is called Driving force-State-Response (DSR) model.

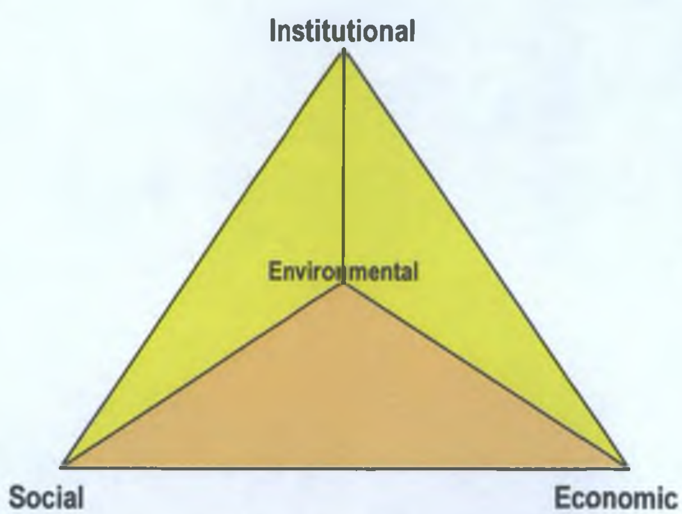


Figure 3.4 The four dimensions of sustainability
(Source: UNEP and DPCSD 1995)

In the DSR model (Figure 3.4), the term 'driving force' is used synonymously for 'Pressure'. The model intends to reflect the economic, social and institutional dimensions of sustainability on an equal footing with the environmental concerns. However, the system provides no advice as to which of the responses listed are considered effective in reducing the pressures and in redirecting the driving forces and/or improving the state, in particular when considering the interdependencies with constraints in other sectors. Based on existing data, its focus is on predetermined environmental stresses, which at a particular time appear to be of major political concern (Spangenberg et al 1998).

Consequently the issues chosen are mainly issues of the state of the environment like forest decline, loss of biodiversity, and climate change. Only remaining stocks are seemingly of interest, and inputs from the ecosphere to the techno- or anthroposphere are not considered. This is a major shortcoming. Focusing on the state of the environment will necessarily lead to very complex analysis, without providing appropriate links to the important driving forces that lead to environmental degradation (Bossel 1999).

Spangenberg et al (1998) propose the development of proactive indicators that do not focus on symptoms or damages but rather concentrate on the underlying trends. The linkages are shown in Figure 3.5. They postulate that these indicators will permit 'ex-ante', measures to be taken on emerging problems (referred to as response indicators in the PSR terminology). Furthermore the indicators need not only meet scientific criteria, but additionally they have to match communication needs.

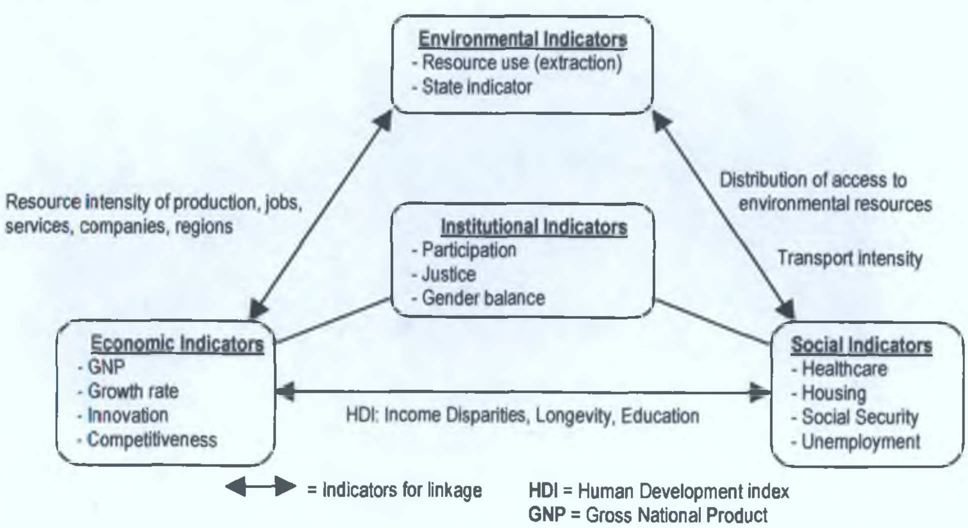


Figure 3.5 Sectoral and interlinkage indicators *(Source: Spangenberg et al 1998)*

These proactive indicators have to be communicable, transparent and reproducible, limited in number but reflect, in the long term, main stresses in a directionally safe and reliable manner. The proactive indicators proposed have to be performance indicators linked to quantifiable policy targets. Interlinkage indicators for the four dimensions of sustainability proposed include:

- Socio-environmental interlinkage indicator, the target being equitable access to environmental resources (on a per capita basis);
- Socio-environmental disturbance indicator which reflects, for example, not only energy, material and land use by the transport system, but also social aspects such as travelling distances and the corresponding shortage of time to be spent with family and friends;
- Enviro-economic interlinkage indicator measuring resource intensity per unit of output, and
- Socio-economic interlinkage indicator using the human development index (HDI).

However Spangenberg et al (1998) admit that generating and processing data for the interlinkage indicators could be cumbersome and expensive.

3.7.3 Driving Force – Pressure – State – Impact – Response (DPSIR) Model: DPSIR is a complementary framework formulated by the indicator community. The OECD subdivided the pressure component to include both direct and indirect pressures (OECD 2001). The United States Environmental Protection Agency (US EPA) also extended the framework to include a component defining the more remote, upstream influences – the Driving Forces (US EPA 1994). In adopting a framework for environmental policy and state of environment reporting, the European Union (EU) incorporated a component for Impacts, in creating the DPSIR framework. Figure 3.6 illustrates the DPSIR conceptual framework.

The DPSIR model is designed to better describe underlying social and economic trends. According to the systems analysis view, social and economic developments exert pressure on the environment and, as a consequence, the state of the environment changes, such as changes in resource availability and biodiversity. Finally, this leads to impacts on human health, ecosystems and materials that may elicit a societal response that feeds back on the driving forces, or on the state or impacts directly, through adaptation or curative action (Smeets and Weterings 1999). Economic indicators focus on small, easily measured parts of the economy that provide a glimpse into the condition of the economy. Social indicators deal with issues of health, safety, well-being and education (Department of Urban Affairs and Planning 2001).

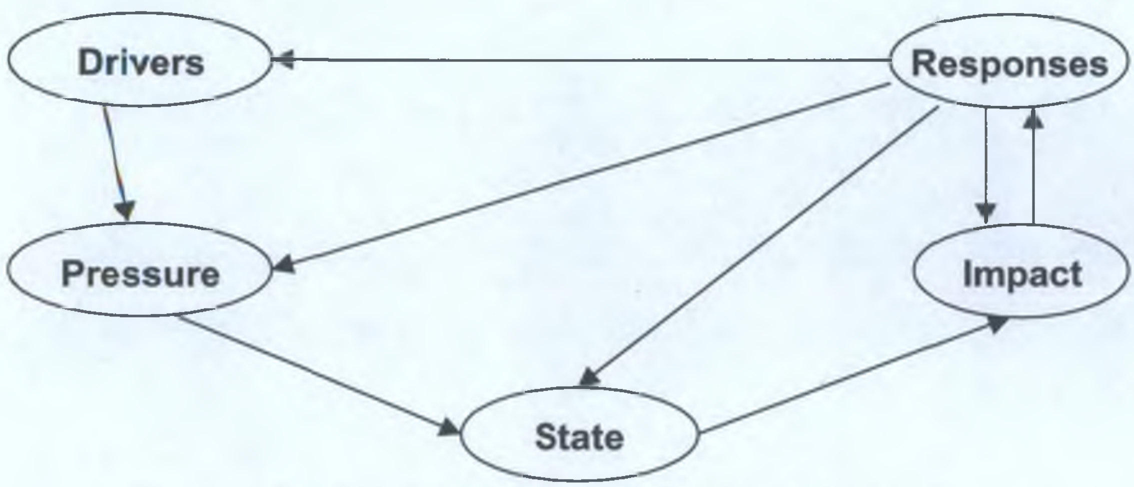


Figure 3.6 The DPSIR framework model (EEA-Eurostat 1999)

Although the DPSIR framework has been criticised for over-simplifying reality and ignoring many of the linkages between issues and feedbacks within the socio-ecological system, the framework is nevertheless a useful conceptual system (Smeets and Weterings 1999).

Obviously, the world is far more complex than can be expressed in simple causal relations in systems analysis (Penfield 1997). There is arbitrariness in the distinction between the environmental system and the human system (OECD

2001). Moreover, many of the relationships between the human system and the environmental system are not sufficiently understood or are difficult to capture in a simple framework (Smeets and Weterings 1999).

The relationships between the elements of the framework, such as driving forces and pressures, may not always be simple; responses to one pressure can become a pressure on another part of the system (Bossel 1999). For example, the clearing of forestland for farming may be identified as a pressure when studying biodiversity, and as a response when studying rural poverty. The demarcation between components is not always clear and debate on the usefulness of these models is on-going (Garcia and Staples 2000). Some more fundamental shortcomings are related to the fact that the framework is based on causal chains in the physical sphere. Causal chains in the social and economic domains tend to be even more complex and unpredictable (Passachier 2002).

The main properties and functions of indicators in the DPSIR framework are summarised by Jesinghaus (1999):

- *Driving force indicators:* these indicate the underlying causes that lead to environmental pressures such as sectoral trends in water and wastewater treatment. Driving force indicators represent human activities, processes and patterns that impact on sustainable development. They are not very responsive or elastic. Powerful economic forces drive the monitored phenomena, such as one-off housing. Therefore, it can hardly be expected that the prevailing trends will change radically in the near future. However, driving force indicators are useful in calculating a variety of pressure indicators and, also help decision makers to plan actions (responses) needed to avoid future problems (pressures).
- *Pressure indicators:* these indicate human activities that directly affect the environment, such as exploitation of land and water resources. They point directly at causes of the problems. One specific feature of pressure indicators is that they must be responsive, that is, a decision maker has

the opportunity to positively alter the indicator by launching appropriate actions. They will also serve as an incentive for rational solutions, since they demonstrate the effectiveness of political action early enough so that those who took the action could be held accountable.

- *State indicators:* these indicators refer to the observable changes to the environment as a result of the earlier mentioned pressures. The change over time is often very slow. For example, a state indicator showing the acidity levels of forest soils points back to the NO_x and SO_2 emissions of the last two decades. However, state indicators can be used to make preliminary assessment of the current situation (what is the current acidity level of forest soils?).
- *Impact indicators:* these reflect the impact of changes in the state of the environment on for example ecosystems, biodiversity, and amenity value. These indicators react even slower than state indicators. Some impacts are only detected when any action to ameliorate them is already too late. In addition, it is rarely possible to establish significant statistical correlations between pressures, state, and impacts due to the enormous delays and the influence of non-environmental variables. The main purpose of impact indicators is to demonstrate cause-effect chains in the DPSIR model, and to facilitate informed discussion about actions to avoid negative impacts in future. In this sense, they may rather be regarded as scientific decision models than statistical indicators.
- *Response indicators:* these reflect the response of decision and policy makers to solve problems and which will in turn influence the driving forces, pressures and states, thus completing a feedback loop. They change through time very quickly, since they monitor the measures that are intended to drive the slow socio-economic system. For example, rising water costs due to the introduction of a water charge can be observed immediately. However the full effects of this measure due to behavioural, technological and other adjustments may be noted in subsequent years.

The Pastille Consortium (2002) listed additional indicator types which could be vital at local scale depending on indicator purpose. They include:

- *Rate indicators* specify the velocity of change of the state of a system such as decrease of ambient air quality within a year;
- *Steering indicators* specify measures which aim to influence the process of change towards a desired situation;
- *Process indicators* specify measures which relate to aspects of the process by which change will be achieved (also known as appraisal and output indicators).

The DPSIR framework has also proved useful in describing the relationships between the origins and consequences of environmental problems. However, in order to better appreciate their dynamics, it is also important to focus on the links between DPSIR elements (Smeets and Weterings 1999). They maintain that, for example, the relationship between the driving force (D) and the pressure (P) by economic activities is a common function of the eco-efficiency of the technology and related systems in use (see Figure 3.7).

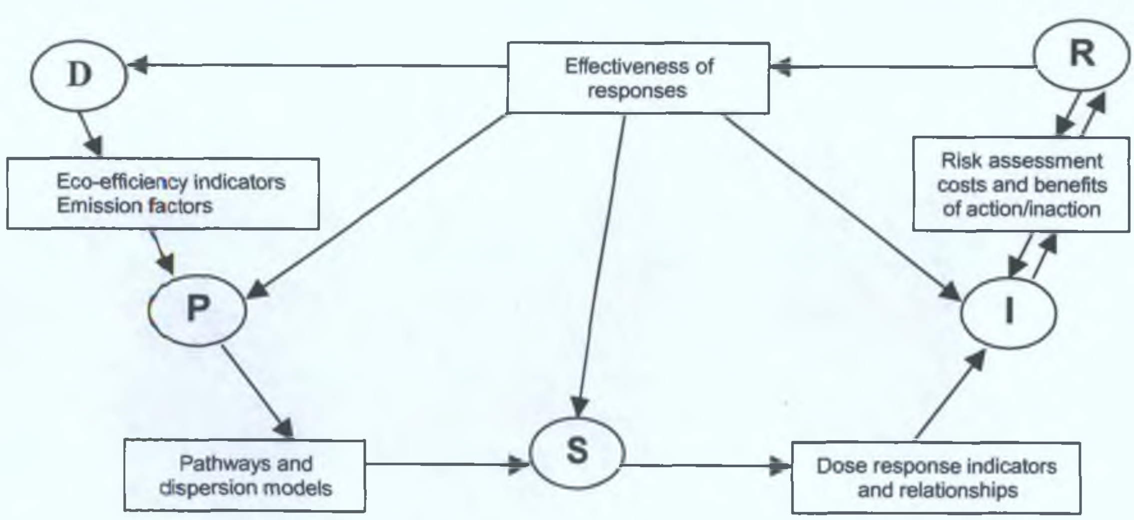


Figure 3.7 Indicators and information linking DPSIR elements
(Source: Smeets and Weetering 1999)

Similarly, the relationship between the impacts (I) on human ecosystems and the state (S) depends on the carrying capacities and thresholds for these systems. Whether society responds (R) to impacts depends on how these impacts are perceived and evaluated, and the results of 'R' on the 'D' depends on the effectiveness of the response.

3.8 Typology of Indicators

Indicators can be classified in many ways, for example, according to whether they are concerned with impacts, processes or outcomes or whether they are quantitative or qualitative (Pastille 2002).

In practice, indicators can be distinguished as *system indicators* or *performance indicators* (IISD 1997).

System indicators summarize sets of individual measurements for different issues characteristic of the human/social system and the ecosystem, and communicate the most relevant information to decision makers. System indicators are based on technical and scientific insights whenever possible. However, due to the uncertainties of the natural and social systems, this is not always possible. Both science and the policy process determine the standards and benchmarks to which indicators are related. SDIs are a product of a compromise between scientific rigour and the needs of decision-making, and urgency of action (IISD 1997).

Performance indicators are tools for comparison, incorporating a descriptive indicator and a reference value or a policy target. They allow decision makers to evaluate actions in relation to policy goals (IISD 1997).

The EEA, according to Bosch (2001), has classified indicators into five simple groups which address the questions outlined in Table 3.2.

Table 3.2 EEA typology of indicators *(Source: Bosch 2001)*

Question	Indicator
- What is happening to the environment and to humans?	Type A or Descriptive Indicators
- Does it matter?	Type B or Performance Indicators
- Are we improving?	Type C or Efficiency Indicators
- What is the effect of policy?	Type D or Policy-effectiveness Indicator
- Are we on the whole better off?	Type E or Welfare Indicators

The EEA (Bosch 2001) have defined the various indicator typologies as follows:

- A descriptive indicator is defined as one that indicates what is happening to the environment or to humans such as concentration of pollutants. They are usually presented as a trend line;
- Performance indicators compare factual conditions with a specific set of reference conditions. They are linked to a reference value or policy target, illustrating how far or close the indicator is from the desired level. They use the same variables as descriptive indicators but are connected with target values such as national policy targets, international policy targets accepted by government, and/or tentative approximations of sustainability levels;
- Efficiency indicators provide insights into the efficiency of products and processes. Efficiency is defined in terms of the resources used, the emissions and wastes generated per unit of desired output. They can be represented as separate lines for the development of an (economic) activity and for environmental pressures;
- Policy effectiveness indicators show the results of the analysis and the reason the policy is developing in a certain direction. This kind of indicator makes clear what has been the influence of structural changes in the economy or in production processes, and of decision-making;
- Welfare indicators measure the balance between economic, social and environmental progress.

3.9 Reporting Indicators

In developing indicators, data must be collected systematically and in a targeted manner (Pastille 2002). Data quality and relevance to the policy domains concerned must also be sign-posted (IISD 1997). Reporting is an essential element in indicator development since the results must be presented to the users in a meaningful way that will satisfy their needs and allow informed decision making (Adriaanse 1993). Against this background, indicator reporting must be done in a way to prevent problems with identification, definition and interpretation (Block and Assche 2000). Clarity of communication is a basic requirement for the presentation of indicators. Figure 3.8 shows a template for reporting SDIs.

Description

- Name
- Definition
- Measurement unit
- Meaning
- Evaluation

Situation

- Local policy objectives
- Higher authorities (regional, national, EU, International)
- Policy areas
- Participation
- NGOs
- References

Data

- Outline of situation
- Data
- Data source
- Shortage of data
- Data quality (availability, accessibility, reliability, comparative quality, currency and cost price)
- Validity
- Weight/ranking

Administration

- Processing phase
- Author
- Contact person
- Communication

Figure 3.8 A format for SDI reporting *(Source: Block and Assche 2000)*

It is important that SDIs in so far as is possible are presented using non-technical language, graphically, and accompanied by brief explanations (Pastille 2002). One criterion that cannot be compromised is that the indicator be understandable to potential users (Maclaren 1995, Hirvonen 1992, Adriaanse 1993). Hodge (1994) insists that they should accurately and unambiguously reflect the degree to which the system component being measured meets the related objective. Text, symbols and charts are the basic building blocks, accompanied by appropriate references and if necessary, background numbers, usually in an appendix (IISD 1997).

Hirvoven (1992) explains that there must be a differentiation between the scale of an indicator (that is, response to changes on an appropriate geographic and/or temporal scale), the scale of reporting, and the scale at which the data is collected or measured. For each indicator, these three may not necessarily be at the same level and they must be viewed as separate considerations.

Reporting indicators so that they are attractive to the media is another possible criterion suggested by Maclaren (1995). This can be a valuable criterion when public awareness and action are an important component in influencing indicator development. Cairns et al (1993) state explicitly that indicators must be non-destructive of the environment. This criterion, they claim, is often taken for granted.

3.10 Use of Environmental Indicators in Ireland: The use of environmental indicators is not a recent development in Ireland. Biological and physio-chemical indicators were adopted in the 1970s by An Foras Forbartha, and more recently by the Environmental Protection Agency (EPA), to evaluate water quality data. In 1999, the EPA published the first national environmental indicators report for Ireland, entitled *Environment in Focus* (EPA 1999), with a third report in 2006. The report provided, for the first time, an assessment and synopsis on the environment in Ireland through the use of key environmental indicators. It presented an overall summary of environmental quality in the State and highlighted the main environmental problems and issues that needed to be addressed at a national level. The EPA in 2000 and 2001, prepared sectoral-based environmental indicator reports for the transport sector and for the rural environment, respectively.

The EPA has discussed the use of environmental indicators for sustainable development since 1996, and this is summarised in Lehane (1999). The publication forms a useful discussion document that proposes a range of national environmental indicators to evaluate progress towards sustainable development. However, the use of indicators to provide a holistic guide to sustainable development is a more all-embracing and complex exercise (Hickie 2000). The EPA's periodic *State of the Environment* reports include much environmental information of a general nature. The most well known of the EPA environmental indicators relate to water quality, for example, the proportion of rivers which are slightly or moderately polluted, or percentage of lakes which are eutrophic (Hickie 2000).

The National Economic and Social Council (NESC) in 2002 published the *National Progress Indicators for Sustainable Economic, Social and Environmental Development*. The report contains eighteen headline and twelve background indicators for measuring sustainable national progress. The aim of the report, according to the authors, is to identify a set of indicators that can be used to measure Ireland's progress towards sustainable economic, social and environmental development. It is also intended that indicators identified in the report will allow for the presentation of a general picture of Ireland's development on key policy priorities over the coming years. International comparisons are cited where possible, in order to place Ireland's progress in the context of other EU and OECD countries. The report concludes by presenting a summary of change in recent years in each of the eighteen headline indicators, outlining the trends in Ireland's progress towards sustainable economic, social and environmental development.

CHAPTER FOUR
PROCESSING AND MANAGING BIOSOLIDS

Biosolids production is a characteristic feature of wastewater treatment. The more wastewater that is generated and treated, the greater is the quantity of biosolids produced. This chapter describes biosolids production processes, its classification, recycling and disposal. It also reviews emerging sewage sludge treatment technologies with their attendant benefits and drawbacks. There is particular focus on the sustainability of various biosolids management options, and public perception on biosolids recycling.

4.1 Definition and Context

Biosolids, also known as treated or stabilised sewage sludge are defined as 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 (Timoney 1998a). The production processes of biosolids from sewage sludge are shown schematically in Figure 4.1. Biosolids contain significant quantities of organic matter, moisture, nutrients and trace elements, and as such are increasingly being viewed as a resource for agriculture and other sectors. While biosolids can be a resource, potential risks associated with microorganisms, contaminants and unstabilised material need to be appropriately managed (NGSMI 2003).

The first 15 European Community (EC15) Member States produce about 8 million tonnes (dry-weight) of sludge per annum. Of this, approximately 40 per cent is applied to agricultural land, six per cent to forest and the rest is disposed of to landfills or incinerated (Andersen 2001).

According to the US EPA (1999), the United States produces about 6.9 million tonnes dry weight of sludge per year of which about 40 per cent is applied to land (67% of this to agricultural land, 12% to domestic gardens/lawns, 9% to public parks/gardens, 9% to reclamation and 3% to forests), and the rest is disposed of via landfilling (17%), incineration (22%) or other unspecified methods (21%).

Recycling of sewage sludge in the EC 15 increased from 2.6 million dry tonnes (MDT) per year in 1992 to 4.2MDT in 2000 ((Lundin et al 2004).

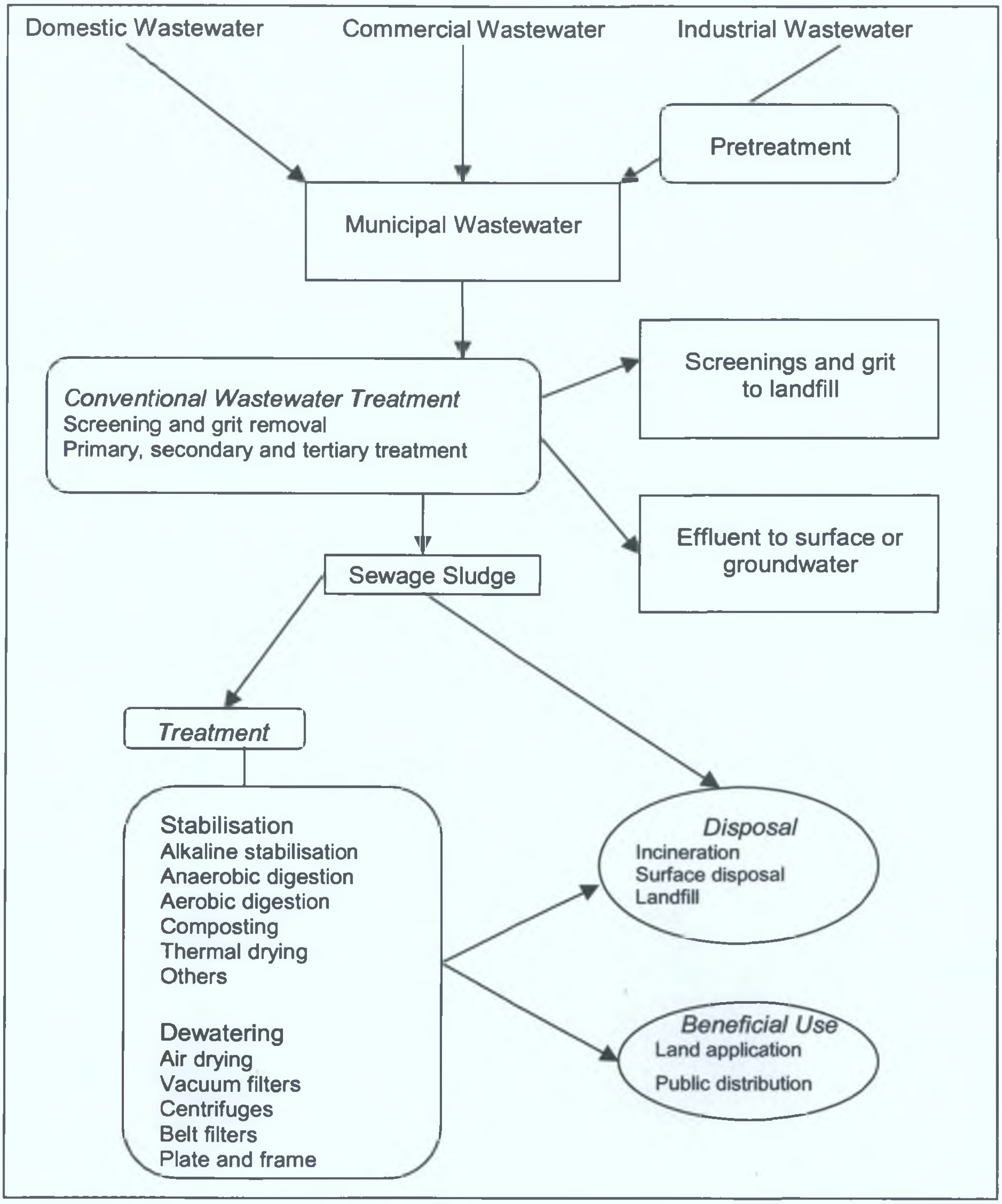


Figure 4.1 Biosolids production *(Source: National Research Council 2002)*

Landfilling of sewage sludge will start to be phased out when the EU Council Directive 1999/31/EC of 26 April 1999 is implemented by member States. The step-wise reduction of biodegradable material to landfills will start with a decrease to 75% of 1995 levels by no later than 2006. The urgency of finding additional appropriate disposal routes or treatment capacity for sewage sludge is thus high.

The fertilising and soil conditioning properties of biosolids are receiving increasing recognition in the context of attempts to rehabilitate degraded soils, particularly in areas which have been subject to intensive cropping. Biosolids are also being widely used in the capping of landfills and the reclamation of contaminated land such as mine tailing sites (US EPA 1999). In recent years, new treatment methods and technologies have improved biosolids quality. At the same time, there is increased awareness of the value of biosolids products and greater demand for their use (US EPA 1999). Source control through increasingly stringent regulations will produce further improvements in biosolids quality, thereby increasing the quantity of biosolids suitable for beneficial use (Kelly 2003). Biosolids should therefore be regarded as a resource, particularly as some of its constituents have a value that can be recovered and used (FWR 2002).

4.2 Biosolids Treatment Processes

The EU Council Directive No. 91/271/EEC concerning urban wastewater treatment requires treatment of wastewater discharging from all major population centres (exceeding 2000 population equivalent [p.e.]) by 31 December 2005 (Articles 4 and 5). The Directive further places a ban on disposal of sewage sludge to sea and freshwater by 31 December 1998 (Article 14). In Ireland, data on agglomerations with a population equivalent greater than 500 persons were reported to the Environmental Protection Agency (EPA) by sanitary authorities for the 2000 and 2001 period. Of the 412 agglomerations, 260 receive secondary treatment (34 of which also receive nutrient reduction), 98 receive primary treatment and 54 either receive preliminary treatment or no treatment (EPA 2003).

Sewage sludge must receive the appropriate treatment to reach the standards necessary to be classified as biosolids. The treatment is also required to meet regulatory requirements that protect public health and the environment, facilitates handling, and reduces costs (NGSMI 2003). Only biosolids that meet certain regulatory requirements for pathogens, vector attraction reduction, and heavy metal content, for example, can be land applied or used as compost. Even those biosolids that are landfilled rather than recycled must meet regulatory requirements (Dumontet et al 2001).

The two most common types of biosolids treatment processes are stabilisation and dewatering.

Dewatering removes excess water from biosolids and generally must be performed before biosolids are composted, landfilled, dried (pelletised or heat dried), or incinerated. A number of dewatering processes can be used, including air drying, vacuum filters, plate-and-frame filters, centrifuges, and belt filter presses (US EPA 1999).

Prior to dewatering, is the process of conditioning. Biosolids conditioning is a process whereby biosolids are treated with chemicals or various other means to improve production rates, caking and solids capture. Two most commonly used conditioning methods are addition of chemicals and heat treatment (Metcalf and Eddy 1991).

The stabilisation processes decrease putrescibility, also known as vector attraction reduction (VAR) (US EPA 1999).

In Ireland, treatment by one or more of the following recommended processes will satisfy the requirements for the production of biosolids when stipulated operating conditions are met. The recommended stabilisation processes (Timoney 1998a) include:

- Mesophilic anaerobic digestion with pre- or post- sanitation;
- Thermophilic anaerobic digestion;
- Thermophilic aerobic digestion;
- Autothermal thermophilic aerobic digestion (ATAD);
- Composting (windrows or aerated piles);
- Alkaline (lime) stabilization;
- Thermal treatment.

Some biosolids treatment processes reduce the volume or mass of biosolids (such as biosolids digestion processes), while others increase biosolids mass (as in addition of lime to control pathogens) (US EPA 1999).

Most of the following discussion on biosolids treatment has been summarised from earlier outputs of the larger Biosolids Research Programme at IT Sligo, especially the work of Lehany J.C. (2003). The discussion is focused mainly on the recommended biosolids production processes in Ireland's *Code of Good Practice for the Use of Biosolids in Agriculture* published by the Department of the Environment and Local Government in 1999.

In addition, attempts have been made to introduce some other emerging treatment processes that are not yet recommended but may be of future interest. According to Kelly (2003), if biosolids management is to be responsive to the trends and rising issues that face the waste treatment industry, new processes must be encouraged, evolved and improved. Time, temperature and pressure provide a framework to optimise biosolids production processes. This framework may prove a useful analytical tool for future process assessment and selection.

4.2.1 Mesophilic anaerobic digestion: Anaerobic digestion involves biologically stabilising biosolids in a closed tank to reduce the organic content, mass, odour (and the potential to generate odour), and pathogen content of biosolids. It involves the incubation of biosolids under anaerobic conditions for at least 15 days at 35° ± 2°C (Selivanovskaya et al. 2001), or alternatively at least 20 days at a temperature of 25°C ± 3°C, where it is subjected to microorganisms which break down the organic content into simpler organic compounds, methane, carbon dioxide, hydrogen and hydrogen sulphide, resulting in stable, innocuous biosolids (Spinosa and Vesilind 2001). The biosolids produced by this process is a Class B product (see Section 4.3).

In order to achieve Class A Biosolids (see Section 4.3), mesophilic anaerobic digestion should incorporate a thermophilic phase or other pasteurising mechanism. A thermophilic phase is where a retention time of at least 1 hour is required at a temperature of greater than 70°C, or, alternatively, a retention time of 2 hours at a temperature greater than 55°C (Timoney 1998a).

Staged mesophilic processing is a multistaged anaerobic process at mesophilic temperatures. Both stages are heated and mixed, providing a sufficient solids residence time (SRT) in the first reactor for methane production. The staged mesophilic digestion generates lower offensive odours (Oleszkiewicz and Mavinic 2002). The advantages of anaerobic digestion are its many applications, in particular in the food and pharmaceutical industry (CIWEM 1997), in addition to the calorific value of the methane gas, reduction in the mass and volume of sludge, low running costs, the high loading rates that can be achieved, low nutrient requirements, and the fact it can be maintained and unfed for prolonged periods of time (Gray 2002).

The disadvantages include long start up times, due to slow growth rate of anaerobic bacteria, highly polluted liquid arising from anaerobic sludge thickening and dewatering, which contains suspended solids, dissolved and particulate organic materials, nitrogen, phosphorus, and other compounds, thus resulting in an increased load to the wastewater treatment plant, in addition to its exposure to chemicals, pH variations and toxic overloads (Spinosa and Vesilind 2001). Another disadvantage of anaerobic digestion is the way in which nonyl phenol

(NP, a detergent) accumulates during the treatment process. Di-(2-ethylhexyl)phthalate (DEHP, a plasticising agent) is not removed. Although a significant percentage of linear alkyl benzene sulphonates (LAS, surfactants) are biodegraded, residues of this substance remain, due to the large amounts initially present in the raw sludge. As a result, eco-labelling initiatives have been prompted in a number of European countries, to influence consumers' choice away from detergents containing these surfactants to alternative products (ICON 2001).

4.2.2 Thermophilic anaerobic digestion: Thermophilic anaerobic digestion operates on the same principle as mesophilic anaerobic digestion, but at a mean retention time of 48 - 72 hours in temperature ranges of 50° to 55°C. A retention time of at least one hour is required at a temperature greater than 70°C, two hours at temperature greater than 55°C, or at least four hours at temperature of greater than 50°C (Timoney 1998a).

Besides the advantage of increased biochemical reaction rates, thermophilic digestion also increases the sludge-processing capability, improves sludge dewatering, and increases bacterial destruction. However, the disadvantages of thermophilic digestion includes higher energy requirements to maintain the temperature necessary for heating, poor quality of supernatant liquid which contains larger quantities of dissolved solids, increased odours, and lower process stability (Spinosa and Vesilind 2001).

Thermophilic digestion can produce a Class A product, but not consistently. For consistent Class A pathogen reduction, a two-stage process is required. Staged thermophilic digestion is a multistaged anaerobic digestion at thermophilic temperatures. All reactors in the staged thermophilic anaerobic digestion operate as methane reactors (to eliminate short-circuiting). The flow from reactors is continuous flow, not batch flow (Oleszkiewicz and Mavinic 2002).

4.2.3 Dual digestion: The dual digestion process consists of two stages; the first stage is in an aerobic reactor followed by the second in an anaerobic reactor. The aerobic reactor is fed with oxygen instead of air, thus producing an exothermic bioreactor. The sludge is naturally heated by the oxidation of the volatile solids, and no additional heat is required when the sludge is directed into the anaerobic reactor, which operates at mesophilic temperatures. Dual digestion requires smaller anaerobic digesters and eliminates the need of an external heat source. However, the disadvantages of dual digestion include odour problems in the aerobic stage, foaming in the aerobic and anaerobic stages, and the temperature of sludge entering the anaerobic reactor must be closely monitored (NGSMI 2003).

4.2.4 Thermophilic aerobic digestion: Thermophilic aerobic digestion involves biologically stabilizing biosolids in an open or closed vessels using aerobic bacteria to convert the organic solids content to carbon dioxide, water, and nitrogen. Pathogens and odours (and the potential to generate odours) are reduced in the process (Timoney 1998a). A mean retention period of at least seven days is required. All sludges are subjected to a temperature higher than 55°C for no less than four hours. The high temperature operation (higher than 55°C) of aerobic digestion is used because it can produce biosolids with low pathogen levels and high solids content. It is a requirement to achieve a 30% reduction in volatile solids (US EPA 1999).

4.2.5 Autothermal thermophilic aerobic digestion (ATAD): ATAD is an aerobic digestion process conducted under thermophilic conditions, where all biosolids are subject to a temperature greater than 55°C for at least 4 hours and a mean retention time of at least 7 days (Girovich, 1996; Snow, 1996). The main advantages of ATAD over aerobic digestion (Table 4.1) are the high treatment rates, decreased reactor volume, more effective pathogen reduction and high volatile solids reduction (Girovich 1996). ATAD is an exothermic reaction process. The heat released during microbial oxidation of organic matter is used to heat the biosolids, in replacement for external heat. The treatment process can achieve removal rates up to 40% of the biodegradable compounds at very short retention times of 3 to 4 days (Timoney 1998a).

Table 4.1 Advantages and disadvantages of ATAD *(Source: Kelly 2003)*

Advantages	Disadvantages
• Meets Class A • Reactor fully enclosed to simplify odour control • Requires no pretreatment of biosolids feed • Biosolids may be totally contained until they are pasteurised and stabilised • No open tankage required • Mechanical systems are simple and process is easy to operate, start-up and shut-down • Energy needs are less than other aerobic treatment systems (<0.7 kWh/kg (DS), vs.>1) • Product will readily dewater to 25%+ dry solids on belt filter press and 30%+ dry solids on a centrifuge • Process may reuse existing digester to save capital cost • The process may be designed to specific plant needs and avoid proprietary system package systems • No boiler or gas handling combustion steps needed	• Product is odorous and system requires complete emissions control and treatment • Biosolids must be thickened to 5% dry solids prior to feed • Product may need to be dewatered; polymer requirements are 2 to 3 times per tonne that which is needed for mesophilically digested biosolids • Product requires cooling to reduce odorous off gassing and reduce polymer needs for dewatering • Side-stream may require treatment • Foam control is necessary • Some processes are proprietary • Requires attention to corrosion control

At present, there is only one plant in Ireland producing Class A Biosolids by ATAD, which is located in Killarney, County Kerry (Lehany 2003).

4.2.6 Composting: Composting is the decomposition of organic matter by microorganisms in an environment that controls the size and porosity of the pile, thereby facilitating an increase in temperature (typically to about 55° to 60°C) to destroy most pathogens. The moisture and oxygen levels of this process are also controlled to reduce the potential for processing odours (Timoney 1998a).

During the process, biosolids are degraded to a humus-like material with excellent soil conditioning properties at a pH range of 6.5 to 8, which is conducive to growing healthy plants and reducing the mobility of metals (Maier et al., 2000). Composting involves mixing dewatered biosolids with a bulking agent (such as wood chips, garden trimmings, bark, rice hulls, straw, or previously composted material) and allowing the biosolids mixture to decompose aerobically (in the presence of oxygen) for a period of time. The biosolids mass is initially increased due to the addition of the bulking agent. The bulking agent is used to lower the moisture content of the biosolids mixture, increase porosity, and add a source of carbon. Depending on the composting method used, the compost can be ready in about 3 to 4 weeks (Starr 2000).

Timoney (1998a) has detailed three different composting processes that may be used:

- Windrow composting: Biosolids and bulking agent mixture are formed into long, open-air piles. The piles are turned frequently to introduce oxygen, ensure that adequate moisture is present throughout the pile, and ensure that all parts of the pile are subjected to temperatures of 55°C maintained over five turnings for at least 15 days, in order to ensure effective destruction of pathogens;
- Aerated static piles: Also known as windrows are rectangular piles supplied with oxygen via blowers connected to perforated pipes or grates running under the piles. Temperatures of more than 55°C must be achieved and maintained uniformly for at least three days;
- In-vessel composting: Takes place in a completely enclosed container where temperature and oxygen levels can be closely monitored and controlled. In-vessel composting also helps contain process and building air so that it can be captured and treated for odours. Temperatures of more than 55°C must be achieved and maintained uniformly for at least three days.

Biosolids compost has less total nitrogen than most other forms of treated sewage sludge. This is due to processing and dewatering, dilution of nutrients by bulking material, and loss of ammonia during the composting process. However the available nitrogen in biosolids compost is released slowly and, thus, is available to plants over a longer period of time, which is more consistent with plant uptake needs. The slow release of nitrogen also reduces nitrogen leaching to the water table, making biosolids compost an excellent soil conditioner and conventional fertiliser (US EPA 1999).

All published Irish waste management plans have recommended composting of municipal and/or green waste at various locations in the regions. There is an obvious cost and operational saving if sludge can be co-composted at these facilities. Of the various types of stabilisation processes available, composting probably has the highest level of desirability in terms of continued application to land because the process decreases the concentration of micropollutants, decreases the heavy metal concentration (from bulking agent addition), kills all pathogens, and produces an odourless product (Maier et al., 2000).

4.2.7 Alkaline stabilisation: Alkaline stabilisation involves a two-stage lime addition process. First, lime is added to raise the pH of biosolids to greater than 12.0 with an accompanying rise in temperature to 70°C for 30 minutes. In the second stage lime is added to raise the pH to greater than 12.0, maintain the pH above 12.0 for 72 hours, and to achieve a temperature of more than 52°C for at least 12 hours. The biosolids are air dried to a dry solid content of more than 50 per cent at the end of the 72-hour period (Timoney 1998a).

The improved structural characteristics of stabilised biosolids (compared to dewatered biosolids cake without lime stabilisation) generally reduce pathogens and odours, allow for more efficient handling operations, and provide a source of lime to help neutralize acid soils. While lime is most commonly used, other alkaline materials, such as cement kiln dust, Portland cement, and fly ash, have also been used for biosolids stabilisation (Bernard & Gray 2000).

In recent years, a number of advanced alkaline stabilisation technologies have emerged, some of which use other chemical additives to replace the lime (in part or fully) and/or supplemental drying. These new technologies aim to: (a) increase solids content and granularity; (b) reduce mobility of heavy metal; (c) increase the agricultural lime value; (d) achieve a higher degree of pathogen reduction, including the production of a biosolids product with pathogens below detectable levels; and (e) achieve long-term stability of the product to allow for storage with minimum potential for odour production or regrowth of pathogens (NAGSMI 2003).

4.2.8 Thermal drying: Thermal drying is a mechanical drying process for biosolids production. It involves using direct or indirect contact with hot gases to remove water from wet sludge. Solar drying is used in some locations. Thermal drying is used to destroy pathogens and eliminate most of the water content, which greatly reduces the volume of biosolids. Solids concentration of the dried product can be 90 to 95 per cent. Basically, there are no specific conditions to be fulfilled in order to apply drying (US EPA 1999).

There are two distinctly different thermal drying methods: indirect and direct drying. In direct dryers, there is a direct contact between the sludge and the heated gas supplying the required heat for evaporation and simultaneously carrying the water vapour formed out of the system. This requires an intensive contact between gas and sludge. The most common types of dryers are the revolving drum dryer and the fluidised bed dryer. With revolving drum dryers, the product is granulated biosolids with a dry solid content of more than 90% at temperatures of more than 80°C (Starr 2000). With fluidised beds, the intensive contact is realised by an upward flow of hot gases, carrying the biosolids particles until they are dried, resulting in a very turbulent gas flow. The dried biosolids could have dry solid content of more than 90 per cent in the form of dust-free granules (Spinosa and Vesilind 2001).

As a result of the intensive contact between gas and sludges and the good heat transfer, the specific performance of the direct dryers can be higher than that of the indirect dryers. Additionally, the mechanical design may be simpler. On the other hand, direct dryers have some disadvantages, including the possibility of explosions, and the need to treat flue gases from the drying process because of the large concentrations of particulates, fly ash, dioxins and acid gases such as sulphur dioxide (SO_2), hydrochloric acid (HCl), hydrofluoric acid (HF), nitrogen oxides (NO_x), and volatile organic compounds (VOC) (Andersen 2001c).

In indirect dryers, heat is transferred to the material to be dried indirectly by heat conduction through a heat transfer surface. Thus, the heating medium, for instance steam or thermal oil, is not in contact with the biosolids. A small stream of air may be used for transport the water vapour formed, although an indirect dryer may well be operated without any air, thereby keeping the odour removal cost at a minimum and heat recovery at a maximum. Among the indirect dryers, the disc dryer is widely used. To ensure a permanently high heat transfer rate, it is crucial to maintain the heat transfer surface – the discs – clean. The stickiness of the biosolids is a challenge in this respect (Spinosa and Vesilind 2001).

Thermal drying, which in most cases includes granulation, is expensive. On the other hand, drying results in a greater volume reduction (moisture content of dried biosolids is less than 10 per cent), and a storable free flowing and hygienic product. Due to great volume reduction, dried biosolids implies reduced costs for transportation, handling and storage (US EPA 1999).

Two other processes not recommended in the *Codes of Good Practice* are *storage* and *mineralisation* (Starr 2000).

4.2.9 Storage: This is possibly the most basic form of sludge treatment and can be accomplished when the sludge is in a liquid or dewatered form. According to Starr (2000), pathogen numbers are reduced to a very low level by natural microbiological die-off. Some undesirable seeds and parasite eggs can however survive the long storage process. The large amount of tankage volume that is required is usually restrictive for the liquid storage option except for very small systems.

Dewatered sludge can be stored on a well draining concrete or granular base with drainage control and run-off treatment. The sludge should be covered to prevent rain from increasing the moisture content and possibly promoting anaerobic conditions. After a storage period of one year the biosolids is classified as Class A and can be spread onto agricultural land (Starr 2000).

4.2.10 Mineralisation: This natural process involves constructing a bunded area and planting with reed-type plants. The sludge must be either stabilised in an extended aeration treatment plant or digested following which it is periodically discharged to the planted area for stabilisation. The plants must be established for at least one year before sludge is introduced to the bed. The depth of sludge can accumulate to 1m over 8 to 10 years (Clark et al 1998). Stabilisation occurs by a combination of uptake of contaminants by the plants and the root structures of the plant, keeping the substrate relatively open to allow oxygen to be transferred. The elevation of the bed slowly increases over the years and when it reaches the maximum possible height, a new area is found or the stabilised biosolids are excavated out and spread onto land. Because of the natural plant uptake and long residence times, a high level of solids reduction and mineralisation of 20% occurs (Starr 2000).

The benefits and drawbacks of the various processes are presented in Table 4.2.

Table 4.2 Summary of advantages and disadvantages of various sludge treatment processes *(Source: Starr 2000)*

Process	Advantages	Disadvantages
Anaerobic Digestion	-Energy Recovery possible -Stable and Robust -Also treat high strength industrial wastewater -Treat broad range of sludges	-High Capital Cost -Relatively complex to optimise performance -Large tankage
Thermophilic Aerobic Digestion	-Pathogen free product -High solids destruction rate	-High energy input required -Odour control required for process tankage -Extremely corrosive inside tank
In-vessel Composting	-Pathogen free product -Reduced concentration of micropollutants -Many disposal options -Low capital cost	-Energy for aeration can be significant
Alkaline Stabilisation	-Provides beneficial product -Low capital cost	- Potential dust nuisance -Transport costs can be significant
Thermal Drying	-Pathogen free product -Desirable product with many uses -Reduced transportation cost	-High capital cost -High operating cost -Mechanically complex
Storage (1 year)	-Low technology -Simple operation -Low capital cost	-Large area required -Higher odour potential
Mineralisation (planted)	-Low technology -Simple operation -High solids destruction rate -Low capital cost	-Large area required -Higher odour potential

4.3 Classification of Biosolids

EU Directive (86/278/EEC of 1986) on Protection of the Environment and in particular of the soil when waste water sludge is used in agriculture concerns the regulations that must be met if sludges are to be used on farmland. The following requirements are common to these regulations:

- Pre-treatment;
- Restriction on the content of heavy metals in sludge;
- Restriction on the amount of dry solids and heavy metals spread per unit of land and time;
- Restriction on the content of heavy metals in the soil on which sludge is spread, and requirements for the pH of the soil;

- Restriction on the content of micropollutants;
- Restriction on the amount of nutrients added to the soil (Nitrogen and Phosphorus);
- Restrictions on the choice of crops;
- Restricted access conditions to farmland on which sludge is spread;
- Legislative compliance control.

The Directive requires a formal request to be made to the regulating authorities prior to land application of biosolids, stating conditions to be met, and the methods and type of biosolids to be used. Consideration is also given to the links between biosolids use and potential transmission of residual pathogens to the human food chain. In addition, the Directive obliges biosolids producers to provide details of biosolids composition to owners of land where biosolids will be applied. Analytical methods, sampling frequencies, monitoring procedures, and record-keeping requirements are also prescribed. The Directive also requires that treated sludge should be used in such a way that account is taken of the nutrient requirements of plants and that quality of the soil as well as the quality of surface and groundwater is not impaired.

The US EPA has had a long-standing policy of promoting the beneficial use of biosolids, and have a regulatory mandate to review and revise related regulations periodically as new research warrants. The current biosolids standards in the US became effective in Part 503 of Chapter 40 of the *Code of Federal Regulations* (40 CFR 503) on March 22, 1993 (US EPA 1994b). More specifically, the regulations are established as General Requirements, Pollutant Limits, Management Practices, Operational Standards, Frequency of Monitoring Requirements, Record Keeping, and Reporting.

Part 503 Biosolids Rule further classified Biosolids as Class A and Class B biosolids based on their level of pathogen reduction:

- *Class A Biosolids* undergo advanced treatment to reduce pathogen levels to below detectable levels. Thermal drying, composting, and high-temperature aerobic digestion are treatment processes that typically achieve Class A pathogen reduction requirements. Either the density of faecal coliforms in the biosolids must be less than 1,000 *most probable number* (MPN) per gram of total solids (dry-weight basis), or the density of *Salmonella* species bacteria in the biosolids must be less than 3 MPN per 4 grams of total solids (dry-weight basis). Either of these requirements must be met at one of the following times; when biosolids are used or disposed, prepared for sale or given away for land application;

- *Class B Biosolids* are biosolids treated to reduce pathogens to levels protective of human health and the environment, but not to undetectable levels. Values of less than 2.0 million MPN per gram of total solids, or less than 2.0 million CFU (colony forming units) per gram of total solids are required at the time of use or disposal. Unlike Class A Biosolids, where pathogens are at levels better than acceptable limits, Class B Biosolids may contain some pathogens. For this reason, Class B Biosolids have site restrictions, which prevent crop harvesting, animal grazing, and access by humans and animals until natural attenuation of pathogens has occurred (US EPA 1994(b), Christy 1997).

The US EPA grading of biosolids is based on stabilisation and chemical contaminant requirements. Stabilisation as stated earlier, is achieved by treating biosolids in ways that reduce or eliminate the potential for putrefaction and which, as a result, reduce pathogens, vector attraction and the potential for offensive odours. Vectors such as flies, mosquitoes, birds and rodents are potential carriers of disease. They can transmit pathogens to humans and other hosts physically through contact or biologically by playing a specific role in the lifecycle of the pathogen. Reduction of the attractiveness of biosolids to vectors reduces the potential for transmitting diseases from pathogens in biosolids. Either subjecting the biosolids to specific physico-chemical process/conditions or preventing access to the biosolids by vectors, usually by incorporation of the biosolids into soil, can achieve VAR. A high quality biosolids is one in which vector attracting compounds such as volatile solids have been substantially reduced or removed. Some pathogen reduction processes are also effective at reducing vector attraction (Meeroff and Bloetscher 1999).

Chemical contaminant requirements are determined by continuous research and maximum contaminant concentrations that are applicable to each of the biosolids contaminant grades are constantly reviewed in the light of relevant new information (US EPA 1994b). If any contaminant concentration is above the limit given, then the product is to be considered a sludge rather than biosolids and the sludge has to be treated, or blended with another substance, in order to become biosolids, or safely disposed of (Oleszkiewicz and Mavinic 2002).

In Ireland, a *Code of Good Practice for the Use of Biosolids in Agriculture* published by the Department of the Environment and Local Government in 1999 is in operation. The Code gives a set of guidelines for the treatment and use of wastewater sludge. Reuse of treated wastewater sludge is regarded in the *Code* as the most sustainable method of sludge management. It has been designed using available data to reflect the requirements of relevant legislation at both EU and Irish levels (see Chapter 5) so that the use of biosolids in agriculture will:

- Be compatible with good agricultural practice;
- Not pose a risk to human, animal or plant health;
- Maintain the integrity of the soil ecosystem;
- Avoid water and air pollution;
- Minimise public inconvenience.

The Code further provides for a mandatory *Certificate of Analysis of the Biosolids* product. In general, the *Certificate of Analysis* should provide information on, *inter alia*, nutrient status of the biosolids, concentration of heavy metals and organic pollutants, presence of faecal *coliforms* or *Salmonella* sp., and treatment processes used to achieve the biosolids product (Timoney 1998a).

4.4 Biosolids Management in Ireland

The Environmental Protection Agency Act, (Urban Waste Water Treatment) Regulations, 1994, (S.I. 419 of 1994) transposed into Irish law the provisions of EU Council Directive 91/271/EEC of 1991 concerning urban wastewater treatment. The Regulations require the provision of wastewater treatment plants depending on the size of the agglomeration and on the type of water body to which the wastewater is discharged.

In 1993, the Department of Local Government and Environment commissioned the *Strategy Study into the Treatment and Disposal of Sewage Sludge in Ireland.* The objective was to identify appropriate solutions for the treatment and disposal of sewage sludge. The study recommended the establishment of 48 hub centres, where centralised sludge treatment/biosolids production would be carried out (Weston 1993).

The designation of hub centres was reviewed in 1997 as part of the *Inventory of Non-Hazardous Sludges in Ireland* with a reduction from 48 to 46 hub centres (Timoney 1998c). Further reviews have taken place since 1997 with the redesignation of hub centres due to logistic and economic reasons. There are currently 36 designated hub centres (Lehany 2003). The *Code of Good Practice for the Use of Biosolids in Agriculture* is another guidance document designed to facilitate the treatment and use of biosolids, especially in agriculture. There are presently five hub centres producing Class A biosolids in Ireland. This includes the hub centre at Ringsend using a thermal drying process. The hub centres at Carlow, Navan, and Osberstown are using alkaline stabilisation while Killarney is using the ATAD process (Lehany 2003) (see Table 4.3).

Table 4.3 Sewage sludge hub centres in Ireland *(Source: Lehany 2003)*

County	Hub Centre	(Recommended) Process
Donegal	Buncrana	Thermal drying
	Letterkenny	Thermal drying
	Gweedore	Thermal drying
	Donegal	Thermal drying
Sligo	Sligo	Mesophilic anaerobic digestion/thermal drying
Leitrim	Carrick-on-Shannon	Composting
Mayo	Derrinumera	Thermal drying
Roscommon	Roscommon	Alkaline stabilisation/composting/ thermal drying
Galway	Tuam	Thermal drying/alkaline stabilisation
Limerick	Limerick	Thermal drying
Clare	Limerick	Thermal drying
Kerry	Tralee	Mesophilic anaerobic digestion/thermal drying
	Killarney	Autothermal thermophilic aerobic digestion
Cork	Mallow	Undecided
	Charleville	Undecided
	Ballincollig	Undecided
Waterford	Dungarvan	Mesophilic anaerobic digestion/thermal drying
Wexford	Enniscorthy	Undecided
Wicklow	Wicklow	Mesophilic anaerobic digestion/thermal drying
	Blessington	Alkaline stabilisation
Dublin	Ringsend	Mesophilic anaerobic digestion/thermal drying
Louth	Drogheda	Mesophilic anaerobic digestion/thermal drying
Monaghan	Monaghan	Undecided
Cavan	Cavan	Composting
Longford	Longford	Composting
Westmeath	Mullingar	Undecided
Meath	Navan	Alkaline stabilisation/thermal drying
Offaly	Tullamore	Undecided
Kildare	Osbertown	Alkaline stabilisation
North Tipperary	Nenagh	Undecided
	Thurles	Undecided
South Tipperary	Clonmel	Mesophilic anaerobic digestion/thermal drying
Laois	Portlaois	Mesophilic anaerobic digestion/thermal drying
Kilkenny	Kilkenny	Undecided
Carlow	Carlow	Alkaline stabilisation

A mix and range of sludge treatment technologies are being proposed or adopted depending on local conditions. Ten Local Authorities are awaiting decisions on recommended sludge treatment technologies from tenders and contractors involved in the *Design, Build and Operate* (DBO) process (Lehany 2003).

In an Environmental Protection Agency report (EPA 2005), a total of 42,298 tonnes (dry solids) of sewage sludge were generated nationally in 2003 from 443 agglomerations with a population equivalent (p.e.) greater than 500 during the reporting period and collectively they represent a total population equivalent (p.e.) of 5,802,424 persons. Approximately 35 per cent was landfilled while 63 per cent was utilised in agriculture, with two percent reused/disposed through unspecified routes.

The Regulations *(Use of Sewage Sludge in Agriculture Regulations, 1998)* require analysis of sewage sludge and specify maximum concentrations of heavy metals in sludge and soils in Ireland. Table 4.4 presents the concentration of heavy metals in biosolids reused in agriculture.

Table 4.4 Maximum concentrations of heavy metals in various biosolids used in agriculture in Ireland in 2003 (*Source: EPA 2005*)

	Heavy Metals ▶	Cd	Cu	Ni	Pb	Zn	Hg
	Limit Concentration (mg/kg DS) ▶	20	1000	300	750	2500	16
Plant Name	Number of Tests	Maximum Value Recorded (mg/kg DS)					
New Nenagh	1	1.0	305	2	66	739	1.4
Athlone	1	5.2	483	44	41	2350	3.0
Ballaghaderreen	1	0.9	399	7	13	266	0.4
Ballybunion	1	1.3	355	9	44	531	0.0
Boyle	1	1.3	454	8	27	205	0.5
Cashel	3	13	278	56	17	103	0.5
Clonmel	1	0.2	450	21	94	-	0.6
Dundalk	42	1.9	380	147	122	9500	0.3
Drogheda	2	0.7	373	38	38	277	-
Kinnegad	1	2.1	372	27	26	988	3.9
Killorgglin	1	3.5	1566	18	57	-	-
Littleton	1	0.5	38	2	10	137	0.5
Moate	1	0.5	13	1	10	24	0.5
Monksland	1	1.8	190	8	7	470	1.7
Mullingar	1	0.5	93	6	13	301	0.5
Navan	1	1	-	-	18	-	1
Orberstown	24	0.6	196	183	93	437	1.0
Portlaoise	2	1	-	-	29	-	1

Two results (highlighted in bold fonts) out of the samples tested during the period 2002 and 2003 exceeded the maximum allowableconcentration of heavy metals in biosolids used in agriculture, namely Zinc at 9500 mg/kg DM (Dundalk) and Copper at 1566 mg/kg DM (Killorgglin). The concentrations of the other metals for these two particular samples were within limit values (EPA 2005).

4.5 Review of Biosolids Reuse

The handling of sewage sludge is one of the most significant challenges in wastewater management (Metcalf and Eddy 1991). Disposing of biosolids by transfer to landfills is considered a beneficial use only when such disposal includes methane gas recovery for fuel. Alternative beneficial uses are receiving greater attention because of a decline in available landfill space and an interest in conserving nutrients, and utilising soil conditioning properties and other recoverable qualities of sewage sludge (Meeroff and Bloetscher 1999). Most of the published sludge management plans for Local Authorities in Ireland have recommended alternatives to use of biosolids in agriculture. Bartlett and Killilea (2001) argued that while there are many benefits associated with applying biosolids to agricultural land, there are also concerns associated with this practice, based on fears of unknown constituents and their transfer mechanisms which could render land application as an unsustainable reuse option.

Biosolids are rich in nutrients such as nitrogen and phosphorus and contains organic matter that is useful when soils are depleted or subject to erosion (Timoney 1998a). Depending on agricultural needs, these benefits can be even greater with composted biosolids, which enhance the physical, chemical, and biological properties of soil (NGSMI 2003). Non-composted biosolids have a high nutrient availability that will decompose and mineralise in soils. The decomposition of land-applied biosolids can provide large amounts of nitrogen and phosphorus for immediate use by crops. Composted biosolids, on the other hand, retain highly stable organic materials that decompose at a slow rate, therefore releasing nutrients at a slower and steadier rate than non-composted biosolids. Composted biosolids thus provide a long-term source of slow-release nutrients (USDA 1998).

4.5.1 Plant nutrients: The effect of biosolids application to crops is an issue of public scrutiny (FWR 2002). Biosolids are a source of nitrogen (N) and phosphorus (P) required for crop production. There is less of the other major crop nutrient, potassium (K), than in animal slurries but there is enough to replace crop uptake from soils with adequate amounts of available K (FWR 2002). Biosolids contain agronomically useful amounts of the secondary plant nutrients calcium, magnesium and sulphur; the last has become particularly important because atmospheric deposition, which used to provide an adequate supply, has decreased as a result of controls on atmospheric emissions (Smith 2000).

Biosolids also provide a broad spectrum of trace elements essential for plant growth. The organic matter in biosolids is usually about 60% of the dry solids content and their addition to land increases the humus content and water-retaining capacity of the soil, improves soil structure and feeds soil microbial biomass. These are very important benefits. The addition of organic matter through successive biosolids applications improves compaction and resistance to erosion of soils (FWR 2002).

Integral to the use of all fertilisers is the balancing of crop nutrient requirements and available nutrients in the soil. The use of biosolids as fertiliser requires proper management to avoid the build-up of nitrates and phosphorus. Inorganic forms of N are readily available to plants, but the organic forms must be mineralised to plant-available forms. For biosolids to be efficiently used as a source of available N, the mineralisation of organic N must be taken into account to avoid over fertilisation and potential leaching of excess nitrates into groundwater. Most biosolids supply more than enough P to satisfy crop needs when applied as a source of N. In soils, available P may be excessive; particularly where animal manure is plentiful and where impacts to groundwater quality are of concern (Timoney 1998a). Tables 4.5 and 4.6 show the total and available P and N respectively in biosolids produced by the various recommended treatment processes in Ireland's *Codes of Good Practice for the Use of Biosolids in Agriculture*.

Table 4.5 Total and available phosphorus in biosolids produced by various recommended treatment processes (*Source: Timoney 1998a*)

Biosolids Type	%DS[1]	Total P applied	Available P (1st cropping year)
Digested low-solids	4	3% of DS[1] = 1.2 kg/tonne	60% of total P = 0.7 kg/tonne
Digested high-solids	25	3.5% of DS =8.8 kg/tonne	35 – 50% of total P = 3.0 – 4.4 kg/tonne
Composted[2]	65	1.0% of DS = 6.5 kg/tonne	20% of total P = 1.3 kg/tonne
Lime stabilised	60	0.4% of DS = 2.4 kg/tonne	46% of total P = 1.1 kg/tonne
Thermally dried	94	3.7% of DS = 34.8 kg/tonne	9 – 50% of total P = 3.1 – 17.4 kg/tonne

[1] DS = dry solids
[2] Wood chips used as bulking agent

Table 4.6 Total and available nitrogen in biosolids produced by various recommended treatment processes (*Source: Timoney 1998a*)

Biosolids Type	%DS[1]	Total N applied	Available N (1st cropping year)
Digested low-solids	4	5% of DS[1] = 2.0 kg/tonne	60% of total N = 1.2 kg/tonne
Digested high-solids	25	3.0% of DS = 7.5 kg/tonne	15% of total N = 1.1 kg/tonne
Composted[2]	65	1.6% of DS = 10.4 kg/tonne	10% of total N = 1.0 kg/tonne
Lime stabilised	60	0.7% of DS = 4.2 kg/tonne	15% of total N = 0.6 kg/tonne
Thermally dried	94	3.7% of DS = 34.8 kg/tonne	20% of total N = 7.0 kg/tonne

[1] DS = dry solids
[2] Wood chips used as bulking agent

To protect both soil and water from pollution by nitrates in Ireland, maximum rates of biosolids application are observed in accordance with the provisions of the *Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates* published by the Department of the Environment and Department of Agriculture, Food and Forestry in 1996.

4.5.2 Soil improvement: As with land application of other organic materials, such as animal manures, biosolids addition improves the physical properties of soils. This in turn, exerts a beneficial influence on water penetration, soil porosity, bulk density, strength, and aggregate stability (O'Connor 1996; Saatre et al 1996; WPCF 1989). Organic matter contained in biosolids is an essential component of soils because it:

- Provides a carbon and energy source for soil microbes;
- Stabilises and holds soil particles together, thus reducing the hazard of erosion;
- Aids the growth of plants by improving the soil's ability to store and transmit air and water;
- Stores and supplies such nutrients as nitrogen, phosphorus, and sulphur, which are needed for the growth of plants and soil organisms;
- Retains nutrients by providing cation-exchange and anion-exchange capacities;
- Maintains soil in an uncompacted condition with lower bulk density matter.

Soil organic matter is also utilised by soil microorganisms as energy and nutrients to support their own life processes. Some of the material is incorporated into the microbes, but most is released as carbon dioxide (CO_2) and water. Some nitrogen is released in gaseous form, but some are retained along with most of the phosphorus and sulphur. The release of CO_2 holds significant implications as a greenhouse gas (Evanylo 1999).

Maintaining an appropriate soil pH is essential in maintaining crop productivity. Lime amended biosolids increases soil pH to neutralise soil acidity, acting as a replacement for agricultural limestone. Lime also increases the volatilisation of the ammonia (NH_3) form of nitrogen (N), thus reducing the N-fertiliser value of biosolids. Soil pH influences the solubility of nutrients. It also affects the activity of microorganisms responsible for breaking down organic matter and most chemical transformations in the soil (Evanylo 1999).

A pH range of 6 to 7 is generally most favourable for agricultural plant growth because most plant nutrients are readily available in this range. However, some plants have soil pH requirements above or below this range. Soils that have a pH below 5.5 generally have a low availability of calcium, magnesium, and phosphorus. At these low pHs, the solubility of aluminium, iron, and boron is high; and low for molybdenum. At pH 7.8 or more, calcium and magnesium are abundant. Molybdenum is also available if it is present in the soil minerals. High pH soils may have an inadequate availability of iron, manganese, copper, zinc, and especially of phosphorus and boron (VDOH 1999).

Many individuals and organisations, though, are concerned about unknown long-term risks of exposure to low levels of some of the contaminants in sewage sludge such as pathogens, heavy metals, dioxins, biocides and flame retardants (Dumontet et al. 2000, Harrison et al. 1999, McLachlan et al. 1996)

4.5.3 Land reclamation: Brownfield remediation has been accelerated using the application of biosolids. Abandoned coalmines and gravel pits leave exposed rock and subsoil which contributes to runoff and water contamination. Biosolids provide nutrients and topsoil which allows a protective vegetative cover to grow (Sajjad 1998).

Another innovative use for biosolids involves accelerated phytoremediation of contaminated sites. After the Chernobyl incident, field experiments were conducted in Finland in which radioactive wastes were remediated through land application of biosolids to barley, straw, and wheat fields. This resulted in a minimum of 2 to 12 fold lower concentrations in the crop than in control plots (Puhakainen and Ylaranta 1992).

4.5.4 Process gas production: Gas from the anaerobic digestion process contains 65 to 70 per cent methane (CH_4) by volume, 25 to 30 percent carbon dioxide (CO_2), and small amounts of N_2, H_2, H_2S, water vapour, and other gases. Total gas production is estimated usually from the percentage of volatile solids reduction. Typical values vary from 0.75 to 1.12m^3/kg of volatile solids destroyed (Evans et al 2002). Gas production can fluctuate over a wide range, depending on the volatile solids content of the sludge feed and the biological activity in the digester. Excessive gas production rates sometimes occur during start-up and may cause foaming and escape of foam and gas from around the edges of floating digester covers (Starr 2000). If stable operating conditions have been achieved and the foregoing gas production rates are being maintained, the operator can be assured that the result will be a well-digested sludge (Lenzy 1999).

Gas production can also be estimated on a per capita basis. The normal yield is 15 to 22$m^3/10^3$ persons-d in primary plants treating normal domestic wastewater. In secondary treatment plants, the gas production is increased to about 28$m^3/10^3$ persons-d (Starr 2000).

4.5.4.1 Gas collection: Digester gas is collected under the fixed or floating cover of the digester. Floating covers float on the surface of the digester contents and allow the volume of the digester to change without allowing air to enter the digester. The covers may also be installed to act as gasholders that store a small quantity of gas under pressure and serve as reservoirs. Floating covers can be used for single-stage digesters or in the second stage of two-stage digesters (Lenzy 1999). Fixed covers provide a free space between the roof of the digester and the liquid surface. Gas storage must be provided so that (i) when the liquid volume is changed, gas, not air, will be drawn into the digester, and (ii) gas will not be lost by displacement. Gas can be stored either at low pressure in external gasholders that use floating covers or at high pressure in pressure vessels if gas compressors are used (Starr 2000).

4.5.4.2 Use of digester gas: Methane gas at standard temperature and pressure has a net heating value of 35,800kJ/m^3. Because biogas is typically about 65 per cent methane, the low heating value of digester gas is approximately 22,000kJ/m^3. By comparison, natural gas, which is a mixture of methane, propane, and butane, has a low heating value of approximately 37,300kJ/m^3 (Starr 2000).

Some biogas must be used to heat the digester to sustain the digestion process. The excess biogas can be used to produce electricity, fuel vehicles, home heating, and industrial processes. The biogas contains contaminants and is not suitable for sale to the general public unless it is put through a scrubbing process. It is generally more cost effective to utilise the biogas in a dedicated plant and remove the contaminants from the exhaust (Evans et al 2002).

4.5.5 Sludge-to-fuel: A technique called "sludge to fuel" (STF) involves a process that converts sludge organic matter into incinerable oil using a solvent, atmospheric pressures, and temperatures in the range off 200-300°C (Millot et al 1989) or, alternatively, high pressures in the range of 10 MPa combined with high temperatures (Itoh et al 1994). One system uses a hydrothermal reactor to convert mechanically dewatered sludge to oil, char, carbon dioxide and wastewater. The char, making up 10% by weight of the product, is sent to a landfill, while the gaseous emissions are treated and released to the atmosphere. The produced oil has approximately 90 per cent of the heating value of diesel fuel and can be sold to offsite users or refineries (Hun 1998).

Other processes produce oils from sludge by employing activated alumina pyrolysis of digested, dried sludges, or toluene-extracted sludge lipids (Abu-Orf and Jarnrah 1995). In either case, sludge-associated metals seem to bind to the residuals, with final product conversion efficiency being dependent on the sludge particle size, temperature, and process heating rate (Takeda et al 1989). Conversion to oil traps heavy metal in the residual and destroys organochlorine compounds that survive treatment within the wastewater treatment plants (Bridle et al 1990). Liquid fuels produced with the STF technology have the potential to be used as a diesel fuel substitute, a heating fuel, or a chemical feedstock (Millot et al 1989).

Biosolids have also been used as a carbon source for odorous gas treatment via adsorption and for flue gas treatment via desulphurisation, albeit both with limited results (Krogmann et al 1997). Palasantzas and Wise (1994) investigated the possibility of producing calcium magnesium acetate using residual biomass from sewage sludge. Reportedly, this production mechanism would generate a cost savings of 68 per cent over conventional disposal costs.

4.5.6 Building materials: Dewatered biosolids have also been used successfully for producing building materials, such as concrete and bituminous mixes, and also as a road subsoil additive utilising chemical fixation processes (Aziz and Koe 1990). The chemical fixation process involves combining biosolids with stabilising agents, such as cement, sodium silicate, pozzolan, or lime, to chemically react with or encapsulate biosolids particles (Metcalf and Eddy 1989). Final residuals of incineration or other thermal process have also been used to generate road sub-base material or concrete aggregate (Takeda et al 1989). Pulverised sludge ash and dewatered sludge/clay slurries have been used successfully in lightweight concrete applications without influencing the product's bulk properties (Tay and Show 1991). Sludge-based concrete has been deemed suitable for load-bearing walls, pavements, and sewers (Lisk 1989).

Biosolids have also been used in cement manufacturing. This industry is highly energy intensive: however the large energy costs of creating clinker at 1500°C can be offset by utilising biosolids as a low-cost and readily available supplemental energy source. Furthermore, biosolids can be injected into the exhaust gas chamber to eliminate NOx emissions using the thermal energy of the hot exhaust gases combined with ammonia contained in the biosolids to convert NOx to nitrogen gas (Kahn and Hill 1998).

4.6 Other Biosolids Disposal Options

With the expected cessation of sea disposal, all outlets for biosolids will now be located on land (FWR 2002). Biosolids can be disposed of through incineration, landfilling and other developing technologies.

4.6.1 Incineration: Energy from biosolids represent a potentially exploitable 'non-fossil fuel' and a source of 'green' energy. The net (i.e. after deducting the heat required to evaporate the water) calorific value (CV) of biosolids is typically about 23 MJ/kgVS. (VS is 'volatile solids'), which is the combustible matter. It is measured by loss on ignition. The CV of brown coal is also about 23MJ/kgDS (FWR 2002). This is a combustion reaction. Incineration is an expensive disposal option for biosolids and leaves the problem of what to do with the residues, which are about 30 per cent of the input mass. They may be regarded as hazardous waste – a cause of the contamination being heavy metals – especially if the biosolids are incinerated along with municipal waste (Smith 2002).

Different techniques are currently performed, classified between mono-incineration when biosolids are incinerated in dedicated incineration plants, incineration with other wastes, or co-incineration when biosolids are used as fuel in energy or material production. Other technologies are also being developed such as wet oxidation or pyrolysis (Hall 2000).

Outputs are flue gases, ashes, and wastewater, as well as the production of energy. Therefore incineration generates emissions into the air (particles, acid gases, greenhouse gases, heavy metals, volatile organic compounds, etc), soil (disposal of ashes and flue gas treatment residues to landfill, atmospheric deposition of air emissions) and water (flue gas treatment wet processes) (FWR

2002). Emissions into the air may be reduced with flue gas treatment (Hall 2000). Emissions depend on the process, but are also influenced by sewage sludge type. Energy production generally counterbalances the energy needs for biosolids drying. Operation of an incineration plant may also produce noise, dust, odour and visual pollution (Lenzy 1999).

Where sludge is incinerated and there is energy recovery, the external benefit is the reduction in the quantity of fossil fuel that would be burnt and the corresponding net addition to CO_2 emissions. Incineration is CO_2 neutral, thus can contribute to reduction when energy is recovered, although a negative aspect of this is that the nutrients are not being used in agriculture. Therefore, there is the lost saving in fossil fuel used for the winning and manufacture of commercial fertiliser (Hall 2000). However, the nitrogen-fertiliser value is destroyed and phosphate is converted to recalcitrant forms from which it cannot be extracted economically at present. Many regard this destruction of phosphate as a serious disadvantage because the world's economic reserves of P are estimated at only 100 years at current rates of extraction (Driver et al 1999).

Other energy and resource related benefits often overlooked are the transport implications for sludge are generally nil or small when comparing incineration with other outlets, as incineration is usually carried out on the wastewater treatment plant site. Also ash from incineration of sludge can be used for construction materials; thus reducing not only the need for quarries for ballast, etc., but it also means isolating contaminants in sludge from the environment, thus avoiding the need for disposal in hazardous waste landfill (Hall 2000).

4.6.2 Landfilling: There are two possibilities in terms of landfilling of biosolids: mono-deposits, where only biosolids are disposed of, and mixed-deposits (most commonly practiced), when the landfill is also used for municipal wastes. The inputs to landfilling are the wastes (organic matter in biosolids decomposes when landfilled and not available for plant growth), and additional resources required for the operation of the landfill site, such as fuel for vehicles, electricity, and additional materials when leachate is treated on-site. Outputs consist of leachate, landfill gas and energy production when the gas is recovered (Andersen 2001c).

Landfill operation therefore generates emissions into the air (mainly greenhouse gases like methane and carbon dioxide, reduced when biogases are collected and burnt), and into the soil and water at dump sites (various compounds such as ions, heavy metals, organic compounds and micro-organisms in leachate). The operation of a landfill also generates other impacts in terms of noise and dust from the delivery vehicles, as well as odours, land use, disturbance of vegetation and the landscape (FWR 2002).

The EU Landfill Directive 1999/31/EC of 1999 introduces targets for the reduction of biodegradable municipal waste to landfill as follows:

- Reduction to 75 per cent of total biodegradable municipal waste (weight) produced in 1995 by 2006;
- Reduction to 50 per cent by 2009;
- Reduction to 35 per cent by 2016.

By keeping biosolids away from landfill sites, the available capacity can be used over a longer period of time. This capacity can be used for materials for which treatment or reuse is not possible. Furthermore, less space is lost for other purposes, such as infrastructure works - this may especially be of importance in densely populated areas. Even if biosolids account for a small percentage of non-hazardous wastes that are landfilled it should not be forgotten that biosolids are mostly organic matter. Organic matter decomposes and its drawbacks (such as emission of methane which is twenty times more powerful than carbon dioxide in terms of climate change effects) have wider implications than just eating up space (Andersen 2001c).

4.7 Emerging Technologies

Several technologies presenting alternatives to conventional combustion processes are currently being developed or introduced onto the market. These technologies mainly include the wet air oxidation process, pyrolysis, and the gasification process.

4.7.1 Gasification and pyrolysis: This is the term used for a number of different processes that transfer energy from solid to the gas phase (Whipps and Whiting 1999). Gasification is a thermal conversion of hydrocarbons to gas by partial combustion of a waste in the presence of oxygen or air. In the absence of air the process is known as pyrolysis (Kelly 2003).

Pyrolysis is the splitting of organic substances into gaseous, liquid, and solid fractions in an oxygen-free atmosphere. The resulting components of this process are a gas stream (primarily hydrogen, methane, carbon monoxide, and various other gases depending on the material pyrolyzed), a tar and/or oil stream (liquid at room temperature containing chemicals, such as acetic acid, acetone, and methanol), and a solid stream (a char consisting of almost pure carbon plus inert material that may have entered the process) (Kelly 2003).

Table 4.7 presents the advantages and disadvantages of the process.

Table 4.7: Advantages and disadvantages of gasification and pyrolysis

(Source: Kelly 2003)

Advantages	Disadvantages
• Destroys organic compounds • Synthesis gas (20-30% H_2, 1-20% CH_4, 50% C/CO_x, 0-25% N_2) can be used as chemical feedstock or after additional processing as a power source • Provides heat that can be converted to steam and power • Lower volumes of the flue gas than incineration • Lower NOx emissions than incineration and low dioxins/furans • Produces stable solid residues that allows further recycling, binds heavy metals into unleachable matrix • H_2S oxidised to elemental sulphur • Reduced CO_2 emission per KW-hr • Meets Class A requirements • >1200°C destroys dioxins	• Use of air lowers energy content compared to anaerobic digestion gas (ADG) by 2 to 5 times. Use of oxygen improves calorific value. Pyrolysis gas is similar to ADG • Some processes produce char that requires further disposal • Risks for scale up • Safety issues especially with pure oxygen • Requires pre-treatment to meet <500*um* as dried feed from dryer • Complex • No current cost data • Limited operating data

4.7.2 Wet air oxidation (WAO): This process is described by Djafer et al (2000) and Gloyna *ed* (1998) as a sub-critical water oxidation process that operates at temperatures of 150-350°C, pressures of 1-10MPa over periods of 15 to 120 minutes. Compared to incineration, the process needs no fuel and produces low emissions. It can produce useful by-products for enhancing treatment and use as construction materials. Table 4.8 illustrates some of the advantages and disadvantages. Other technologies may be available, which are most often combinations of these three main processes. These technologies present advantages in terms of flue gas and ash treatment. Moreover, they also seem to have reduced impacts on the environment compared to conventional combustion processes (Kelly 2003).

Table 4.8: Advantages and disadvantages of wet air oxidation *(Source: Kelly 2003)*

Advantages	Disadvantages
- Improves dewaterability - Low energy and no fuel requirements - Low air pollution concerns; no NO_x, SO_2, HCl, dioxins, furans and fly ash - Maximum biosolids reduction in small footprint - Suited to problem sludges with high metal content or synthetic organics - Possible use of product acids for enhanced biological nutrient removal - Immobilisation of heavy metals in form of hydroxides, carbonates and insoluble phosphates - Reduction of greenhouse gas (CO_2) production - Residual solids are intrinsically resistant to leaching - Chemical oxygen demand (COD) and volume of solid sludge reduction of 70 and 90% - High organic nitrogen removal to 70% through oxidation to elemental nitrogen with catalyst - Provides a Class A product - Over 100 plants in operation since 1985	- Operates at 10 to 100 atmospheres and high temperatures 150-350°C - Capital cost is high - Maintenance cost is high - If unusable, waste liquors contain high concentrations of carboxylic acids that require treatment - Use of deep shaft WAO systems are yet unproven - Does not reduce total solids significantly (7%) - Deep shaft systems have encountered solids build-up and plugging - Systems are prone to scaling, calcium concentrations in the feed are limiting - High ammonia production may be a problem with downstream treatment - High corrosion problems have caused some operations to be suspended, many are currently at their end of life design and need replacement - Cleaned and thickened feed to 5% dry solid

4.7.3 Incineration combined with phosphorus recovery (Bio-Con): This process was developed by Bio-Con A/S, Denmark and is a sludge incineration process which integrates recovery of phosphorus, energy and precipitation chemicals. The installation, which would be usually built at the wastewater treatment plant (WWTP), includes three processes; drying, combustion and recovery. In the drying process, dewatered sludge would be dried to 90% DM before it would be fed to the incinerator. The flue gas would be led to a cleaning system. The ash and slag that remains after combustion would be dissolved in sulphuric acid before entering a set of ion exchangers. In the first cation exchanger, the iron ions would be collected (regeneration with sulphuric acid gives the precipitation chemical used at the WWTP). In an anion exchanger, sulphate would be collected as potassium sulphate. In the third section, phosphate would be collected as phosphoric acid, after regeneration with hydrochloric acid. Phosphoric acid is suitable for use as a raw material in the phosphate industry and has a higher processing value than ferric phosphate. In this process, 80% of the phosphorus and 70% of the precipitation chemicals would be recovered. In the fourth section, the heavy metals would be collected and disposed of. The ion exchange process has only been tested in pilot-scale and there remain uncertainties concerning costs as well as function (Lundin et al 2003).

4.7.4 Fractionation with phosphorus recovery (Cambi-KREPRO): This is a modification of the KREPRO system that has been operated in small-scale since 1995 at Helsingborg WWTP in Sweden (Hansen et al 2000). The system uses heat, pressure and sulphuric acid to dissolve phosphates, metals and a large fraction of organic compounds from the sludge. In this option, dewatered sludge would be hydrolysed at a temperature of 150°C and a pH-value between 1 and 2. The remaining organic fraction has a concentration of about 45-50% DM and would be incinerated in the existing incineration plant in Göteborg. It contains about half of the heavy metals that end up in the ash. The rest of the metals would be removed in a separate step with sulphide precipitation and placed in a hazardous waste landfill (Lundin et al 2003). Phosphorus would be recovered as ferric sulphate with ferrous ion as a precipitation agent. The dissolved organic material would be used as a carbon source for denitrification in the WWTP (thus reducing the need for an external carbon source, in this case ethanol). The ferric phosphate fraction contains about 80% of the phosphate in the sludge and would be spread on agricultural land. Excess iron would be used at the WWTP as a precipitation chemical. Even though the combined system Cambi-KREPRO has not been tested in full scale, the different process units have been studied extensively. Uncertainties about cost remain (Lundin et al 2003).

4.7.5 Supercritical water oxidation (SCWO): The supercritical water oxidation of undigested sewage sludge was identified by Svanstrom et al (2003) as an environmentally attractive technology, particularly when heat is recovered from the process. SCWO is carried out at temperatures above 374°C and Pressure above 22.1 MPa. It is an excellent reaction medium for oxidation of various waste streams, especially aqueous wastes that are too dilute for efficient incineration (Kritzer and Dinjus 2001).

Describing the process, Svanstrom et al (2003) and Tester and Cline (1999) observe that above the critical point, the properties of water change so that it acts as a non-polar solvent. Many organic compounds and light gases, including oxygen, are completely miscible with SCW so that problematic organic pollutants and oxygen can be homogenized in one fluid phase. The absence of gas-liquid phase boundaries eliminates organic-oxidant mass transfer resistance. The lower viscosity of SCW and higher diffusivities of reactants and products in SCW also favours faster reactions. For example, at 450° to 600°C (roughly half the temperature of conventional incineration), many organic contaminants are rapidly (0.1-100 seconds) and efficiently (99.9 to >99.99%) oxidized, with their constituent carbon, hydrogen, and nitrogen atoms being completely mineralised to CO_2, H_2O and molecular nitrogen. Heteroatoms such as sulphur, chloride and phosphorus, are rapidly oxidized to inorganic acids which can be neutralized.

These attributes make SCWO attractive for rapid and thorough destruction of hazardous organic substances, in particular for high water content wastes such as sewage sludge (Svanstrom et al 2003). SCWO (or hydrothermal oxidation) can be used to provide complete destruction of pathogens in sewage sludge and complete conversion of organic matter into innocuous molecules; COD conversion efficiencies are in excess of 99.9% (Griffith and Raymond 2002). Nitrogen-containing molecules are quickly hydrolysed to ammonia and subsequently converted to molecular nitrogen. CO_2, the major oxidation product, can be recovered from the process. Oxygen is added in stoichiometric excess, but can be recycled to keep the net consumption low. The solid residue from SCWO processing of sewage sludge consists mainly of silt, sand and clay particles and meets all pathogen and vector reduction requirements (Svanstrom et al 2003). A recent analysis found that the total cost for SCWO processing of sewage sludge is about US $120-200 per dry metric tonne at 10% solids, which is generally less expensive than landfilling and incineration (Griffith and Raymond 2002; Modell and Svanstrom 2001).

4.7.6 Energy production using the BESI process: The BESI developed by Biomass Energy Solution Incorporated, United States is not an incineration process. The BESI process begins at the point sewage sludge is produced. After attaining a designated total solids requirement through thickening, the sludge is anaerobically digested in a BESI digester that converts 75% of volatile solids in sludge to fuel gas containing 65% methane. The BESI gasifier converts solids to fuel gas and stabilises metals in the residue. The gas from the BESI digester and BESI gasifier are both fed to a generation set to generate electric power. Energy production capacity is about 1.2 to 1.4 megawatts of electric power per dry tonne per hour. The BESI process can often be implemented utilising on-site equipment such as storage tanks, and drying equipment. Existing stand-by power generating units can be modified to use the fuel gas generated by BESI process. Existing boiler can be adapted to use BESI gasifier fuel gas, substituting purchase of other forms of fuel.

There is presently no available detailed or extensive technical study on the process, and uncertainties are still large concerning costs, composition and disposal of the BESI gasifier residue.

4.8 Sustainability of Biosolids Management Options

A fundamental premise of biosolids management is that they can be beneficially recycled (Harrison and Oakes 2002). In other words, rather than viewing biosolids as waste products that should be disposed of, (for example, by way of landfilling or incineration), they are viewed as a valuable resource for industry (Sullivan 1998).

The recycling of biosolids to land has not been without controversy. However, the general trend has been towards increased use of biosolids on land, driven by a number of factors, namely the banning of ocean and sea discharges of sludge, increasing cost of landfilling (and diminishing space for new landfills), mounting pressure to prevent or minimise the disposal of organic material to landfills to reduce generation of greenhouse gases, operating incinerators can cause atmospheric pollution, resulting ash from incineration will require disposal, and increasing awareness of the agronomic and economic benefits to be gained from applying biosolids to land (Harrison and Oakes 2002; Lundin et al 2003; Harrison et al 1999). The continued recycling and future reuse of biosolids will greatly depend on the following.

4.8.1 Volume and mass reduction: Biosolids production cannot be avoided due to the progressive application of EU Directive 91/271/EEC of 1991. As effluent quality standards are tightened to reduce nutrient emission, biosolids production will inevitably increase (Marmo 1999). According to Meeroff and Bloetscher (1999), biosolids production cannot be minimised although there are technologies which reduce the mass of biosolids for disposal (dewatering, drying, volatile solids destruction).

Tilche et al (2000) has identified instruments for reducing the generation of excess sludge building on existing wastewater treatment processes, without altering the composition of sewage. These include:

- Use of biochemical energy contained in the wastewater for conversion processes that need energy (denitrification, P removal) and not only for carbon oxidation;
- Application of wastewater treatment processes that are characterised by low biomass growth;
- Application of long sludge age systems (extended aeration, membrane bioreactors, biofilm processes);
- Management of activated sludge food chain, stimulating the balanced growth of bacterial predators (with warning of not grazing the slow growers, like nutrifiers);

- Enhancement of biological sludge stabilisation (pre-treatments, thermophilic anaerobic digestion).

They propose the accurate monitoring of growth in sludge production. This is to make possible eventual recommendations on limiting the amount of sludge to be generated, moving wastewater treatment companies towards the application of best available technologies (BAT), as in most industrial sectors where the Industrial Pollution Prevention and Control (IPPC) in EU Directive 96/61/EC of 1991, are applicable. Tilche et al contend that municipal wastewater treatment is becoming an industry itself, and therefore, a future IPPC system candidate. They further contend that sludge reduction using BAT could have positive effects on biosolids quality and practices resulting in lower environmental costs. Although incineration is included as an outlet for biosolids, it is strictly a treatment process to destroy biosolids organic matter and reduce its mass and volume (Smith 2000). Incineration still leaves a residue of mineral ash, representing up to 30% of the dry weight of the original biosolids, to which up to 20% water may have to be added to give it physical stability. For the foreseeable future, incinerator ash is expected to go mainly to landfill (Evans and Lowe 2002). Research is being undertaken to find a use for this material as a fine aggregate (sand) replacement in building products. However, ash from biosolids does not have unique advantages over sand and the rate of production, even from the largest incinerators, is very small compared with that of a sand quarry (FWR 2002).

4.8.2 Protection of health: Health concerns are often the major issues that biosolids management programmes must address. A large number of disease-causing bacteria, viruses, and parasites, including *Salmonella* and *Shigella*, are found in untreated wastewater and biosolids (US EPA 1999). To the extent that people are unaware of how thoroughly biosolids are treated to control pathogens, public concern over exposure to pathogens can impede beneficial use programmes (NGSMI 2003). Various biosolids regulations require treatments to reduce pathogen levels below detectable limits and reduce odour and vector attraction. In some cases, site restrictions are required that allow further pathogen destruction and reduce potential public exposure (US EPA 1999, Andersen 2001b, NGSMI 2003).

Concerns have been raised about the possible health effects associated with inhalation of airborne dust ('bioaerosols') originating from composting facilities (US EPA 1999). Conversely, studies report that methods used for biosolids land application do not result in airborne release of biological agents to the same extent as in wastewater treatment facilities (Rylander et al 1983). Wastewater treatment workers who are exposed to higher amounts of airborne releases of organisms have not been found to be at higher risk than the general population. A study of the health effects of occupational exposure to wastewater carried out in the United States followed over 100 wastewater treatment plant workers at three activated sludge sewage treatment plants (Clark et al 1979). The study included stool examinations, cultures and antibody surveys, and concluded that there was no increased incidence of infection in workers.

However, in a more recent study by Dowd et al (2000) and the Hazard ID on workers exposed to Class B biosolids released by the National Institute of Safety and Health (NIOSH 2000) in the United States have served to elevate public concern about transmission of airborne pathogens. The NIOSH Hazard ID reports that a limited number of air samples collected at land application and storage sites confirms the potential for workers to be exposed to pathogenic organisms and recommends a range of personal protective equipment and hygienic practices, depending upon activity in which the worker is engaged. The Dowd et al risk assessment, based upon computer modelling, concludes that there is some risk of infection to biosolids land application site workers as well as to surrounding residents from storing and land application of biosolids. They stated that the modelling results represent a worse case scenario and indicated a need for epidemiological screening.

Public concerns also persist regarding the presence of pollutants and pathogens in biosolids that might find their way to humans through plant uptake, direct contact, and animal ingestion. Although considerable independent research exists to demonstrate that risks to human health are negligible, the public might perceive higher risks due to the origin of biosolids and past management practices (USDA 1997).

Biosolids that have been treated to the point where they attain Class A quality are essentially free of pathogens (USDA 1997). However, biosolids that do not attain the Class A stabilisation standards potentially contain pathogens at infectious levels, so they are not able to be sold or given away direct to the public and there is a need to manage the risks by reducing the pathogen levels prior to land application (such as storage), by soil incorporation, by restricting end uses to areas with low public exposure, or by imposition of exclusion periods following land application (NGSMI 2003).

In addition to the risk of infection arising from direct contact with biosolids that do not attain Class A stabilisation, there is a potential food safety issue. The survival of some pathogens in the soil, most notably parasites and viruses, is not well understood. More information is therefore needed concerning the fate, and amounts of, such pathogens in soil after biosolids application especially in the colder parts of Europe (Andersen 2001c).

4.8.3 Heavy metals and organic contaminants: The main metals of potential concern, from a human health perspective, are cadmium, lead and mercury (Smith 1996). Heavy metals are naturally present in soil at varying level, and may originate from several anthropogenic sources such as fertilisers, animal manure, biosolids, or atmospheric deposition (Andersen 2001c).

Once applied to soil, heavy metals in biosolids are distributed between different soil media. Scientific evidence show that heavy metals accumulate in the upper layers of the soil and their concentration decreases very rapidly with depth (0-

15cm and 15-40cm) except, may be, in sandy soils where such enrichment can reach down to the 60-80cm layer (McGrath and Cegarra 1992). This is due to binding to the different existing organic or mineral particles. Their mobility and bioavailability to plants and micro-organisms may be influenced by several factors of which the pH level of the soil is of greatest importance (Sloan et al 1997). McGrath et al (1994) report that sewage sludge-borne metals present a particular affinity to organic matter.

Concern has been expressed about the consequences of metal application onto soil on micro-organism population and biodiversity. Available scientific literature shows contradictory results, depending on the species taken into consideration, the local conditions of the experiments, and the confusion of short-term laboratory experiments with long-term field trials (Chaney and Ryan 1994). On the basis of long-term field trials, some studies concluded that diversity and population of soil micro-organisms could be negatively affected by sludge-borne metals in the long-term, at metal levels in soil which were in some cases below current regulatory prescriptions (Andersen 2001c).

Plant uptake occurs for all heavy metals and is described by transfer factors (Sloan et al 1997). Some metals are of biological interest for the plant. Uptake will increase with increasing metal levels in soil but only applies to the bioavailable part of the metals present in soil. pH Value is the most important factor influencing metal uptake (Sloan et al 1997). In particular, a decrease in the pH value in soil in the range of pH 7 to pH 4 causes an increase in the uptake of Cd, Ni and ZN. The same effect is observed for Cu, but is less marked. Lastly, when considering usual acidity levels in agricultural soils, a pH decrease had no noted effect on Pb and Cr uptake (McGrath and Cegarra 1992).

Heavy metals concentrate in the roots and vegetative parts of plants and are less present in the generative parts such as wheat grain. However, sewage sludge-borne metal uptake by plants is very low when compared to the total amount of metals present in soil (Andersen 2001c). The US National Research Council

(1996) found that levels of cadmium in crops grown in sludge-amended soils could be elevated. The study also showed that cadmium does accumulate in kidney and liver of livestock and could pose a risk to human health when consumed. The organic contaminants generally considered when assessing risks from biosolids are the persistent organochlorine pesticides such as DDT and dieldrin, polychlorinated biphenyls (PCBs) and dioxins. These organochlorine chemicals are also known as persistent organic pollutants (POPs). Human exposure to POP chemicals is primarily via the food chain, especially from grazing animals, where the contaminants accumulate in body fat. An international treaty on POPs has been developed, the Stockholm Convention, which aims to protect people's health by reducing further exposures to these chemicals (Smith 1996).

It should be noted, however, that there are other organic contaminants present in biosolids, about which we know very little, especially with regards to their fate once applied to land, their availability from biosolids material and any risk they may pose. These chemicals which include; brominated diphenyl ethers, alkyl phenols, alkylbenzene sulphonates and phthalates, are becoming a focus of increased regulatory consideration (Carrington et al 1998).

4.8.4 Protection of the environment: Protecting the three environmental media of air, water and land, in addition to human health are essential prerequisites for whichever biosolids management option is used (Smith 1996). The means of protection (standards, legislation, monitoring, and enforcement) must be effective (USDA 1997).

Biosolids may contain hazardous chemical constituents derived from both domestic and industrial sources. The environmental and health risks presented by their presence in biosolids have been researched extensively. In the USA, the federal rules for the use or disposal of biosolids (US EPA 1993) are based on a 14-pathway risk assessment (US EPA 1992) that was subjected to international peer review during its preparation. The USA, EU and Ireland have selected the same suite of inorganic 'potentially toxic elements' (PTEs) to monitor and control (Timoney 1998a; CEC 1986). The first line of control is to regulate discharges from non-domestic premises; this has been very effective (FWR 2002). There is significant domestic contribution of some elements, notably copper from plumbing and zinc from cosmetics and galvanising. However, these elements are also essential trace elements for crop nutrition (US EPA 1993). In recent years, there has been growing attention to potentially harmful trace organic compounds (e.g. PCBs, dioxins and PTEs). Some of the compounds of interest are potentially endocrine disrupters (FWR 2002b). Some European countries have adopted standards for organic contaminants in sewage biosolids intended for agricultural use but there is no consistent approach to the selection of contaminants or to numerical limits (Smith 2000).

The leaching of nutrients (N and P), metals, or organic substances from biosolids into ground water is an issue of potential concern. Biosolids generally have low N content (1-6%) relative to nitrogenous fertilisers. Further, relative to raw sewage or low grade sewage products, the organic matter in high grade biosolids, compost in particular, is highly stabilised and even high rates of application pose little risk of nitrate leaching (Smith 1996). The mineralisation of organic N in sewage sludge takes place quite slowly relative to other wastes, for example, poultry litter and pig effluent. The key to both minimising the risk of nitrate leaching and to the efficient use of biosolids in rural areas is to take into account the rate of mineralisation of organic N in the biosolids and to match application rates as closely as possible to the agronomic nutrient needs of crops (Andersen 2001).

Application of biosolids to land is generally aimed at enhancing the fertility of soils. However, concerns have periodically been raised about the potential for sludge or biosolids application to adversely effect soil micro-organisms and/or the long term fertility of soils. The proper functioning of the microbial biomass is essential to the intrinsic fertility of agricultural soils because of its role in mineralising nutrients from the soil organic matter to support plant growth (McGrath and Cegarra 1992).

In Ireland, a recent *'End of Project Report'* on soils of the South-East by McGrath and McCormack (1999), forms a database of heavy metal levels for part of the country. In the southeast, 21% of soils (by area) are disqualified from application of sludge because of previous enrichment with heavy metals. In south Kildare the proportion rises to 63% by area. Biosolids are used on the basis of its nutrient content, principally that of phosphorus. Nationally, the nutritional value is small, and never likely to exceed more than one or two per cent of the nutrients produced by farm animals. Despite its small volume and thus the small proportion of land area required for recycling (particularly if land used for animal production is considered suitable) significant constraints are imposed by codes of good practice, the Rural Environmental Protection Scheme (REPS) and local authority bye-laws (McGrath and McCormack 1999). These reduce considerably the available land bank for the utilisation of biosolids in Ireland (McGrath and McCormack 1999).

The potential for offensive odours can be a significant obstacle, if not the greatest obstacle, to increasing the beneficial use of biosolids. Not only do the odours themselves cause a public concern, but odours also trigger fears that 'foul-smelling' residues from municipalities and industry must be toxic and harmful (US EPA 1999).

Considerable information is available on abating or controlling odours generated from composting or other biosolids reuse operations, and new methods are being developed. Odours can be controlled by treating malodorous biosolids with lime prior to shipping to an application site, minimising anaerobic conditions, maximising the ability of microbes to break down substances, injecting biosolids into the soil rather than spreading them on the land surface, and collecting, treating, and dispersing any odours that are formed (USDA 1997; Walker 1998) Mitigating odour problems is another opportunity for the successful implementation of an environmental management system where generators, processors, and recyclers of biosolids products will decrease the generation of odours in addition to minimising other nuisance impacting public acceptance and perceived oversight. Thus odour problems can be prevented or mitigated with technology, advanced planning, and/or good management practices (US EPA 1999).

4.8.5 Quality assurance: In 1996, in response to the recommendations of the Royal Commission on Environmental Pollution in its report *Sustainable Use of Soil (19)*, the UK Government commissioned a comprehensive review of the scientific evidence underpinning the existing controls on the agricultural use of biosolids (Carrington et al 1998). The review concluded that the strategies adopted in the Code of Practice for controlling risks to health are, in principle, logical and sound. However, the review also concluded that there is a lack of definitive information on the survival of some of the more recently identified pathogens, for example *E. coli* O157:H7. There is also recognition that changing public concerns, the recognition of the precautionary principle and the need for sustainability, in the face of increasing pressures on agricultural land for recycling biosolids all require more attention be given to the measures for controlling risks to health of man, food, animals and crops. The review made recommendations to strengthen the microbiological safety relating to biosolids use in agriculture and to reduce the already small risks still further. The main recommendations include phasing out the use of untreated sewage sludge on land and the use of more stringent operating conditions for some of the treatment processes. It also recommends that some additional processes involving thermal treatment should be introduced, and that only biosolids treated by thermal processes should be applied to the surface of grazing land.

In order to minimise risks associated with the use of biosolids and maintain confidence of stakeholders, quality control and management practices are required. Their collective use and documentation provides quality assurance (Hall 2002). The most effective way of ensuring a consistently high quality product is to implement control and monitoring mechanisms at different stages in the biosolids life cycle, rather than just one quality check of the final product. This allows that if one check or control fails, any problems should be picked up by the other mechanisms (NGSMI 2003).

Limit values for heavy metals and other contaminants in biosolids have been progressively reduced in many countries in Europe, and this trend is expected to continue (Smith 2000). While lower standards are affordable in physical terms due to considerable improvements in biosolids quality over the last 30 years, concentration of some heavy metals and other contaminants are close to the minimum achievable due to the contribution from diffuse sources (plumbing, domestic production, road run-off). Further significant reductions in metal concentration are likely to be achievable through reformulation of products, and separate drainage (Marmo 2001).

Reductions in limit concentrations of heavy metals and other contaminants are to minimise accumulation in soil as far as possible. Atmospheric deposition and the use of fertilisers, farmyard manure and other wastes also contribute to soil loads (and globally, considerably exceed those from biosolids), but these are currently not well controlled (Hall 2002).

4.8.6 Proximity principle and economics: There is some ambiguity as to whether biosolids are, in practice, a waste or a product (Clark et al 1998). This ambiguity has been effectively addressed in most legislations and regulations in relation to the use of biosolids. In Ireland, for example, the *Code of Good Practice for the Use of Biosolids in Agriculture* has been designed with a clear view of biosolids as a resource. In doing this, the Code provides a framework for biosolids management that:

- Promotes responsible management of biosolids;
- Protects public health and the environment;

- Is sustainable and encourages consistent practices;
- Informs and is acceptable to the community allowing for local conditions and requirements to be considered .

If biosolids is defined as a waste, it therefore, should be disposed off in the region of origin in accordance with the proximity principle. However, transborder movement of biosolids occurs which implies that it is a product (secondary raw material) rather than waste (Marmo 2001). Further, the distance to land application sites is increasing as available land closer to the point of generation becomes more developed, thus requiring biosolids to be hauled further (NGSMI 2003)

The cost of biosolids management is set to increase as City and County Councils have to manage greater quantities of biosolids within tighter quality constraints. Generally speaking, the current price of sewage treatment in most of the EU does not include the cost of sustainable management of biosolids, and hence no effective price signals are being sent to wastewater generators. This cost will ultimately have to be carried by the contributing population (Andersen 2001d).

A comparison of the generalised treatment and disposal costs for some management options show that conventional treatment (digestion) and use in agriculture or disposal to landfill are the lowest cost options, although both are more expensive than more technical solutions due to high operating costs of small wastewater treatment plants (Andersen 2001d). The cost to farmers of applying biosolids, monitoring, record keeping, and meeting the management practices national and local regulatory agencies can impede biosolids use in agriculture. In the case of landfill, full site construction costs are included for mono–disposal. Composting, thermal drying and incineration are generally much more expensive than the other options but still have wide range of costs, reflecting size of plant, and type of technology (US EPA 1999, Hall 2000).

In the future, sludges will need to be treated to higher standards, particularly with regard to assured pathogen removal for biosolids use in agriculture (Clark et al 1998). This will inevitably increase the costs of the agricultural outlet, and will make City and County Councils re-evaluate whether the agricultural outlet remains financially viable, compared with, say, incineration (Andersen 2001d). Where high capital costs are involved, the City and County Councils will need to be confident that the investment period is secure. Investments are usually made with a 20-year horizon and the option selected may be contrary to longer-term sustainable development policy goals (NGSMI 2003).

A wide range of other wastes is used on land. The sludge production in the EU is about seven million tonnes (dry matter). This compares with some 200 million tonnes of municipal waste that are generated each year in the EU (Marmo 2001). Municipal waste includes industrial waste (from food processing, paper sludges, abattoirs, composted municipal solid waste) and farmyard manure. Such wastes are poorly regulated, or not at all in the case of farmyard manure, yet the latter contributes more nutrients and some heavy metals to soil than do biosolids (USDA 1997).

4.8.7 Agricultural use of biosolids: In 2002, the European Commission's DG Environment reported that research carried out in the past 30 years continues to demonstrate that a responsible and well-monitored use of biosolids (in compliance with the requirements of Directive 86/278/EEC) causes neither environmental damage nor endangers the food chain. With the more stringent conditions to be applied to the treatment of biosolids before use in agriculture, the prospects for sustaining this vital outlet well into the 21st century are good. But the rapid developments in this area arising from 'external factors' such as the 'emerging' pathogens issue indicate that water utilities need to be proactive and to continuously improve the quality of biosolids operations and to maintain dialogue with other parties in the food production and distribution chain (FWR 2002). The subject of engaging with others involved in the food chain has been the subject of a scoping study for the European Environment Agency.

Representatives of all sections of the chain agreed that a partnership is needed for the sustainable use of organic resources on land (biosolids, compost, manure, etc.) to build mutual trust, share information, identify gaps in knowledge and develop 'welcomed' practice by consensus. The National Biosolids Partnership in USA inspired the idea but this will be broader both in terms of the membership and the materials (Evans and Lowe 2002).

It is now widely accepted that landfill disposal of organic wastes, such as biosolids, is not a sustainable option due to concern over gas and leachate emissions and the need to conserve landfill void for those wastes that cannot be reused or recovered (Marmo 2001). National measures in the EU (to meet targets introduced in the Landfill Directive 1999/31/EC OJ L182, 16.7.99) vary but include limits on organic matter, taxes on reactive wastes and carbon taxes, and the separation of municipal solid wastes.

There is considerable concern amongst soil scientists in Europe about the loss of organic matter in intensively cultivated soils, with implications for soil fertility, crop production and soil erosion (Kato et al 2002). Furthermore, there are concerns over the continuing loss of peat bogs and their associated unique ecology, and sources of alternative organic materials to substitute peat are actively sought by many suppliers of growing media (McGrath and McCormack 1999). Use of organic wastes on land is therefore, necessary for sustainable agriculture as biosolids possess significant soil conditioning and fertilising properties. The wide array of elements that are essential for plant growth, coupled with the organic content of biosolids, have led some authors to suggest that biosolids are a more 'complete' fertiliser than most other proprietary fertilisers (Hall 2000). However, the presence of a wide variety of chemicals in biosolids (in trace amounts) with the potential for uptake by plants and animals, together with the potential presence of pathogens, means that biosolids cannot be treated like other fertilisers (Kato et al 2002).

Not only is biosolids use on land the preferred option under the waste management hierarchy, but it is also usually the best practicable environmental option (that is, objective balance of practicability, affordability, sustainability and acceptability). However, the security of the outlet is susceptible to public and retailer perception, and as a consequence, over-regulation (NGSMI 2003). The risks, based on extensive scientific study of the likelihood of biosolids doing harm to the environment and health are well characterised, and this should be the basis on which precautionary measures are based to provide long-term protection and public confidence. The degree of precaution required should be considered alongside what is practicable, affordable, desirable and necessary (US EPA 1999).

Palumbo et al (2004), calculate that an increase of 0.15 per cent of organic carbon in Italian arable soils would lock in soil and soil biomass the same amount of carbon released into the atmosphere in one year because of the use of fossil fuels. It can be safely assumed that similar proportions are valid for the whole of the EU. It follows that the use of biosolids is an effective and sensible means of diverting carbon dioxide from the atmosphere and converting it into organic carbon in soils and therefore, a valid tool for limiting greenhouse effect.

4.8.8 Perception and partnerships (public, political, retail): Biosolids use on land is probably the most researched of all waste management options, yet it still attracts considerable prejudice and low public acceptance (Clark et al 1998). This is mostly due to its faecal origin and fear of industrial contamination with heavy metals and poorly biodegradable trace organic compounds as well as potentially pathogenic organisms present in wastewater (Hall 2000). Urban wastewater are composed of a mixture of wastewater from different sources such as small shops and businesses, hospitals and medical centres, personal hygiene, washing of dishes and laundry, urine and faeces, runoff from roads and impermeable surfaces, industrial aqueous discharges where primary treatment may be required at source before discharge into the public sewer (Marmo 2001).

The low public acceptance of biosolids is despite the considerable improvements in quality and developments in treatment technologies. There is also a common misunderstanding between hazard and risk (NGSMI 2003). Current food retailer concerns over public perception of crops grown in biosolids treated soil will result in increasing restriction of its use and the need for advanced treatment for assured pathogen removal in order to secure the agricultural outlet (Hall 2000). Public concern also persists regarding the perceived lack of oversight of biosolids regulations (NGSMI 2003).

Understanding what the public concerns can allow biosolids managers and policymakers to address these concerns as part of their biosolids management programme and policy respectively (US EPA 1999). One very effective approach toward accomplishing public education is to establish a biosolids partnership that includes representatives from all key stakeholders including university and other scientists, water quality professionals, public health officials, agricultural groups and farmers, the environmental community, regulatory officials, the media and interested members of the local community (US EPA 1999).

Although some in the environmental community may oppose biosolids use, obtaining the involvement of an environmental group can result in a more successful effort (Hall 2000). A matrix of options and criteria can be created by the relative weighting of each criterion, according to the importance attached to it. The summation of the weighted scores for the options then produces a ranking of short-listed options. It can never be emphasized enough that a high degree of public acceptance is essential for biosolids projects. General goodwill towards the concept of beneficial use of biosolids can be mobilised provided procedures for managing the risks are in place, and the local community is well informed (NGSMI 2003).

The increased use of stakeholder processes/partnerships over the past decade represents a societal interest in more interactive forms of decision making. Rather than a transitory phenomenon, this development reflects a culmination of a series of environmental, political, societal, and technological developments that have begun to yield significant changes in the methods of making environmental decisions (Yosie and Herbst 1998).

Table 4.9 summarises the criteria that determine the final choice of biosolids management options.

Table 4.9: Possible evaluation criteria for the choice of biosolids management options *(Source: NGSMI 2003)*

SOCIAL CRITERIA	OPERATIONAL CRITERIA
• Public acceptance	• Impact on operations staffing requirements
• Potential for odours	• Easy to operate
• Public perception of end product	• Easy to maintain
• Public health and safety	• No major restraining requirements
• Operator/worker safety	• Reliability
• Protection of the environment	
TECHNICAL CRITERIA	**ECONOMIC AND IMPLEMENTATION CRITERIA**
• Proven technology	• Capital costs
• Design complexities	• Operation and maintenance
• Applicability to local situation	• Suitability for private sector participation including financing and operation
• Land requirements	• Suitability for alternate delivery methods
• Impact on plant processes	• Product marketability (diversity of end use)
• Storage constraints	
• Impacts on water plant residuals	
• Impacts on plant expansion	
• Ability to cope with adverse conditions	

Partnerships begin with how people, rather than experts, perceive their own reality, and extend to understand how this reality is related to what happens in the rest of society, to forming new relationships within and outside the locality, and imagining alternative parts of social transformation to the present ones

(Singh and Gilman 1996). It stresses the need to support and protect people's capacity to act and produce. Yet people's productive lives are not reduced in narrow economic terms (UNDP 1998).

These processes develop individual, family and community capacities to explore the impact of different courses of action and assess alternatives in a matrix of interactions between policy, science and technology (Bell and Morse 2001). The importance of this approach is that it allows governments and all stakeholders to identify appropriate policy options, and provides an approach for integrated implementation (NGSMI 2003). The focus of partnerships is on community strengths not weaknesses, what shapes people lives and how the various influencing factors can be adjusted so that, taken holistically, they produce a more beneficial system outcome. Increased use of stakeholder processes is part of a broader trend of organisational realignment (UNDP 1998). The use of stakeholder-based approaches to policy and programme formulation, implementation and evaluation has been elucidated in chapter two.

CHAPTER FIVE
LEGISLATION AND REGULATORY OVERVIEW

Various legislations and regulations at EU and national levels are being put in place to ensure a sustainable wastewater and biosolids management system. An overview of these legislation and regulations, including codes of good practice is presented in this chapter.

5.1 The Irish State

Ireland is a unitary state established as such under the terms of the Constitution of Ireland in 1937. Local and regional authorities are in place. All legislation is adopted at national level. Minor pieces of legislation in the form of local bye-laws may be adopted by the local authorities. In these instances there must, however, be an existing piece of national legislation which would enable a local authority to create the bye-law (*ó Riordán* 1999).

The Government operates through a cabinet system of governance. The Minister for the Environment, Heritage and Local Government oversees the regional and local authorities in Ireland. The system of local government includes, at its apex, the County Council/City Council. These number 34 and include the cities of Dublin, Cork, Limerick, Galway and Waterford. Underneath the County/City Council structure are a number of smaller municipal authorities including Urban District Councils, Borough Councils and Town Commissioners with responsibility for various smaller towns (Scannell 1994).

Some eight regional authorities were established in the State in 1994 as a result of changes to the European Union (EU) Structural Funds regime. Their function is to co-ordinate a regional review of the implementation of the Structural Fund programmes and to provide a co-ordinating facility for local authority policies which have a regional dimension. Their role is thus limited and subject to the terms and conditions of regional review established in the Irish Community Support Framework (*ó Riordán* 1999).

Ireland became a member of the EU on 1 January 1973. As a result, its environmental legislation is greatly influenced by the EU. EU legislation has the full backing of the Irish Constitution and is accorded the legal primacy which the Constitution provides. In addition, the Irish Courts no longer retain an exclusive interpretative role in Irish law as the Treaty of Rome provides for ultimate interpretation by the EU Court of Justice (Scannell 1994, *ó Riordán* 1999).

The EU has three legally binding instruments through which Community policy is implemented. Regulations which are directly applicable in each Member State of the EU. In Ireland, as elsewhere, Regulations automatically become the law and do not require to be expressly incorporated by domestic legislation. Directives which, while binding on all Member States, may be implemented through Irish law in the form of primary or secondary legislation. Directives must be processed by, in the Irish case, the national legislative framework. Decisions, which address specific aspects of a policy, are binding on the persons to whom they are addressed, including Member States, individuals and legal persons. (*ó Riordán* 1999).

5.2 Environmental Legislation in Ireland

According to Scannell (1994), environmental controls have been in-place in Ireland since the 19^{th} century. Early statutes dealing with what are now considered environmental issues included the Public Health (Ireland) Act 1878, which dealt with public drainage, water supplies, and public nuisances; and the Rivers Pollution Prevention Act 1876 which concerned water pollution. Irish environmental law is now so extensive. The greatest single influence on the development of Irish environmental law and policy, especially as it relates to pollution control, has been the activity of the EU in the environmental sphere (Scannell 1994). The body of law now associated with Irish environmental policy has been almost totally reformed in the past decade to take account of the EU process. This has resulted in significant amendment to legislation in the following areas:

- Air, water and soil pollution;
- All planning legislation;
- All waste management legislation ;
- All water quality legislation;
- Nature protection;
- Industrial licensing.

This body of law covers particularly the provision of housing, roads, water and sanitary services, and the planning and development functions, which in turn cover private and public sector development at local level (*ó Riordán* 1999).

In the last three decades since the first Environmental Action Programme, the EU has introduced a large number of Directives and Regulations concerning prevention of pollution and conservation of natural resources and these have become the main source of Irish legislation and the main driving force in the development of environmental policy (Scannell 1994). Responsibility for various aspects of the environment in Ireland is spread across a number of Government departments and agencies (see Section 5.5). Remedies for environmental damage can be sought through constitutional and common law, statute law and European law. Major instruments for protection of the environment in Ireland lie in the processes for land use and for planning control which have now been strongly reinforced by the Directive on Environmental Impact Assessment (Scannell 1994). The first ever report on the state of the environment was published by An Foras Forbartha in 1985. The report analysed the current environmental situation in Ireland and indicated, somewhat circumspectly, the areas where problems were occurring or imminent (Scannell 1994).

5.3 Biosolids Legislation in the EU and Ireland

The framework of applicable laws, regulations, guidelines in the local authority, regional or national jurisdiction is an important consideration in the development and implementation of a biosolids management programme. While the promulgation of a regulatory framework is not part of the biosolids management programme, a thorough working knowledge of the legislation and guidelines pertaining to biosolids management should be resident within the management staff of the biosolids management programme (US EPA 1994b).

In the EU, there are prevailing legislation and national guidelines pertaining to most aspects of biosolids management programme. These include:

- Environmental assessment as part of the planning process;
- Monitoring and reporting requirements;
- Storage requirements;
- Transportation requirements;
- Emission criteria;
- Design, construction, and operation of biosolids processing and end-use/disposal facilities;
- Biosolids quality criteria;
- Land application rates and site management procedures;
- Requirements for documentation;
- Contingency planning;
- Staff training; and
- Quality assurance.

The key element of good practice in regard to compliance is a thorough knowledge and understanding of applicable laws and regulations, including certificates of approval or permits that govern operations (Andersen 2001b).

The legal framework established by the EC and regulating the various sewage sludge routes is mainly composed of Directives which have to be transposed into national legislation of Member States. A list of these directives is given in Appendix B. A summary of the most relevant ones to biosolids management are given following:

5.3.1 The Council Directive 86/278/EEC of 1986 on the protection of the environment, and in particular of the soil, 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. To this end, it prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. Treated sludge is defined as having 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". To provide protection against potential health risks from residual pathogens, sludge must not be applied to soil in which fruit and vegetable crops are growing or grown, or less than ten months before fruit and vegetable crops are to be harvested. Grazing animals must not be allowed access to grassland or forage land less than three weeks after the application of sludge. The Directive also requires that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired.

The Directive specifies rules for the sampling and analysis of sludges and soils. It sets out requirements for the keeping of detailed records of the quantities of sludge produced, the quantities used in agriculture, the composition and properties of the sludge, the type of treatment and the sites where the sludge is used. Limit values for concentrations of heavy metals in sewage sludge intended for agricultural use and in sludge-treated soils are in Annexes I A, I B and I C of the Directive. It was brought into Irish legislation under (Statutory Instrument) SI 183 of 1991.

5.3.2 The Waste Framework Directive 91/156/EEC of 1991 (amending 75/442/EEC) gives credence to the waste management hierarchy. It outlines the waste management hierarchy with preference given to waste prevention followed by waste reduction, re-use, recycling and energy recovery. This Directive establishes principles for the use and disposal of waste, waste management plans, approval procedures and monitoring. In addition, this Directive provides the definition for the term 'waste'. A list of different types of waste is provided by the Commission Decision 2001/118/EC which amends Decision 2000/532/EC. Directives specific to certain wastes such as biosolids are applied additionally to the Waste Framework Directive.

5.3.3 The Urban Waste Water Treatment Directive 91/271/EEC of 1991 is aimed at protecting the environment from the harmful effects of uncontrolled discharge of wastewater. It was brought into Irish legislation under SI 419 of 1994. The Directive sets the following targets for secondary treatment of wastewaters coming from agglomerations:

- At the latest by 31 December 2000 for agglomerations of more than 15,000 population equivalent (p.e.);
- At the latest by 31 December 2005 for agglomerations between 10,000 and 15,000 p.e.;
- At the latest by 31 December 2005 for agglomerations of between 2,000 and 10,000 p.e. discharging to fresh waters and estuaries.

There are more stringent provisions for agglomerations discharging into sensitive areas such as fresh waters or estuaries. The Directive supports the use of biosolids in article 14 and introduces detailed monitoring requirements. It requires Member States to submit reports every two years on their sludge disposal activities.

5.3.4 The Council Directive 91/676/EEC of 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, known as the Nitrates Directive, requires identification by Member States of Nitrates Vulnerable Zones (NVZ). These zones are defined as areas where water quality has or will exceed EC drinking water standard in terms of nitrates concentration (defined in Directive 75/440EEC concerning the quality required of surface water intended for the abstraction of drinking water in Member States).

5.3.5 The European Standard Commission (CEN): In addition to the legal framework, the CEN committees and the International Standard Organisation (ISO) establish international standards and set out recommendations on biosolids management. In particular, CEN has published a report on *'Characterisation of sludges – Guide to preserve and extend sludge utilisation and disposal routes'* (CR 13846). The standards, which have been published by CEN concerning characterisation of sewage sludge used in biosolids production, are:

- Water quality – Sampling – Part 13: Guidance on sampling of sewage, waterworks and related sludges (EN/ISO 5667-13);
- Characterisation of sludges – Determination of pH value of sludges (EN 12176);
- Characterisation of sludges – Utilisation and disposal of sludges – Vocabulary (EN 12832);
- Characterisation of sludges – aqua regia extraction methods – Determination of trace elements and phosphorous (EN 13346);
- Characterisation of sludges – Determination of the loss on ignition of dry mass (EN 12879);
- Characterisation of sludges – Determination of dry residue and water content (EN 12880);
- Characterisation of sludges – Determination of Kjeldhal nitrogen (EN 13342).

5.3.6 Other EU Directives: Some other Directives related to waste management have also implications on biosolids management. The Landfill Directive 1999/31/EC will contribute to making the disposal of biosolids to landfill more difficult, as this it aims at reducing the quantity of biodegradable waste going to landfills, and prohibits the landfilling of both liquid and untreated wastes. In addition, Directive 2000/76/EC on the incineration of waste sets limit values for emission of pollutants to air due to waste incineration. The Commission Decision 98/488/EC establishing the ecological criteria for the award of the Community eco-label to soil improvers, specifies that these products must not contain sewage sludge.

5.4 Regulating the Agricultural Outlet

In majority of Member States, the specific regulations which have been introduced covering the recycling of sewage sludge mainly concern the use of biosolids in agriculture, while the disposal of sludge is addressed by general legislation on landfill and incineration of waste (Anderson 2001b).

In Ireland, the use of biosolids in agriculture is regulated by the Waste Management (Use of Sewage Sludge in Agriculture) Regulations and by the Waste Management Regulations. These regulations give effect to the provisions of Council Directive 86/278/EEC. In a larger context, the main legislation concerning the hydraulic resources is the Local government (Water Pollution) Act of 1977 and as regards the waste products, the Waste Management Act of 1996.

As specified in the Council Directive 86/278/EEC, the Irish legislation holds that sludge must be subjected to biological, chemical or thermal treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use. Untreated sludge may be used in agriculture provided that it is previously injected or otherwise worked into land. Residual sludge from septic tanks may be used on grassland provided that the grassland is not grazed within six months following such use.

The Department of Agriculture, Food and Forestry in 1994 the Rural Environment Protection Scheme (REPS), aimed at improving management of animal manure. In addition, a *Code of Good Practice for the Use of Biosolids in Agriculture* was published in 1998. It advises and provides recommendations for biosolids producers in relation to:

- Treatment of biosolids to achieve pasteurisation;
- Evaluating spread lands for the use of biosolids;

- Transportation and spreading of biosolids;
- Nutrient management planning;
- Quality control; and
- Liaising with the customer.

The recommendations in the *Code of Good Practice* were designed to reflect the requirements of relevant legislation at both EU and Irish levels. The *Code of Good Practice* complements the *Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates*, published by the Department of Environment and Department of Agriculture, Food and Forestry in July 1996.

The Urban Waste Water Treatment Regulations, 2001 (S.I. No. 254 of 2000), were made by the Minister for the Environment on 14 June 2001 and amended on 15 July 2004. The Regulations give further effect to the provisions of EU Council Directive 91/271/EEC of 21 May 1991, as amended concerning urban wastewater treatment, and Directive 2000/60/EC of 23 October 2000 – The Water Framework Directive. The Urban Waste Water Treatment Regulations, 2001 (S.I. No. 254 of 2000) revoke the Environmental Protection Agency Act, 1992 (Urban Waste Water Treatment) Regulations, 1994 (S.I. No. 419 of 1994) as amended by S.I. 208 of 1999.

5.5 Agencies with Biosolids Management Responsibility

Responsibility for the management of biosolids in Ireland lies primarily with the Department of the Environment, Heritage and Local Government. However many other government departments also have general and specific responsibilities. As a general rule Government departments on behalf of their ministers deal with overall policy matters at national level. The execution or administration of much biosolids policies is the responsibility of local or regional authorities. In addition, statutory bodies exercise important environmental protection and control functions and others provide information, research and other support services.

5.5.1 The Department of the Environment, Heritage and Local Government

In 1998, the Department commissioned the preparation of an *Inventory of Non-Hazardous Sludges in Ireland.* The *Inventory* quantified all sludges arising from municipal, industrial and agricultural sectors and identified current management strategies for each sludge type. The *Inventory* was one of its kind in Europe. The Department had earlier in 1993 published a *Strategy Study on Options for the treatment and Disposal of Sewage Sludge in Ireland*. This *Strategy Study* identified 48 regions nationally, each, within which a hub-centre for sludge treatment was located. To further assist local authorities in planning for the beneficial reuse of municipal wastewater sludge, the Department of the Environment, Heritage and Local Government commissioned a series of documents including; *A Study of International Practices on the use of Biosolids in Agriculture* (Fehily Timoney & Co., 1998); *Code of Good Practice for the Use of Biosolids in Agriculture* (Fehily Timoney & Co., 1999); and *Sludge Management Plans: A Guide to their Preparation and Implementation* (Fehily Timoney & Co., 1999). The primary aims of these reports were to; identify the volume of non-hazardous sludges arising in the country and to note its current method of management; assess if the agricultural route is the most sustainable beneficial reuse option for municipal wastewater sludge; and advise on the proper use of municipal wastewater sludge in agriculture.

5.5.2 Local Authorities: In Ireland, Local Authorities act as sanitary authorities in the provision of public water supplies, the treatment of sewage sludge from wastewater treatment plants. This function has essentially existed since the adoption of the Public Health (Ireland) Act 1878. The 1878 Act, updated by an Act in 1948, enables the local authorities to collect wastewater and to treat it. This is increasingly covered by the EU Urban Waste Water Directive of 1991, which banned marine disposal of wastewater sludge from 31st December 1998. One of the principal recommendations of the *Strategy Study on Options for the treatment and Disposal of Sewage Sludge in Ireland* was that local authorities would prepare plans for the management of wastewater sludge arising in each of the 48 regions. Each of these Plans will incorporate a region-specific inventory of non-hazardous sludges which will serve as a data source from which national inventory can be verified and updated. These Plans will also aim towards integrating the proper and sustainable management of all sludges into every day life in each of the 48 regions and where appropriate, incorporated into the County Development Plans of relevant Local Authorities. The Waste Management Act, 1996 further reinforced the local authority's responsibility in sludge management planning by including all non-hazardous sludges as part of the waste stream to be managed under a Waste Management Plan.

5.5.3 The Environmental Protection Agency (EPA): The EPA is required under Section 61 (3) of the Environmental Protection Agency Act, 1992, to report on a biennial basis on the quality of effluents being discharged from wastewater treatment plants, sewers or drainage pipes which are vested in, controlled or used by sanitary authorities. There are five reports to date covering the period 1998 to 2003. The Urban Waste Water Treatment Regulations, 2001 (Statutory Instrument 254 of 2001), which incorporate and update the Environmental Protection Agency Act, 1992 (Urban Waste Water Treatment) Regulations, 1994 as amended in 1999, place a responsibility on local authorities to provide treatment of urban waste water, to monitor discharges from agglomerations (communities) and to transmit the results of such monitoring to the EPA.

5.5.4 The Office of Environmental Enforcement: This office was established in 2003. It is a new Office within the EPA, dedicated to the implementation and enforcement of environmental legislation in Ireland. The Office of Environmental Enforcement delivers enhanced enforcement in two ways. It is directly responsible for enforcing EPA licences issued to waste, industrial and other activities. It also supervises the environmental protection activities of local authorities, through auditing their performance, providing advice and guidance, and in appropriate cases, giving binding directions. The Protection of

Environment Act, 2003 confers new powers on the EPA regarding the monitoring of performance of statutory functions of local authorities.

5.5.5 The Department of Agriculture and Food: The Department is concerned with the effects of environmental pollution on agriculture, and the promotion of EU agriculture policies for environmentally sensitive areas. It is also responsible for farm development schemes including pollution prevention schemes, the pollution implications of agricultural practices and the promotion of organic and other environmentally friendly farming methods. The Waste Disposal Act, SI 148 of 1998, regulates both processed sewage sludge and receiving land. This principally limits heavy metal contents of both sludge and soil.

5.5.6 Teagasc: This is the Agriculture and Food Development Authority. It was established in 1988, as the national agency with overall responsibility for the provision of research, training and advisory services to the agriculture and food industry. It incorporated the training functions of the Agricultural Institute. The rationale for this was that considerable benefit could be derived from the co-ordination and integration of the research service with the training and advisory services. With agriculture under environmental scrutiny, Teagasc prepared codes of good practice for farming to ensure that agriculture would not cause pollution of soil, water and air. Highlights here include the evaluation and development of improved slurry spreading technologies, the development of a blueprint for environmentally compatible dairy farming, for hardwood farm forestry and the establishment of technical/economic basis for organic sheep/cattle systems. A growing proportion of Teagasc resources are now being devoted to specialised advisory programmes aimed at minimising nutrient loss from agriculture. The purpose is the adoption of more environmentally sustainable farming systems together with compliance by farmers with a battery of regulations including the *Codes of Good Practice for the Use of Biosolids in Agriculture*.

CHAPTER SIX
RESEARCH DESIGN AND METHODOLOGY

The primary objective of this study is to develop a set of SDIs for managing biosolids at the local and regional levels. This chapter describes the procedure and approaches that are adopted in the course of this research. The chapter commences with the research design and followed by a full description of the instrument for data collection (including its validation and reliability), and procedure for data treatment and analyses. Included also, are details of the population and sampling techniques employed in the study.

6.1 Research Design

The research method employed in the course of this study is the descriptive survey within the context of an interactive research. Due to its focus on real life problems, interactive research, according to the Economic and Social Research Council (ESRC), often requires collaborations between a wide range of disciplines and expertise. Interactive research refers to a style of activity where researchers, policy makers and user groups interact through the entire research process, including scooping the research agenda, project development and execution, monitoring and evaluation of outcomes. This method of research takes a pragmatic, utilitarian and user-orientated approach and is considered by many to be a vital element in establishing effective participatory networks as advocated in LA 21 (ERSC 1999).

This particular study involved ascertaining and analysing the concerns of major stakeholders in the sustainable management of biosolids. It involves also, the review of a list of candidate indicators and the selection of the most relevant indicators (using some criteria) by the stakeholders (see Figure 6.1).

The descriptive survey research method was employed to collect data that will describe in a systematic manner, the perceptions of the major stakeholders.

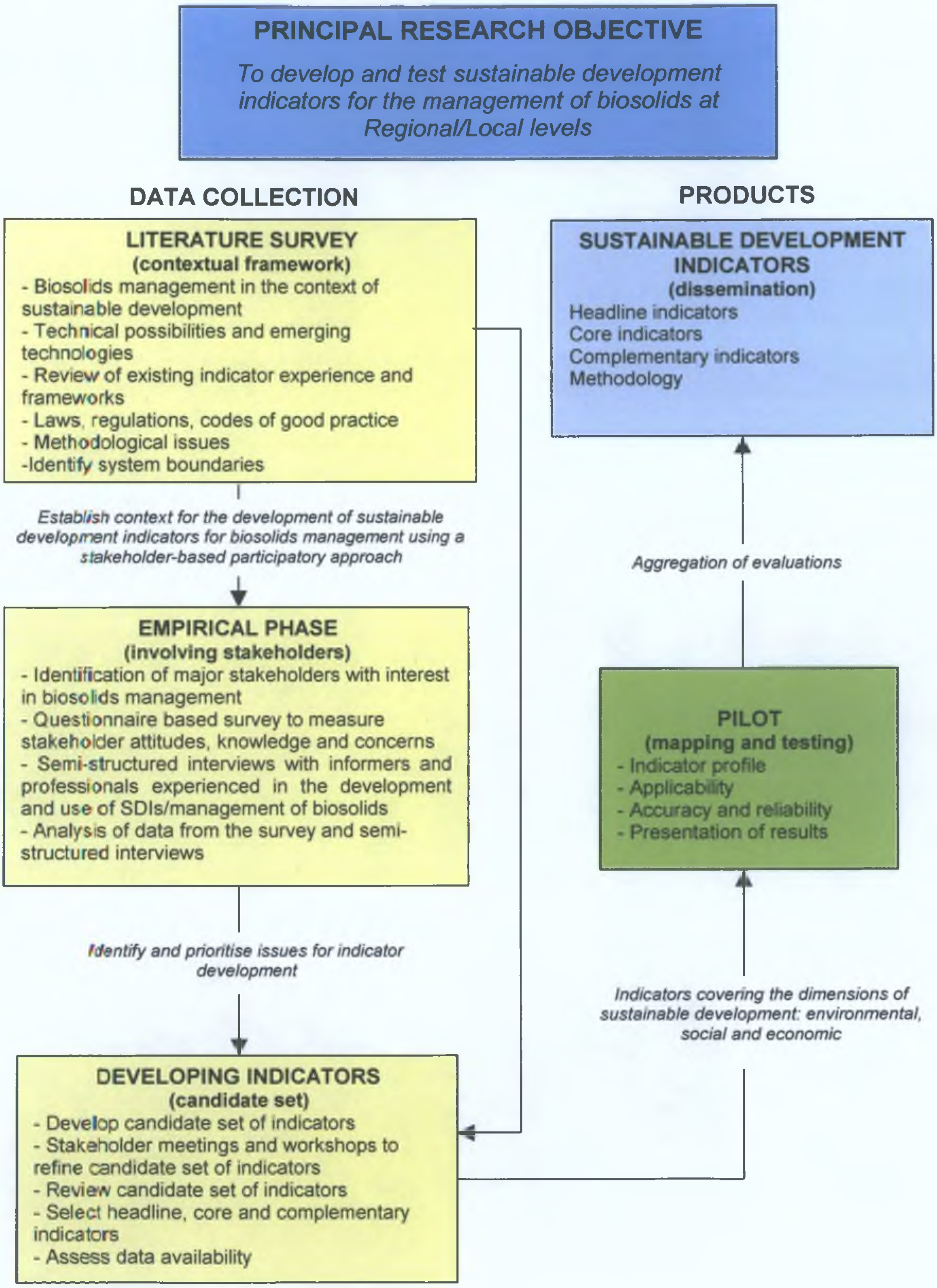


Figure 6.1 Design of research study

This data collection and analytical method promoted interaction and stakeholder involvement in the overall indicator development process.

The first phase is the review of related literature to establish the context for the development of SDIs for biosolids management using a stakeholder-based participatory approach. This is followed by the empirical phase where issues for indicator development are identified and prioritised. The third phase involves the development and selection of headline, core and complementary set of indicators, and leads on to the pilot/testing phase. This phase involves the application of the indicators in a selected region/local authority with a view to assessing and reviewing how clearly they relate to specific stakeholder concerns. The final phase is the dissemination of the research products which include the set of indicators (headline, core and complementary) for managing biosolids, and the methodology used in the research study.

6.2 Identification of Stakeholders

A stakeholder-based participatory process was adopted in the research design. There are many stakeholders with interest in biosolids management (Andersen 2001, Palme et al 2004, US EPA 1999). For both quantitative and qualitative empirical data collection methodologies, four groups of major stakeholders were identified namely:

Group I: Regulatory agencies including Local Authorities who also own and operate wastewater treatment plants in Ireland. The EPA, Department of the Environment, Heritage and Local Government that regulate the management of biosolids in collaboration with the Local Authorities are also included in this group.

Group II: Organisations including farming organisations, forestry associations, corporate organisations (including food manufacturing and retail companies, insurance companies, waste management companies), government organisations with (non regulatory) environmental responsibilities, chambers of commerce, non-governmental organisations (NGOs) and community-based organisations with interest in the biosolids issue.

Group III: Individuals with interest in biosolids management. They may be neighbours to various wastewater and sewage sludge processing plants, and biosolids reuse/disposal sites, or concerned citizens.

Group IV: This group is made up of experts outlined as in Table 6.1. They were used as informants who provided additional literature and details on specific aspects relative to some of the stakeholder concerns, and data requirements for the generation of SDIs. They were not included in the 'Stakeholder Survey', which was carried out using structured questionnaires (described more fully in Section 6.4). These informants form the bulk of respondents targeted for the semi-structured interviews.

Table 6.1: Major biosolids stakeholders

Group I	Group II	Group III	Group IV
Regulatory Agencies • Local Authorities • Department of Heritage, Local Government and the Environment • Environmental Protection Agency	***Organisations*** • State organisations with environmental responsibilities • Non governmental organisations • Community based organisations • Corporate organisations (businesses and chambers of commerce) • Farming and forestry organisations	***Individuals*** • Unaffiliated persons, citizens and members of the public with interest in biosolids management	***Experts*** • Researchers, consultants and academics.

To populate Group II, a list of all NGOs and governmental organisations with relevant interests in biosolids management was obtained from ENFO (Irish Information on the Environment Agency). A website, www.indexireland.com and the yellow pages were used to identify relevant corporate organisations. Initial contacts by way of telephone calls were made to the identified organisations in order to acquaint them with, and solicit their participation in the project. The telephone calls also facilitated the identification of a contact person in the participating organisations.

6.3 Data Collection

To satisfy the information needs of any study or research project, an appropriate methodology has to be selected and suitable tools for data collection (and analysis) have to be chosen (Mouton 2001). This study adopted a methodological approach where both quantitative and qualitative methods were used in the study. When these methods are combined, the advantages of each methodology complement those of the other, making a stronger research design that will yield more valid and reliable findings (Decrop 1999). Quantitative data is collected under controlled conditions in order to rule out the possibility that variables other than the one under study may account for the relationships identified, while qualitative data is collected within the context of its natural occurrence (Massey 2003). Both quantitative and qualitative methods seek reliable and valid results. Data that is consistent or stable, as indicated by the researcher's ability to replicate the findings, is a major concern in the quantitative approach, while the validity of qualitative findings is paramount so that data is representative of a true and full picture of the constructs under investigation (Bowen 2003). The following is an overview of quantitative and qualitative approaches to research.

Qualitative forms of investigation tend to be based on recognition of the importance of the subjective, experiential world of human beings (Babbie 1995, Blanche and Durrheim 1999). Gilbert (1993) notes that qualitative methodologies provide avenues that can lead to the discovery of these deeper levels of meaning. Easterby-Smith et al (1991) describe the task of the qualitative methodologies as to capture what people say and do as a product of how they interpret the complexity of their world, and to understand events from the viewpoints of the participants. Since qualitative reports are not presented as a statistical summation, but rather adopt a more descriptive, narrative style, this type of research is likely to be of particular benefit to policy and decision makers (Easterby-Smith et al 1991, Blanche and Durrheim 1999). However, it is on those grounds that qualitative research has often been described as not being empirical. Nevertheless, this argument does not hold, since, according to Gilbert (1993) and Jennings (2001), the term 'empirical' has nothing to do with numbers or the manipulation of variables, but refers instead to whether phenomena are capable of being found in the real world and assessed by means of the senses. The problem of validity and reliability is a criticism often levelled at qualitative methods. Cresswell (1994) contends that because of the nature of qualitative data and its origin in single contexts, it is difficult to apply conventional standards of reliability and validity. The richness, individuality and subjective nature of a participant's perspective and understanding are not amenable to scientific criteria. Neuman (1994) and Walle (1996) argue that this does not make such understanding any less real or valid for that participant.

Quantitative research method adopts a deductive approach to the research process. Researchers who adopt a more deductive approach use theory to guide the design of the study and the interpretation of the results (Neuman 1994). The overall objective is to test or verify a theory, rather than develop one. Thus the theory offers a conceptual framework for the entire study, serving also as an organising model for the research questions or hypotheses and for the entire data collection procedure (Veal 1997, Blanche and Durrheim 1999). A quantitative methodology abstracts data from the participants into statistical representations rather than textual pictures of the phenomenon. The entire research process is objectively constructed and the findings are usually representative of the population being studied. The main strengths of the quantitative approach lie in precision and control. Control is achieved through the sampling and design, and precise and reliable quantitative measurement.

The method thus provides answers which have firmer basis than intuition or opinion (Welman and Kruger 2001). However, Massey (2003) points to the fact that scientific quantitative approach denigrates human individuality and the ability to think. It fails to take account of people's unique ability to interpret their experiences, construct their own meanings and act on these (Gilbert 1993).

6.3.1 Primary research methods for data collection. A questionnaire survey was the main instrument providing empirical data, and was designed around opinion statements as a means of exploring stakeholders' perceptions of a wide range of environmental, economic and social aspects of biosolids management. The survey modalities are detailed in section 6.4.

Semi-structured interviews were conducted to provide further insights and illuminations into some of the responses received, but mostly, to obtain information from the expert group. Blanche and Durrheim (1997) contend that the benefits of an unstructured interview include the opportunity it affords the interviewer to interact with respondents in a conversational setting so as to reach the heart of the subject under investigation. However, semi-structured interviews are generally more effective, in that they allow fuller exploration of the topic and yet retain a degree of the structure, which ensures that most of the information obtained is relevant and manageable (Veal 1997). In the present study, coherence and trustworthiness were achieved through a process of verification, by questioning and paraphrasing (during the interviews), using internal validity. Neuman (1994) defines internal validity as the absence of errors internal to the design of the study. The researcher's reflection and paraphrasing during the interview confirmed understanding and the meaning attributed to the statements.

6.3.2 Secondary research methods for data collection. An extensive survey of related literature was undertaken as presented in Chapters 2, 3 and 4. The aim is to acquaint the researcher with the various biosolids management concepts, options and emerging technologies in the processing of sewage sludge into biosolids. The review also involved an assessment of the issues associated with the development of appropriate sustainability indicators based on stakeholder concerns, availability of data and international best practice in the development of SDIs. The overall review of secondary sources was conducted using consultants' reports, books, academic journals, leaflets, articles in the popular press, unpublished manuscripts, statistics and archives that are of relevance to the research topic. Database searches on the World Wide Web (internet) were conducted using the keywords: sustainable development, sustainable development indicators, biosolids, and sewage sludge. In order to ensure that recent literature was covered in the course of the study, an iterative approach was adopted.

6.4 Biosolids Stakeholder Survey

A survey was designed using a set of questionnaires to provide empirical data to measure stakeholder knowledge, attitude and concerns in relation to biosolids management. It is important to ensure that questions are not put to stakeholders to whom they are clearly irrelevant. As a result, three categories of questionnaires were designed around a set of core questions which were applicable to all groups of stakeholders to be covered in the survey (see Appendices C1, C2 and C3). The set of core questions was used to:

- Identify stakeholder concerns with various biosolids management options
- Identify information and action required to address these concerns
- Assess the feasibility of SDIs as a biosolids management tool that can be used in planning, policy and decision making.

Closed questions were the predominant type used in the survey. To identify main stakeholder concerns and information needed to address these concerns, respondents were asked to rank their perception of each concern in order of priority, and information suggested addressing these concerns in order of usefulness. A Likert scale (Likert 1932) of 1 – 5, with a 'Don't know' option is used. The pool of concerns and information suggested addressing these concerns are derived from the literature survey (see Chapter 4). This pool was used to formulate 23 statements incorporating the 5-point Likert scale to measure stakeholders' opinion on each statement. Respondents were asked to rate each statement on an ordinal scale of 1-5. They were also asked to make additional comments on any aspects of biosolids management and/or the study as a way of identifying other relevant concerns and issues not included in the questionnaire.

6.4.1 The Likert method used in design of questionnaire. Likert (1932) proposed a method of attitude measurement; a summated scale for the assessment of survey respondent's attitudes. The same method remains in use today, and is appropriate to the current research context. Likert scale questionnaire surveys have been used in the social sciences for measuring perceptions and attitudes of the host community towards social, economic and environmental impacts (Ap and Crompton 1993, Lankford 1994, McCool and Martin 1994). A Likert scale instrument is therefore developed for the purpose of this study to assess stakeholders' perceptions of the social, economic and environmental issues associated with biosolids management. The research variables are measured on a 5-point Likert-type scale, with a score of 1 representing 'not serious/not useful' and a score of 5 representing 'most serious/most useful'. The scale was designed to elicit stakeholders' opinion on a range of issues relating to biosolids management. Individual items can be, and normally are, analysed by counting how many respondents gave a particular response to the item.

A problem with the use of Likert-style questions is that they may not assess opinions accurately because they provide an insufficient range of alternatives and do not take full account of respondents' reasoning. However, using such a rating system enables quantitative analyses of results, and does not discriminate against less literate respondents (Kelly and Moles 2002). To overcome some of the problems associated with forced choice response formats, respondents are given the option to include comments on any other issues and concerns of significance to them. Respondents have choice of explaining the reasons for their choice of options, and this allowed the researcher to get a 'feeling' for a respondent's views. Likert (1932), Lankford (1994), and Veal (1997), list the advantages of the Likert method as including the fact that the method is based entirely on empirical data regarding subjects'/stakeholders' responses rather than the subjective opinion of experts. There is also the advantage of ease of preparation coupled with the fact that it produces more homogenous scales and validity and reliability is reasonably high. Cover letters introducing the study and explaining what is to be done were attached to each questionnaire (Appendices G1, G2 and G3).

6.4.2 Validity/Pilot survey. A pilot survey was executed in March 2004, using a sample population of 15 respondents (five respondents from each of Groups I, II and III) to test the questionnaires. This was done primarily to ensure the clarity of the questions and to measure whether the questionnaires could be completed within a reasonable period of time (about 20 minutes). Another reason for conducting the pilot survey was to elicit some comments about the content validity, as respondents are asked to describe any difficulties they had in completing the pilot questionnaire accurately. As a result of the pilot survey, several changes were made to the questionnaire. For example, a confidentiality clause which prohibits disclosure of respondent's identity and responses to the questions, was added to the questionnaire. This is to gain the confidence of respondents. Also, as a result of the pilot survey, efforts were made to keep the wording of the questions as clear and unambiguous as possible by using vernacular language. For example, odour is characterised as 'objectionable smell'. To promote a high response rate, possible personal and corporate benefits and the possible development of a partnership were highlighted in the cover letter used to introduce the survey.

6.4.3 Questionnaire distribution. The 'Biosolids Stakeholder' questionnaires were disseminated to the identified regulatory agencies, participating organisations and individuals. The questionnaires were in the form of a four-page document (for Groups I and II) and three-page document (for Group III) with a one-page cover letter to give respondents an appreciation of the purpose of the study. All questionnaires to all stakeholders were sent by mail in May 2004. Reminders were mailed in July and August 2004 to those who had not responded at that stage. Telephone calls were also used as part of the follow up procedure. Unaffiliated members of the public, who were not contacted but have interest in the research study, could obtain the questionnaires through the ENFO library, and on the (Institute of Technology Sligo) biosolids sustainable management research website. The questionnaires for all the groups of stakeholders were made available at the website from May to August 2004.

6.4.4 Semi-structured personal interviews. The personal interviews were a source of qualitative data. They were semi-structured in nature and were conducted on an individual basis. The interviews made it possible to further clarify some stakeholder responses to the questionnaire, thereby enriching the data. The experts or informants were mainly interviewed to clarify some issues in the Sludge Management Plans (SMPs) they had prepared for local authorities. Each interview lasted from five to about 10 minutes. All respondents were assured that the information given by them would be used for the purpose of the study and would not be released to the public. The respondents were encouraged to speak on the topic as widely as they deemed fit, and to relate to their own experiences. These interviews are based on the use of an interview guide (Veal 1997, Jennings 2001), which is a written list of questions and topics that need to be covered in a particular order. The interviews were broadly guided by open-ended questions emanating from the questionnaire responses for stakeholders or from the SMPs and other documents prepared by the experts. The interviewer intervened only for clarification or further explanation. The interviews were conducted by telephone.

Within the limits of quantitative research, external validity of the semi-structured interviews was addressed by the use of interview guidelines generated from literature (Veal 1997, Jennings 2001). This ensured that interviews focussed on the topic under investigation. Welman and Kruger (2001) describe external validity as a mechanism that ensures that the process implemented to collect data has collected the intended data successfully. To achieve this, the purpose of the interview is clearly explained to the respondents and issues of concern are resolved satisfactorily. This encouraged frankness during the interviews. The above steps ensured that the interviews are conducted under conditions acceptable to the respondents, and therefore ensured that the process was trustworthy. A rapport with the respondents was successfully established through initial contacts made by telephone calls prior to the interviews.

6.4.5 Sampling techniques used. The main purpose of sampling is to achieve representativeness; the sample should be assembled in a way as to be representative of the population from which it is taken (Gilbert 1993, Jennings 2001). Jennings (2001) defines population as all study subjects or study units that are focused on the research project. Because of time and resource limitations, a combination of two non-probability sampling methodologies was employed. In non-probability sampling, there is an assumption that there is an even distribution of characteristics within the population (Welman and Kruger 2001). Elements are chosen arbitrarily as there is no way to estimate the probability of any one element being included in the sample. Also, no assurance is given that each item has a chance of being included, making it impossible either to estimate sampling variability or to identify possible bias (Veal 1997). Reliability cannot be measured in non-probability sampling; the only way to address data quality is to compare some of the survey results with available information about the population (Mouton 2001). Still, there is no assurance that the estimates will meet an acceptable level of error (Veal 1997). Statisticians are reluctant to use these methods because there is no way to measure the precision of the resulting sample. Despite these drawbacks, non-probability sampling methods can be useful when descriptive comments about the sample itself are desired. Secondly, they are quick, inexpensive and convenient (Welman and Kruger 2001).

One of the two non-probability sampling techniques used in this study is purposive sampling. Purposive sampling is also referred to as judgmental sampling, since it involves the researcher making a decision about who or what study units will be involved in the study (Jennings 2001). Andersen (2001), US EPA (1999) and NGSMI (2003) have identified certain stakeholders (described in section 6.2) whose involvement and participation is argued, are vital to achieving the sustainable management of biosolids. Therefore, the survey was aimed at these stakeholders. Snowball sampling is also employed. It is a non-probability method that relies on referrals from initial respondents to generate additional respondents (Vogt 1993). Organisations and individuals willing to participate in the survey were asked to identify candidates who met similar criteria for inclusion in the study. Extra copies of the questionnaire were sent to each organisation with a request to send copies to those other organisations with similar interests and characteristics. While this technique can lower the cost of the search for respondents, Welman and Kruger (2001) posit that it may introduce bias because the technique itself reduces the likelihood that samples will represent a good cross section from the population.

In a non-probability sample, there is the possibility of over or underestimating the population parameter. This usually happens by systematically excluding a section of the population from the sample. Unaffiliated individuals who completed a questionnaire may have done so because they were particularly active in the community or interested in the biosolids issue. This may have resulted in under-representation of the less civically active or environmentally conscious members of the community or public (Kelly and Moles 2002). To minimise this, the survey questionnaires were made available on the IT Sligo's research website. They were also obtainable from some community libraries and ENFO to improve accessibility and achieve a wider reach.

6.4.6 Sample Size. Sample size was not predetermined but was left until the saturation of information through the snowball sampling technique. A total of 407 questionnaires were distributed to various stakeholders, and 17 personal interviews were conducted. The persons interviewed include nine experts who are used as informants (Appendix E4) specifically because of their knowledge of the topic under investigation. Table 7.1 in Chapter 7 gives the detailed response rate achieved.

6.5 Data Analysis

The data for this study was collected from survey questionnaires, personal interviews and review of secondary sources. The data from the questionnaires were compiled in Microsoft Excel 2003®, a computer database program and analysed with the aim of calculating percentages presented as tables, charts and graphs. The data were checked and cleaned by examining the compiled and keyed data for any incorrectly assigned numbers and correcting these errors, and by reviewing the original data. In order to enable direct comparison between stakeholders groups, and to avoid the confusion of the different sample sizes, it was decided to convert each group response, to a question, into a percentage of the group sample size. Unless otherwise stated, the percentages shown are the percentage of the total number of respondents in each group.

Qualitative data collected through interviews were coded into themes already established in the interview structure. The essence of the analysis is to sort and evaluate the information gathered in relation to the questions posed (Finn et al 2000). Data is also analysed to identify similarities and dissimilarities (Babbie 1995). This type of analysis is favoured for its potential to assist in describing trends in the quantitative data and also determining whether there were relationships between variables/issues.

6.6 Developing Indicators

A set of candidate indicators consisting of possible measures addressing the issues emerging from the stakeholder survey was developed without regard for constraints in applying them. These candidate indicators are based on the DPSIR framework. Most national and international bodies base their sets of indicators on the DPSIR framework. According to this system, social and economic developments exert *Pressure* on the environment, and as a consequence, the *State* of the environment changes. This leads to *Impacts* on human health, ecosystems and materials that may elicit societal *Response* that feeds back on the *Driving Force* or on the impacts directly, through adaptation or curative action (OECD 1999). The advantages and shortcomings of this framework have been extensively discussed in Section 3.7.3 of Chapter 3. The candidate indicators also cover the various domains of biosolids management namely; production, quality, cost, legislation/regulation, training/research and recycling/disposal.

The candidate indicators were individually reviewed. A draft set of indicators which emerged from the review process is presented in Section 8.2 of Chapter 8.

6.7 Selecting Indicators

The biosolids stakeholder survey questionnaires administered in May to August 2004 included the question 'Would you like to attend stakeholder meetings to discuss the findings of this survey and the draft set of indicators'? All those who responded 'yes' were contacted for this stage of the research study to select the headline, core and complementary indicators from a draft set. All the local authorities were also included in the indicator selection process irrespective of whether or not they returned the first set of questionnaires. A set of 65 consultation documents was sent to these stakeholders and the group of experts (see Appendix E3).

The OECD (2001) have developed a set of criteria for selecting operational indicators based upon three simple ideas: policy relevance and utility for users, analytical soundness and measurability. A cover letter introducing this stage of the research study and detailing what is to be done accompanied each consultation document (Appendix D).

6.8 Preliminary Testing of Indicators

Pilot indicator testing was used as an approach to evaluate whether data exist to support the selected headline and core set of indicators. It was also used to appraise how easy or difficult it is to apply data to the selected indicators, and how useful these indicators are as tool for managing biosolids. Based on the result of this testing, recommendations are presented on how to proceed with the development, selection and application of indicators. Because of time constraint, the complementary set of indicators could not be tested.

County Sligo in the North-West of Ireland was chosen as the location for the pilot test. The objectives are to evaluate the applicability of the SDIs in County of Sligo, and to gauge the sustainability of County Sligo's biosolids management programme. The Council is on the verge of initiating the building of its state-of-the-art sewage sludge treatment plant. It had, in 2002, published a sludge management plan for the County.

Twelve SDIs (comprising of five 'headline' and seven 'core' indicators) were successfully tested with readily available data. The current situation for many indicators tested are given in Chapter 9.

6.8.1 Collection of data for the preliminary testing indicators. The indicators were tested using secondary data obtained from Sligo County Council and other relevant agencies. A data availability survey form for collecting available data (see Appendix H) was forwarded to the Director of Environmental Services in March 2006. This was followed up with visits in April, May and June 2006 to collect available data from the staff of the County Council and by consulting relevant records and publications.

CHAPTER SEVEN
RESULT OF STAKEHOLDER SURVEY

Result of the stakeholder survey is presented in this chapter. The survey was carried out by making contact with all of the four groups identified as major stakeholders (see Section 6.2 of Chapter 6) in the sustainable management of biosolids in Ireland. The main purpose of the survey is to identify stakeholder concerns and information/action required to address these concerns. The survey also set out to examine the feasibility of using indicators as a tool for the sustainable management of biosolids.

7.1 Response Rate

Essential to any reliable survey is a strong response rate. As with any postal survey the objective is to achieve as high a response rate as possible. Babbie (1995) has suggested that a response rate of 50 per cent would be adequate while Baldauf et al (1999) believe that 15 per cent is an acceptable rate for a survey. Baldauf et al highlight the distinction that needs to be made between organisational or business studies and individual surveys and suggest that different research strategies need to be adopted accordingly. Considering the nature and scale of this study, as well as the strategies adopted, the overall response of almost 39.6% recorded is an achievement. Table 7.1 shows the response rate for the identified groups of stakeholders.

A total of 407 survey questionnaires were distributed to various stakeholders. Although the snowball technique was adopted, the number of questionnaires distributed was closely tracked. All participating stakeholders who volunteered to contact and send on questionnaires to other stakeholders were requested to keep track of the number of questionnaires sent. It was however, not possible to track questionnaires downloaded from the website but were not returned. In calculating the response rate, 37 questionnaires that were returned unopened due to wrong forwarding addresses were discounted from the total number of questionnaires sent.

Table 7.1 Response rate of identified groups

Groups	Number of Questionnaires Sent	Number of Questionnaires Returned	Response Rate (%)
I. Regulatory Agencies	36	18	50
II. Organisations			
a) State Organisations with Environmental Responsibilities	19	7	37
b) Non Governmental Organisation/Community Based Associations	45	21	47
c) Corporate Organisations	24	8	33
III. Individuals	283	87	31
Total	***407***	***141***	***Average: 39.6***

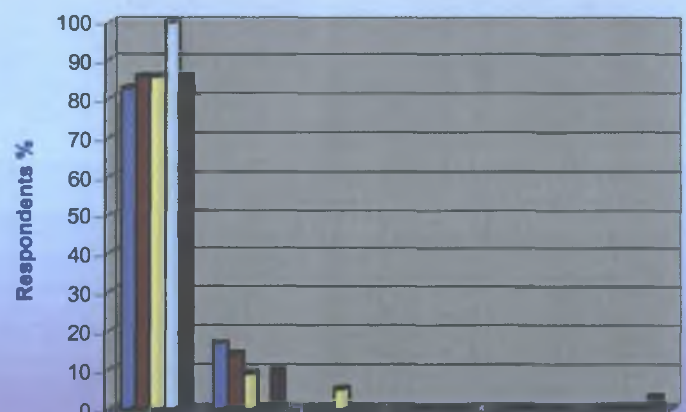
For clarity of presentation, Group II (Organisations) is split into three namely, state organisations with environmental (but non regulatory) responsibilities with a response rate of 37%, non governmental/community based organisations (NGOs/CBOs) with a response rate of 47%, and corporate organisations with a response rate of 33%. Regulatory agencies have the highest response rate of 50% representing 18 out of 36 questionnaires sent. Of the 18 returned questionnaires, one each is from the EPA and Department of the Environment, Heritage and Local Government. The balance is from 16 Local Authorities and Borough Councils out of 34 surveyed. South Dublin County Council and Sligo Borough Council are excluded from the survey. Dublin City Council and Sligo County Council, respectively handle the wastewater and sewage sludge from these two councils. The lowest return rate is 31% representing returns from 87 unaffiliated individuals (with interest in biosolids management) out of 283 surveyed. An overall average return rate of 39.6% is, therefore, achieved. Of the total four stakeholder groups identified, responses were received from at least one respondent from each group for an overall group response rate of 100%. Appendices E1, E2, E3, and E4 contains a list some of the stakeholders contacted at various stages of the study. The snowball technique used in distributing the questionnaires meant that a comprehensive list of all those contacted is improbable. Individual names are not listed in due respect to the confidentiality clause. The comprehensive survey result for all groups of stakeholders is presented in Appendix F.

7.2 Identification of Issues

The following section refers to information gathered from three similar but slightly different survey tools (see Appendices C1, C2 and C3). The reasons for the use of slightly different instruments are stated in the methodology (refer to Section 6.4 of Chapter 6). Question A7 of the survey questionnaire (Appendix F) asked all groups of stakeholders to rate the severity of some issues identified with the sustainable management of biosolids. The following charts depict the responses for each stakeholder group.

7.2.1 Need for protection of clean air, water and soil. Figure 7.1 shows the responses in relation to the need for protection of clean air, water and soil.

Figure 7.1 Need for protection of clean air, water and soil



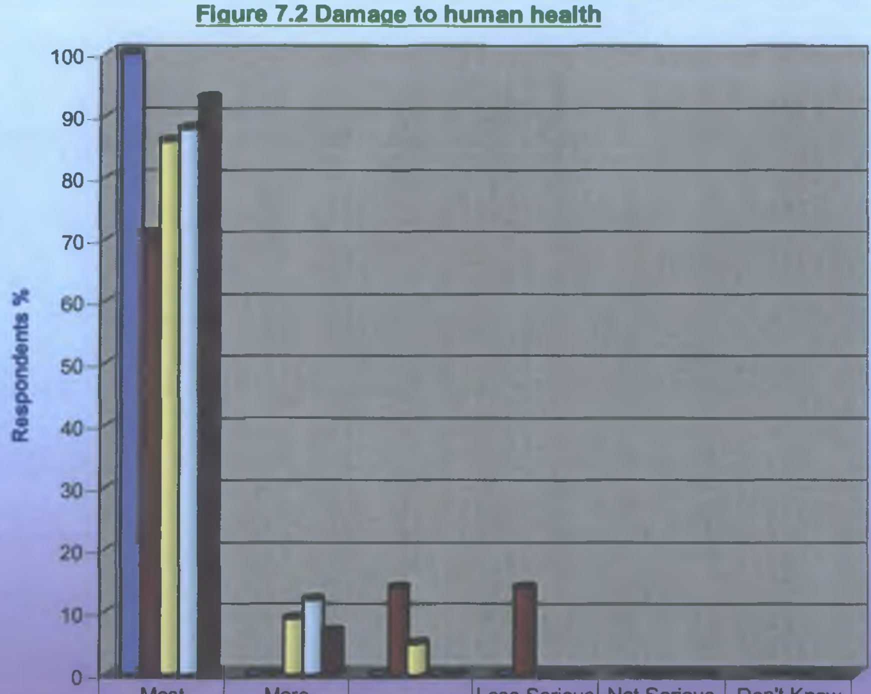
	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	83	17	0	0	0	0
State Orgs	86	14	0	0	0	0
NGOs/CBOs	86	9	5	0	0	0
Coporate Orgs	100	0	0	0	0	0
Individuals	86	10	0	0	0	3

Ratings

All surveyed corporate organisations rate the need to protect the three media of the environment (namely; air, water and soil) as a 'most serious' issue. Other groups of stakeholders including regulatory agencies (83%), state organisations with environmental responsibilities (86%), non governmental and community based organisations NGOs/CBOs (86%), and unaffiliated individuals (86%) agree with this position. No respondent rated it as not a 'serious issue'. However, 3% of unaffiliated individuals chose the 'don't know' option.

7.2.2 Damage to human health. Figure 7.2 depicts the response of various stakeholders surveyed regarding the risk of damage to human health when biosolids are used.

Figure 7.2 Damage to human health



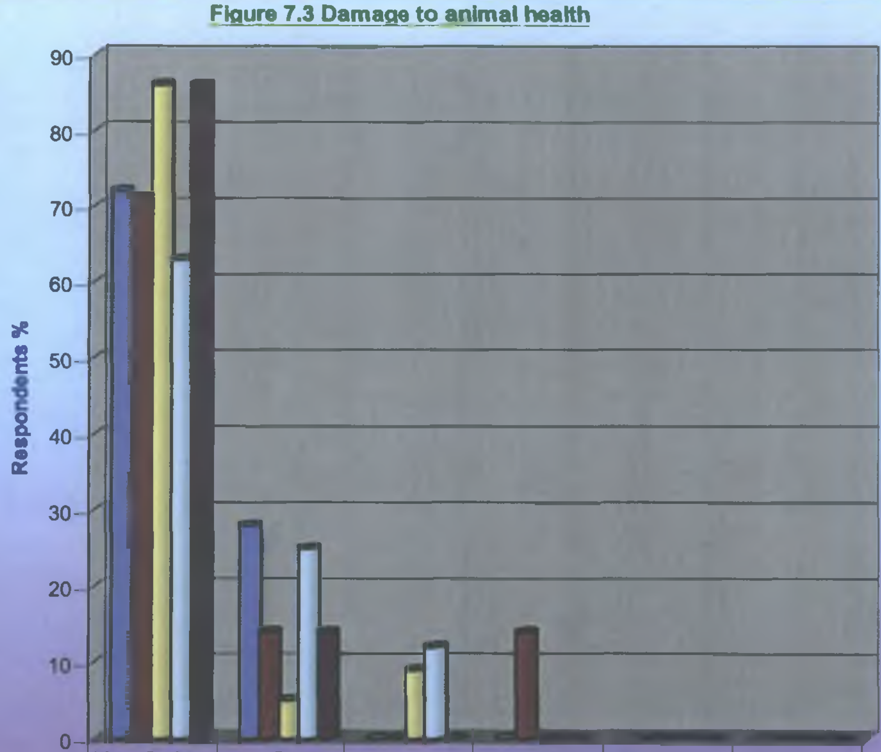
	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	100	0	0	0	0	0
State Orgs	71	0	14	14	0	0
NGOs/CBOs	86	9	5	0	0	0
Coporate Orgs	88	12	0	0	0	0
Individuals	93	7	0	0	0	0

Ratings

All regulatory agencies rate it as 'most serious'. Unaffiliated individuals (93%), corporate organisations (88%) and NGOs/CBOs (86%) also rated it as 'most serious'. Rating the issue as 'more serious' are 12% of corporate organisations, 9% of NGOs/CBOs and 7% of unaffiliated individuals. An equal split of 14% of state organisations with environmental responsibilities rate it as a 'serious' and 'less serious' issue. Five per cent of NGOs/CBOs representing one out of 21 surveyed rate the risk of damage to human health as 'serious'.

7.2.3 Damage to animal health. There is strong evidence indicating that animal health is an issue when biosolids are used. Most respondents rate the issue from 'serious' to 'most serious'. Figure 7.3 shows the response/rating for each group surveyed.

Figure 7.3 Damage to animal health



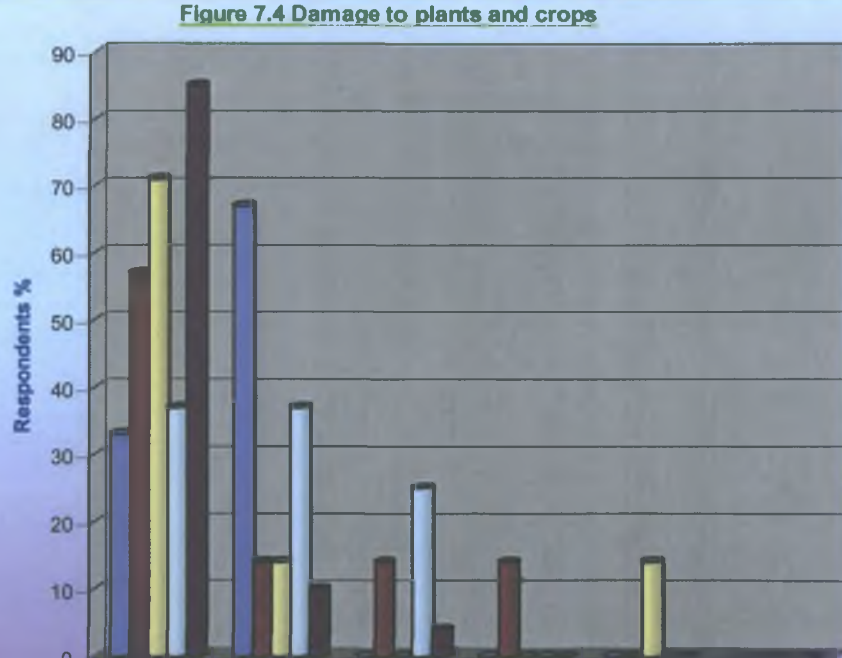
	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	72	28	0	0	0	0
State Orgs	71	14	0	14	0	0
NGOs/CBOs	86	5	9	0	0	0
Coporate Orgs	63	25	12	0	0	0
Individuals	86	14	0	0	0	0

Ratings

Twenty eight per cent of state organisations with environmental responsibilities rate it as 'more serious' (14%) and 'less serious' (14%), while 71% rate it as 'most serious'. Corporate organisations (63%) rate it as 'most serious', 25% rate it as 'more serious' while 12% rate it as 'serious'. No group of respondents rated it as 'not serious'. All unaffiliated individuals rate it either 'more serious' (86%) or 'most serious' (14%). Eighty six per cent of NGOs/CBOs representing 18 out 21 surveyed rate the issue as 'most serious', another 5% or one respondent rate it as 'more serious', while 9% or two respondents rate it as 'serious'.

7.2.4 Damage to plants and crops. Figure 7.4 shows the third or 33% of regulatory agencies consider the risk of damage to plants and crops as 'most serious' in contrast to 85% of unaffiliated individuals respondents rating it also as 'most serious'.

Figure 7.4 Damage to plants and crops



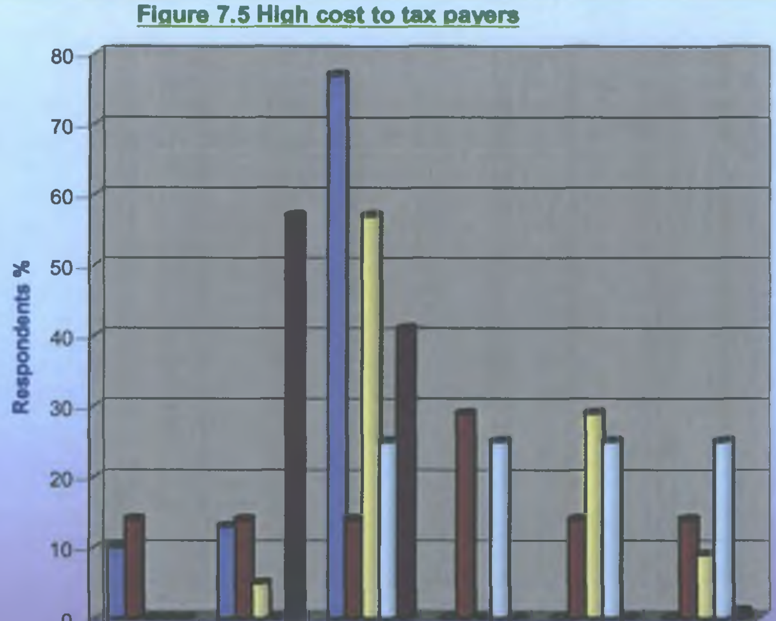
	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	33	67	0	0	0	0
State Orgs	57	14	14	14	0	0
NGOs/CBOs	71	14	0	0	14	0
Coporate Orgs	37	37	25	0	0	0
Individuals	85	10	4	0	0	0

Ratings

However, 67% of regulatory agencies rate it as 'more serious'. Also, 14% of NGOs/CBOs rate it as 'more serious' and 71% rate the issue as 'most serious' while another 14% consider it as 'not serious'. State organisations with environmental responsibilities (14%) rate the risk of damage to plants and crops as 'less serious' while 57% rate it as 'most serious'. Figure 7.4 shows that there is an almost general agreement amongst stakeholders that damage to plants and crops is an issue in the sustainable management of biosolids.

7.2.5 High cost to tax payers. Figure 7.5 shows the responses from all the groups. Less than 20% of each group surveyed rate the cost to tax payers as 'most serious'.

Figure 7.5 High cost to tax payers



	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	10	13	77	0	0	0
State Orgs	14	14	14	29	14	14
NGOs/CBOs	0	5	57	0	29	9
Coporate Orgs	0	0	25	25	25	25
Individuals	0	57	41	0	0	1

Ratings

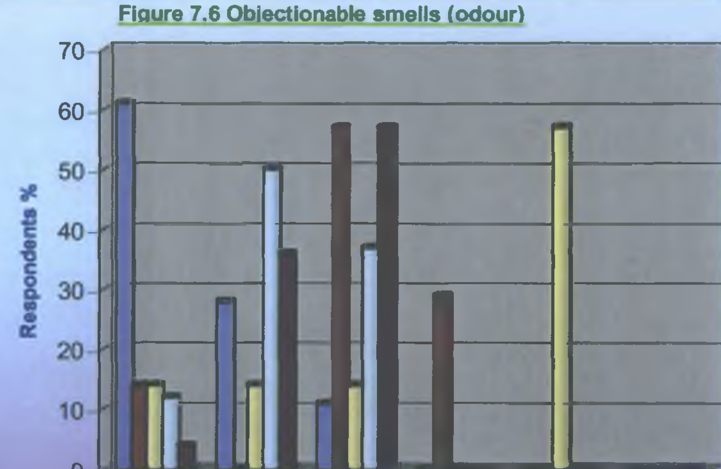
Unaffiliated individual stakeholders (57%) rate it as 'more serious'. Most respondents took the middle ground of rating it as 'serious'. State organisations with environmental responsibilities (14%), NGOs/CBOs (29%), and corporate organisations (25%) rated it as 'not serious'. State organisations with environmental responsibilities (14%), NGOs/CBOs (9%), corporate organisations (25%) and individuals (1%) 'do not know' if managing biosolids sustainably will come at a high cost to tax payers.

One NGO qualified their rating of the issue as 'serious' with this comment:

> The taxpayer will probably pay either way. If costs are externalized and the environment is regarded as a 'cheaper treatment', the tax payer will pay in degraded water quality and increased water treatment costs, water filtration installation costs and so on.

7.2.6 Objectionable smells (odour). Figure 7.6 shows that the only rating for 'most serious' higher than 50% was from the regulatory agencies.

Figure 7.6 Objectionable smells (odour)



	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	61	28	11	0	0	0
State Orgs	14	0	57	29	0	0
NGOs/CBOs	14	14	14	0	57	0
Coporate Orgs	12	50	37	0	0	0
Individuals	4	36	57	0	0	0

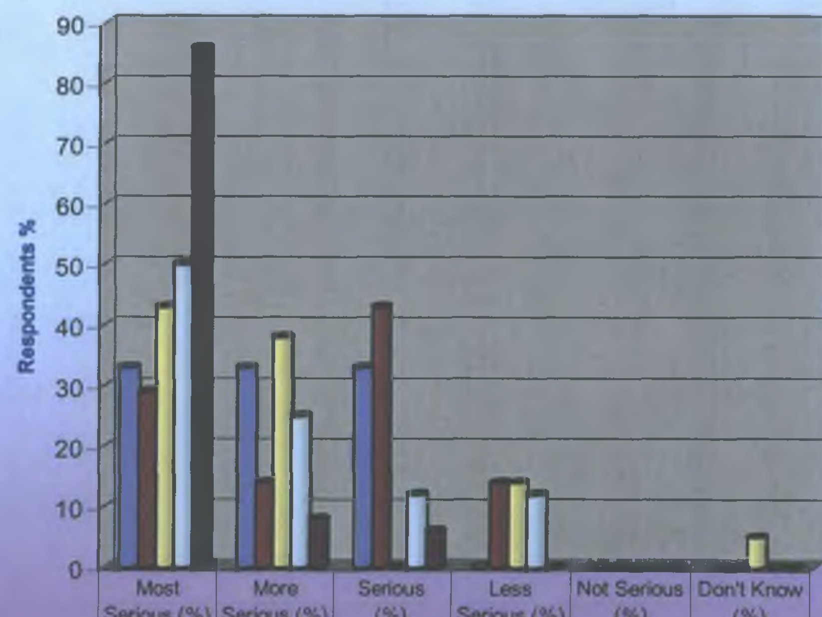
On this issue, 57% of NGOs/CBOs rate it as 'not serious' and 29% of state organisations with environmental responsibilities rate it as 'less serious'.

Generally, most respondents except NGOs/CBOs rate the issue as 'serious' to 'most serious'. It is notable that only 4% of individuals rate it as 'most serious'. Eleven per cent of regulatory agencies, 57% of state organisations with environmental responsibilities, 14% of NGOs/CBOs, 37% of corporate organisations and 57% of unaffiliated individuals comprise the highest average rating of 'serious'.

7.2.7 Not being able to find out who is responsible if a problem occurs.

Figure 7.7 shows the response on the issue of not knowing who is responsible in the event of any incident as a result of biosolids use.

Figure 7.7 Not being able to find out who is responsible if a problem occurs

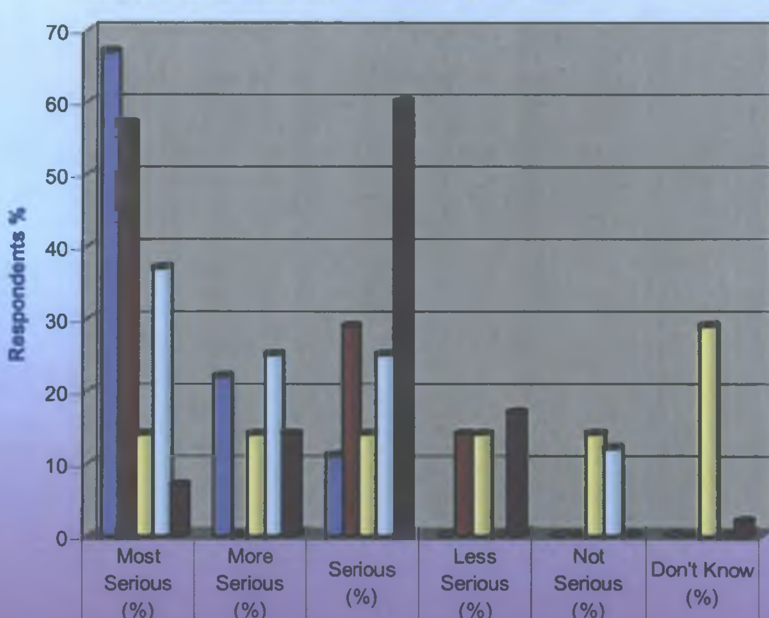


	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	33	33	33	0	0	0
State Orgs	29	14	43	14	0	0
NGOs/CBOs	43	38	0	14	0	5
Coporate Orgs	50	25	12	12	0	0
Individuals	86	8	6	0	0	0

It is rated as 'most serious' by 33% of regulatory agencies, 29% of state organisations with environmental responsibilities, 43% of NGOs/CBOs, 50% of corporate organisations and 86% of unaffiliated individuals. Figure 7.7 also indicates that 14% of regulatory agencies, 14% of NGOs/CBOs and 12% of corporate organisations rate it as 'less serious'. Generally, most respondents rate this issue as 'most serious' 'more serious' and 'serious'. Five per cent of NGOs/CBOs took the 'don't know' option. There is no rating of the issue as 'not serious'. However, the rating by 86% of unaffiliated individuals as 'most serious' stands out and shows clearly the severity of the concern to the general public.

7.2.8 Nobody would want to use biosolids. Figure 7.8 shows that the miscellany of responses on the issue of nobody wanting to use biosolids is aptly captured by the fact that as many as 29% of NGOs/CBOs chose the 'don't know' option.

Figure 7.8 Nobody would want to use biosolids

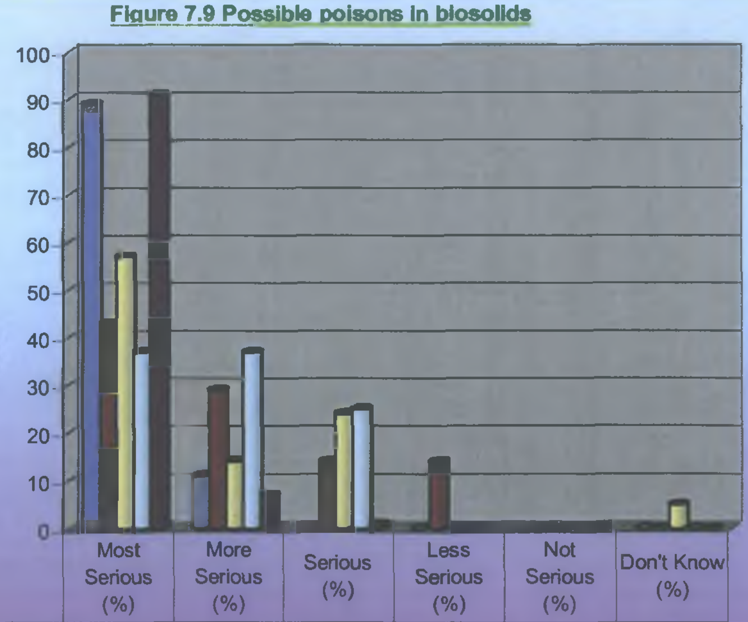


	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	67	22	11	0	0	0
State Orgs	57	0	29	14	0	0
NGOs/CBOs	14	14	14	14	14	29
Coporate Orgs	37	25	25	0	12	0
Individuals	7	14	60	17	0	2

There is also an equal split of 14% each rating the issue of nobody wanting to use biosolids as 'serious', 'more serious' and 'most serious'. This is however, sharply contrasted by 67% of regulatory agencies rating the issue as 'most serious', 22% as 'more serious' and 11% as 'serious'. It is also interesting to note that 60% of unaffiliated individuals rate the issue as 'serious', 14% as 'more serious' with only 7% rating it as 'most serious'. State organisations with environmental responsibilities (29%) and corporate organisations (14%) rate the issue as 'most serious'. Fourteen per cent of NGOs/CBOs rate the issue as 'not serious'. This is corroborated by 12% of corporate organisations rating it also as 'not serious'. Despite the divergence in responses, it is observable that neither unaffiliated individuals nor state organisations with environmental responsibilities, and regulatory organisations rate this issue as 'not serious'.

7.2.9 Possible poisons in biosolids. Figure 7.9 shows that 91% of unaffiliated individuals and 89% of regulatory agencies strongly view the issue of possible poisons in biosolids as a 'most serious' issue.

Figure 7.9 Possible poisons in biosolids

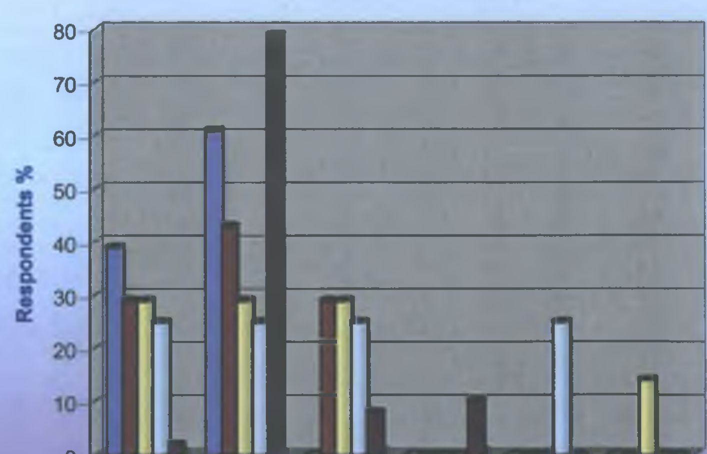


	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	89	11	0	0	0	0
State Orgs	43	29	14	14	0	0
NGOs/CBOs	57	14	24	0	0	5
Coporate Orgs	37	37	25	0	0	0
Individuals	91	7	1	0	0	0

Most NGOs/CBOs (57%), state organisations with environmental responsibilities (43%) and corporate organisations (37%) also rate this issue as 'most serious'. It is imperative to state from the foregoing that most stakeholders surveyed rate the issue as 'most serious'. Seven percent of unaffiliated individuals, 37% of corporate organisations, 14% of NGOs/CBOs, 29% of state organisations and 11% of regulatory agencies rate the issue as 'more serious'. Figure 7.9 also show that 14% of state organisations with environmental responsibilities, 24% of NGOs/CBOs, 25% of corporate organisations and 1% of individuals rate the issue as 'serious'. A number of state organisations with environmental responsibilities (14%) rate it as 'less serious' while 5% of NGOs/CBOs chose the 'don't know option'. No group of stakeholders surveyed rate this issue as 'not serious'.

7.2.10 Problems if we don't use biosolids. Figure 7.10 shows that only 2% of unaffiliated individuals rate the issue of problems if we don't use biosolids as

Figure 7.10 Problems if we don't use biosolids



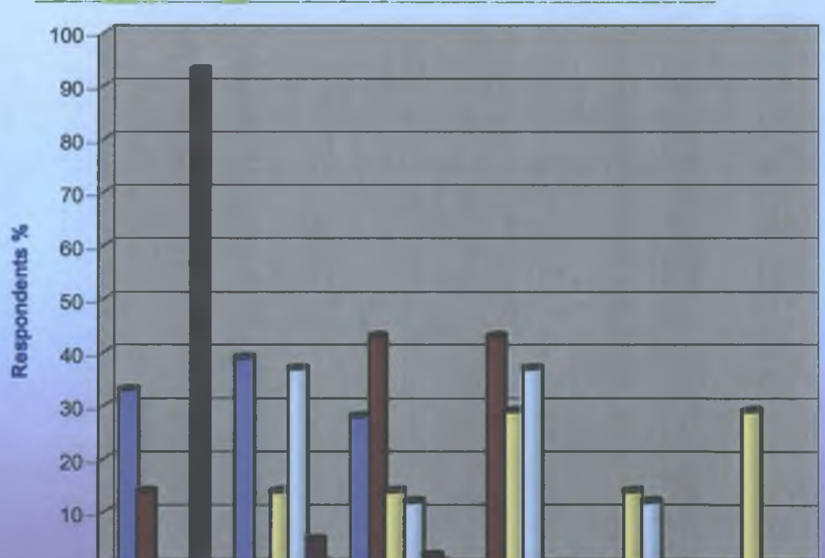
	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	39	61	0	0	0	0
State Orgs	29	43	29	0	0	0
NGOs/CBOs	29	29	29	0	0	14
Coporate Orgs	25	25	25	0	25	0
Individuals	2	79	8	10	0	0

Ratings

'most serious' with 79% rating it as 'more serious, 8% as 'serious' and 10% as 'less serious'. Most stakeholders including regulatory agencies (61%), state organisations with environmental responsibilities (43%), NGOs/CBOs (29%) and corporate organisations (25%) rate this issue as 'more serious'. However, 39% of regulatory agencies, 29% of state organisations with environmental responsibilities, 29% of NGOs/CBOs and 25% of corporate organisations rate the issue as 'most serious'. The issue is also rated as 'serious' by 29% of state organisations with environmental responsibilities, 29% of NGOs/CBOs and 25% of corporate organisations. Fourteen per cent of NGOs/CBOs chose the 'don't know' option and 25% of corporate organisations rate the issue as 'not serious'.

7.2.11 Fear of loss of property and land value to biosolids' use. Figure 7.11 illustrates the various stakeholders' ratings in relation to the fear of loss of property and land value due to use of biosolids.

Figure 7.11 Fear of loss of property and land value to biosolids use

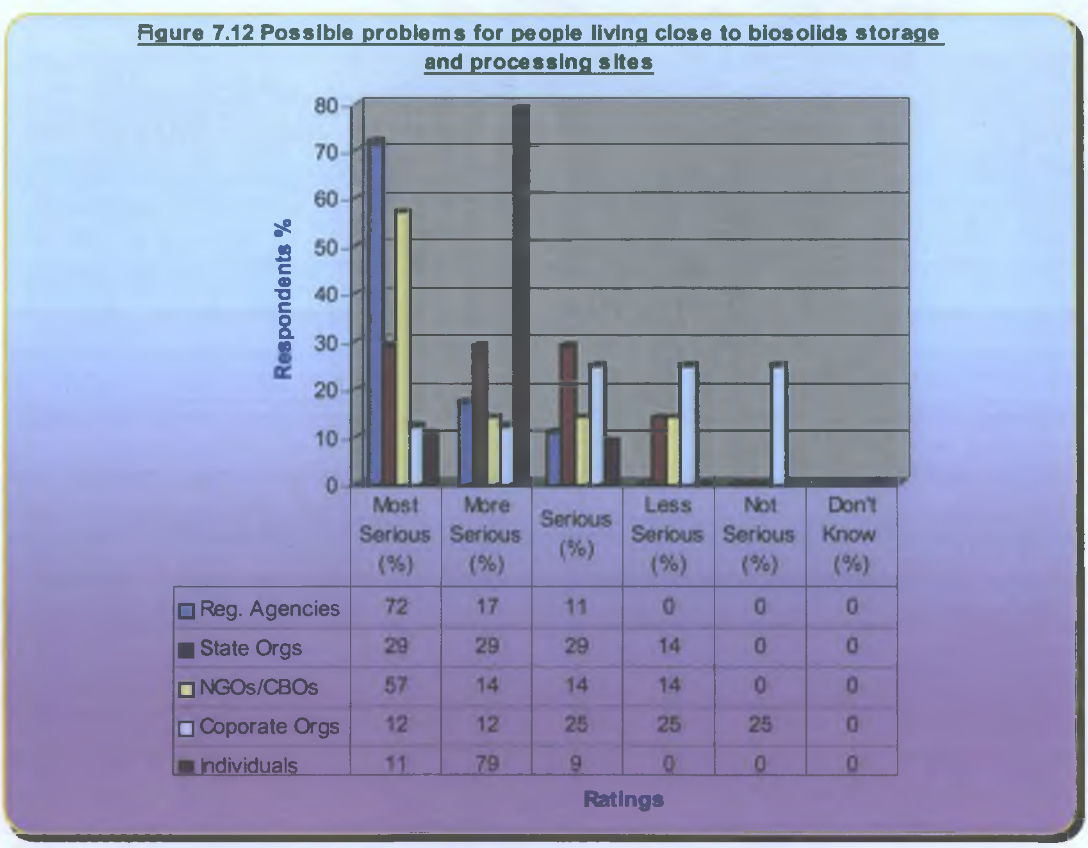


	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	33	39	28	0	0	0
State Orgs	14	0	43	43	0	0
NGOs/CBOs	0	14	14	29	14	29
Coporate Orgs	0	37	12	37	12	0
Individuals	93	5	2	0	0	0

Ratings

The majority of unaffiliated individuals (93%) rate this issue as 'most serious', 5% rate it as 'more serious' and only 2% rate it as 'serious'. Nevertheless, 29% of NGOs/CBOs opt for 'don't know', 14% rate it as 'not serious', and 29% rate it as 'less serious'. The remaining 28% of NGOs/CBOs are split equally and rate the issue as 'more serious' and 'serious'. No corporate organisation rate the issue as 'most serious', 12% rate it as 'not serious', another 12% rate it as 'serious', 37% rate it as 'less serious' and yet, another 37% rate it as 'more serious'. Regulatory agencies seemed to more concerned than other organisations with 33% rating the issue as 'most serious', 39% as 'more serious' and 26% rate it as 'serious'. Only 14% of state organisations with environmental responsibilities rate this issue as 'most serious', 43% each rate it as 'serious' and 'less serious'.

7.2.12 Possible problems for people close to biosolids facilities. Survey results in Figure 7.12 show that regulatory agencies (72%), NGOs/CBOs (57%),

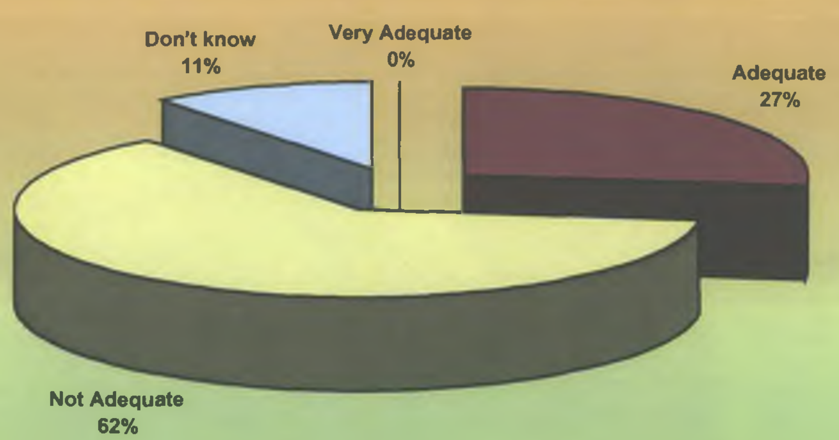


	Most Serious (%)	More Serious (%)	Serious (%)	Less Serious (%)	Not Serious (%)	Don't Know (%)
Reg. Agencies	72	17	11	0	0	0
State Orgs	29	29	29	14	0	0
NGOs/CBOs	57	14	14	14	0	0
Coporate Orgs	12	12	25	25	25	0
Individuals	11	79	9	0	0	0

state organisations with environmental responsibilities (29%), corporate organisations (12%) and unaffiliated individuals (11%) rate the possibility of problems for people living close to biosolids storage and processing sites as 'most serious'. However, 25% of corporate organisations rate the issue as 'not serious'. Yet in contrast an outstanding 79% of unaffiliated individuals rate it as 'more serious'. Other stakeholders rate the issue as 'more serious' include; state organisations with environmental responsibilities (29%), regulatory agencies (17%), NGOs/CBOs (14%) and corporate organisations (12%). Counter to that, 25% of corporate organisations, 14% each of state organisations with environmental responsibilities and NGOs/CBOs rate the issue as 'less serious'.

7.2.13 Adequacy of legislation and regulations. Figure 7.13 shows the combined response of organisations and unaffiliated individuals when asked whether they consider the present regulations and legislation in respect of biosolids management adequate (Question C3 of Appendix F). The regulatory agencies were excluded from this concern for the obvious reason that their performance is the subject of the question.

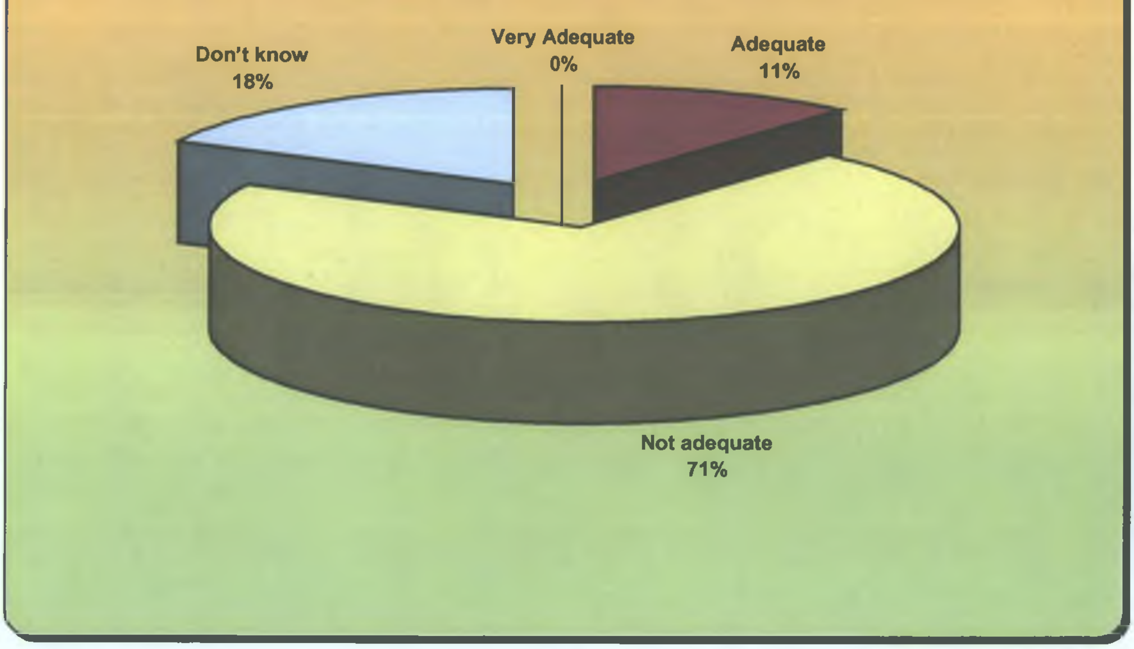
Figure 7.13 Adequacy of legislation and regulation



None of the two groups surveyed consider the present level of regulation and legislation 'very adequate'. An outstanding 62% of respondents consider them 'inadequate'. Only 27% of respondents consider them 'adequate', while 11% chose the 'don't know' option.

7.2.14 Implementation of legislation and regulations. Figure 7.14 shows the combined response of organisations and unaffiliated individuals when asked whether they consider the current level of implementation of biosolids management regulations and legislation adequate (Question C4 of Appendix F). Again, for the obvious reason that their performance is the subject of review, regulatory agencies are excluded from this aspect of the survey.

Figure 7.14 Implementation of legislation and regulations



Mirroring, the response in Section 7.2.13, and even worse, 71% of respondents consider the current level of legislation and regulation implementation in relation to biosolids management as 'not adequate'. Only 11% consider it 'adequate', and 18% selected the 'don't know' option. None of the respondents consider the implementation of legislation and regulations in relation to biosolids management as 'very adequate'.

7.2.15 Summary of stakeholder rating of concerns. Table 7.2 shows the stakeholder ratings of issues raised in relation to the use of biosolids for all the groups surveyed. The objective of the summary is to show the average ratings of the identified issues/concerns.

Table 7.2 Stakeholder ratings of issues raised in relation to the use of biosolids

S/No	Possible Problems	Most Serious (5)	MoreSerious (4)	Serious (3)	Less Serious (2)	Not Serious (1)	Don't Know
1	Need for protection of clean air, water and soil	122 (87%)	15 (11%)	1 (0%)			3 (2%)
2	Damage to human health	129 (91%)	9 (6%)	2 (1%)	1 (0%)		
3	Damage to animal health	116 (82%)	21 (15%)	3 (2%)	1 (0%)		
4	Damage to plants and crops	102 (72%)	28 (20%)	7 (5%)	1 (0%)	3 (2%)	
5	High cost to tax payers	4 (3%)	55 (39%)	63 (45%)	4 (3%)	9 (6%)	6 (4%)
6	Objectionable smells (odour)	20 (14%)	44 (31%)	62 (44%)	2 (1%)	12 (9%)	
7	Not being able to find out who is responsible if a problem occurs	96 (68%)	24 (17%)	15 (11%)	5 (4%)		1 (0%)
8	Nobody would want to use biosolids	26 (18%)	21 (15%)	61 (43%)	23 (16%)	5 (4%)	8 (6%)
9	Possible poisons in biosolids	113 (80%)	16 (11%)	9 (6%)	1 (0%)		1 (0%)
10	Problems if we don't reuse biosolids	19 (13%)	91 (65%)	17 (12%)	9 (6%)	2 (1%)	3 (2%)
11	Fear of loss of property and land value to biosolids use	88 (62%)	17 (12%)	13 (9%)	12 (9%)	4 (3%)	6 (4%)
12	Possible problems for people living close to biosolids storage and processing sites	38 (27%)	78 (55%)	17 (12%)	6 (4%)	2 (1%)	

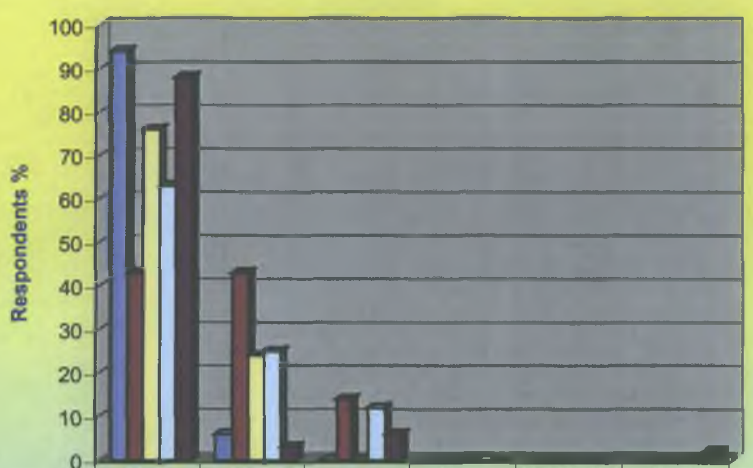
The number of respondents in each category appears in bold figures followed by the percentage of respondents in brackets. All groups of stakeholders predominantly rate the issues from 'serious' to 'most serious'. More than 60% of all stakeholders surveyed rate seven issues as 'most serious'. Two issues are predominantly rated as 'more serious' and three issues as 'serious'. The lead ratings for these issues are highlighted in green ('most serious'), turquoise ('more serious') and yellow ('serious').

7.3 Identification of Possible Actions to Address Stakeholder Concerns

Figures 7.15 to 7.25 show the survey result for Question A8, which asked all groups of stakeholders to rate the usefulness of some suggested actions to address the concerns identified in response to Question A7 (Appendix F).

7.3.1 Scientific studies. Figure 7.15 shows that regulatory agencies (94%) rate it as 'most useful' and another 6% rate it as 'more useful'.

Figure 7.15 Scientific studies to learn more about the risks in spreading biosolids on land



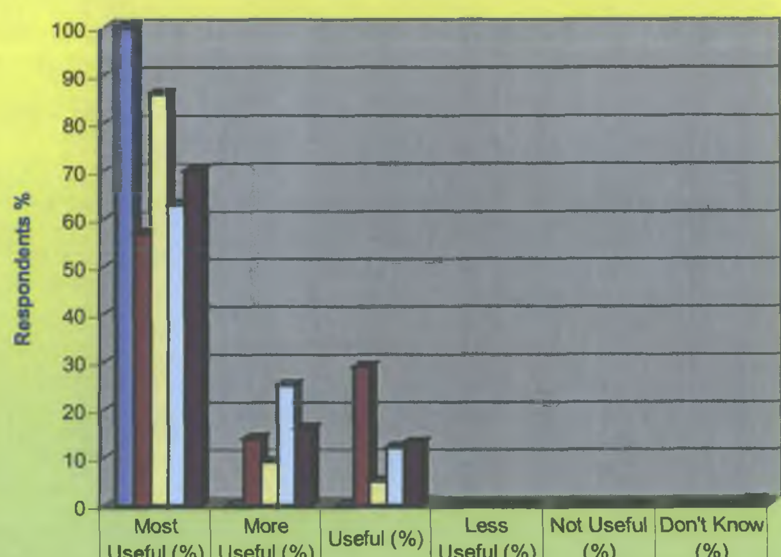
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	94	6	0	0	0	0
State Orgs	43	43	14	0	0	0
NGOs/CBOs	76	24	0	0	0	0
Coporate Orgs	63	25	12	0	0	0
Individuals	88	3	6	0	0	2

Ratings

State organisations with environmental responsibilities are equally split with 43% each rating it as 'most useful' and 'more useful', while 14% rate it as 'useful'. Other ratings of 'most useful' are by unaffiliated individuals (88%), corporate organisations (63%), and NGOs/CBOs (76%). Rating it as 'more useful' are 25% of corporate organisations, 24% of NGOs/CBOs and 3% of unaffiliated individuals. Twelve per cent of corporate organisations and 6% of unaffiliated individuals rate it as 'useful'.

7.3.2 Development of tests. The development of tests to ensure that there is little risk to humans and animals from biosolids received a 100% rating as 'most useful' from regulatory agencies as Figure 7.16 depicts.

Figure 7.16 Development of tests to ensure that there is little risk to humans and animals for biosolids



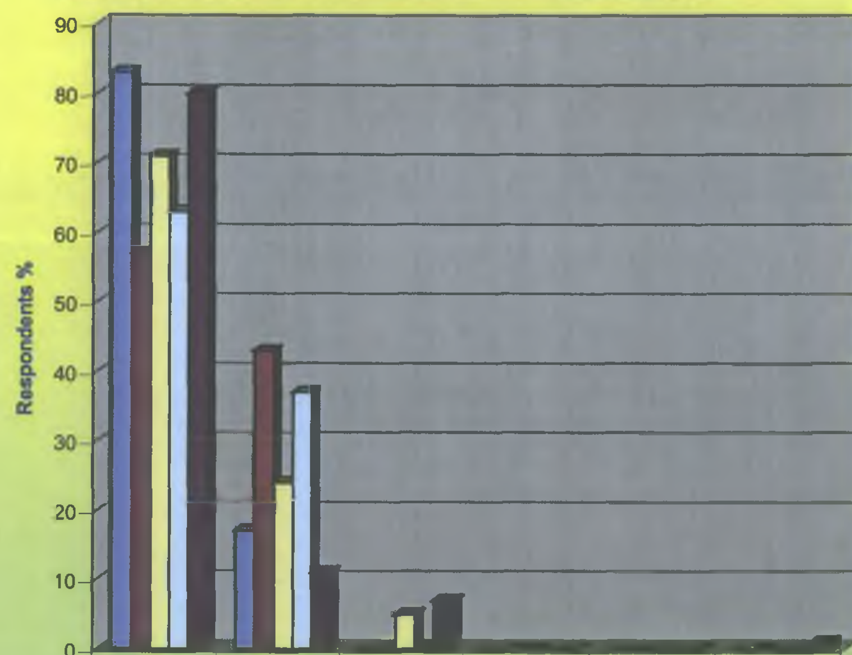
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	100	0	0	0	0	0
State Orgs	57	14	29	0	0	0
NGOs/CBOs	86	9	5	0	0	0
Coporate Orgs	63	25	12	0	0	0
Individuals	70	16	13	0	0	1

Ratings

Significantly, 86% of NGOs/CBOs, 70% of unaffiliated individuals, 63% of corporate organisations and 57% of state organisations with environmental responsibilities corroborate this rating. Other ratings were either 'more useful' or 'useful'. No stakeholder group rated it as 'not useful'

7.3.3 Clear information. Figure 7.17 shows that making clear information available to everybody has a majority rating of 'most useful' by the participating stakeholders: 83% of regulatory agencies, 57% of state organisations with environmental responsibilities, 71% of NGOs/CBOs, 63% of corporate organisations and 80% of unaffiliated individuals.

Figure 7.17 Clear information available to everybody

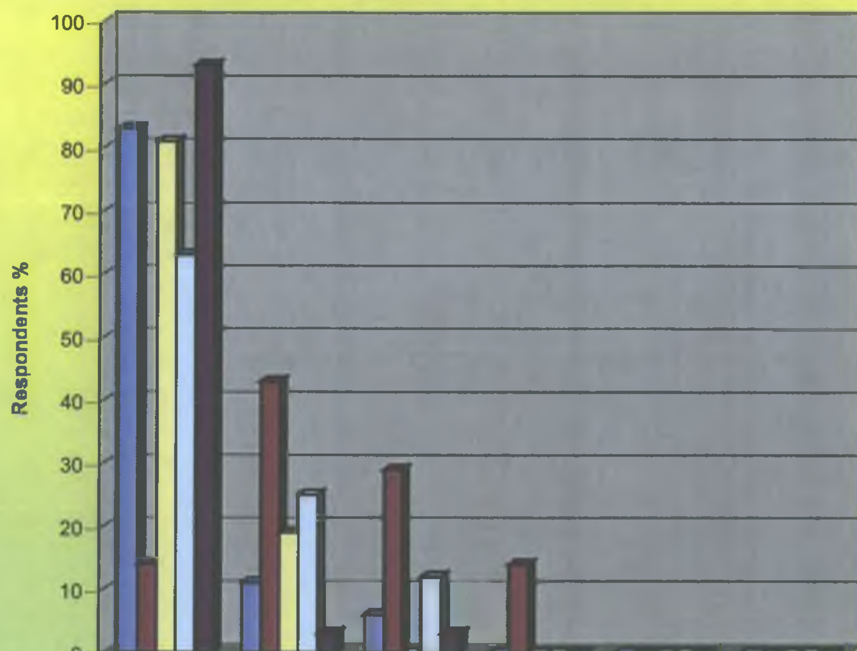


	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	83	17	0	0	0	0
State Orgs	57	43	0	0	0	0
NGOs/CBOs	71	24	5	0	0	0
Coporate Orgs	63	37	0	0	0	0
Individuals	80	11	7	0	0	1

This is followed by the rating of 'more useful' from 17% of regulatory agencies, 43% of state organisations, 24% of NGOs/CBOs, 37% of corporate organisations and 11% of unaffiliated individuals. Five per cent of NGOs/CBOs and 7% of unaffiliated individuals rate it as 'useful'. One per cent of unaffiliated individuals chose the 'don't know' option.

7.3.4 Establish clear responsibility. The establishment, clearly of who is responsible if there is an accident or a problem when biosolids are used is a 'most useful' action to take according to 93% of unaffiliated individuals, 83% of regulatory agencies, 81% of NGOs/CBOs, and 63% of corporate organisations who took part in the survey (see Figure 7.18).

Figure 7.18 Establish clearly who is responsible if there is an accident or problem



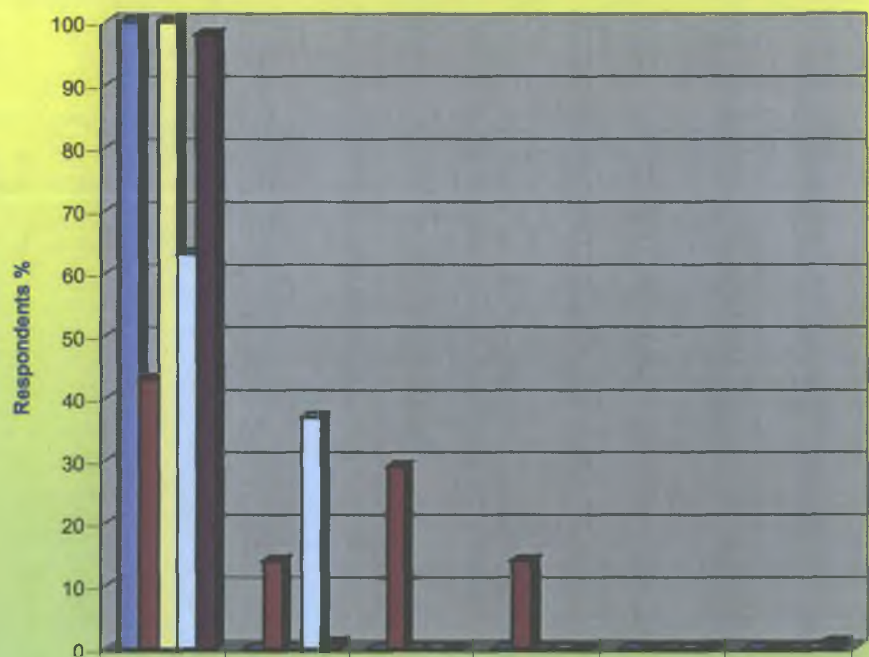
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	83	11	6	0	0	0
State Orgs	14	43	29	14	0	0
NGOs/CBOs	81	19	0	0	0	0
Coporate Orgs	63	25	12	0	0	0
Individuals	93	3	3	0	0	0

Ratings

Only 14% of state organisations rate the suggested action as 'most useful' while 43% rate it as 'more useful', and 29% as 'useful'. It is only in this group of stakeholders that a rating of 'less useful' (14%) is recorded. Other stakeholder groups' ratings are predominantly 'more useful' and to a lesser extent, 'useful'.

7.3.5 Make rules to prevent use of biosolids if poisons are present. All regulatory agencies and NGOs/CBOs who took part in the survey rate the suggested action to make rules preventing the use of biosolids when contaminants are present as 'most useful' (see Figure 7.19).

Figure 7.19 Make rules to prevent use of biosolids if poisons are present



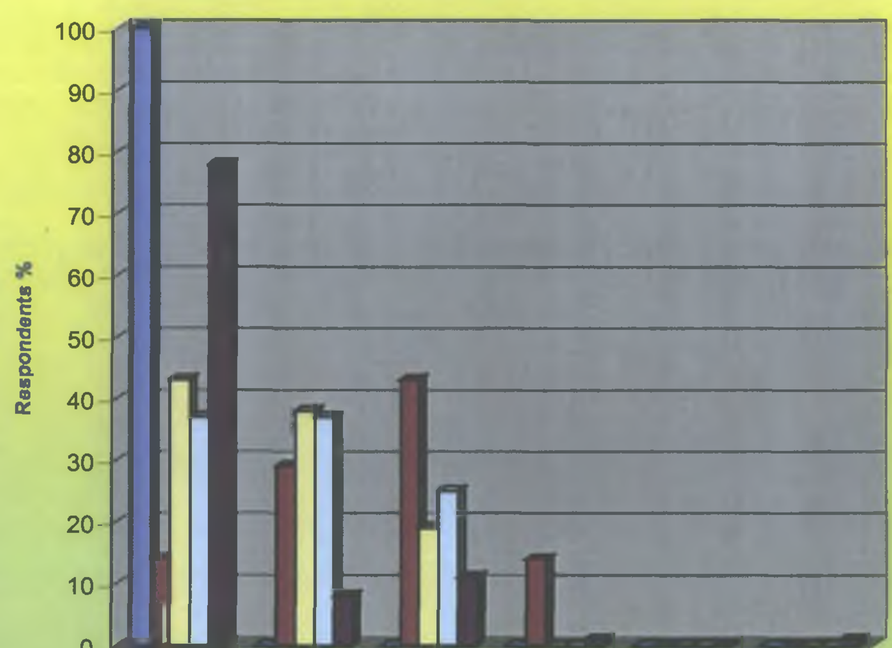
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	100	0	0	0	0	0
State Orgs	43	14	29	14	0	0
NGOs/CBOs	100	0	0	0	0	0
Coporate Orgs	63	37	0	0	0	0
Individuals	98	1	0	0	0	1

Ratings

Buttressing this rating are 98% of unaffiliated individuals, 63% of corporate organisations and 43% of state organisations with environmental responsibilities. In addition, 37% of corporate organisations, 14% of state organisations with environmental responsibilities and 1% of unaffiliated individuals rate it as 'more useful'. Other state organisations with environmental responsibilities rate it as 'useful' (29%) and 'less useful' (14%). A per cent of unaffiliated individual selected the 'don't know' option.

7.3.6 Written instructions on safety. Figure 7.20 shows that writing instructions on safe use of biosolids has an overall majority rating of 'most useful' by the participating stakeholders: 100% of regulatory agencies, 14% of state organisations with environmental responsibilities, 43% of NGOs/CBOs, 37% of corporate organisations and 78% of unaffiliated individuals.

Figure 7.20 Written instructions on safety



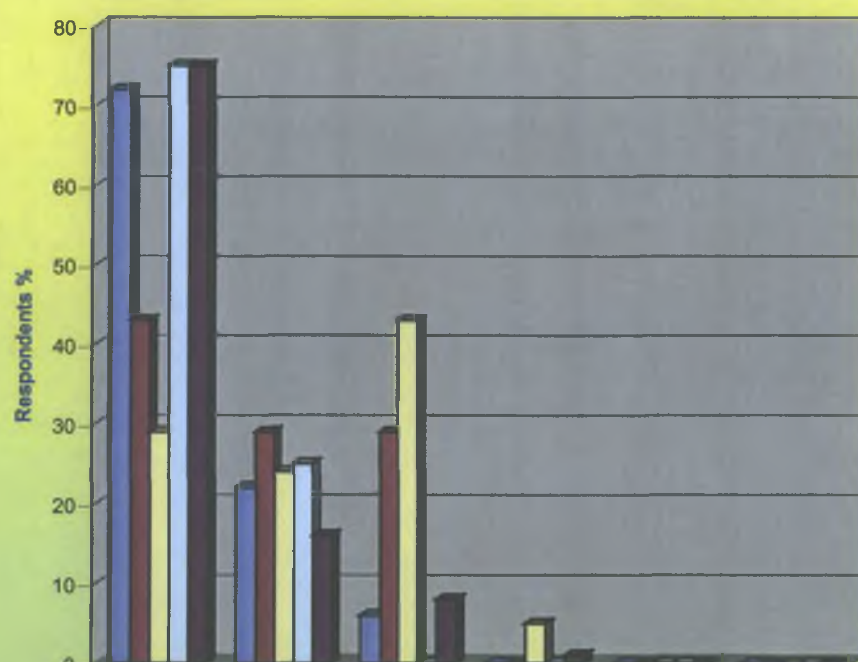
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	100	0	0	0	0	0
State Orgs	14	29	43	14	0	0
NGOs/CBOs	43	38	19	0	0	0
Coporate Orgs	37	37	25	0	0	0
Individuals	78	8	11	1	0	1

Ratings

The rating of 'more useful' by 29% of state organisations with environmental responsibilities, 38% of NGOs/CBOs, 37% of corporate organisations and 8% of unaffiliated individuals follows this trend. However, majority of state organisations with environmental responsibilities (43%), 19% of NGOs/CBOs, 25% of corporate organisations and 11% of unaffiliated individuals rate it as 'useful'. A percent of unaffiliated individuals selected the 'don't know' option while another 1% of the same group and 14% of state organisations with environmental responsibilities rate it as 'less useful'.

7.3.7 Improved information to consumers. Improving information to consumers on the safe use of biosolids is rated as 'most useful' by 72% of regulatory agencies, 43% of state organisations with environmental responsibilities, 29% of NGOs/CBOs, 75% of corporate organisations and another 75% of unaffiliated individuals (see Figure 7.21).

Figure 7.21 Improved information to consumers on the safe use of biosolids



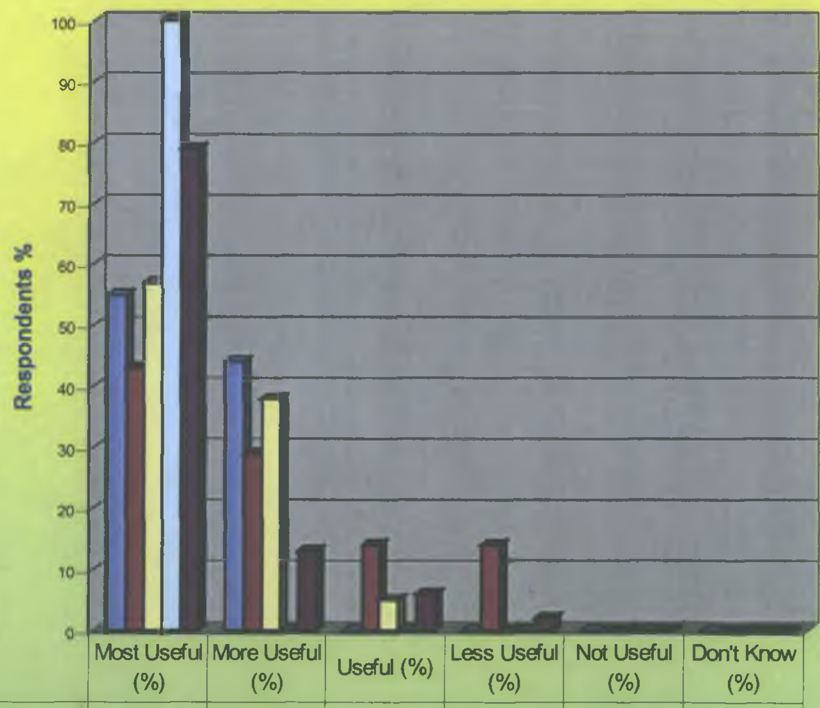
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	72	22	6	0	0	0
State Orgs	43	29	29	0	0	0
NGOs/CBOs	29	24	43	5	0	0
Coporate Orgs	75	25	0	0	0	0
Individuals	75	16	8	1	0	0

Ratings

Following is the rating of 'more useful' by 22% of regulatory agencies, 29% of state organisations with environmental responsibilities, 24% of NGOs/CBOs, 25% of corporate organisations and 16% of unaffiliated individuals. An outstanding 43% of NGOs/CBOs rate it as 'useful'. The ratings of 'useful' are by regulatory agencies (6%), state organisations with environmental responsibilities (29%) and unaffiliated individuals (8%). There are also ratings of 'less useful' by 5% of NGOs/CBOs and 1% of unaffiliated individuals.

7.3.8 Better training for farmers and landowners. Figure 7.22 shows that no group of stakeholders rates improved training of farmers and landowners on the use of biosolids as 'not useful'.

Figure 7.22 Better training for farmers



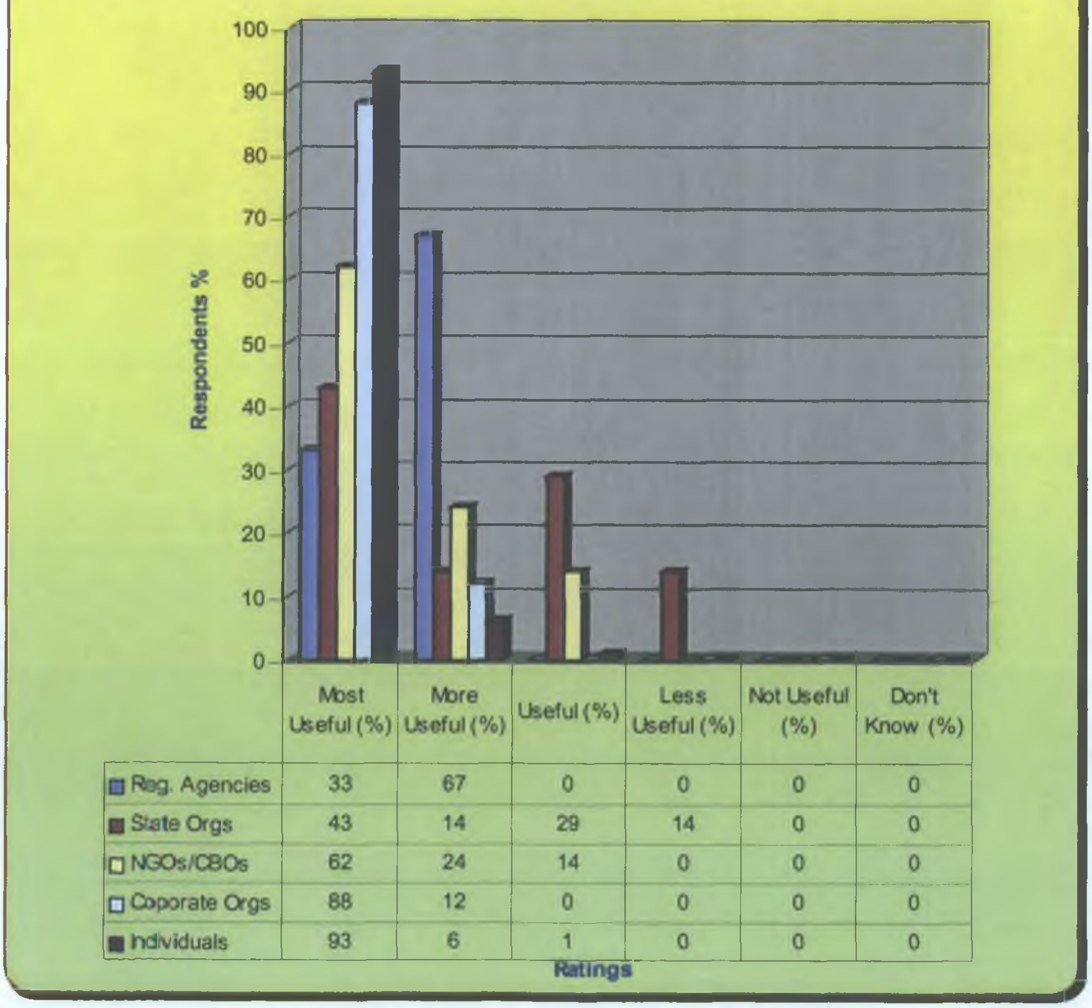
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	55	44	0	0	0	0
State Orgs	43	29	14	14	0	0
NGOs/CBOs	57	38	5	0	0	0
Coporate Orgs	100	0	0	0	0	0
Individuals	79	13	6	2	0	0

Ratings

Majority of all stakeholder groups surveyed including a remarkable 100% of corporate organisations, 79% of unaffiliated individuals, 57% of NGOs/CBOs, 55% of state organisations with environmental responsibilities and 55% of regulatory agencies; consider improved training of farmers and landowners on the use of biosolids as 'most useful' action. There are 44% of regulatory agencies, 29% of state organisations with environmental responsibilities, 38% of NGOs/CBOs and 13% of unaffiliated individuals who rate it as 'more useful'.

7.3.9 Improved information to farmers. Figure 7.23 shows that 93% of unaffiliated individuals, 88% of corporate organisations, 62% of NGOs/CBOs, 43% of state organisations with environmental responsibilities and 33% of regulatory agencies rate it as 'most useful'.

Figure 7.23 Improved information to farmers

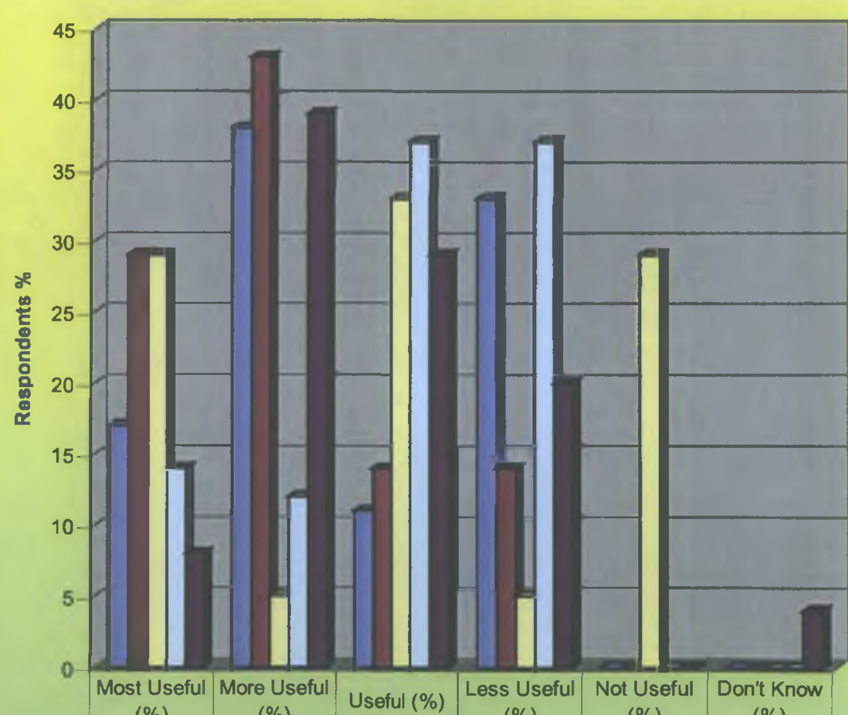


	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	33	67	0	0	0	0
State Orgs	43	14	29	14	0	0
NGOs/CBOs	62	24	14	0	0	0
Coporate Orgs	88	12	0	0	0	0
Individuals	93	6	1	0	0	0

With the exception of 14% of state organisations with environmental responsibilities, all other stakeholders surveyed rate the need for improved information to farmers as either 'useful', 'more useful' or 'most useful'. Less than 30% each of state organisations with environmental responsibilities, NGOs/CBOs, corporate organisations and unaffiliated individuals rate it as either 'more useful' or 'useful'. In addition, 67% of regulatory agencies rate it as 'more useful'.

7.3.10 Taking everybody's view into consideration. Figure 7.24 shows a significant split among stakeholders in relation to taking everybody's view into account when managing biosolids. This is buttressed by the fact that less than 30% of each stakeholder group survey rates it as 'most useful', and less than

Figure 7.24 Taking everybody's view into account



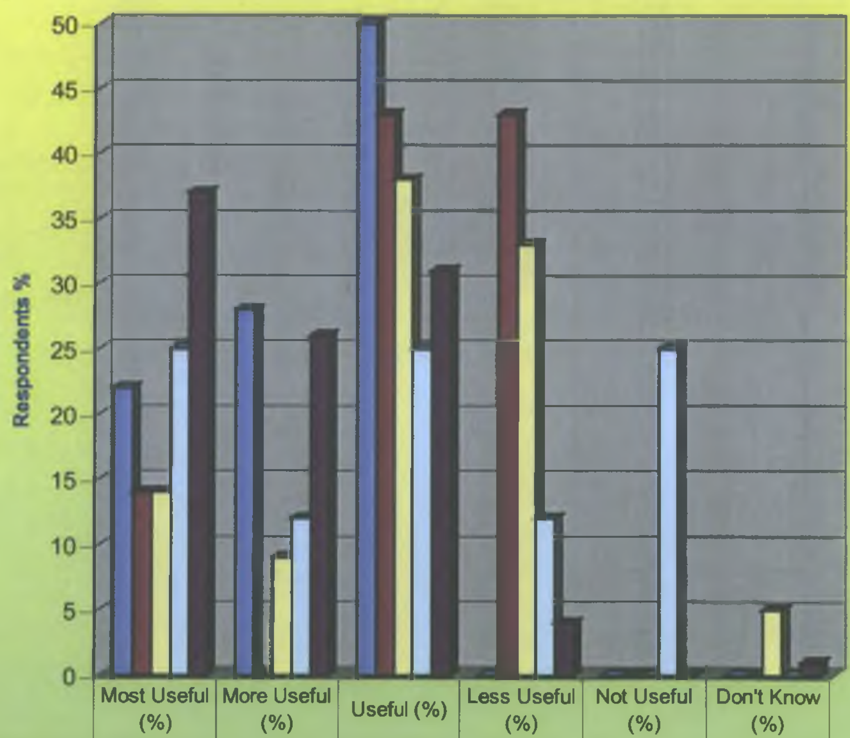
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	17	38	11	33	0	0
State Orgs	29	43	14	14	0	0
NGOs/CBOs	29	5	33	5	29	0
Coporate Orgs	14	12	37	37	0	0
Individuals	8	39	29	20	0	4

Ratings

45% of each group rate it as 'more useful'. The rest rate it either as 'useful' or 'less useful' with a salient 29% of NGOs/CBOs rating it as 'not useful' while 4% of unaffiliated individuals selected the 'don't know' option. The schism among stakeholders on this suggested action is best captured by a comment by a respondent that many stakeholders are not scientifically educated and need basic information about biosolids to participate effectively in any discussion.

7.3.11 Compensation for people. Figure 7.25 shows that 25% or less of all stakeholder groups except unaffiliated individuals (37%), rate compensation for

Figure 7.25 Compensation for people badly affected by accidents in use of biosolids



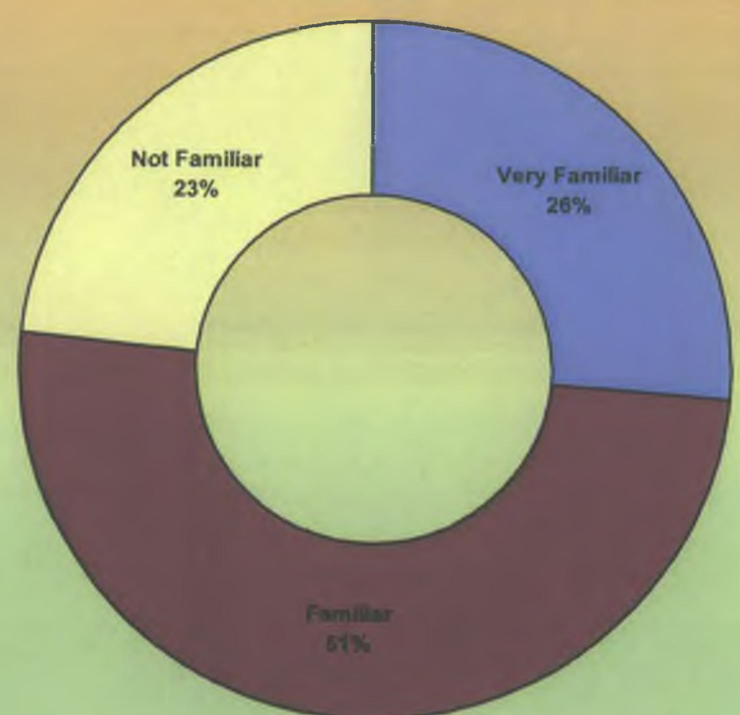
	Most Useful (%)	More Useful (%)	Useful (%)	Less Useful (%)	Not Useful (%)	Don't Know (%)
Reg. Agencies	22	28	50	0	0	0
State Orgs	14	0	43	43	0	0
NGOs/CBOs	14	9	38	33	0	5
Coporate Orgs	25	12	25	12	25	0
Individuals	37	26	31	4	0	1

Ratings

people badly affected by accidents in use of biosolids as 'most useful'. State organisations with environmental responsibilities are equally split with 43% each rating it as 'useful' and 'less useful'. While 25% of corporate organisations rate it as 'useful', another 25% rate it as 'not useful'. The disparity in the rating by unaffiliated individuals is noticeable with 26% rating it as 'more useful' 31% as 'useful', 4% as 'less useful' and 1% selecting the 'don't know option'.

7.3.12 Familiarity with sustainable development. Question A5 in Appendix F was used to gauge the level of awareness of stakeholders of the concept of sustainable development. Almost a quarter of stakeholders surveyed are 'not familiar' with the concept, 51% are 'familiar' with it while 26% are 'very familiar' with the concept. This is conveyed in Figure 7.26.

Figure 7.26 Familiarity with sustainable development



7.3.13 SDIs as management tool. Question A6 in Appendix F was used to assess the feasibility of using sustainable development indicators as a tool for managing biosolids. All stakeholders surveyed were asked if they consider sustainable development indicators useful as a tool for the management of biosolids. Figure 7.27 show that 83 respondents or 59% consider SDIs as 'very useful', 22% or 31 respondents consider them as 'useful' while 19% or 27 respondents selected the 'don't know' option

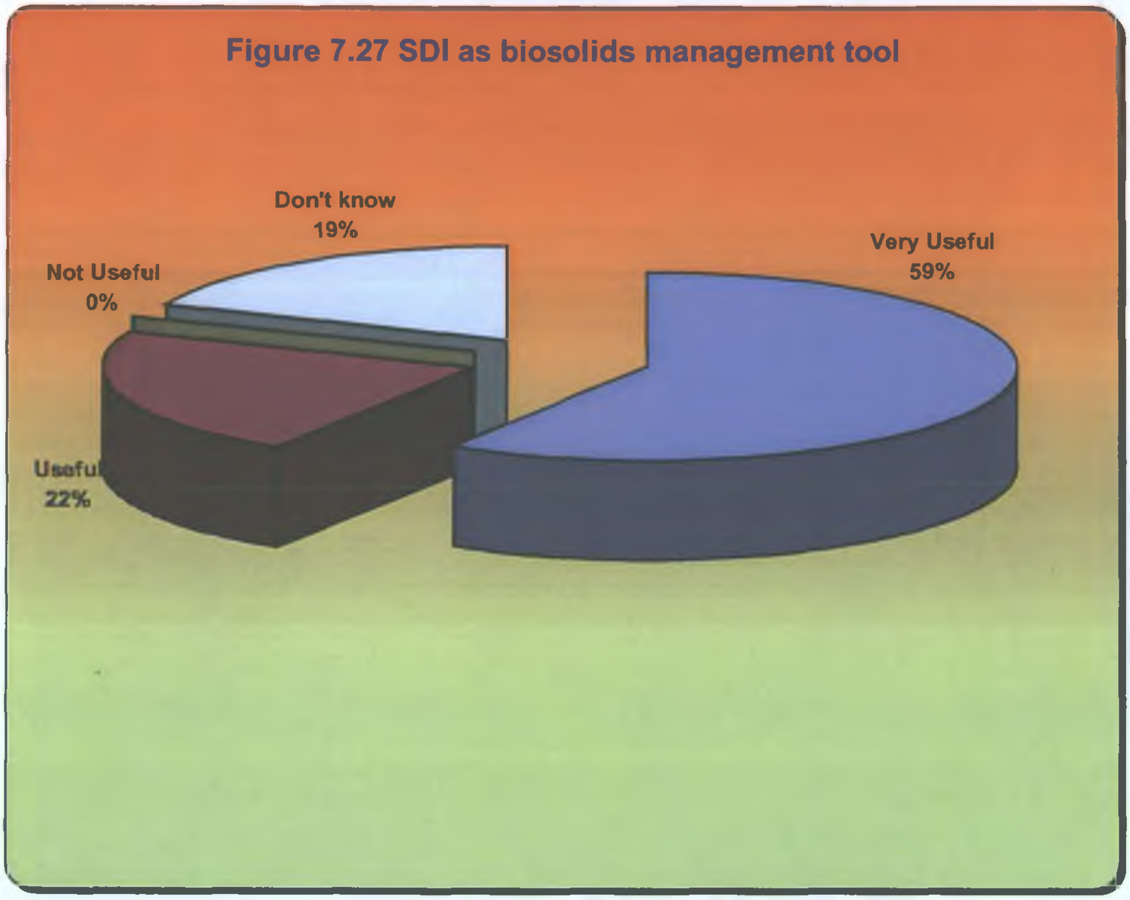


Figure 7.27 SDI as biosolids management tool

7.3.14 Summary of stakeholder rating of suggested actions. The overall stakeholder ratings of suggested actions to address concerns in relation to the management of biosolids are presented in Table 7.3. All groups of stakeholders predominantly rate the suggested actions from 'useful' to 'most useful'. More than 62% of all stakeholders surveyed rate nine suggested actions as 'most serious'. The ratings highlighted in green ('most useful'), turquoise ('more useful') and yellow ('useful') are the predominant for each suggested action. The number of respondents in each category appears in bold figures followed by the percentage of respondents in brackets.

Table 7.3 Stakeholder ratings of suggested actions

S/No	Information/Action	Most Useful (5)	More Useful (4)	Useful (3)	Less Useful (2)	Not Useful (1)	Don't Know
1	Scientific studies to learn more about the risks in spreading biosolids on land	**118** (84%)	**14** (10%)	**7** (5%)			**2** (1%)
2	Development of tests to ensure that there is little risk to humans and animals from biosolids	**106** (75%)	**19** (13%)	**15** (11%)			**1** (0%)
3	Clear information available to everybody	**109** (77%)	**24** (17%)	**7** (5%)			**1** (0%)
4	Establish clearly who is responsible if there is an accident or a problem	**119** (84%)	**14** (10%)	**7** (5%)	**1** (0%)		
5	Make rules to prevent use of biosolids if poisons are present	**132** (94%)	**5** (4%)	**2** (1%)	**1** (0%)		**1** (0%)
6	Written instructions on safety	**89** (63%)	**20** (14%)	**19** (13%)	**2** (1%)		**1** (0%)
7	Improved information to consumers on the safe use of biosolids	**93** (66%)	**27** (19%)	**19** (13%)	**2** (1%)		
8	Better training for farmers and landowners on use of biosolids	**102** (72%)	**29** (21%)	**7** (5%)	**3** (2%)		
9	Improved information to farmers	**103** (73%)	**24** (17%)	**6** (4%)	**1** (0%)		
10	Taking everybody's view into account	**19** (13%)	**46** (33%)	**38** (27%)	**28** (20%)	**6** (4%)	**4** (3%)
11	Compensation for people badly affected by accidents in use of biosolids	**42** (30%)	**31** (22%)	**49** (35%)	**15** (11%)	**2** (1%)	**2** (1%)

CHAPTER EIGHT

DEVELOPMENT AND SELECTION OF INDICATORS

This chapter describes various stages in the development of the set of indicators for managing biosolids. The indicators are organised according to the DPSIR framework. It also describes in detail the indicator selection process involving all the participating stakeholders. The chapter concludes by presenting the selected set of indicators organised as headline, core and complementary indicators.

8.1 Development of Candidate Indicators

A set of 33 candidate indicators were formulated from the concerns identified in chapter seven and the suggested actions to address them. Stakeholders have suggested some of these candidate indicators during the survey (see Appendix F). The 33 candidate indicators are organised according to the DPSIR framework described in Section 3.7.3 of Chapter 3. The name, brief description, issue addressed and typology of each candidate indicator are given. These candidate indicators are further grouped into six biosolids management domains namely; production, composition and quality, cost, transportation and energy, and regulation/others. Following is the set of 33 candidate indicators.

8.1.1 Domain: Production

8.1.1.1 Candidate Indicator: Total annual biosolids production per capita trend over time.

Definition and Explanation: This indicator will measure the amount of biosolids produced annually over the years per capita. The aim is to the show trend in quantities generated as more treatment plants come on stream, better access to the sewer network occurs, and as more stringent legislations are put in place, locally, nationally and internationally.

Issue Addressed: Problems if we don't use biosolids; the need to protect soil, air and water.

Type of Indicator: State

8.1.1.2 Candidate Indicator: Annual biosolids production (dry weight) by treatment process (per cent) over time.

Definition and Explanation: This indicator will depict the quantity of biosolids produced annually by the various treatment types namely:

i. Mesophilic anaerobic digestion
ii. Thermophilic anaerobic digestion
iii. Thermophilic aerobic digestion
iv. Composting: Windrows; aerated static piles or in-vessel
v. Alkaline stabilisation
vi. Thermal drying

The treatment process adopted will vary in each community depending on many variables including type, quality and quantity of wastewater generated in the locality, availability of land, crop grown in the locality, and topography.

Issue Addressed: Problems if we don't use biosolids; need to protect soil, air and water; legislation/regulation.

Type of Indicator: State

8.1.1.3 Candidate Indicator: Sewerage access provided over time.

Definition and Explanation: This indicator will graphically show the gradual increment (or otherwise) over time of access to sewer systems (wastewater treatment plants) by the various communities. As access increases, the quantity of biosolids will also be expected to increase. This indicator is expected to steer the need for adequate planning and implementation of a well-structured sustainable biosolids management programme.

Issue Addressed: Problems if we don't use biosolids; need to protect soil, air and water.

Type of Indicator: State

8.1.1.4 Candidate Indicator: Annual animal, industrial and sewage sludge production trends over time.

Definition and Explanation: Approximately 30 million tonnes of animal manure requires land spreading annually in Ireland. Annual Irish sewage biosolids is about 20,000 tonnes but may increase to 120,000 tonnes by 2013 as a consequence of changes in European and National water legislation. This indicator will compare sewage sludge production with other sludge types, showing total and itemized quantities over time.

Issue Addressed: Problems if we don't use biosolids.

Type of Indicator: State

8.1.1.5 Candidate Indicator: Annual quantity of wastewater treated versus annual quantity of wastewater produced over time.

Definition and Explanation: This indicator will compare the total wastewater generated annually from households and connected industries with the total wastewater treated annually. Untreated wastewater constitutes an enormous source of pressure to the environment. The annual untreated quantity of wastewater dictated with this indicator is expected to inform future management planning.

Issue Addressed: Problems if we don't use biosolids; legislation/regulation.

Type of Indicator: State

8.1.2 Domain: Composition and quality

8.1.2.1 Candidate Indicator: Biosolids composition showing compounds of agricultural value.

Definition and Explanation: Sewage sludge produced by wastewater treatment is usually processed to make it suitable for reuse. However, the various treatment processes alter the amount of compounds of agricultural value. This indicator will provide average quantitative information on biosolids composition in terms of agricultural nutrients/fertiliser value.

Issue Addressed: Nobody would want to use biosolids.

Type of Indicator: State.

8.1.2.2 Candidate Indicator: Pollutant concentrations to show the effect of treatment on biosolids composition.

Definition and Explanation: Sewage sludge produced by wastewater treatment is usually processed to reduce its water content, fermentation propensity and pathogen contents. This indicator will depict available techniques and pollutant-limiting improvements accruable from the various biosolids' processing routes.

Issue Addressed: Nobody would want to use biosolids; damage to animal and human health, plants and crops; need to protect soil, air and water; legislation/regulation.

Type of Indicator: Response

8.1.2.3 Candidate Indicator: Quality requirements in relation to pathogen and vector attraction for land application of over time.

Definition and Explanation: There are five main types of pathogens observed in biosolids: bacteria, viruses, fungi, and yeast, parasitic worms, and protozoa. Human and animals are sensitive to some of these organisms, which may cause numerous pathologies ranging from simple digestion troubles to lethal infections. This indicator will show typical permissible pollutant limits, pathogen and vector attraction requirements for land application of biosolids.

Issue Addressed: Nobody would want to use biosolids; possible poisons in biosolids, damage to human and animal health, plants and crops, need to protect air, water and soil; legislation/regulation.

Type of Indicator: Response

8.1.2.4 Candidate Indicator: Quantities of biosolids failing quality requirements in relation to heavy metals for land application over time.

Definition and Explanation: Soils naturally contain heavy metals, originating from parent rock. As the soil and parent rock types are numerous, a great variety of levels are observed within different localities. Metals also enter soil from a variety of other sources, including air, artificial fertilisers and animal slurries. It is therefore important to know the background levels of metals in soils before application of biosolids to avoid adverse effects on soil, plant, animal or human health. This indicator will show quantities of biosolids failing quality requirements in relation to typical permissible levels for heavy metals for land application of biosolids as provided in Directive 86/278/EEC (mg/kg of dry matter).

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: Pressure

8.1.2.5 Candidate Indicator: Heavy metal levels in some 'virgin' soils compared to those applied with biosolids over time.

Definition and Explanation: This indicator will compare heavy metal levels in soils treated/untreated with biosolids. Baseline studies of some local soils are known from research to be high in heavy metals naturally. This indicator will show the effects of a managed biosolids application on land in respect of heavy metal content over a period.

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: Impact.

8.1.2.6 Candidate Indicator: Content of organic matter in biosolids and in other urban waste and animal manure.

Definition and Explanation: In Ireland biosolids are subject to some selected treatment: aerobic and anaerobic digestion, thermal treatment, lime treatment, and composting of biosolids. Organic matter is mostly constituted of soluble matter such as hydrocarbons, amino acids, small proteins or lipids. Its content in urban biosolids is high (usually more than 50% of the dry matter) but varies according to treatment and conditioning. This indicator will show comparatively, the amount of organic matter in biosolids so selectively treated compared to other urban wastes and animal manure

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: State

8.1.2.7 Candidate Indicator: Total and available Phosphorus content in biosolids after selected treatments.

Definition and Explanation: In Ireland biosolids are subject to some selected treatment: aerobic and anaerobic digestion, thermal treatment, lime treatment, and composting of biosolids. This indicator will show comparatively, the amount of phosphorus in biosolids so selectively treated.

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: State

8.1.2.7 Candidate Indicator: Total and available Nitrogen content in biosolids after selected treatments.

Definition and Explanation: In Ireland biosolids are subject to some selected treatment: aerobic and anaerobic digestion, thermal treatment, lime treatment, and composting of biosolids. This indicator will show comparatively, the amount of nitrogen in biosolids so selectively treated.

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: State

8.1.2.8 Candidate Indicator: Biosolids recycling and use of animal wastes over time.

Definition and Explanation: Approximately 30 million tonnes of animal manure requires land spreading annually in Ireland. Annual Irish sewage biosolids is about 20,000 tonnes but may increase to 120,000 tonnes by 2013 as a consequence of changes in European and National water legislation. The annual amount of biosolids recycled through the various routes is compared with that of animal wastes utilized over same period.

Issue Addressed: Nobody would want to use biosolids.

Type of Indicator: State

8.1.2.9 Candidate Indicator: Biosolids recycling and use of mineral fertilisers over time

Definition and Explanation: The annual amount of biosolids recycled through the various routes is compared with the amount of mineral fertilisers used over same period.

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value.

Type of Indicator: State

8.1.3 Domain: Cost

8.1.3.1 Candidate Indicator: Comparison with cost of fertilizer per tonne or nutrient value of biosolids.

Definition and Explanation: This indicator will compare graphically the cost of fertiliser to that of biosolids of equivalent nutrient value.

Issue Addressed: High cost to tax payer; fear of loss of property and land value.

Type of Indicator: Driving force

8.1.3.2 Candidate Indicator: Comparative cost of various biosolids disposal routes per tonne of dry matter.

Definition and Explanation: Whatever the disposal route, total costs are mainly composed of investment and operating costs of infrastructure and of operations required for biosolids treatment. This indicator will compare the cost of the various disposal and reuse routes per tonne of dry matter.

Issue Addressed: High cost to tax payer

Type of Indicator: Driving force.

8.1.3.2 Candidate Indicator: Annual cost of transporting biosolids over time.

Definition and Explanation: This indicator will show annual cost of transporting biosolids including personnel, equipment, energy and other ancillary costs.

Issue Addressed: High cost to tax payer

Type of Indicator: Driving force.

8.1.4 Domain: Disposal

8.1.4.1 Candidate Indicator: Annual quantity and percentage of biosolids recycled over time (tonnes; %)

Definition and Explanation: The progressive implementation of the EU Urban Waste Water Treatment Directive 91/271/EEC is increasing the quantities of biosolids requiring reuse and disposal in Ireland. The indicator will show the total amount (tonnes) and percentage (%) of biosolids recycled per year over time.

Issue Addressed: Nobody would want to use biosolids; legislation/regulation.

Type of Indicator: Response

8.1.4.2 Candidate Indicator: Annual quantities and percentage of biosolids disposed of and recycled through various routes.

Definition and Explanation: The amount of biosolids reused or disposed of through the various routes including agricultural and non-agricultural uses, landfilling and incineration per annum will be depicted over time.

Issue Addressed: Nobody would want to use biosolids; need to protect soil, water and air; problems if we don't use biosolids; legislation/regulation.

Type of Indicator: State

8.1.4.3 Candidate Indicator: Annual quantity and percentage of biosolids disposed at landfill over time.

Definition and Explanation: With the EU Landfill Directive 2000/53/EC requiring us to divert increasing amounts of organic and putrescible wastes from landfills, coupled with urgent deficit in landfill capacity in most of our local authorities, the diversion of biosolids away from landfills is a major policy goal. This indicator will show the amount of biosolids landfilled annually over time.

Issue Addressed: Nobody would want to use biosolids; need to protect soil, water and air; legislation/regulation.

Type of Indicator: Pressure.

8.1.4.4 Candidate Indicator: Quantifiable air-borne emission of pollutants from various biosolids disposal routes.

Definition and Explanation: Annual amounts of quantifiable emission of pollutants from biosolids to the air will be shown for relevant disposal options most especially from incineration and landfilling. This will be compared to limits set in the incineration directive 2000/76/EC (of 4 December 2000). Emissions of interest will include halogen and derived acids, No_x, SO_2, particulate matter, VOCs (CH_4, CO_2, and CO)

Issue Addressed: Need to protect soil, water and air; legislation/regulation.

Type of Indicator: Pressure

8.1.4.5 Candidate Indicator: Annual emissions of leachate to soil over time for various biosolids disposal routes.

Definition and Explanation: Leaching and runoff could enable the transfer of compounds into soil and their introduction into the food chain. Operation accidents can also happen, generating an increase in the emissions to soil and possible reduction of agricultural yields. This indicator will show annual amounts of this leachate to soil over time.

Issue Addressed: Nobody would want to use biosolids; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: Pressure

8.1.4.6 Candidate Indicator: Annual emissions of untreated and treated leachate to groundwater over time for various biosolids disposal routes.

Definition and Explanation: Leaching and runoff could enable the transfer of compounds into water and their introduction into the food chain. Operation accidents can also happen, generating an increase in the emissions to water and possible reduction in water quality. This indicator will compare annual amounts of untreated leachate with treated leachate to water over time.

Issue Addressed: Need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: Pressure

8.1.4.7 Candidate Indicator: Annual discharge of organic pollutants to surface water for various biosolids disposal routes.

Definition and Explanation: The fate of organic pollutants in the environment and the food chain from biosolids is not well documented. Potential transfer pathways to water are either transfer to surface water through runoff, or to groundwater through leaching. This transfer may be avoided when spreading is not performed near surface water, or on bare or sloping land. The indicator will attempt to show annual emissions to surface water over time.

Issue Addressed: Need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: Pressure.

8.1.5 Domain: Transport and energy

8.1.5.1 Candidate Indicator: Efficiency of travel modes in transporting biosolids.

Definition and Explanation: Fuel used for transporting biosolids is important because of the contribution of all fossil based fuels to climate change. This indicator will show the efficiency of various transport modes employed in moving biosolids divided by distance travelled.

Issue Addressed: High cost to tax payer; need to protect soil, water and air.

Type of Indicator: Impact

8.1.5.2 Candidate Indicator: Logistics efficiency of transporting biosolids.

Definition and Explanation: As stated earlier fuel used for transporting biosolids is important because of the contribution of all fossil based fuels to climate change. This indicator will measure the fuel used in transporting biosolids per tonne of substance handled. This will give a full picture of the efficiency and improvements (or otherwise) in logistics employed.

Issue Addressed: High cost to tax payer; need to protect soil, water and air.
Type of Indicator: Impact

8.1.5.3 Candidate Indicator: Tonnes of biosolids transported by rail or water as a proportion of total waste transported.

Definition and Explanation: This indicator will be used to monitor the uptake of transport modes other than road transport. These other forms of transport may offer 'cleaner' possibilities.
Issue Addressed: High cost to tax payer; need to protect soil, water and air.
Type of Indicator: State

8.1.6 Domain: Regulation and others

8.1.6.1 Candidate Indicator: Number of enforcement notices served over time.

Definition and Explanation: A prosecution or enforcement notice could be seen as an indication of deficient management systems. This indicator is expected to provide a level of detail a little greater than simply reporting prosecutions. Not all enforcement notices result in prosecution, even when some level of deficiency is observable.
Issue Addressed: Possible problems for people in proximity of biosolids facilities; fear of loss of property and land value; need to protect soil, water and air; legislation/regulation.
Type of Indicator: Response.

8.1.6.2 Candidate Indicator: Biosolids training and research funding compared to quantity recycled over time.

Definition and Explanation: Research and training have been identified by stakeholders as requirements for safe recycling of biosolids and building of public confidence. This indicator will compare the amount of funds utilised in biosolids research and training, and quantity recycled per annum over time.
Issue Addressed: High cost to tax payers; need to protect soil, water and air; possible poisons in biosolids; legislation/regulation.

Type of Indicator: Response

8.1.6.3 Candidate Indicator: Annual number of training activities conducted for biosolids' stakeholders over time.

Definition and Explanation: Training and better information dissemination are necessary activities to encourage more reuse of biosolids and better public perception. This indicator will show the frequency of various stakeholder training activities compared to amounts of biosolids recycled annually over time.

Issue Addressed: Nobody would want to use biosolids; fear of loss of property and land value; possible poisons in biosolids; legislation/regulation.

Type of Indicator: *Response*

8.1.6.4 Candidate Indicator: Results of stakeholder surveys over time.

Definition and Explanation: Results of stakeholder satisfaction surveys on the reuse of biosolids will give a more nuanced picture of a sustainable biosolids management programme. It will also be a means of identifying latent issues that antagonise stakeholders but do not actually result in complaints. This indicator will be an effort towards understanding the impact of various biosolids policy, regulations and implementation.

Issue Addressed: Nobody would want to use biosolids.

Type of Indicator: Impact

8.1.6.5 Candidate Indicator: Annual odour complaints validated as coming from biosolids disposal and reuse over time.

Definition and Explanation: This indicator will contribute towards monitoring environmental performance of a sustainable biosolids management programme. It would require a clear procedure for recording complaints; clear protocols for validating complaints as coming from biosolids as opposed to other wastes; and a robust procedure for following-up and closing-out complaints. The indicator will show number of complaints validated as coming from biosolids compared to number of processing plants over time.

Issue Addressed: Nobody would want to use biosolids; odour; legislation/regulation.
Type of Indicator: Impact

8.2 Draft Set of Indicators

The candidate indicators were individually reviewed by answering the following questions (summarised from Hodge and Hardi 1997):

i. Is the candidate indicator a simple single variable, or can it be composed of many?
ii. Is the candidate indicator a quantitative objective measure, or can it be adapted to a qualitative description with some degree of subjective judgement?
iii. Is the candidate indicator diagnostic of specific causes of change, or is it sufficient that it detects any changes?
iv. Is the candidate indicator dealing only with the past and current time frames or should it be proactive and anticipate changes?

In addition to these criteria, consideration was also given to the availability of data of sufficient quantity and quality, or that can be generated within a timeframe and budget, to provide spatial and temporal trends; non-overlap of the indicators; and the ease of understanding the information to be relayed by the indicator (Lundin et al 1997).

During the two reviews some candidate indicators were rephrased or discarded completely. For example, all the candidate indicators within the cost domain were discarded and replaced with a more appropriate draft indicator namely; 'Comparative cost of biosolids production processes per tonne of dry matter'.

Following is the resulting draft set of 22 indicators organised along six modified biosolids management domains namely; production, quality, cost, disposal/recycling, legislation/regulation and training/research.

8.2.1 Biosolids Management Domain: Production

Indicator 1: Domestic and industrial/commercial population equivalent (p.e.) of WWTPs

Regulations require the provision of wastewater treatment plants depending on the size of the agglomeration and on the type of water body to which the wastewater is discharged. This indicator will show the numerical rating of domestic and commercial population equivalent of Wastewater Treatment Plants (WWTPs).

Type of Indicator: Driving Force

Indicator 2: Total annual biosolids production (dry weight)

A total of 29,810 tonnes (2000) and 33,559 tonnes (2001) respectively, of dry solids were reported to have been produced in Ireland by agglomerations with population equivalent greater than 500. This indicator will show the amount of biosolids produced annually over time.

Type of Indicator: State

Indicator 3: Biosolids production (dry weight) by treatment process

This indicator will depict the quantity of biosolids produced annually by the various treatment types namely: mesophilic anaerobic digestion, thermophilic anaerobic digestion, thermophilic aerobic digestion, composting, alkaline stabilisation and thermal drying.

Type of Indicator: State

Indicator 4: Access to sewerage

This indicator will show the gradual increment (or otherwise) over time of access to central sewer systems (wastewater treatment plants) by the various communities. As access increases, the quantity of biosolids will also be expected to increase.

Type of Indicator: Driving Force

Indicator 5: Quantity of treated wastewater as a percentage of total quantity of wastewater

This indicator will compare the total wastewater generated annually from households and connected industries with the total wastewater treated annually. Untreated wastewater constitutes an enormous source of pressure to the environment.

Type of Indicator: Pressure

Indicator 6: Phosphorus and Nitrate recycling

Biosolids are a source of nitrogen (N) and phosphorus (P) required for crop production. This indicator will report the amount of Phosphorus and Nitrogen recycled through the use of biosolids in agriculture.

Type of Indicator: Driving Force

8.2.2 Biosolids Management Domain: Quality

Indicator 7: Quantity of biosolids not meeting stipulated quality standards

This indicator will measure percentage compliance with regulation over time in relation to biosolids quality requirements. It will also show quantities of biosolids failing quality requirements in relation to typical permissible levels for heavy metals and other contaminants as provided in regulations.

Type of Indicator: Pressure

Indicator 8: Soil quality

It is important to know the background levels of heavy metals in soils before application of biosolids to avoid adverse effects on soil, plant, animal or human health. This indicator will present summary of sampling and analysis results from soils subjected to biosolids application.

Type of Indicator: Impact

Indicator 9: Catchments' river/lake quality

This indicator will present sampling and analysis results from rivers and lakes local to biosolids spread lands, for example Dissolved Oxygen, Biological Oxygen Demand, pH, Nitrate, Phosphorus and Coliforms.

Type of Indicator: Impact

Indicator 10: Crop production

Land application of biosolids is aimed at improving soil conditions and crop yield. This indicator will show crop yields (by tonnage per area per annum) on land where biosolids have been applied.

Type of Indicator: Impact

8.2.3 Biosolids Management Domain: Cost

Indicator 11: Comparative cost of biosolids production processes per tonne of dry matter

Whatever the production process, total costs are mainly composed of investment and operating costs of infrastructure and of other operations required for biosolids management. This indicator will compare the cost of the various biosolids production processes per tonne of dry matter.

Type of Indicator: Driving Force

8.2.4 Biosolids Management Domain: Legislation/Regulations

Indicator 12: Enforcement notices

A prosecution or enforcement notice could be seen as an indication of deficient management systems. This indicator is expected to provide a level of detail a little greater than simply reporting prosecutions. Not all enforcement notices result in prosecution, even though some level of deficiency is observable.

Type of Indicator: Response

Indicator 13: Stakeholder surveys

Results of biosolids stakeholder satisfaction surveys will give a nuanced picture of a sustainable biosolids management programme. It will also be a means of identifying latent issues that antagonise stakeholders but do not actually result in complaints. This indicator will be an effort towards understanding the impact of various biosolids policy, legislation/regulations and implementation programmes.

Type of Indicator: Impact

8.2.5 Biosolids Management Domain: Training/Research

Indicator 14: Training

Training and better information dissemination are necessary activities to encourage more reuse of biosolids and better public perception. This indicator will show the frequency of various stakeholder training activities compared to amounts of biosolids recycled annually over time.

Type of Indicator: Response

Indicator 15: Research funding

Research and training have been identified by stakeholders as requirements for safe recycling of biosolids and building of public confidence. This indicator will compare the amount of funds utilised in biosolids research and training, and quantity recycled per annum over time.

Type of Indicator: Response

Indicator 16: Information packs

General goodwill towards the concept of beneficial use of biosolids can be mobilised provided procedures for managing the risks are in place, and the local community is well informed. This indicator will show the annual number of information packs distributed per capita (per county).

Type of Indicator: Response

8.2.6 Biosolids Management Domain: Disposal/Recycling

Indicator 17: Nutrient value of biosolids sent to landfills

When biosolids are landfilled, reusable nitrogen, phosphorus and organic matter are lost in the process. This indicator will show the amount of these nutrients lost annually through the landfilling of biosolids.

Type of Indicator: Driving Force

Indicator 18: Quantity and percentage of biosolids recycled

The progressive implementation of the EU Urban Waste Water Treatment Directive 91/271/EEC is increasing the quantities of biosolids requiring reuse and disposal in Ireland. The indicator will show the total amount (tonnes) and percentage (%) of biosolids recycled per year over time.

Type of Indicator: Response

Indicator 19: Quantity and percentage of biosolids sent to landfills

The EU Landfill Directive 2000/53/EC stipulates the diversion of increasing amounts of organic and putrescible wastes from landfills. Coupled with urgent deficit in landfill capacity in most of our local authorities, the diversion of biosolids away from landfills is inevitable. This indicator will show the amount of biosolids landfilled annually over time.

Type of Indicator: Pressure

Indicator 20: Quantities and percentage of biosolids recycled through various routes

The amount of biosolids reused through the various recycling routes including agricultural and non-agricultural uses, and incineration (with energy recovery) per annum will be depicted over time.

Type of Indicator: State

Indicator 21: Public complaints

This indicator will present the number of complaints validated as coming from biosolids recycling/disposal processes as a percentage of WWTPs.

Type of Indicator: Impact

Indicator 22: Register of biosolids reuse contractors

Recycling of sewage sludge in the EC 15 increased from 2.6 million dry tonnes (MDT) per year in 1992 to 4.2MDT in 2000. Annual Irish sewage sludge is expected to increase to 120,000 tonnes by 2013 as a consequence of changes in European and National Water legislation. This indicator will measure the number of qualified biosolids reuse contractors in Ireland.

Type of Indicator: Response

8.3 Selection of Indicators

A careful selection and application of indicators can be the first step in developing the essential comprehensive picture of sustainable biosolids management. The draft set of indicators was sent out to the stakeholders who have indicated during the survey stage to participate in further activities, and all local authorities for selection.

The result of the consultation and ranking of the indicators by the stakeholders are detailed in Table 8.1.

Table 8.1 Selection of indicators by stakeholders

S/No	Indicator Name	Type	PR	SM	VT	DA	RT	SS	Total
Management Domain: Production									
1	Domestic and industrial/commercial population equivalent (p.e.) to Wastewater Treatment Plants	Driving Force	139	124	126	132	114	120	**755**
2	Total annual biosolids production (dry weight)	State	140	140	140	138	140	140	**838**
3	Biosolids production (dry weight) by treatment process	State	123	135	132	131	132	132	**785**
4	Access to sewerage	Driving Force	89	101	98	115	118	125	**646**
5	Quantity of treated wastewater as a percentage of total quantity of wastewater	Pressure	105	90	76	76	76	76	**499**
6	Phosphorus and nitrogen recycling	Driving Force	115	105	110	105	124	106	**665**
Management Domain: Quality									
7	Quantity of biosolids not meeting stipulated quality standards	Pressure	120	94	119	83	122	117	**655**
8	Soil quality	Impact	131	121	121	72	74	92	**611**
9	Catchment river/lake quality	Impact	90	78	64	84	91	94	**501**
10	Crop production	Impact	80	88	106	70	106	110	**560**
Management Domain: Cost									
11	Comparative cost of biosolids production processes per tonne of dry matter	Driving Force	83	81	91	81	112	115	**563**
Management Domain: Legislation/Regulations									
12	Enforcement notices	Response	113	109	96	78	68	68	**532**
13	Stakeholder surveys commissioned by Local authorities	Impact	92	61	69	43	71	71	**407**
Management Domain: Training/ Research									
14	Training of farmers and non-agricultural users of biosolids	Response	102	94	94	78	95	91	**554**
15	Funding of biosolids research	Response	104	800	70	62	52	72	**440**
16	Information packs	Response	103	119	124	57	114	117	**634**
Management Domain: Disposal/Recycling									
17	Nutrient value of biosolids sent to landfills	State	96	100	92	42	84	90	**504**
18	Quantity of biosolids recycled	Response	114	130	127	113	122	118	**724**
19	Quantity and percentage of biosolids sent to landfills	Pressure	117	123	126	101	115	119	**701**
20	Quantity and percentage of biosolids recycled through various routes	State	115	112	122	110	120	114	**683**
21	Public complaints from biosolids processing, recycling and reuse	Impact	106	98	64	54	54	78	**454**
22	Register of biosolids contractors	Response	125	113	110	118	117	111	**694**

Legend: PR-Policy relevance; SM-Simplicity; VT-Validity; DA-Data availability; RT-Representativeness; SS-Sensitivity

For the purpose of this research study, the following six criteria were used by stakeholders to select and indicate their judgement on the contribution of each indicator to the achievement of each criterion.

- *Policy relevance*: Is the candidate indicator relevant to biosolids policy?
- *Simplicity*: Is the candidate indicator understandable by all stakeholders?
- *Validity*: Is the candidate indicator scientifically credible and reliable?
- *Data availability*: Is the candidate indicator easily measured?
- *Representativeness*: Is the candidate indicator representative of system variability over space and time?
- *Sensitivity*: Will the candidate indicator be rapid in showing changes within the system?

The participating stakeholders rated each indicator according to the listed criteria. The lowest rating is 1 while 5 is the highest for each criterion. A cover letter introducing this stage of the research study and detailing what is to be done accompanied each consultation document (Appendix D). Sixty-five consultation documents were sent to these stakeholders and 31 were returned giving a response rate of 47%.

The top five ranking draft indicators are classified as *'Headline Indicators'*, the next top seven as *'Core Indicators'* and the rest as *'Complementary Indicators'* (see Table 8.2).

The reasons for the categorisation of the indicators are elucidated in Section 10.1.1 of Chapter 10. The subsequent testing of these indicators will show to what extent they are useful in managing biosolids towards increased sustainability.

Table 8.2 Headline, core and complementary set of indicators

Headline Indicators	*Core Indicators*
▪ Total annual biosolids production (tDS); ▪ Annual biosolids production (tDS) by treatment processes; ▪ Domestic and commercial population equivalent of wastewater treatment plants; ▪ Quantity of biosolids recycled annually; ▪ Quantity of biosolids sent to landfills annually.	▪ Register of contractors involved in biosolids management; ▪ Quantity of biosolids recycled through various routes annually; ▪ Phosphorus and nitrogen recycling; ▪ Annual quantity of biosolids not meeting stipulated quality standards; ▪ Access to sewerage; ▪ Information packs; ▪ Soil quality where biosolids are applied.
Complementary Indicators	
▪ Comparative cost of biosolids production processes per tonne of dry matter; ▪ Catchments river/lake quality; ▪ Crop production; ▪ Enforcement notices; ▪ Stakeholder surveys; ▪ Training;	▪ Quantity of treated wastewater versus total quantity of wastewater generated per annum; ▪ Research funding; ▪ Estimated nutrient value of biosolids sent to landfills; ▪ Public complaints.

CHAPTER NINE

PRELIMINARY TESTING OF THE SET OF INDICATORS

Application of the headline, core and supplementary set of indicators over time is expected to ascertain whether it could measure or otherwise reflect environmental, social and economic improvements as a result of the proper and progressive implementation of a biosolids management policy and programmes. This chapter describes the preliminary application of the set of headline and core indicators developed in Chapter 8. It also describes the study area, availability of data and overall usefulness of the individual indicators. It concludes by presenting the indicators that are successfully tested.

9.1 The Study Area

Sligo County Council was chosen to test the 'suite' of 22 indicators. Sligo is a county in the Connacht province, North-West of Ireland, sitting on the coast of the Atlantic Ocean. It was chartered as a county in 1579, and has a varied landscape with fine coastline and beaches, mountains and wooded hills, lakes, rivers and waterfall. The town of Sligo is a seaport and commercial centre. Sligo's history dates from the mid-13th century.

Sligo County has a population of about 60,863 according to the 2006 preliminary census report. This represents an increase of 2,663 or 4.6% over the 2002 census figure and 2,379 or 4.26% increase during the 1991 to 1996 intercensal period. Based on the 'Gradual Growth' and 'Faster Growth' models, it is predicted that under favourable circumstances, County Sligo's population could be in the range of 70,000 to 75,000 by 2011 (CSO 2001).

The choice of Sligo County is informed first, by its designation as a Gateway City in the National Spatial Strategy. The promotion and development of Sligo as a Gateway City have also been provided for through the framework of the Sligo and Environs Development Plan 2004-2010. Second, Sligo is located in Region Five in the 'Sludge Strategy Study' published by the Department of the Environment, Heritage and Local Government in 1993. Region Five has Sligo as the hub centre for the treatment of sewage sludge throughout much of south Sligo, the northern half of County Leitrim and part of County Cavan (Weston-FTA 1993). Third, Sligo County's proximity to the College contributes to the optimisation of available time and resources.

9.2 Sludge Management in County Sligo

There is no sludge treatment facility in the County. However, the Sligo County Council Sludge Management Plan (SMP) has been adopted. It was prepared with regard to the Department of Environment, Heritage and Local Government document *Sludge Management Plans – A Guide to their Preparation and Implementations* 1999 and the *Waste Management Act* of 1996.

According to the SMP, the total volume of non-hazardous sludges generated annually in County Sligo is estimated at 75,470 tonnes dry solid (tDS). Sludges generated by Local Authority water and wastewater treatment plants account for 0.5% of the total sludge arisings. The SMP anticipates that the volume of wastewater sludge generated will double when the Urban Wastewater Directive is fully implemented. Industrial sludge accounts for only 0.1% and mainly arise from local meat processing and creameries. Cattle slurry generated during a 26 week over wintering period accounts for 89.9% of all agricultural slurries, ewes housed for a six week period is 4.7% with the remainder arising from pigs, spent mushroom compost and other livestock.

The principal policy proposals in the SMP to manage non-hazardous sludge in the County are that:

- Sligo Town will become a sludge hub centre for the county with a number of sludge collection centres in the county to feed the hub;
- Biosolids will be produced at the Sligo hub centre by the process of Mesophilic Anaerobic Digestion. (There are indications from staff of the Council during interviews that a thermal dryer may be a preferred method of biosolids production). This should be operational in four years;

- A public information strategy will be initiated to focus and educate the public in relation to the benefits of biosolids reuse and the sludge management procedures in place.

It concludes that at present time and stage, there is no advantage of including agriculture sludge in the biosolids production process in Sligo.

Sligo County Council have hired a contractor to dispose of all its sewage sludge arising from 27 wastewater treatment plants. All of the County's wastewater treatment plants have treatment capacity below 300 BOD/day corresponding to PE of 5000 persons. Evergreen Fields remove the sludge, which is in liquid format, from each plant by tanker. It is transported to farm storage facilities in Tipperary, Meath, Louth, Westmeath, Roscommon and Galway. The sewage sludge is treated by long-term storage (minimum of three months) before being land-spread. The County Council have no sludge storage facilities. It has, however, six drying beds located at Ballymote, Collooney, Grange, Strandhill and Tubbercurry with an estimated combined capacity of 203.43tds. Total sludge production in the county for 2002 and 2003 was estimated at 169 tDS and16 tDS, respectively according to EPA (2005) report.

9.3 Calculation of Indicators

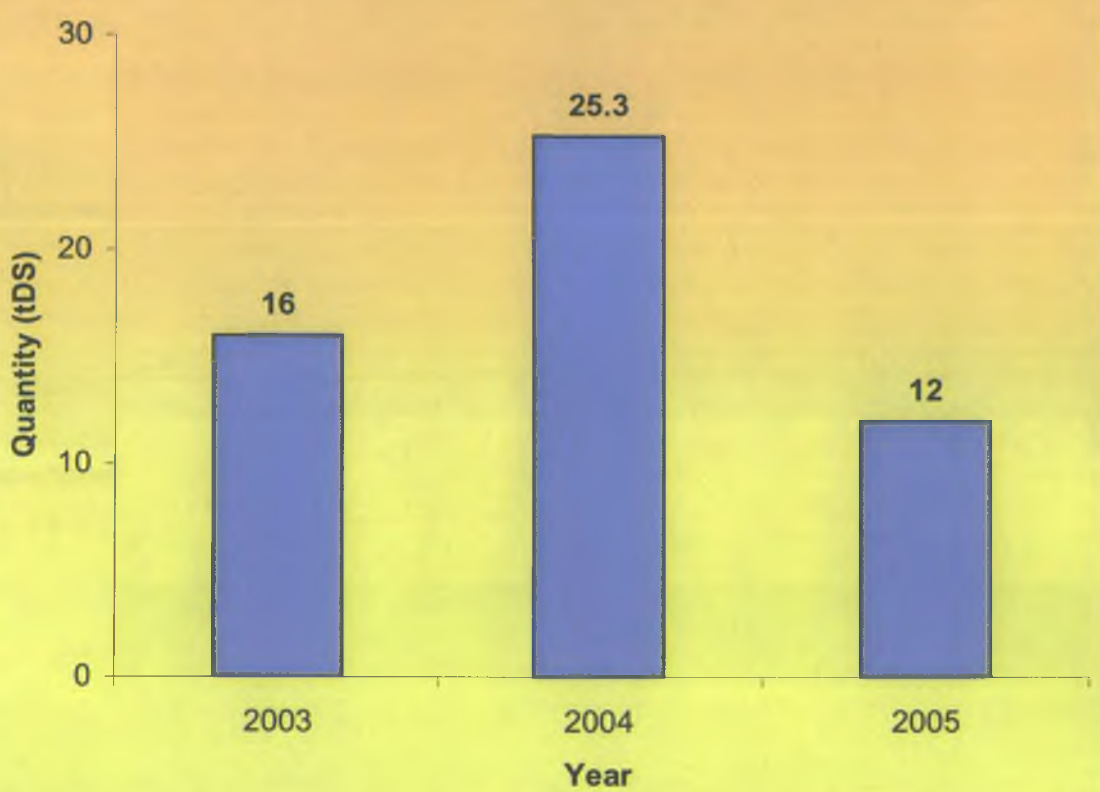
The objectives here are to evaluate the applicability of the headline and core set of indicators in County of Sligo, and to assess their usefulness across the range of biosolids management domains. Information required for the testing of the indicators was outlined in the data availability survey form (see Appendix H), which was forwarded to the County's Director of Environmental Services in early March 2006.

Calculation of headline and core indicators followed from the input data obtained in June 2006 from the Water Services Section. It included information and records on the wastewater treatment plants, submissions by contractors, storage facilities locations, quantity and format of sludge, soil sampling results and a copy of the County's SMP. Results presented are preliminary and not final.

9.3.1 Headline Indicator Set

Indicator 2: Total annual biosolids production (tDS)

Figure 9.1 Total annual biosolids production in Couny Sligo

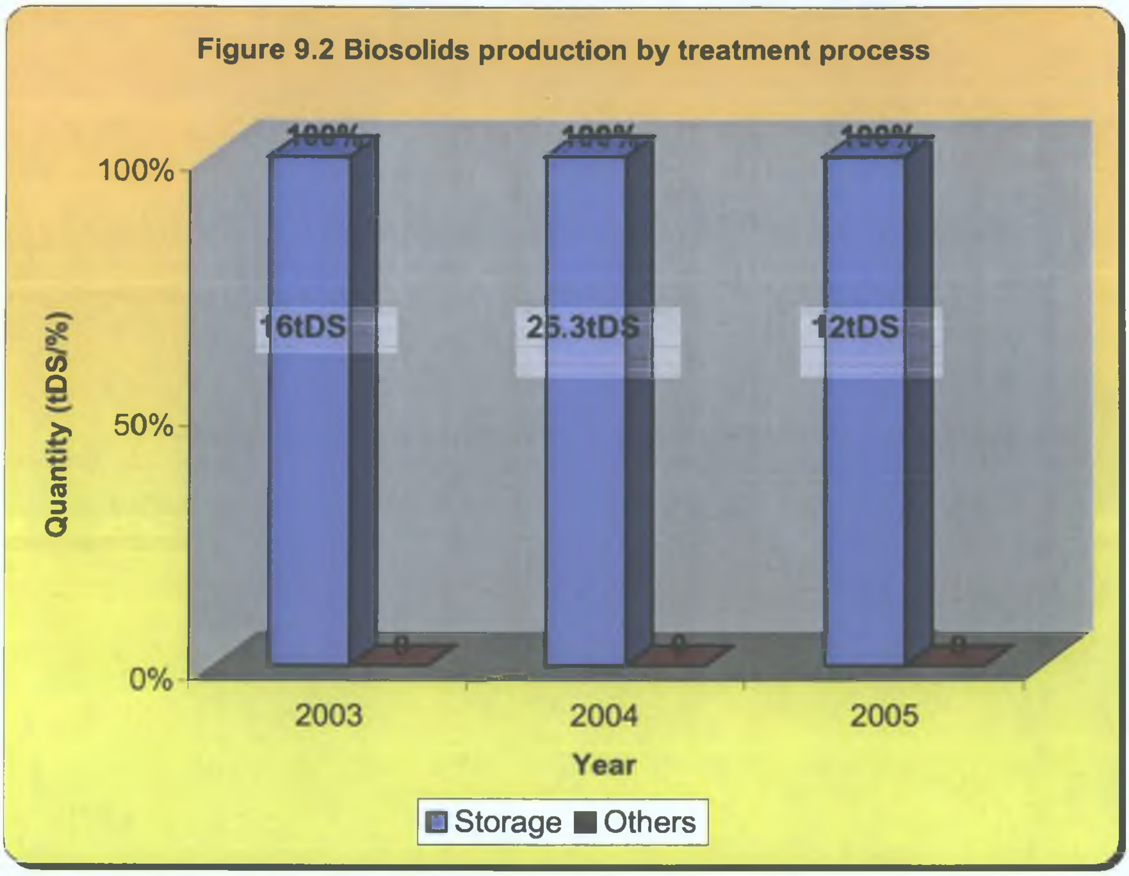


Type of indicator: State

Source of data: Local Authority

Comment: There is available data in the County to test this indicator. A total of 16 tDS (2003), 23.5 tDS (2004) and 12 tDS (2005) were produced from all wastewater treatment plants in County Sligo (Figure 9.1). The figures for 2004 and 2005 are provisional and will be confirmed before submission to the EPA. This indicator highlights an obvious question of accuracy and reliability of the sludge production data supplied. It is expected that the amount of biosolids produced annually will be on the increase rather than a decrease. The figures for 2004 and 2005 do not follow this trend. Since these figures are provisional, it is hoped that the final figures will correct or explain the decrease in 2005 figures.

Indicator 3: Biosolids production (tDS and %) by treatment process



Type of indicator: State

Source of data: Local Authority

Comment: It has been stated in Section 9.2 that Sligo County has no sewage sludge treatment facilities. Evergreen Fields are contracted by the County to remove the sludge from the wastewater treatment plants in liquid format by tanker. The contractor transports the sludge to farm storage facilities in Tipperary, Meath, Louth, West Meath, Roscommon and Galway where they are treated by long-term storage (minimum of three months) before being land-spread. This indicator depicts that storage is the only sludge treatment method presently used by County Sligo contractors. It is pertinent to point out that the *Code of Good Practice for the Use of Biosolids in Agriculture* does not recommend storage of sewage sludge as best practice. Mesophilic anaerobic digestion is the recommended option in County Sligo's SMP.

Indicator 1: Domestic and industrial/commercial population equivalent (p.e.) to WWTPs

Table 9.1 Status of WWTPs in Sligo County in 2005

Plant	Design PE	House Count	Actual PE	% Difference
Aclare	200	62	217	9%
Ballinacarrow	250	47	165	-34%
Ballinafad	150	37	130	-14%
Ballintogher	200	76	266	33%
Ballisodare	575	466	1631	184%
Ballymote	3000	705	2468	-18%
Buninadden	80	45	158	97%
Carney	150	97	340	126%
Castlebaldwin	100	29	102	2%
Cliffoney	450	242	847	88%
Collooney	1400	416	1456	4%
Coolaney	250	88	308	23%
Culfadda	150	39	137	-9%
Curry	400	51	179	-55%
Dromore West	250	137	480	92%
Drumcliffe	150	20	70	-53%
Easkey	450	180	630	40%
Enniscrone	1400	779	2727	95%
Geevagh	250	24	84	-66%
Grange	280	165	578	106%
Gurteen	600	163	571	-5%
Monastraedan	400	34	119	-70%
Mullaghmore	320	373	1306	308%
Riverstown	600	131	459	-24%
Rockfields	Not available	18	63	Not available
Rosses Point	1500	428	1498	0%
Strandhill	1500	597	2090	39%
Tubbercurry	1400	667	2335	67%

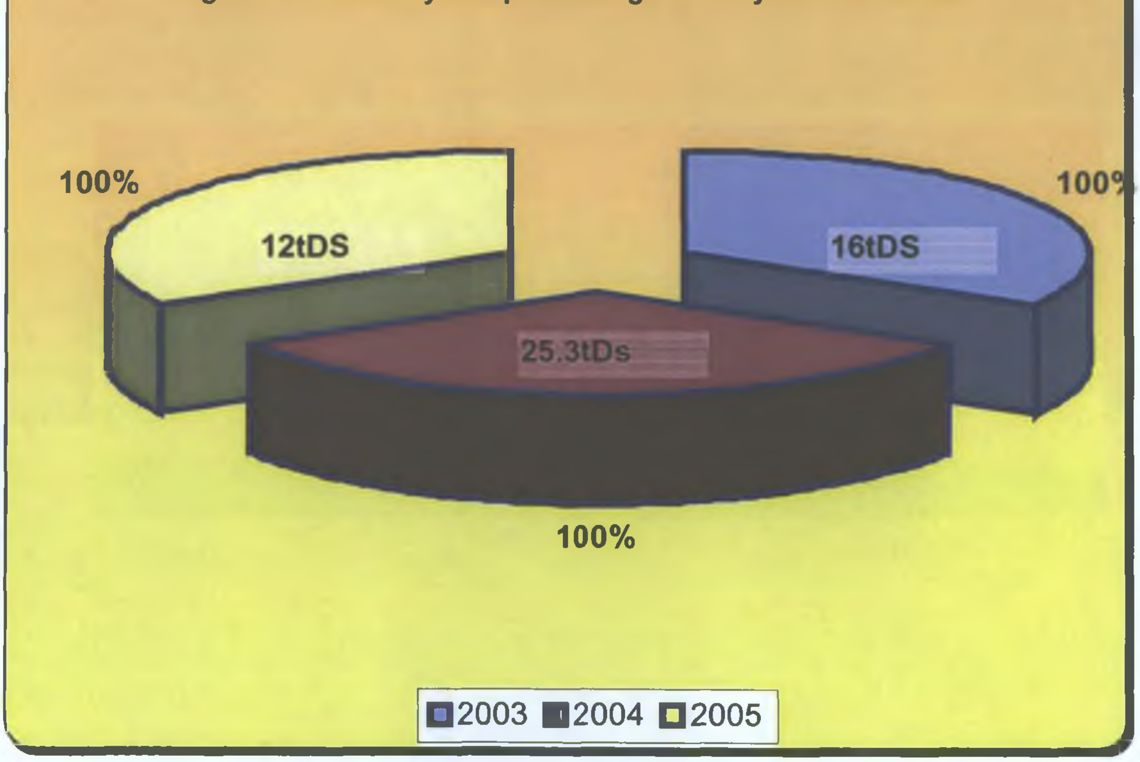
Type of indicator: Driving Force

Source of data: Local Authority

Comment: Various Regulations in Ireland require the provision of wastewater treatment plants depending on the size of the agglomeration and on the type of water body to which the wastewater is discharged. This indicator shows the designed and actual numerical count of domestic and commercial population equivalent (p.e.) to wastewater treatment plants in the County. According to the 2005 house count to determine the actual population in each agglomeration, 16 wastewater treatment plants (in red print, Table 9.1) out of the 28 were found to be serving population above their design capacity. However documents obtained for the Water Services Section show that Aclare, Ballinacarrow, Ballisodare, Carney, Enniscrone, Grange, Strandhill and Tubbercurry wastewater treatment plants are being upgraded. There is available data to test this indicator.

Indicator 18: Quantity and percentage of biosolids recycled

Figure 9.3 Quantity and percentage of recycled biosolids



Type of indicator: Response

Source of data: Local Authority

Comment: Available data and documents obtained for the Local Authority show that all treated sewage sludge from the County was recycled for the period 2003-2005 through land spreading. The contractors (Evergreen Fields Limited) corroborated this claim when contacted by the researcher. The Water Services Section keeps a record of all farm holdings and addresses where all treated sewage sludge from the County are spread.

Indicator 19: Quantity and percentage of biosolids sent to landfills

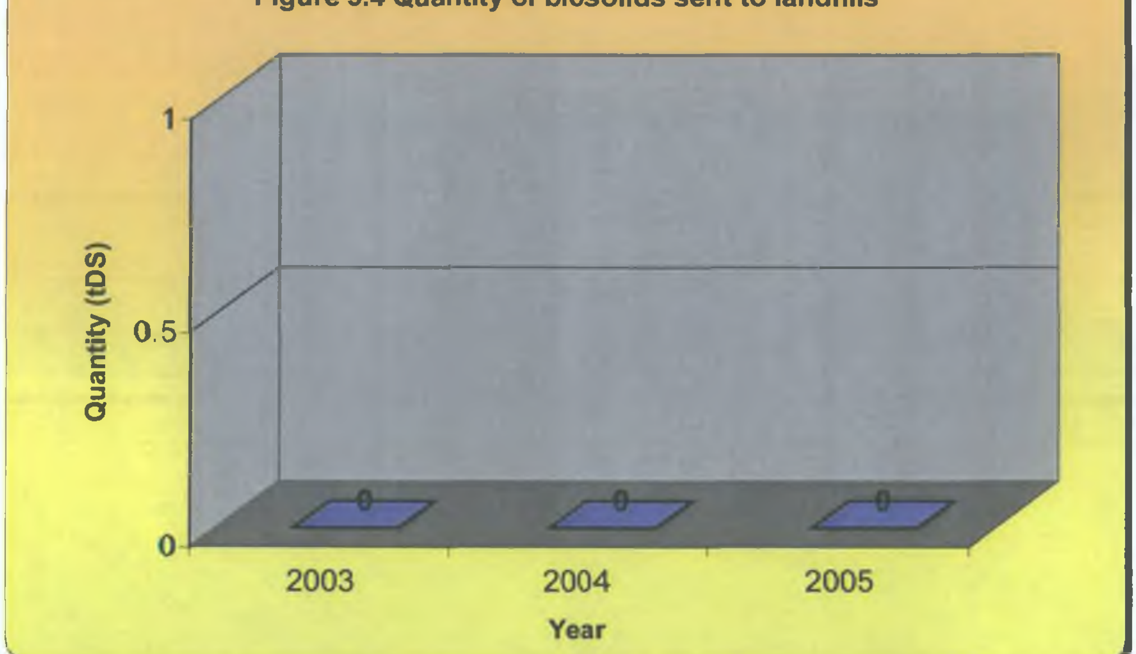


Figure 9.4 Quantity of biosolids sent to landfills

Type of indicator: Pressure

Source of data: Local Authority

Comment: The EU Landfill Directive 2000/53/EC stipulates the diversion of increasing amounts of organic and putrescible wastes from landfills. Coupled with urgent deficit in landfill capacity in most local authorities, the diversion of biosolids away from landfills is inevitable. Available data and documents show that County Sligo in is full compliance of this Directive. The indicator, therefore, shows that no biosolids arising from the Sligo County were landfilled for the period 2003-2005.

9.3.2 Core Indicator Set

Indicator 22: Register of biosolids reuse contractors

Table 9.2 Name and address of current contractors

Contractor	Address
Evergreen Fields Limited	Smyths Transport, Flaskaghmore, Dunmore, County Galway
Damien Wimsey	9 Hillcrest, Strandhill, County Sligo
Ormonde Organics	Ballinnalacken, Attanagh, via Portlaoise, County Kilkenny

Type of indicator: Response
Source of data: Local Authority
Comment: Local Authorities have a responsibility to treat and dispose of safely the resultant sewage sludge from wastewater treatment plants to comply with the Waste Management Act (Use of Sewage Sludge in Agriculture) Regulations, 1998, S.I. No. 148 of 1998 and the Waste Management Act (Use of Sewage Sludge in Agriculture)(Amendment) Regulations, 2001, S.I. No. 267 of 2001.

Sligo County Council have engaged contractors to facilitate compliance. However, it is the Local Authority that have ultimate responsibility for ensuring that all sludge handling complies with legislation. This indicator shows the number of qualified biosolids reuse contractors authorised to operate in the Local Authority. Evergreen Fields Limited are the major contractors with the responsibility of desludging all the wastewater treatment plants in the County. The other contractors provide lands for the spreading of the County's treated sewage sludge. Sligo County has not yet used Damien Wimsy Contractor's lands. Data is readily available to test this indicator.

Indicator 20: Quantities and percentage of biosolids recycled through various routes

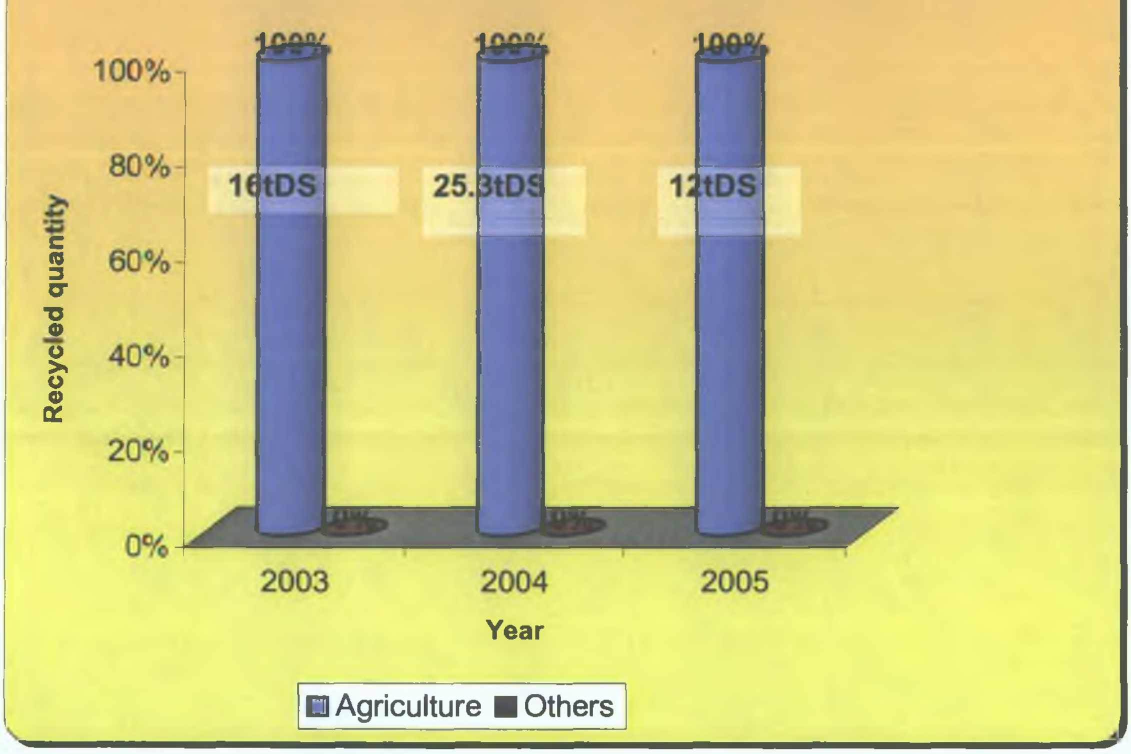


Figure 9.5 Biosolids recycled through various routes

Type of indicator: State

Source of data: Local Authority

Comment: Data used in testing this indicator show that within the period 2003-2005 all treated sewage sludge from the County were recycled through the agricultural route (land spreading). The *Code of Good Practice for the Use of Biosolids in Agriculture* and Sligo County's SMP require a Nutrient Management Plan (NMP) be carried out on the land prior to sludge spreading. Both documents require that the correct quantity of sludge be spread on the land according to the NMP. Other requirements by these documents include the testing of sludge for pathogen kill and soil for P and heavy metal content. The researcher could not obtain records of any recent tests. However, monthly reports for 2006 from Evergreen Fields Limited show that sludge analysis results are being awaited. The sustainability of the agricultural route for recycling biosolids is discussed in Section 10.3 of Chapter 10.

Indicator 6: Total and available Nitrogen and Phosphorus recycled

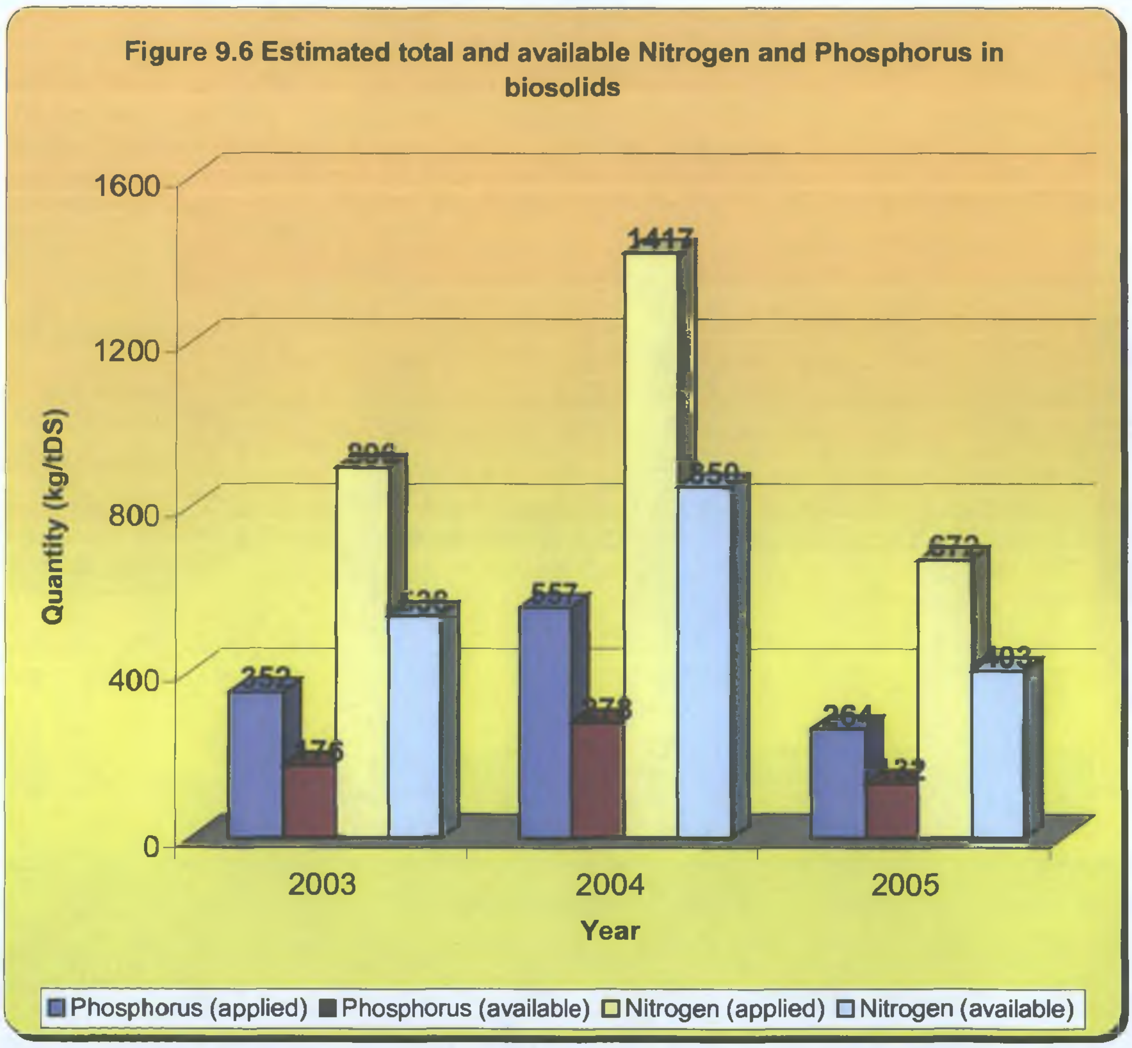


Figure 9.6 Estimated total and available Nitrogen and Phosphorus in biosolids

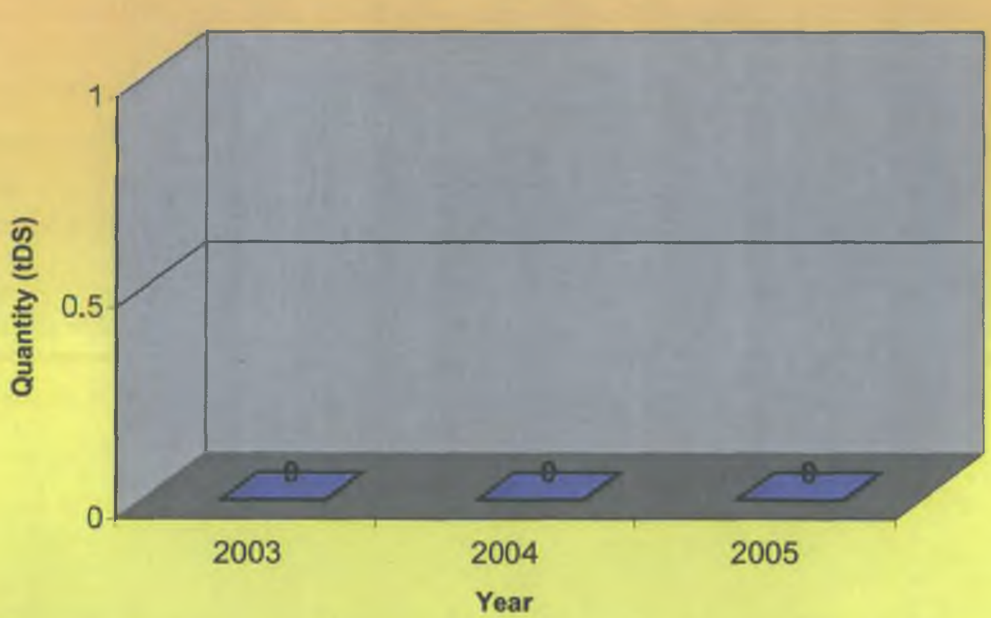
Type of indicator: Driving Force

Source of data: Local Authority

Comment: Biosolids are a source of nitrogen (N) and phosphorus (P) required for crop production. This indicator shows the estimated amount of P and N recycled through the reuse of biosolids in agriculture using the annual production figures (see Figure 9.1). There are no data for testing this indicator. However, since the total annual biosolids production is known (Figure 9.1), the levels of N and P are derived based on information from the *Code of Good Practice for the use of Biosolids in Agriculture*. Although N accounts for some 5.6% of the biosolids product, only 60% of this is actually available as a plant nutrient. Phosphorus accounts for an estimated 2.2% of the biosolids while only 50% of this is available as a plant nutrient.

Indicator 7: Quantity of biosolids not meeting stipulated quality standards

Figure 9.7 Quantity of biosolids not meeting stipulated standards



Type of indicator: Pressure

Source of data: Local Authority

Comment: This indicator is intended to measure percentage compliance with regulation over time in relation to biosolids quality requirements. It will also show quantities of biosolids failing quality requirements in relation to typical permissible levels for heavy metals and other contaminants as provided in regulations. Neither records available at the Sligo County Council offices nor EPA reports (2003 and 2005) identify any quantity of biosolids from the County failing stipulated quality standards. There was neither evidence of monitoring by the EPA on the County nor record to show that the County maintained any form of surveillance on its contractors.

Indicator 4: Access to sewerage

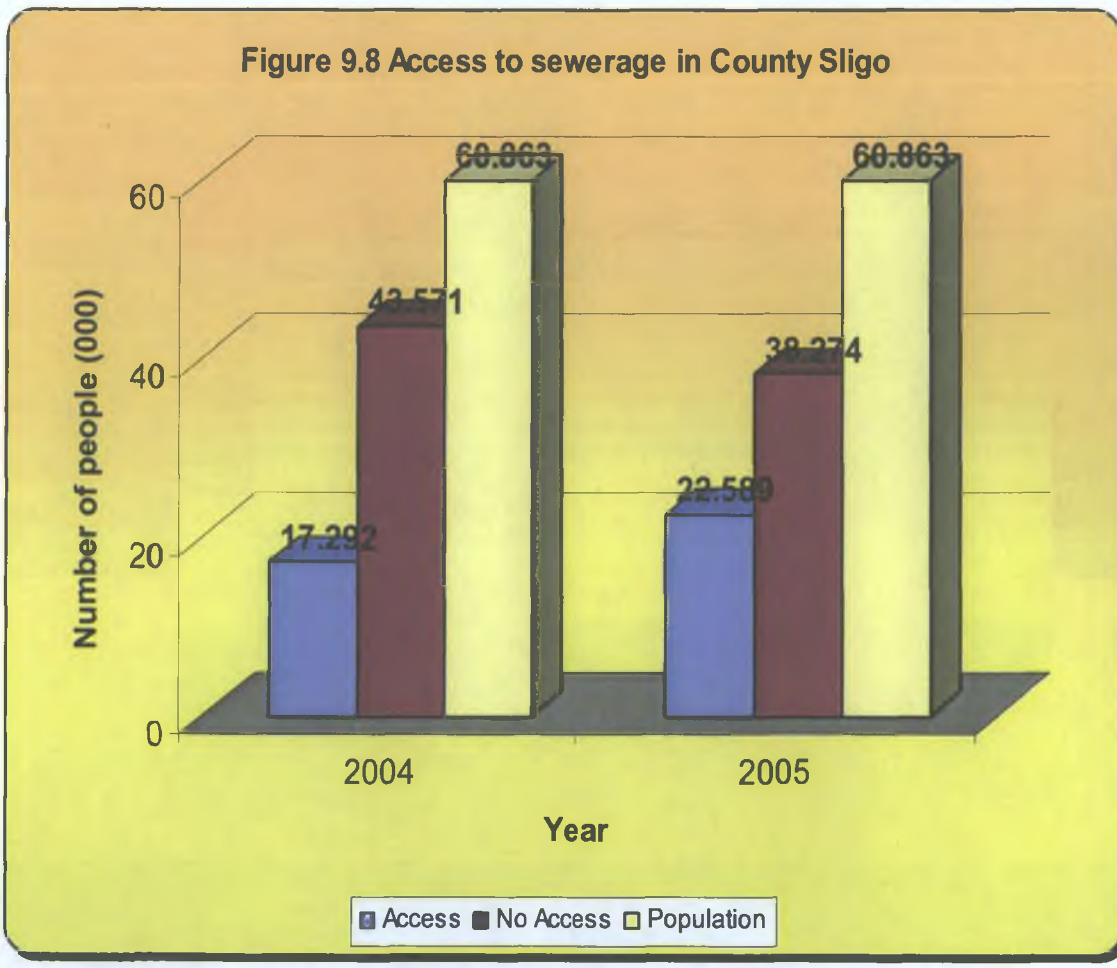


Figure 9.8 Access to sewerage in County Sligo

Type of indicator: Driving Force

Source of data: Local Authority

Comment: There is no readily available data to test this indicator. It was calculated normalising the house count figures for 2004 and 2005 (which approximate the population served by the County's wastewater treatment plants) against the 2006 census figures. This indicator shows the increment in 2004 and 2005 of access to central sewer systems (wastewater treatment plants) in the County. Taking population growth between 2002 and 2006 into consideration in deriving the indicator, the disparity between those with and without access is depicted in Figure 9.8. A little above 28% of the entire County Sligo inhabitants had access to sewerage in 2004 increasing to 37% in 2005. Conversely, as many as 43,571 residents or 71% in 2004, and 38,274 residents or 63% in 2005 have no access to sewerage and could be using stand-alone septic tanks. There are no records nationally or in the local authorities to account for the sewage sludge emanating from these septic tanks. As access to sewerage increases, the quantity of biosolids will be expected to increase.

Indicator 16: Information packs

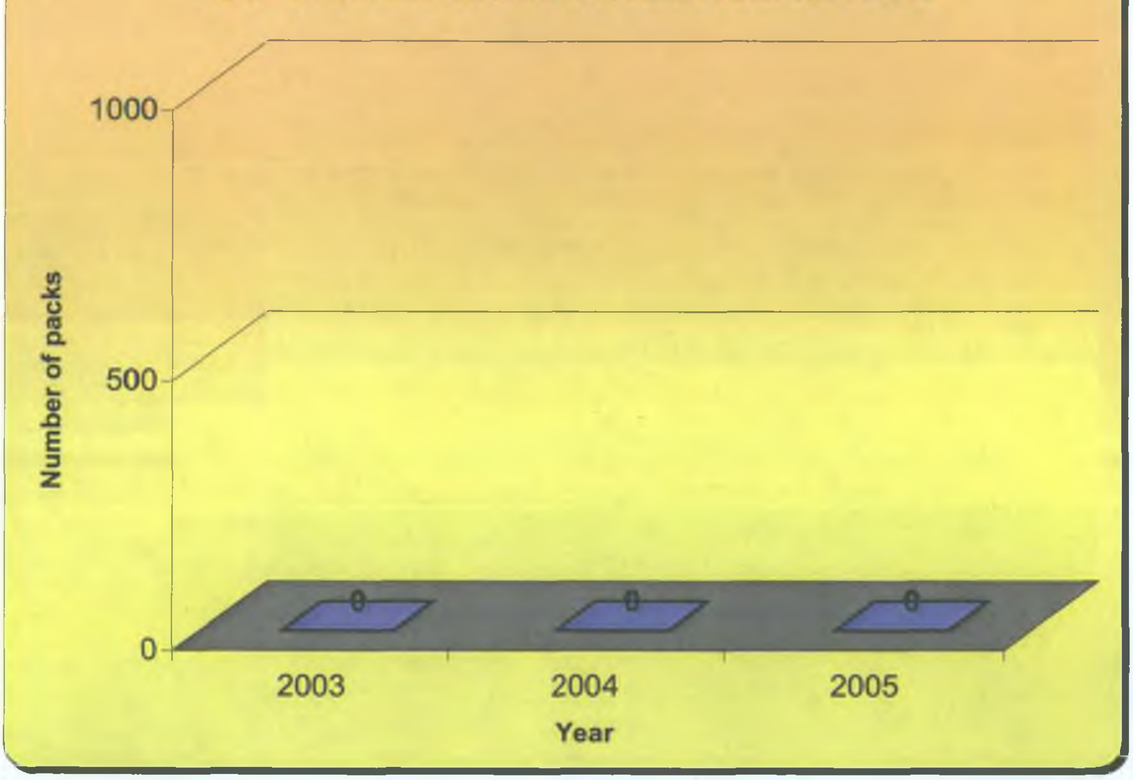


Figure 9.9 Information packs to promote biosolids reuse

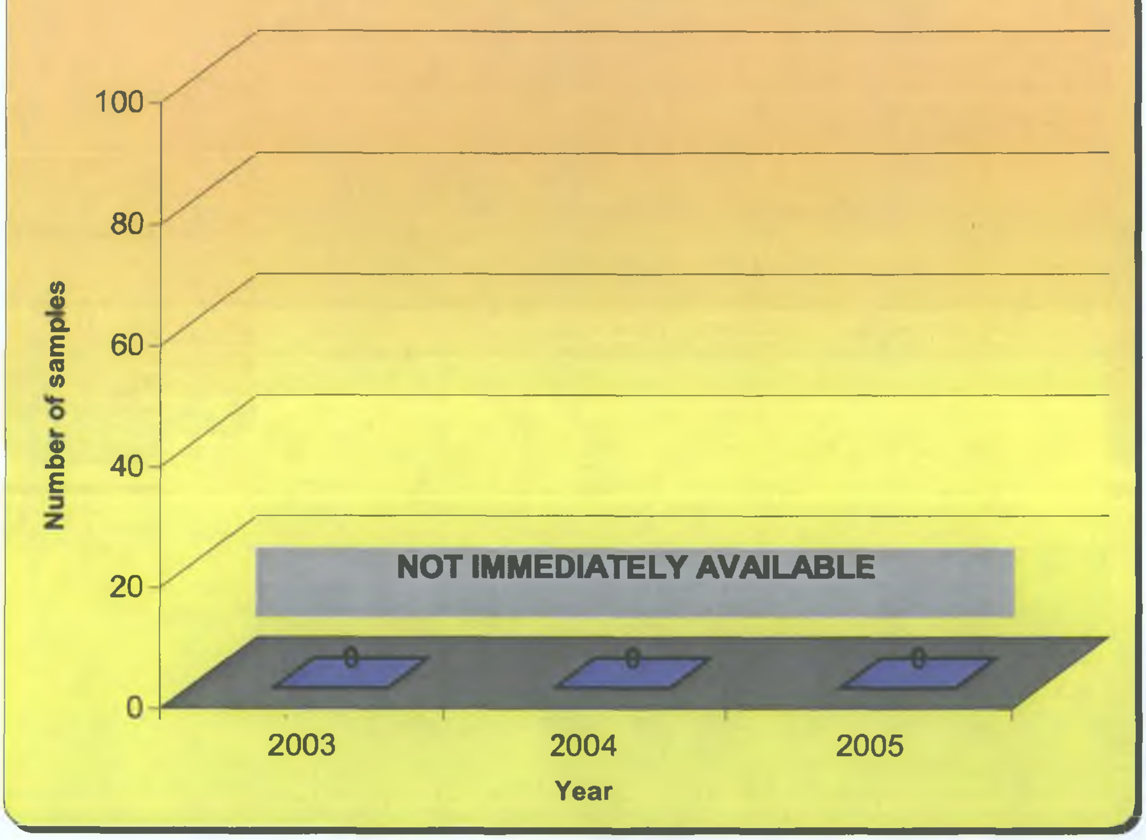
Type of Indicator: Response

Source of data: Local Authority

Comment: General goodwill towards the concept of beneficial use of biosolids can be mobilised provided procedures for managing the risks are in place, and the local community is well informed. Sligo County's SMP identifies the preparation and distribution of information packs to farmers, farming representative organisations, agricultural planners and advisers as a veritable avenue to inform the local community and stakeholders of the availability of a new and beneficial fertiliser. This indicator shows that no information packs has been produced or distributed over the period 2003 to 2005 or at any other times.

Indicator 8: Soil quality

Figure 9.10 Soil quality assessment of spread lands



Type of indicator: Impact

Source of data: Local Authority

Comment: The *Code of Good Practice for the Use of Biosolids in Agriculture* and Sligo County's SMP require that the levels of P and heavy metals in soils before and after application of biosolids be assessed to avoid adverse effects on soil, plant, animal or human health. The SMP has gone further to identify lands in the County that suitable for the land spreading of biosolids. However, County Sligo is presently a net exporter of untreated sewage sludge. The researcher was shown the Nutrient Management Plan and results of soil sample test prior to the use of the spread lands used by the County's contractors. Each farm or land receiving biosolids should be soil sampled and analysed in accordance with the *Teagasc Code of Practice for Soil Sampling.* It requires soils to be tested every 5 years for heavy metals and every 2 years for P, organic matter, pH, clay content and total potassium. There were no available reports of such field assessments of spread lands used by the County's contractors within the 2003-2005 period or for any other period.

9.3.3 Complementary Indicator Set

There are ten *Complementary Indicators* could not be tested due to lack of data. They include

- Comparative cost of biosolids production per tonne of dry matter;
- Catchments river/lake quality;
- Crop production;
- Enforcement notices;
- Stakeholder surveys;
- Training;
- Quantity of treated wastewater versus total quantity of wastewater generated per annum;
- Research funding;
- Estimated nutrient value of biosolids sent to landfills;
- Public complaints.

The description of these indicators and what they will measure are given in Chapter 8.

CHAPTER TEN
DISCUSSION

The researcher has successfully applied the headline and core set of indicators in Sligo County Council in a preliminary test. Not withstanding the comments made on each tested indicator in Section 9.3 of Chapter 9, it is still open to question whether the validity and reliability of the indicators can be assured. This chapter examines further the robustness of these indicators and the data used. It also evaluates the suitability, value and ease of determination of the headline and core set of indicators. Finally it outlines the strengths and weaknesses of the techniques used in this research, and the problems encountered.

10.1 The Set of Indicators

A significant result arising from the first stakeholder survey is that 81% of responding stakeholders find SDIs a veritable tool for managing biosolids. Findings emanating from this survey also indicate that though stakeholders have their varied interests, there is a good degree of convergence on the issues to be addressed (and information/action required) in order to achieve a sustainable biosolids management. Table 7.2 and Table 7.3 (in Chapter 7) show that there is enough agreement amongst stakeholders as to the need for a proactive and accountable method of managing biosolids. According to the survey results, a proactive biosolids management programme must include conducting scientific research into, and training on risks of biosolids recycling; improved information availability and accessibility; public participation in the biosolids' decision-making process; and improved legislation and regulation on biosolids management. It was based on these stakeholder expectations that the set of 22 SDIs for managing biosolids were formulated.

The set of SDIs emanating from this research study is developed along the expectation that it will contribute to a rational decision making process for the sustainable management of biosolids. From literature (Kuik and Verbruggen 1991, Bell and Morse 2001; Peterson 1997), there has been a worldwide attention to the generation and utilisation of information in the form of SDIs. These SDIs serve as yardsticks in tracking overall conditions towards the achievement of sustainable development. It is with this prospect that the current set of indicators for managing biosolids was developed.

10.1.1 Headline, core and complementary set of indicators: In developing the headline, core and complementary set of indicators, it was necessary for the researcher to take into consideration the final users of the SDIs namely, decision makers and the general public. Kuik and Verbruggen (1991) emphasise that a large set of SDIs will complicate understanding and communication of sustainable development issues among the end users. Therefore, Bell and Morse (2001) suggest that a way must be found to simplify information communicated by indicators. The most common approach, according to Moldan and Billharz (1997), is to aggregate different indicators into indices. However, they contend that aggregation can lead to a misrepresentation of the real overall picture of the issues. As an alternative, the researcher took a subjective decision to categorise the indicators into headline, core and complementary sets of indicators (see Section 8.3 of Chapter 8). Yuan et al (2003) acknowledge that this technique permits the richness of the draft set of indicators to be preserved whilst allowing more focused attention on those indicators (headline and core sets) perceived as important by the stakeholders.

According to the total scores from the ranking in Table 8.1, it is possible to observe that stakeholders participating in the selection process had scored some indicators higher than the others, using the given criteria. The headline indicators are a small set made up of the five highest-ranking SDIs perceived by stakeholders as being the most important (at least, in relative terms). These indicators give a broad overview of whether sustainable biosolids management is being achieved. It is interesting to note that all the five headline indicators are in relation to quantities of biosolids produced, recycled or disposed off (see Table 8.2). The recycling of resources is a pillar of sustainable development (Marmo

2000). However, whether these headline indicators represent sustainable biosolids management priorities or not depends on their relationship with any declared biosolids management sustainability objectives.

The core set contains the next seven highest-ranking indicators. These indicators highlight other key issues of sustainable management of biosolids including quality, nutrient recycling and public information. The complementary set (of ten indicators) contains most of the indicators linked to and allowing for the monitoring of the effectiveness of concrete and specific policy measures such as quality of catchments rivers and lakes in the proximity of biosolids application sites, research funding for improving biosolids management within a local authority, public complaints as a result of biosolids processing facilities and or reuse sites, training of farmers in the use of biosolids, and enforcement notices for non compliance of various biosolids processing and reuse regulations. In particular, the complementary set captures the correlation and combination of dimensions (economic/social/ environmental) not adequately reflected in the headline and core indicators. The ten complementary indicators when communicated in conjunction with the five headline and seven core indicators would give a more complete picture of sustainable biosolids management in a chosen area.

10.1.2 Ease of determination

The process of determining the headline and core set of indicators reported in this study was straightforward once data were obtained. However the quality of the data used is of some concern. This is discussed in Section 10.2. Data for testing indicators such as 'P and N recycling' and 'access to sewerage' required some degree of processing using formulae obtained from literature (see comments on Indicator 4 and Indicator 6, Section 9.3 of Chapter 9).

There was no data available to test the indicator 'soil quality where biosolids are applied'. Officials spoken to in Sligo County Council posited that it was the responsibility of the biosolids recycling contractors hired by the County Council to conduct such tests as prescribed in the *Teagasc Code of Practice for Soil Sampling*. This is further confirmed in the County's SMP. However, Sligo County Council have ultimate responsibility for the appropriate handling of its sludge. It is observed by the researcher, however, that there are Nutrient Management Plans for the lands where the treated sludge is spread.

10.1.3 Suitability of indicators

The indicators used in the pilot test in County Sligo appear to be useful and have practical application. The indicator 'domestic and commercial population equivalent of wastewater treatment plants' (Table 9.1) is already being used to determine which plants need to be upgraded. A house count is carried out annually by the County Council to determine the actual population equivalent of its wastewater treatment plants. This is compared to the design population equivalent and appropriate decisions are then made as to the adequacy of each plant to the population served.

Another indicator 'register of contractors involved in biosolids management' is also in place but in a different and more cumbersome format. A folder that contains contract documents of companies involved in biosolids management in the County and location of spread lands used by County Sligo contractors is maintained in the Water Services Section. The indicator simplifies the folder style of keeping information by using a tabular format (Table 9.2).

The 'annual biosolids production' indicator when tested was quick in detecting an obvious inconsistency with the data provided. The indicator shows that the quantity of biosolids produced in 2004 was 25.3 tDS and only 12 tDS in 2005 (Figure 9.1). This calls to question the way these figures are calculated particularly, when the house count in 2005 showed that most wastewater treatment plants were operating beyond design capacity (see Table 9.1). That the indicator is able to highlight this incongruity is an attestation to its sensitivity to changes in the system.

In order to provide a more complete picture of biosolids management in the County, the SDIs should be applied to biosolids management objectives of the local authority. This will require the setting of targets. Although there are officers assigned the responsibility of managing the wastewater treatment plants, there are no specific objectives or targets set for managing sewage sludge. In future when these targets are set, they could be quantitative, for example, 0% for quantity of biosolids sent to landfills, or 100% for recycling of P and N. It could also be in the form of directions, for example, as high as possible for quality of soil samples from land used for spreading biosolids. Since there will always be certain losses from the system, such targets are impossible to achieve. Sustainable management of biosolids is not necessarily about meeting targets, but more importantly, about moving towards sustainability. Hence, there is no disadvantage in setting targets that are difficult, or even impossible to attain, as long as they lead (the local authority or region) to sustainable biosolids management. However, short-term targets aimed towards long-term goals will make it easier to comprehend and communicate accomplishments to stakeholders.

The process of testing the headline and core indicators gained considerable support among the staff of the Sligo County Council involved in managing biosolids. They expressed the opinion that the indicators would be useful and wished to continue to be involved in monitoring the indicators in future, if time and resources are made available. They also agreed that the SDI set is an interesting instrument and requested that a copy of the finished product be made available to them.

Using the headline indicators together with the core and complementary sets could be an effective approach to influencing sustainable biosolids management policy. The headline, core and complementary indicators could also be used to effectively disseminate biosolids management information for public consumption. The categorisation of the indicators into headline, core and complementary indicators makes it more appealing to managers and policy makers who would not read reports that exceed a certain length.

10.1.4 Interpretation and value

One of the ways that the information presented through the indicators in this study could be used is to compare time series indicators from the same local authority. This could be used to show whether a local authority is becoming more sustainable in its management of biosolids with time. Tracking the performance of a local authority in time is likely to be the most appropriate use of these indicators.

A second way is to compare local authorities with similar biosolids management programmes to identify differences in management outcomes. This should be approached with a considerable degree of caution. In particular, it is important that a balanced view is taken when making such comparisons.

The third is to compare local authorities with different biosolids management programmes to identify advantages and disadvantages of the various programmes using the indicator set. Before any general statements about the sustainability of different biosolids management programme are made, it would be necessary to eliminate the effects of endogenous (such as soils and climate) and management factors. The elimination of endogenous effects from any comparison is crucial because Bengtsson et al (1997) argue, for example, that since the degree to which nutrients in biosolids can substitute for mineral fertiliser depends on several factors such as soil properties and spreading technique, the result of such comparison of indicators or data would be inconclusive.

The value of these indicators, however, relates to the long-term (biosolids management) sustainability goals of the local authorities. The SDIs developed and tested in this research study represent the start of a process. As local authorities gain experience in trying to use them, additional or revised indicators are likely to surface. Because of the diversity among the local authorities, the indicators are presented as a 'suite' to be used at each local authority's discretion according to its local realities (without undermining the accuracy, validity and usefulness of the indicators). The SDIs would also enable decision makers and the public to track the sustainability of a local authority's biosolids management programme into the future.

The EPA could use the indicators to support its already existing requirements for better assessment of sustainability of the biosolids management programme of various local authorities. These will include using the indicators to systematically anticipate the occurrence of events that may constitute important areas for research (for example, monitoring the extent of soil degradation/improvement where biosolids are spread), and to develop research plans for strategic issues of sustainable biosolids management. Such strategic issues include linkages between population growth/increased access to sewerage in the local authorities and biosolids management requirements/capabilities, and impact on land-use implementation (location of biosolids treatment facilities and re-use sites). Accordingly, more indicators may have to be developed or existing ones modified to account for these emerging issues.

10.1.5 Communicating indicators: County Sligo SMP recommends the use of information packs and public meetings to ensure support of biosolids management in the County. To try to solve the data-communication problem that may arise in such gathering, the researcher used diagrammatic charts and tabular formats to present the tested indicators. The use of these tools is to greatly accelerate both the speed and depth of readers' perception of the data relativities. This is shown in Section 9.3 of Chapter 9. The use of pie charts, line graphs and radial charts have the same benefits in perceptual depth and speed (Pastilles 2002). The tabular format should present some problem in this regard. Colour schemes are therefore, used to enhance the indicators' aesthetics and ability to capture the readers' attention. Red colour ordinarily, invokes a sense of danger. The use of red colour to highlight over-loaded wastewater treatment plants in Table 9.1 is simply to arouse curiosity and focus immediate attention on them. As stated in Section 10.1.5, it is necessary to review the presentation technique adopted in this study. This is to ensure that decision makers and the general public properly understand and accurately interpret the indicators.

10.1.6 Evaluation of tested indicators: The SDIs applied in County Sligo should have been evaluated by the participating stakeholders using a set of criteria including: security and reliability of data sources, data quality and quantity, data availability (how available, how long it took to evaluate and compile the data), data accessibility, representativeness, comparability, cost effectiveness, ease of determination and implementation of indicators, and their presentation.

Such a review is a significant part of any indicator development process. For example, all sewage sludge from County Sligo wastewater treatment plants are exported to other counties. While County Sligo could be referred to as a net exporter of sewage sludge, the receiving counties are net importers. There is currently no indicator to reflect this situation. A post-application evaluation of the current indicator set would be needed to either modify an existing indicator or develop a new one to capture this scenario.

However, there was no time to carry out this aspect of the study due to the delay in obtaining available data. This is a significant weakness in the study and is recommended in Chapter 11 for further research.

10.2 Data Collection

One of the key considerations in selecting a suite of indicators is the factor of data availability, as the success of any subsequent empirical analysis depends on the availability of good and appropriate data (Moldan & Billharz 1997). In this research study, data gathering techniques used are proffered in Chapter 6. The study did not however, limit the development of SDIs to just those for which data would be readily available, but instead to created a 'suite' of headline, core and complementary sets of indicators. This 'suite' of indicators provides an initial model of what a comprehensive set of indicators for biosolids management in a local authority/region would look like. It also provides an indication of what type of data to gather and or generate.

The initial objective of deriving most of the data required for testing the indicators from "sister projects" of the biosolids research programme was not possible. Because of the structure of these studies, most of the data contained in them were mainly point values recorded for a single period, rather than an accumulation of data in a time series.

10.2.1 Gaps in data: This study considers the identification of data gaps as important as identifying data availability. Experience gathered by the researcher during the course of testing the SDIs showed gaps and constraints associated with the nature of data available in Sligo County Council. While there were considerable amount of data to test the headline and core indicators, most of the data required for testing the complementary indicators were not readily available. There was complete absence of long-term data sets in relation to biosolids management that had been gathered with consistent monitoring protocols. Again, some available data were in format and units that required further processing to enable their use in the indicator testing process.

Due to the absence of a structured framework for data utilisation in the County Council, data gathering and storage are scattered in different sections of the local authority. Some members of staff remarked that if the SDIs were accepted as an official tool for managing biosolids in the County, time and resource would be needed for the collection and generation of relevant data. In light of the above constraints in obtaining relevant data, the testing of the SDIs was limited to the headline and core sets.

10.2.2 Reliability of data used: The EPA (2005) reported that Sligo County Council had sludge production figures of 169 tDS and 16 tDS for the years 2002 and 2003 respectively. With an increasing access to sewerage as shown in Figure 9.8, and an observed over-shooting of the design population equivalent of most wastewater treatment plants as shown in Table 9.1, it is very improbable that sludge production figures of the County could decrease by 153 tDS or one 1,056% in one year. Central to the theme of sustainable development is the task of making available pertinent information on sustainable development to facilitate the decision making process. Information does not itself make the process work, but without it, there will be significant impediments to planning and management, lack of reliable accountability, and consequent undermining of public understanding and cooperation.

The inability of the researcher to obtain accurate measurement of the total quantity of biosolids produced by Sligo County Council has compromised the accuracy of all those indicators that are subsequently based on the total annual biosolids production in the County. The integrity of the indicators and validity of the information they convey are dependent on the reliability and accuracy of available or generated data. The Local Authority have neither data quality assurance nor data quality control standards set to ensure scientific legitimacy.

10.3 Land Spreading of Biosolids

Sligo County is currently a net exporter of untreated sewage sludge (see comments on Indicator 3, Section 9.3.1 of Chapter 9). All untreated sludge from the County is taken to destinations outside of the County by the contracting firm

Evergreen Fields for storage and subsequent land spreading. The researcher was informed by the County staff that the choice to take untreated sludge out of the County is the contractor's. The County Sligo SMP has identified sites in County Sligo where biosolids could be land spread.

The main advantage with using biosolids on agricultural land is that it is a simple way of recovering P as well as other compounds of agricultural value. In this research study, only the benefits of recycling P and N were accounted for (see Figure 9.6).

However, there is a subtle consideration of a thermal drying facility (at the proposed new Sligo WWTP) for treating sewage sludge by engineering staff of the Sligo County Water Services Section over the mesophilic anaerobic digestion recommended in its SMP. The consideration is driven by the uncertainty of the long-term sustainability of the agricultural outlet, especially, whether the availability of suitable spreading sites will match anticipated upsurge in sludge production as a result of increasing access to central sewerage. The researcher was informed that the engineers are therefore, currently looking at alternative outlets other than land spreading for the County's treated sludge. They anticipate that the various advantages of thermally dried sludge product could provide a veritable alternative. These advantages include; the ease of storage and transportation, significant reduction in volume, possession of calorific value equivalent to brown coal, and use in horticulture.

10.4 Biosolids Regulation and Implementation

Figures 7.13 and 7.14 depict the views of stakeholders participating in this study on the adequacy of biosolids legislation and regulation, and their implementation respectively. Sixty two percent of respondents consider biosolids legislation and regulation inadequate, while 87% consider their current level of implementation as inadequate. From the discrepancies observed in the sludge production figures, it is fair to state that there is an inadequate system in Sligo County Council for monitoring and reporting sludge treatment, production and disposal. While there is a Water Services Section in the Local Authority, there are insinuations of lack of resources and appropriate training in relation to monitoring and controlling biosolids reuse to ensure compliance with regulations.

There is however, no evidence of public complaints to the Local Authority in relation to biosolids processing or reuse. Officers of the Water Services Section confirm receiving complaints with regard to overflow and smell emanating from a few wastewater treatment plants, but not from sludge use. With all the County's sewage sludge exported, it would be improbable to receive any related complaints within the County.

The Sligo County SMP recommends the use of public meetings to inform residents about biosolids reuse and availability. While the SMP emphasised the reuse of biosolids, it did not recommend using such forum for public accountability. There is complete absence of public accountability in relation to biosolids reuse in the County. This is not completely unexpected since all sludge from the County is exported. The danger in the prevailing situation is that it confers, falsely, a sense of sustainable biosolids management.

10.5 Stakeholder Participation

One of the most outstanding results from this study is the recognition of SDIs by key stakeholders as useful tool for managing biosolids (see Figure 7.27). Researchers such as Schelin et al (2003) call for involvement of the indicator users in the construction of SDIs in order to gain commitment, motivation and relevance. In this study, the stakeholder participatory approach enabled both the researcher and stakeholders to contribute important knowledge and experience. Following are the major motivations and constraints of this approach experienced during the course of this study.

10.5.1 Motivations: This study has illustrated that participation of stakeholders in the development of indicators for sustainable biosolids management has its advantages. First, the participatory approach captures a wealth of information from participants of varied background, knowledge, experience and perspectives (Campbell and Salagrama 1999). The results of the stakeholder survey and indicator selection consultation could be adjudged as holistic, descriptive, current, relevant and an accurate depiction of how the stakeholders perceive the management of biosolids. Because stakeholders participated voluntarily, it meant that financial costs are kept low. The information obtained from both stakeholder survey and indicator selection consultation can be described as 'hard' (backed up with facts and figures) and 'soft' (seen more as nuances). The indicator development process not only includes, but also equally values both types of information. A mix of 'hard' (quantitative) and 'soft' (qualitative) information in the data collection process is better suited to capture the multi-facet criteria of sustainable biosolids management.

A second motivation is that the participating stakeholders had the opportunity to ensure that their viewpoint is integrated in the process. For example, the stakeholders suggested the indicators for measuring soil quality, and a register of biosolids reuse contractors. The views of the stakeholders were of immense benefit to the research study. The suggestion of indicators by the stakeholders and their comments on some issues may have resulted in the development of overlapping candidate indicators that are difficult to measure (see Section 8.1 of Chapter 8). Measuring sustainable development, to say the least, is a daunting task. However, Byron (1991) contend that there could be little or no need at all to measure things that are easiest to quantify.

10.5.2 Constraints: Table 2.3 (Chapter 2) illustrates the challenges faced when stakeholders are involved in the development of indicators. This research study was no exception. Some of the stakeholders involved in this study lacked the capacity or expertise to contribute to all aspects of the study. In the design of the stakeholder survey, a 'don't know' option was included in all responses to accommodate this weakness. A constraint of voluntary stakeholder participation is the slow pace it introduces in the study. An iteration approach had to be adopted by the researcher to accommodate the time needs of the stakeholders. The researcher has also pointed out in the methodology that sampling technique used may have resulted in under-representation of the stakeholders (see Section 6.4.5). To minimise this, the survey questionnaires were made available on the IT Sligo's research website. They were also obtainable from some community libraries and ENFO to improve accessibility and achieve a wider reach.

Bell and Morse (2001) advance that both expert and stakeholder viewpoints are crucial to the indicator development process. However, the researcher recognises that stakeholder participation may introduce bias especially when the outcome of such a process is expected to influence decision making. In this study, therefore, the methodology and analysis of the survey result were designed to ensure an unbiased, critical, and fair input by the participating stakeholders.

10.6 Comparison with national and international initiatives

The development and selection of indicators for measuring progress towards sustainability in relation to biosolids management at the local/regional level should be mindful of similar activities locally, nationally and internationally. Chapter 3 of this thesis is used to review considerable number of literature as possible in relation to SDIs. While there is a gamut of indicator development initiatives worldwide (UNCSD 1996), the researcher was unable to obtain any similar specific study on SDIs for biosolids management. This situation meant that the results from this study could not be compared with similar ones internationally. Nationally and locally, there is presently no similar initiative in relation to biosolids. However, the published SMPs for various local authorities contain recommendations for the establishment of a database of research results to provide detailed information to farmers and other members of the public on:

- The performance of biosolids as a fertiliser;
- The long-term effects of biosolids in soils;
- The availability of nutrients in biosolids and in soils; and
- Any similar specific and/or scientific data which may be required.

This suggested database is to be used as part of a public information strategy to promote the benefits of biosolids reuse in agriculture/horticulture. How this 'detailed information' is to be presented to the farmers and general public is not defined. Moreover, the sustainable management of biosolids extends far beyond its use in agriculture/horticulture.

Notwithstanding this lack of direct local and international comparability, the SDIs resulting from this research have been developed following the internationally recognised DPSIR framework (reviewed in Section 3.7.3 of Chapter 3). This ensures that the indicators selected, while specific to local circumstances, do not deviate from international practice so much as to be worthless in an international context. In addition, the SDIs cover all key aspects of biosolids management.

CHAPTER ELEVEN
CONCLUSION AND RECOMMENDATIONS

The principal objective of this study is to develop and test (preliminarily) indicators for managing biosolids at the regional/local level. The main focus is to provide a framework for proactive and sustainable management of biosolids, through the provision of readily understandable information. Figure 6.1 in Chapter 6 depicts the research process adopted in this study. This chapter presents the synthesis, conclusion and recommendations arising from the study. It commences by summarising the major findings of the research. A table outlining data availability for the pilot testing of the indicators in Sligo County is presented. The chapter concludes with a set of recommendations and suggestions for future research.

11.1 Overall Outcomes

It was possible in this study to develop an indicator system that includes five headline, seven core and ten complementary indicators using a stakeholder participatory approach. Field application of the indicators in County Sligo has shown that a number of inferences could be drawn about their practicality and suitability for the sustainable management of biosolids. First, when a comprehensive assessment of a local authority's biosolids management programme is the target, the indicator set proved to be representative of the dimensions related to sustainable development namely; social, economic, environmental and institutional. Second, the ability of these indicators to map the sustainability of a local authority's biosolids management programme is apparent but need further thorough analysis, especially, over the parameters which define sustainable practices. This is imperative if plausible comparison of different or similar biosolids management programmes (based on information provided by the indicators) are to be made. Third, resulting from the need for public accountability in relation to biosolids management, local authorities will find this set of indicators a useful tool for evaluating and communicating existing situation, as well as progress made. Fourth, the indicator set provides a rational basis for making future relevant development decisions.

11.1.1 Methodology used: This research demonstrates the potential for using participatory approaches to gather qualitative and quantifiable information on the sustainability of a regional/local biosolids management programme. A methodology was adopted in which a stakeholder participatory approach was used to develop SDIs for managing biosolids at the regional/local level. Taking a stakeholder approach was an effective way of integrating a wide range of relevant aspects, actors and expertise into the study. Involving stakeholders made the study more transparent. Such approach also enhanced the researcher's ability to use a 'bottom-up' consultation process in the identification and selection of the SDIs.

While the methodology aimed to capture most key concerns with the sustainable management of biosolids as identified by the participating stakeholders, it was improbable to translate all the issues into indicators of sustainable development. Nevertheless, the resulting set of SDIs is quite comprehensive and suitable for local authorities that could afford the time and resources for its genuine implementation. The methodology could also be adapted to strengthen sustainability-oriented planning and decision-making (in relation to biosolids management at regional and local levels) through the creation and use of partnerships.

11.1.2 The indicator set: A set of 22 SDIs was developed and data were collected from Sligo County Council to quantify 12 of them (comprising of five headline and seven core indicators). The complementary indicators could not be quantified due to lack of data. The successfully applied indicators were used to gain insight on the sustainability and future trends of biosolids management in the County. The current situation for many indicators tested demonstrates that the County is not moving towards sustainability and immediate improvements are necessary to make its management of biosolids sustainable (see Section 11.2).

Table 11.1 List of SDIs indicating data availability in County Sligo

SDI	Typology	Management Domain	Data Availability
Category: Headline Indicators			
Total annual biosolids production (dry weight)	State	Production	Available but not reliable
Annual biosolids production (dry weight) by treatment processes	State	Production	Available
Domestic and commercial p.e of WWTPs	Driving Force	Production	Available
Quantity of biosolids recycled annually	Response	Disposal/Recycling	Available but not reliable
Quantity of biosolids sent to landfills annually	Pressure	Disposal/Recycling	Available
Category: Core Indicators			
Register of biosolids contractors	Response	Disposal/Recycling	Available
Quantity of biosolids recycled through various routes annually	State	Disposal/Recycling	Available
Phosphorus and Nitrogen recycling	Driving Force	Disposal/Recycling	Requires further processing
Annual quantity of biosolids not meeting stipulated quality standards	Pressure	Quality	Available but not reliable
Access to sewerage	Driving Force	Production	Available
Information packs	Response	Training/Research	Available
Soil quality	Impact	Quality	Not readily available
Category: Complementary Indicators			
Comparative cost of biosolids production processes per tonne of dry matter	Driving Force	Cost	Not available
Catchments river/lake quality	Impact	Quality	Not readily available
Crop production	Impact	Quality	Not readily available
Enforcement notices	Response	Legislation/Enforcement	Not readily available if any
Stakeholder surveys	Impact	Legislation/Enforcement	Not readily available if any
Training	Response	Training/Research	Not readily available if any
Quantity of treated wastewater versus quantity generated annually	Pressure	Production	Not readily available
Research funding	Response	Training/Research	Not readily available if any
Estimated nutrient value of biosolids sent to landfills	State	Disposal/Recycling	Not readily available
Public complaints	Impact	Disposal/Recycling	Not readily available

The ease of determination and usefulness of the SDIs varied. However, the study has shown that it is relatively straightforward to estimate the headline and core indicators. It is, nevertheless, debatable whether any valid comparison of information provided by the indicators can be made between different types of biosolids management programmes implemented by the various local authorities.

The pioneering nature of the study made it difficult to compare results with similar international SDI initiatives. However, the study provides an essential tool in the form of SDIs to assist local authorities assess their performance and make rational decisions in relation to sustainable biosolids management. With the right mix of support and appropriate strategies, the SDIs can play very significant roles in tracking the sustainability of local biosolids management programmes and providing bases for dealing with emerging priorities and ideas, and for building credibility amongst stakeholders. Spangenberg and Valentin (1999) assert that experience has shown that as a result, the quality of decisions and their implementation can be significantly improved.

11.1.3 Data availability: It is pertinent to emphasise that both questionnaire responses from stakeholders to formulate the candidate indicators, and data to quantify the selected SDIs were difficult to obtain. Although sustainable biosolids management is emerging as a formidable challenge to local authorities, low level of public interest and lack of data, especially at local scale is striking.

Since SDIs require data other than those gathered for classical statistics, the problem becomes dire. Most of the datasets available in County Sligo where the SDIs were tested lacked times series and reliability (see Table 11.1). It would have been preferable if all indicators were applied for the same year and also for several years in order to measure the changes through time.

The need for identification and systematisation of data by local authorities for sustainable biosolids management appears exigent. The researcher believes that the evolution of research on the field of SDIs for biosolids management will contribute to the improvement of the quality and quantity of data available.

11.2 Recommendations

There is presently no universal solution to the issue of biosolids management. However, any proposed solution must be appropriate to local conditions (Campbell 2000). The development, selection and testing of the SDIs has not proceeded without constraints, as can be appreciated from the foregoing. Following are some recommendations aimed at ameliorating the difficulties that have been discussed.

11.2.1 Revision and use of indicator set: The set of 22 SDIs is not to be regarded as a final set for managing biosolids, but as a product of this study. It is recommended that to sustain their relevance, this set will need to be continuously monitored and revised using some or all of the criteria listed in Section 10.1.6 of Chapter 10.

Additional or revised indicators may emerge from this process. It is strongly recommended that such a process be carried out using an evolutionary or gradual approach, with emphasis on an indicator-by-indicator mastering process. This is to avoid producing an unwieldy list of additional indicators. The approach if effectively utilised, can over time, lead to a significantly strengthened set of SDIs. A stakeholder approach in undertaking the revision is strongly recommended.

A detailed methodology note should accompany each headline, core and complementary indicator. Each note should include a brief definition of the particular indicator, the rationale for its inclusion, other organisations that use the indicator, data sources and availability, link with other indicators and issues. It should also outline which aspect of sustainability the indicator is relevant to.

Once the SDIs have been adopted and established by any local authority, it is suggested to integrate it into the biosolids management programme as an important tool for a continuous improvement process. It is further recommended that monitoring and publishing quantified indicators become a significant part of reviews of the SMPs of local authorities. Some of the published SMPs already contain a limited number of indicators for managing biosolids.

11.2.2 Data requirements: The paucity of available data was a fundamental issue in applying the indicators in County Sligo. Available data were not all in a readily useable format. They varied substantially in terms of their coverage, timeliness, regularity and consistency over time and level of aggregation. Some were simply not collected. The quality of available data was also of key concern. Local authorities should devote resources and time to the collection and retention of data in relation to their biosolids management programmes. Primary data from each wastewater treatment plant should be accurate and verifiable and retained distinctly after aggregation at county level. This will provide a fall back position when discrepancies arise as it is good practice to always have more than one source of data with same type of information. Data need to be collected over time to allow the identification of trends. Appendix H can be used as a template for designing data collection plan. It is further recommended that local authorities install data quality assurance or data quality control standards set to eliminate (and prevent) observed discrepancies, and ensure accuracy of the information provided through the SDIs. On the long-term, local authorities need to give consideration to the generation and collection of relevant data in relation to biosolids management. This will include the resources and methods of such data acquisition.

Data obtained from sludge disposal contractors hired by local authorities must be subjected to systematic scrutiny to ensure their accuracy. The 'systematic scrutiny' could take the form of periodic (preferably quarterly) and structured audit of the contractors. The audit elements must include the major aspects of biosolids management namely; sludge removal, transportation, destination, treatment, storage, and recycling/disposal. Local authorities should provide the contractors with generic formats for the collection and submission of data to ensure uniformity over time, and in situations where the services of more than one contractor are employed.

Data on issues such as number of odour and leak complaints made by the public in a given period are very important in biosolids management. The Sligo County have no register of complaints arising specifically from sludge handling activities. It is recommended that local authorities create a complaints register to log any complaints validated to be made in relation to biosolids management including traffic resulting from sludge transportation, odour from treatment facilities, storage, agricultural and non-agricultural use sites.

11.2.3 EPA surveillance: The EPA should consider the use of SDIs in managing biosolids at the local level. Local authorities should be encouraged to adapt and use these indicators as standard practice. It is recommended that the EPA include the application and monitoring of these indicators in their audits of local authorities. The utilisation of these SDIs by the EPA and the local authorities will provide a functional tool for facilitating effective decision making and communication in relation to sustainable biosolids management.

11.3 Further Research

The ideal set of indicators for the sustainable management of biosolids at local/regional level in Ireland will take time to emerge. The present set of indicators resulting from this study will need to be reviewed, modified and adjusted over time, or replaced as policy priorities and prevailing circumstances change.

There is a need for more research on the relationship between information communicated through the indicators and the sustainability of various biosolids management programmes in the local authorities, when comparisons are to be made. This is informed by the fact that what may be considered a sustainable practice in one county may not be sustainable in the other.

The generation of data for testing of the complementary set of indicators, and the post-application evaluation of the headline and core indicators merit further consideration.

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Appendix A

The Bellagio Principles (IISD 1997)

1. Guiding vision and goal
Assessment of progress towards sustainable development should be guided by a clear vision of sustainable development and goals that define that vision.

2. Holistic perspective
Assessment of progress towards sustainable development should:
- include a review of the whole system as well as its parts
- consider the wellbeing of social, ecological and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts
- consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms

3. Essential elements
Assessment of progress toward sustainable development should:
- consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate
- consider the ecological conditions on which life depends
- consider economic development and other, non-market activities that contribute to human/social wellbeing

4. Adequate scope
Assessment of progress toward sustainable development should:
- adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short term decision- making
- define the space of study large enough to include not only local but also long distance impacts on people and ecosystems
- build on historic and current conditions to anticipate future conditions: where we want to go, where we could go

5. Practical focus
Assessment of progress toward sustainable development should be based on:
- an explicit set of categories or an organising framework that links vision and goals to indicators and assessment criteria
- a limited number of key issues for analysis
- a limited number of indicators or indicator combinations to provide a clearer signal of progress
- standardising measurement wherever possible to permit comparison
- comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate

6. Openness
Assessment of progress toward sustainable development should:
- make the methods and data that are used accessible to all
- make explicit all judgements, assumptions, and uncertainties in data and interpretations

7. Effective communications
Assessment of progress towards sustainable development should:
- be designed to address the needs of the audience and set of users
- draw from indicators and other tools that are stimulating and serve to engage decision-makers
- aim, from the outset for simplicity in structure and use of clear and plain language

8. Broad participation
Assessment of progress toward sustainable development should:
- obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women. and indigenous people to ensure recognition of diverse and changing values
- ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action

9. Ongoing assessment
Assessment of progress toward sustainable development should:
- develop a capacity for repeated measurement to determine trends
- be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently
- adjust goals, frameworks, and indicators as new insights are gained
- promote development of collective learning and feedback to decision-making

10. Institutional capacity
Continuity of assessing progress toward sustainable development should be assured by:
- clearly assigning responsibility and providing ongoing support in the decision-making process
- providing institutional capacity for data collection, maintenance, and documentation
- supporting development of local assessment capacity

Appendix B

EU Legislation on Biosolids Management

- Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sludge is used in agriculture, O.J. (Official Journal) No. L181, 04/07/1986, p.6;
- Council Directive 91/271/EEC amending Directive 75/442/EEC on waste, O.J. No. L135, 30/05/1991 p. 40 – 52;
- Waste Framework Directive 91/156/EEC amending Directive 75/442/EEC on waste, O.J. No. L78, 26/03/1991, p.32;
- Directive 75/442/EEC on waste, O.J. No. L194, 25/07/1975, p.47;
- Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, O.J. No. L375, 31/12/1991, p. 1 – 8;
- Commission Decision establishing the ecological criteria for the award of the Community ecolabel to soil improvers (98/488/EC) O.J. No. L219, 1988
- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, O.J. No. L182, 16/07/1999, p. 1 – 19;
- Council Directive 2000/76/EC of 4 December 2000 on the incineration of waste, O.J. No. L332, 28/12/2000, p. 91;
- Commission Decision 2001/118/EC, O.J. No. L047, 16/02/2001, p. 1 – 31;
- Commission Decision 2000/532/EC, O.J. No. L226, 06/09/2000, p. 3 – 4.

Additional documents:

- Report from the Commission to the Council and the European Parliament on the implementation of Community waste legislation Directive 75/442/EEC on waste, Directive 91/689/EEC on hazardous waste, Directive 75/439/EEC on waste oils and Directive 86/278/EEC on sewage sludge for the period 1995 – 1997, COM (1999) 752(01);
- Report from the Commission concerning the implementation of Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment, as amended by Commission Directive 98/15/EC of 27

February 1998 – summary of the measures implemented by Member States and assessment of the information received pursuant to Articles 17 and 13 of the Directive, COM (1998) 775;

- Communication on the review of the Community strategy for waste management, COM(96) 399, 30/07/1996.

Appendix C1

Questionnaire for Unaffiliated Individuals

SLIGEAC

Centre for Sustainability, Institute of Technology, Ballinode, Sligo

Developing and Testing of Sustainable Development Indicators for Biosolids Management at Local / Regional Level

Biosolids Stakeholder Survey

Confidentiality

The information given in response to this questionnaire will be treated as confidential. It will not be released to the public and will not appear in any of the reports from this project. Reference will only be made to the Centre for Sustainability, IT Sligo.

HEA

Higher Education Authority
An tÚdarás um Ard-Oideachas

Brief Description: Biosolids, also known as treated sewage sludge, are the by-product left behind after water is separated from wastewater in wastewater treatment plants. It is high in organic content and plant nutrients and, in theory, makes good fertiliser. However, most countries including Ireland regulate its use to ensure that adequate quality standards are met, and environmental integrity maintained within economic reason.

We are distributing this questionnaire to various interested people. Tick the box most appropriate to you:

☐ A member of the general community ☐ Farmer

☐ Landowner ☐ Food retailer

☐ Others (specify). ....

1. **Biosolids are sewage sludge treated to be safe. I knew this already.**

   Yes ☐ No ☐

2. **Have you heard of the following recommended treatment processes for biosolids production? Please tick the appropriate box.**

Anaerobic digestion	Yes	☐	No	☐
Aerobic digestion	Yes	☐	No	☐
Composting	Yes	☐	No	☐
Lime treatment	Yes	☐	No	☐
Thermal drying	Yes	☐	No	☐

3. **In Ireland, 51 per cent of sewage sludge is presently spread on agricultural land. Do you think this a good idea?**

   Yes ☐

   No ☐

   Don't know ☐

4. **In Ireland, about 33 million tonnes of untreated vegetable and animal wastes are spread on land. Do you think this is a good idea?**

   Yes ☐

   No ☐

   Don't know ☐

5. **Do you think untreated waste from the following industries should be spread on agricultural land?**

Industry	Yes	No	Don't know
Abattoirs			
Dairy processing			
Sugar processing			
Leather and tannery			
Pharmaceutical			

6. **Do you think there are any problems with the following methods of getting rid of biosolids? Please tick (✔).**

	Yes	No	Don't know
Put in dumps	☐	☐	☐
Use on agricultural land	☐	☐	☐
Use in other green areas with high public access (e.g. golf courses)	☐	☐	☐
Use in other green areas with low public access (e.g. motorway verges)	☐	☐	☐
Incineration	☐	☐	☐
Covering ugly industrial sites....................	☐	☐	☐
Use in forestry	☐	☐	☐
Others (please specify)	☐	☐	☐

7. **Here are some possible concerns in getting rid of biosolids. Tick a box to show how serious you think each one is.**
(**5** = most serious, **4** = more serious, **3** = serious, **2** = less serious, **1** = not serious)

Possible Problems	**5**	**4**	**3**	**2**	**1**	**Don't know**
Need for protection of clean air, water and soil						
Damage to human health						
Damage to animal health						
Damage to plants and crops						
High cost to tax payers						
Bad smells						
Not being able to find out who is responsible if a problem occurs						
Nobody would want to use biosolids						
Possible poisons in biosolids						
Problems if we don't reuse biosolids						
Fear of loss of property and land value due to biosolids use						
Possible problems for people living close to biosolids storage and processing sites						
Others that you can think of...						

8. **Here are some possible ways to reduce bad effects of the concerns identified in Question No 7. Tick a box to show how useful you think they would be.**
(**5** = most useful, **4** = more useful, **3** = useful, **2** = less useful, **1** = not useful)

Information / action	5	4	3	2	1	Don't know
Scientific studies to learn more about the risks in spreading biosolids on land						
Development of tests to ensure that there is little risk to humans and animals from biosolids						
Clear information available to everybody						
Establish clearly who is responsible if there is an accident or a problem						
Make rules to prevent use of biosolids if poisons are present						
Written instructions on safety						
Improved information to consumers on the safe use of biosolids						
Better training for farmers and landowners on use of biosolids						
Improved information to farmers						
Taking everybody's view into account						
Compensation for people badly affected by accidents in use of biosolids						
Others that you can think of…						

9. **Are you familiar with the idea of 'sustainable development'?**

Very familiar ☐
Familiar ☐
Not familiar ☐

10. **Are you familiar with 'sustainable development indicators' (SDIs)?**

Very familiar ☐
Familiar ☐
Not familiar ☐

11. Please add any additional ideas and opinions in this box

Comment

It would help us a lot if you were able to give us more information on your views, and hear the views of others.

a) Would you come to a meeting to discuss your views in more details?

Yes ☐ No ☐

If yes,

b) Which of these days suits you most?

Friday☐ Saturday☐

c) Where will be your preferred location for such meetings? List three locations in order of preference:

First preference..

Second preference ....

Third preference ....

d) What time of the day suits you most for the meetings?

Morning (10 am to 12 noon) ☐

Afternoon (2 pm to 4pm) ☐

Evening (5 pm to 8 pm) ☐

We would like to contact you when we have arranged meetings. If you wish to be told about these meetings, please PRINT name/address/telephone number/email in the box provided

Name...

Address...

....

Telephone (Home/Mobile)...

Email ....

Thanks for your time and cooperation

Please return completed questionnaires to

Magnus Amajirionwu
Centre for Sustainability
Institute of Technology
Ballinode, Sligo
Tel: 071 915 5414 Fax: 071 914 4500
e-mail: Amajirionwu.Magnus@itsligo.ie

Appendix C2
Questionnaire for Regulatory Agencies

Centre for Sustainability, Institute of Technology, Ballinode, Sligo

Developing and Testing of Sustainable Development Indicators for Biosolids Management at Local / Regional Level

Biosolids Stakeholder Survey

Confidentiality

The information given in response to this questionnaire will be treated as confidential. It will not be released to the public and will not appear in any of the reports from this project. Reference will only be made to the Centre for Sustainability, IT Sligo.

Brief Description: Biosolids, also known as treated sewage sludge, are the by-product left behind after water is separated from wastewater in wastewater treatment plants. It is high in organic content and plant nutrients and, in theory, makes good fertiliser. However, most countries including Ireland regulate its use to ensure that adequate quality standards are met, and environmental integrity maintained within economic reason.

Name of Respondent. ....

Job Title ....

Contact Address. ....

Email. ....

Telephone..**Fax**..

1. Is there a Biosolids Management Plan in your Local Authority Area?

- Yes ☐
- No ☐
- Don't know ☐

(If 'yes' please enclose a copy when returning your response to this questionnaire)

2. If 'yes', was the Plan subject to any form of formal public consultation? Please check (✔).

- Public participated during development of plan ☐
- Plan was presented at public meetings ☐
- Plan was subject to Environmental Assessment ☐
- Others, please specify.................................. ☐
- None ☐

3. Is there a biosolids processing facility in your Local Authority Area?

- Yes ☐
- No ☐
- Don't know ☐

If 'yes', please state type(s) and capacity: ....

....

....

....

....

If answer to Question 1 to 3 is 'no', please go to Question No. 7

4. **What principal mode of transport is used to deliver the biosolids to the end-use/disposal site?** ☐ **Road** ☐ **Rail** ☐ **Water**

5. **What is the approximate average distance from the biosolids facility to the disposal or reuse sites?**

....

6. **Please indicate below whether or not your Local Authority biosolids facility accepts sludge from the following industries?**

Industry	Yes	No	Don't know
Abattoirs			
Dairy processing			
Sugar processing			
Leather and tannery			
Pharmaceutical			

7. **The following issues have been raised in relation to biosolids. Please indicate the level of importance your Local Authority attach to each of them.** (**5** = most important, **4** = more important, **3** = important, **2** = less important, **1** = not important)

Possible concerns	5	4	3	2	1	Don't know
Need for protection of clean air, water and soil						
Damage to human health						
Damage to animal health						
Damage to plants and crops						
High cost to tax payers						
Objectionable smells (odour)						
Not being able to find out who is responsible if a problem occurs						
Nobody would want to use biosolids						
Possible poisons in biosolids						
Problems if we don't reuse biosolids						
Fear of loss of property and land value due to biosolids use						
Possible problems for people living close to biosolids storage and processing sites						

Possible concerns *(contd)*	5	4	3	2	1	Don't know
Others that you can think of...						
Others (contd)						

8. **Some possible ways of reducing the effects of the issues identified in Question No 7 are presented below. Tick a box to show how useful your Local Authority think they would be.** (**5** = most important, **4** = more important, **3** = important, **2** = less important, **1** = not important)

Information / action	5	4	3	2	1	Don't know
Scientific studies to learn more about the risks in spreading biosolids on land						
Development of tests to ensure that there is little risk to humans and animals from biosolids						
Clear information available to everybody						
Establish clearly who is responsible if there is an accident or a problem						
Make rules to prevent use of biosolids if poisons are present						
Written instructions on safety						
Improved information to consumers on the safe use of biosolids						
Better training for farmers and landowners on use of biosolids						
Improved information to farmers						
Taking everybody's view into account						
Compensation for people badly affected by accidents in use of biosolids						
Others that you can think of...						

9. **Is your Local Authority familiar with the idea of 'sustainable development indicators' (SDIs)?**

Very familiar ☐
Familiar ☐
Not familiar ☐

10. If yes, does your Local Authority consider sustainable development indicators as useful tools for biosolids management?

Very useful ☐
Useful ☐
Not useful ☐
Don't know ☐

11. If yes, please suggest some specific indicators that should be developed to address the concerns in relation to the disposal and recycling of biosolids.

Suggested Indicator Title	Issue Addressed	Suggested source(s) of Information/data	Brief Definition

12. Please add any additional ideas and opinions in this box considered relevant to this study.

It would help us a lot if your Local Authority were able to give us more information on your views, and hear the views of others.

a) Would your Local Authority be prepared to send representative(s) to attend stakeholder meetings to discuss the findings of this survey and the draft set of indicators?

Yes ☐ No ☐

b) If 'yes' which of these days suits your Local Authority most?

Friday☐ Saturday☐

c) Where is your Local Authority's preferred location for such meetings? List three locations in order of preference:

First preference...

Second preference ....

Third preference ....

d) What time of the day will suit your Local Authority most for the meetings?

Morning (10 am to 12 noon) ☐

Afternoon (2 pm to 4pm) ☐

Evening (5 pm to 8 pm) ☐

We will contact you when we have arranged meetings.

Thanks for your time and cooperation

Please return completed questionnaires to

Magnus Amajirionwu
Centre for Sustainability
Institute of Technology
Ballinode, Sligo
Tel: 071 915 5414 Fax: 071 914 4500
e-mail: Amajirionwu.Magnus@itsligo.ie

Appendix C3

Questionnaire for Organisations

SLIGEAC

Centre for Sustainability, Institute of Technology, Ballinode, Sligo

Developing and Testing of Sustainable Development Indicators for Biosolids Management at Local / Regional Level

Biosolids Stakeholder Survey

Confidentiality

The information given in response to this questionnaire will be treated as confidential. It will not be released to the public and will not appear in any of the reports from this project. Reference will only be made to the Centre for Sustainability, IT Sligo.

HEA

Higher Education Authority
An tÚdarás um Ard-Oideachas

Brief Description: Biosolids, also known as treated sewage sludge, are the by-product left behind after water is separated from wastewater in wastewater treatment plants. It is high in organic content and plant nutrients and, in theory, makes good fertiliser. However, most countries including Ireland regulate its use to ensure that adequate quality standards are met, and environmental integrity maintained within economic reason.

Name of Organization ....

Contact Address. ....

Email. ....

Name of Respondent ....

Job Title ....

Telephone..**Fax**..

We are distributing this questionnaire to various interested organisations. Tick the box(es) most appropriate to your organisation:

☐ Farming organisation ☐ Environmental NGO

☐ State organisation with environmental responsibilities

☐ Food manufacturer ☐ Food retail

☐ Community based organisation ☐ Sporting organisation

☐ Community/town association ☐ Media

☐ Insurance company ☐ Waste management company

☐ Others (specify). ....

1. **Biosolids are sewage sludge that has been treated (or stabilized) to allow beneficial reuse in farming and other non-agricultural activities. Did your organisation know this?**

   Yes ☐

   No ☐

2. **Has your organisation heard of the following recommended treatment processes for biosolids production? Please tick the appropriate box.**

Anaerobic digestion	Yes	☐	No	☐
Aerobic digestion	Yes	☐	No	☐
Composting	Yes	☐	No	☐
Lime treatment	Yes	☐	No	☐

Thermal drying Yes ☐ No ☐

3. **In Ireland, 51 per cent of sewage sludge is presently spread on agricultural land. Does your organisation consider this a good idea?**

Yes ☐

No ☐

Don't know ☐

4. **In Ireland, about 33 million tonnes of untreated vegetable and animal wastes are spread on land. Does your organisation think this is a good idea?**

Yes ☐

No ☐

Don't know ☐

5. **Does your organisation think untreated waste from the following industries should be spread on agricultural land?**

Industry	Yes	No	Don't know
Abattoirs			
Dairy processing			
Sugar processing			
Leather and tannery			
Pharmaceutical			

6. **Does your organisation have any concerns with the following disposal and recycling routes for biosolids: Please tick (✓).**

	Yes	No	Don't know
Disposal to landfill	☐	☐	☐
Use on agricultural land	☐	☐	☐
Use in other green areas with high public access (e.g. golf courses)	☐	☐	☐
Use in other green areas with low public access (e.g. motorway verges)	☐	☐	☐
Incineration	☐	☐	☐
Land reclamation (e.g. disused mine sites)	☐	☐	☐

Use in forestry	☐	☐	☐
Others (please specify)....................................	☐	☐	☐

7. **The following issues have been raised in relation to the use of biosolids. Tick a box to show how serious your organisation thinks each one is.**
(**5** = most serious, **4** = more serious, **3** = serious, **2** = less serious, **1** = not serious)

Possible Problems	5	4	3	2	1	Don't know
Need for protection of clean air, water and soil						
Damage to human health						
Damage to animal health						
Damage to plants and crops						
High cost to tax payers						
Objectionable smells (odour)						
Not being able to find out who is responsible if a problem occurs						
Nobody would want to use biosolids						
Possible poisons in biosolids						
Problems if we don't reuse biosolids						
Fear of loss of property and land value due to biosolids use						
Possible problems for people living close to biosolids storage and processing sites						
Others that you can think of...						

8. **Some possible ways of reducing the effects of the concerns identified in Question No 7 are presented below. Tick a box to show how useful your organisation thinks they would be.**
(**5** = most useful, **4** = more useful, **3** = useful, **2** = less useful, **1** = not useful)

Information / action	5	4	3	2	1	Don't know
Scientific studies to learn more about the risks in spreading biosolids on land						
Development of tests to ensure that there is little risk to humans and animals from biosolids						
Clear information available to everybody						
Establish clearly who is responsible if there is an accident or a problem						
Make rules to prevent use of biosolids if poisons are present						
Written instructions on safety						
Improved information to consumers on the safe use of biosolids						
Better training for farmers and landowners on use of biosolids						
Improved information to farmers						
Taking everybody's view into account						
Compensation for people badly affected by accidents in use of biosolids						
Others that you can think of…						

9. **Does your organisation consider the present *regulations/legislations* in respect of biosolids management adequate?**

Very adequate ☐

Adequate ☐

Not adequate ☐

Don't know ☐

10. **Does your organisation consider the current level of *implementation* of regulations/legislations in respect of biosolids management adequate?**

Very adequate ☐
Adequate ☐
Not adequate ☐
Don't know ☐

11. **How familiar is your organisation with the idea of 'sustainable development'?**

Very familiar ☐
Familiar ☐
Not familiar ☐

12. **Does your organisation consider sustainable development indicators useful as a tool for the management of biosolids?**

Very useful ☐
Useful ☐
Not useful ☐
Don't know ☐

13. **If useful, does your organisation have any indicators in mind that should be developed to address its concerns on the disposal and recycling of biosolids?**

Suggested Indicator Title	Issue Addressed	Suggested source(s) of Information/data	Brief Definition

14. Please add any additional ideas and opinions in this box

Comment

It would help us a lot if you were able to give us more information on your views, and hear the views of others.

a) Would your organisation be prepared to attend stakeholder meetings to discuss the findings of this survey and the draft set of indicators?

Yes ☐ No ☐

b) If 'yes' which of these days suits your organisation most?

Friday☐ Saturday☐

c) Where is your organisation's preferred location for such meetings? List three locations in order of preference:

First preference..

Second preference ....

Third preference ....

d) What time of the day will suit your organisation most for the meetings?

Morning (10 am to 12 noon) ☐

Afternoon (2 pm to 4pm) ☐

Evening (5 pm to 8 pm) ☐

We will contact you when we have arranged meetings.

Thanks for your time and cooperation

Please return completed questionnaires to

Magnus Amajirionwu
Centre for Sustainability
Institute of Technology
Ballinode, Sligo
Tel: 071 915 5414 Fax: 071 914 4500
e-mail: Amajirionwu.Magnus@itsligo.ie

Appendix D

Selection of Indicators Questionnaire

INSTITUTE OF TECHNOLOGY SLIGO

IN COLLABORATION WITH THE

UNIVERSITY OF LIMERICK

BIOSOLIDS STAKEHOLDER CONSULTATION

(Selection of Indicators)

June 2005

Name of Respondent...

Position...

Organisation...

Tel..**Email**...

<u>Selection of Core Set of Indicators</u>

<u>Definition of Rating Criteria</u>

Policy relevance:	Is the candidate indicator relevant to biosolids policy?
Simplicity:	Is the candidate indicator understandable by all stakeholders?
Validity:	Is the candidate indicator scientifically credible and reliable?
Data availability:	Is the candidate indicator easily measured?
Representativeness:	Is the candidate indicator representative of system variability over space and time?
Sensitivity:	Will the indicator be rapid in showing changes within the system?

1. <u>Biosolids Management Domain: Production</u>

1.1 Name of Indicator: Domestic, and industrial/commercial population equivalent (p.e.) to WWTPs

Brief Description: Regulations require the provision of wastewater treatment plants depending on the size of the agglomeration and on the type of water body to which the wastewater is discharged. This indicator will show the numerical rating of domestic and commercial p.e. to WWTPs.

Type of Indicator: Driving Force

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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....

1.2 Name of Indicator: Total annual biosolids production (dry weight)

Brief Description: A total of 33,559 tonnes (2001) and 42,298 tonnes (2003) respectively, of dry solids of sewage sludge were reported to have been produced in Ireland by agglomerations with population equivalent greater than 500. This indicator will show the amount of biosolids produced annually over time per capita.

Type of Indicator: State

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes □ No □
If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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1.3 Name of Indicator: Biosolids production (dry weight) by treatment process

Brief Description: This indicator will depict the quantity of biosolids produced annually by the various treatment types namely: mesophilic anaerobic digestion, thermophilic anaerobic digestion, thermophilic aerobic digestion, composting, alkaline stabilisation and thermal drying.

Type of Indicator: State

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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1.4 Name of Indicator: Access to sewerage

Brief Description: This indicator will show the gradual increment (or otherwise) over time of access to sewer systems (wastewater treatment plants) by the various communities. As access increases, the quantity of biosolids will also be expected to increase.

Type of Indicator: Driving Force

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					

Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes ☐ No ☐

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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1.5 Name of Indicator: Quantity of treated wastewater as a percentage of total quantity of wastewater.

Brief Description: This indicator will compare the total wastewater generated annually from households and connected industries with the total wastewater treated annually. Untreated wastewater constitutes an enormous source of pressure to the environment.

Type of Indicator: Pressure

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	**Rating**				
	1	**2**	**3**	**4**	**5**
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes ☐ No ☐

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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1.6 Name of Indicator: Phosphorus and Nitrate recovery

Brief Description: Biosolids are a source of nitrogen (N) and phosphorus (P) required for crop production. This indicator will report on the number of WWTPs with Phosphorus and Nitrogen recovery facilities.

Type of Indicator: Driving Force

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	**Rating**				
	1	**2**	**3**	**4**	**5**
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes ☐ No ☐

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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2. Biosolids Management Domain: Quality

2.1 Name of Indicator: Quantity of biosolids not meeting stipulated quality standards

Brief Description: This indicator will measure percentage compliance with regulation over time in relation to biosolids quality requirements. It will also show quantities of biosolids failing quality requirements in relation to typical permissible levels for heavy metals and other contaminants as provided in regulations.

Type of Indicator: Pressure

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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2.2 Name of Indicator: Soil quality

Brief Description: It is important to know the background levels of heavy metals in soils before application of biosolids to avoid adverse effects on soil, plant, animal or human health. This indicator will present sampling and analysis results from soils subjected to biosolids application.

Type of Indicator: Impact

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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2.3 Name of Indicator: Catchment river/lake quality

Brief Description: This indicator will present sampling and analysis results from rivers and lakes local to biosolids spread lands, for example Dissolved Oxygen, Biological Oxygen Demand, pH, Nitrate, Phosphorus and Coliforms.

Type of Indicator: Impact

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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2.4 Name of Indicator: Crop production

Brief Description: Land application of biosolids is aimed at improving soil conditions and crop yield. This indicator will show crop yields (by tonnage per area per annum) on land where biosolids have been applied.

Type of Indicator: Impact

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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3. Biosolids Management Domain: Cost

3.1 Name of Indicator: Comparative cost of biosolids production processes per tonne of dry matter

Brief Description: Whatever the production process, total costs are mainly composed of investment and operating costs of infrastructure and of other operations required for biosolids management. This indicator will compare the cost of the various biosolids production processes per tonne of dry matter.

Type of Indicator: Driving Force

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ……………………………………………………………………………

Please comment on this indicator

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4. Biosolids Management Domain: Legislation/Regulations

4.1 Name of Indicator: Enforcement notices

Brief Description: A prosecution or enforcement notice could be seen as an indication of deficient management systems. This indicator is expected to provide a level of detail a little greater than simply reporting prosecutions. Not all enforcement notices result in prosecution, even though some level of deficiency is observable.

Type of Indicator: Response

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ……………………………………………………………………………

Please comment on this indicator

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4.2 Name of Indicator: Stakeholder surveys commissioned by Local Authorities

Brief Description: Results of biosolids stakeholder satisfaction surveys will give a nuanced picture of a sustainable biosolids management programme. It will also be a means of identifying latent issues that antagonise stakeholders but do not actually result in complaints. This indicator will be an effort towards understanding the impact of various biosolids policy, legislation/regulations and implementation programmes.

Type of Indicator: Impact

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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5. Biosolids Management Domain: Training/Research

5.1 Name of Indicator: Training of farmers and non-agricultural users of biosolids

Brief Description: Training and better information dissemination are necessary activities to encourage more reuse of biosolids and better public perception. This indicator will show the frequency of various stakeholder-training activities compared to amounts of biosolids recycled annually over time.

Type of Indicator: Response

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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5.2 Name of Indicator: Funding for biosolids research

Brief Description: Research and training have been identified by stakeholders as requirements for safe recycling of biosolids and building of public confidence. This indicator will compare the amount of funds utilised in biosolids research and training, and quantity recycled per annum over time.

Type of Indicator: Response

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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5.3 Name of Indicator: Information packs

Brief Description: General goodwill towards the concept of beneficial use of biosolids can be mobilised provided procedures for managing the risks are in place, and the local community is well informed. This indicator will show the annual number of information packs distributed per capita (per county).

Type of Indicator: Response

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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6. Biosolids Management Domain: Disposal/Recycling

6.1 Name of Indicator: Nutrient value of biosolids sent to landfills

Brief Description: When biosolids are landfilled, reusable nitrogen, phosphorus and organic matter are lost in the process. This indicator will show the amount of these nutrients lost annually through the landfilling of biosolids.

Type of Indicator: Driving Force

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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6.2 Name of Indicator: Quantity and percentage of biosolids recycled.

Brief Description: The progressive implementation of the EU Urban Waste Water Treatment Directive 91/271/EEC is increasing the quantities of biosolids requiring reuse and disposal in Ireland. The indicator will show the total amount (tonnes) and percentage (%) of biosolids recycled per year over time.

Type of Indicator: Response

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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6.3 Name of Indicator: Quantity and percentage of biosolids sent to landfills

Brief Description: The EU Landfill Directive 2000/53/EC stipulates the diversion of increasing amounts of organic and putrescible wastes from landfills. Coupled with urgent deficit in landfill capacity in most of our local authorities, the diversion of biosolids away from landfills is inevitable. This indicator will show the amount of biosolids landfilled annually over time.

Type of Indicator: Pressure

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator
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6.4 Name of Indicator: Quantities and percentage of biosolids recycled through various routes

Brief Description: The amount of biosolids reused through the various recycling routes including agricultural and non-agricultural uses, and incineration (with energy recovery) per annum will be depicted over time.

Type of Indicator: State

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?
Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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6.5 Name of Indicator: Public complaints from biosolids processing, recycling and reuse

Brief Description: This indicator will present the number of complaints validated as coming from biosolids recycling/disposal processes as a percentage of WWTPs.

Type of Indicator: Impact

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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6.6 Name of Indicator: Register of biosolids recycling/disposal contractors.

Brief Description: Recycling of sewage sludge in the EC 15 increased from 2.6 million dry tonnes (MDT) per year in 1992 to 4.2MDT in 2000. Annual Irish sewage sludge is expected to increase to 120,000 tonnes by 2013 as a consequence of changes in European and National Water legislation. This indicator will measure the number of qualified biosolids reuse contractors in Ireland.

Type of Indicator: Response

Indicator Rating: Please rate this indicator according to the criteria listed in the Table. The lowest score is 1 while 5 is the highest. Tick (√).

Criterion	Rating				
	1	2	3	4	5
Policy relevance					
Simplicity					
Validity					
Data availability					
Representativeness					
Sensitivity					

Does your Local Authority/Agency/Organisation have data for this indicator?

Yes □ No □

If 'No' where do you suggest it could be obtained from ....

Please comment on this indicator

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Please include any general comments/thoughts on the study below:

Thanks for your time and cooperation.

Appendix E1
List of County Officers Contacted

JobTitle	Department	Address	County
The Director of Services	Infrastructure and Environmental Services	County Buildings, Athy Road	County Carlow
The Director of Services	Environment Section	Courthouse	County Cavan
The Director of Services	Environment Section	Norwich Union House	89/90 South Mall, Cork
The Director of Services	Environment Section	Three Rivers Culture, Lifford	County Donegal
The Director of Services	Environment Department	Marine Road	Dun Laoghaire, Dublin
The Assistant City Manager	Environment and Culture Department	Civic Offices	Wood Quay, Dublin 8
Director of Services	Environment Section	Main Street, Swords	Fingal, County Dublin
The Director of Services	Environment Section	Prospect Hall	Galway
The Director of Services	Environment Section	City Hall, College Road	Galway
The Director of Services	Environment Section	St Mary's, Naas	County Kildare
The Director of Services	Environment Section	County Hall, John Street	Kilkenny
The Director of Services	Environment and Community Section	Portlaoise	County Laois
The Director of Services	Environment and Sanitary Department	Carrick-on-Shannon	County Leitrim

JobTitle	Department	Address	County
The Director of Services	Environment Section	County Hall, Dooradoyle	Limerick
The Director of Services	Environment Department	2nd Floor, City Hall	Limerick
The Director of Services	The Environment Section	Greater Water Street	Longford
The Director of Services	Environment Department	County Hall, Millenium Centre	Dundalk
The Director of Services	Environment Section	Second Floor, Aras an Chontae	The Mall, Castlebar
The Director of Services	Environment Section	County Hall, Navan	County Meath
The Director of Services	Environment and Transport Section	County Offices	The Glen, Monaghan
Director of Services	Environment Section	Courthouse, Tullamore	County Offaly
Director of Services	Environment Section	Roscommon West Business Park	Circular Road, Roscommon
The Director of Services	Environment Section	County Hall, Riverside	Sligo
The Director of Environmental Services	Environment Section	Tallaght	South Dublin County Council Dublin 24
The Director of Services	Environment Section	Courthouse, Nenagh	County Tipperary
The Director of Services	Physical Planning and Environment	County Hall, Emmet Street	Clonmel, County Tipperary
Director of Services	The Environment Department	Civic Offices	Dungarvan, County Waterford

JobTitle	Department	Address	County
The Director of Services	Environment Section	Lombard Street	Waterford
The Director of Services	Environment Section	County Building, Mount Street	Mullingar, County West Meath
The Director of Services	Environment Section	Wexford	County Wexford
The Director of Services	Environment Section	County Buildings, Wicklow	County Wicklow
The Director of Services	Environment Section	Ratass, Tralee	County Kerry
The Director of Services	Environment Section	New Road Offices	Ennis, County Clare
The Director of Services	Environment Section	City Hall, Cork	County Cork

Appendix E2
List of Organisations Contacted

The Chief Executive Officer
APHA
7 Whitfriars
Aungier Street
Dublin 2

The Chief Executive Officer
Bio-Dynamic Agricultural Assoc. in Ireland
Watergarden
Thomastown, County Kilkenny

The Chief Executive Officer
Braade/Carrickein Conservation Group
Airport Road
Kincasslagh, County Donegal

The Chief Executive Officer
Council for the West
Unit 13, Business Centre
Market Yard, Sligo

The Chief Executive Officer
Dublin Food Co-op
12A North King Street
Dublin 7

The Chief Executive Officer
Ecological Trades Community
Joe Gowran/Mark Wilson
Drumcliff, Sligo

The Chief Executive Officer
Ecology Society
NUI, Comhaltas Na Mac Leinn, Galway

The Chief Executive Officer
Earthwatch
7 Upper Camden Street, Dublin 2

The Executive Chief Officer
Environmental Action Alliance
8 Foxfield Road
Raheny, Dublin 5

The Chief Executive Officer
Environmental Health Officers Assoc.
North-Western Health Board
Ardaghowen, Sligo

The Chief Executive Officer
Environment Policy Committee
IBEC, Confederation House
84-86 Baggot Street, Dublin 2

The Chief Executive Officer
Environmental Sciences Assoc. of Ireland, Agriculture Building
UCD Belfield, Dublin

The Chief Executive Officer
Environmental Action Alliance
40 St Joseph's Terrace
Portalington
County Offaly

The Chief Executive Officer
Environmental Research & Design Assoc
Gleneely
Carndonagh, County Donegal

The Chief Executive Officer
Fanor Conservation Trust
c/o John Mcnamara
Admiral's Rest, Fanore, County Clare

The Chief Executive Officer
Forest Friends Ireland
PO Box 7814
Dublin 1

The Chief Executive Officer
Forest Stewardship Council
Bury Quay, Tullamore, County Offaly

The Chief Executive Officer
Friends of the Irish Environment
Allihies, County Cork

The Chief Executive Officer
Garden & Landscape Designers Assoc
73 Deerpark Road
Mount Merrion, County Dublin

The Chief Executive Officer
Green Schools, An Taisce
Tailor's Hall
Back Lane, Dublin 8

The Chief Executive Officer
Inishowen Comm. Organic Coop Ltd
Drung
Quigleys Point, County Donegal

The Chief Executive Officer
Inishowen Environmental Group
Magheramore,Carndonagh
Inishowen, County Donegal

The Chief Executive Officer
Irish Assoc of Health Food Stores
Unit 2d
Kylemore Industrial Estate, Dublin 10

The Chief Executive Officer
Irish Countrywomen's Association
58 Merion Road
Dublin 4

The Chief Executive Officer
Irish Doctors Environmental Assoc
34 Haliday Square, Stoneybatter, D 4

The Chief Executive Officer
Irish Farmers Association
Irish Farm Center, Bluebell, Dublin 12

The Chief Executive Officer
Irish Field & Country Sports Soc. Ltd
The Old Forge, Low Street,
Rathdrum, County Wicklow

The Chief Executive Officer
Cork Environmental Alliance
34 Princess Street
Cork

The Chief Executive Officer
c/o Jaqueline Hodgson
Cooragurteen
Ballydehob, County Cork

The Chief Executive Officer
Dublin Healthy Cities Project
Carmichael House
North Brunswick Street, Dublin 7

The Chief Executive Officer
The Earth Education Centre
Dromcollagher Enterprise Centre
Dromcollagher, County Limerick

The Chief Executive Officer
Agricultural Science Association
Irish Farm Centre
Bluebell, Dublin 12

The Chief Executive Officer
Assoc. of Agric. & Horticultural Colleges
Salesian Agricultural College
Pallaskenry, County Limerick

The Chief Executive Officer
Assoc. Of Consulting Engrs of Ireland
51 Northumberland Road
Dublin 4

The Chief Executive Officer
Association of Building Engineers
Hogan House
Hogan Place, Dublin 2

The Chief Executive Officer
Clean Technology Center
Unit 1, Melbourne Business Park
Modelfarm Road, Cork

The Chief Executive Officer
East Clare Clean Enviromental Group
Aughrim, Scariff, County Clare

The Chief Executive Officer
Irish Games Protection Association
47 Laverty Court, Dublin 2

The Chief Executive Officer
Irish Garden Plant Society
c/o National Botanic Gardens
Glasnevin, Dublin 9

The Chief Executive Officer
Irish Geological Association
c/o Ballymore
New Ross, County Wexford

The Chief Executive Officer
Irish Landscape Institute
6 Merrion Square, Dublin 2

The Chief Executive Officer
Irish Mountaineering Club
6 Arbour Terrace, Dublin 7

The Chief Exexcutive Officer
Irish Naturist Association
PO Box 1077,Churchtown, Dublin 14

The Chief executive Officer
Irish Oak 2000
Trident Marina, Kinsale, County Cork

The Chief Executive Officer
Irish Organic Farmers & Growers Assoc
Organic Farm Center
Harbour Road, Kilbeggan
County Westmeath

The Chief Executive Officer
Irish Organic Society
Springmount
Ballyboughal
County Dublin

The Chief Executive Officer
Irish Org. for Geographic Information
Museum Building
Trinity College, Dublin 2

The Chief Executive Officer
Irish Pharma. & Chem. Mfc Association
Confederation House
84-86 Lower Baggot St, Dublin 2

The Chief Executive Officer
Irish Trust for the Protection of Animals
740 South Circular Road
Dublin 8

The Chief Executive Officer
Irish Underwater Council
78a Patrick Street, Dun Laoghaire
County Dublin

The Chief Executive Officer
Irish Uplands Forum
c/o Dave Hogan
Clon, Cleggan, County Galway

The Chief Executive Officer
Irish Wildlife Federation
3 Lower Mount Street,
Dublin 2

The Chief Executive Officer
Irish Wildlife Trust
107 Lower Baggot Street
Dublin 2

The Chief Executive Officer
Irish Women's Environmental Network
Carmichael House
Brunswick Street, Dublin 7

The Chief Executive Officer
Just Forest
Bury Quay
Tullamore, County Offaly

The Chief Executive Officer
KIWI
c/o 30 Royal Meadows
Kilcock, County Kildare

The Chief Executive Officer
Macra na Feirme
Irish Farm Centre
Bluebell, Dublin 12

The Chief Executive Officer
Macrobiotic Association
Altidore Castle
Kilpeddar, County Wicklow

The Chief Executive Officer
Mayo Environmental Group
Carrickbawn, Newport Road
Westport, County Mayo

The Chief Executive Officer
Moville/Greencastle Environmental Grp
Ballybrack, Moville,
County Donegal

The Chief Executive Officer
Muintir na Coillte,Drumcliff ,Sligo

The Chief Executive Officer
National Botanic Garden,Glasnevin, D9

The Chief Executive Officer
Nat. Environmental Education Center
Knocksink Wood National Nature
Reserve, Enniskerry, County Wicklow

The Chief Executive Officer
Natioanl Cooperative Council
PO Box 4446
Dublin 9

The Chief Executive Officer
Natioanl Fed. of Group Water Schemes
Ballygaddy Road
Tuam, County Galway

The Chief Executive Officer
National Field Study Centre
Ballinafad
County Sligo

The Chief Executive Officer
National Youth Council of Ireland
3 Montague Street
Dublin 2

The Chief Executive Officer
Network of Irish Env & Dev Orgs
DESC, St Patrick's College
Drumcondra, Dublin 9

The Chief Executive Officer
Organic Centre
Rossinver, County Leitrim

The Chief Executive Officer
Organic Traders of Ireland
Trawlebawn, Bantry, County Cork

The Chief Executive Officer
Organic Trust, Vernon House,
2 Vernon Avenue, Clontarf, Dublin 3

The Chief Executive Officer
Oxfam Ireland
9 Burgh Quay, Dublin 2

The Chief Executive Officer
Plant and Wildlfie Society
The Burrow
Portane, County Dublin

The Chief Executive Officer
Royal Horticultural Society
Swanbrook House, Bloomfield Avenue,
Morehampton Rd, Dublin 4

The Chief Executive Officer
Rural Innovation Centre
St Patrick's Agricultural College
Poplar Vale, County Monaghan

The Chief Executive Officer
Rural Resettlement Irl. Ltd
Kilbaha
Kilrush, County Clare

The Chief Executive Officer
School Wildlife Gardeners Association
Scoil Treasa, Donore Avenue,
South Circular Road, Dublin 8

The Chief Executive Officer
Self-Help Development Ireland
Hacketstown
County Carlow

The Chief Execuitve Officer
Society of Irish Foresters
34 Upper Drumcondra Road
Dublin 9

The Chief Executive Officer
Sonairte
National Ecology Centre
The Ninch, Laytown, County Meath

The Chief Executive Officer
Sustainable Communities Ireland
159 Lower Rathmines Road, Dublin 6

The Chief Executive Officer
Sustainable Ireland
159 Lower Rathmines Road, Dublin 6

The Chief Executive Officer
An Tairseach
Dominican Farm & Ecology Centre
Wicklow Town, County Wicklow

The Chief Executive Officer
An Taisce,The National trust
Tailor's House, Back Lane
Dublin 8

The Chief Executive Officer
An t-lonad Glas
Community College
Dromcollogher, County Limerick

The Chief Executive Officer
Tree Council of Ireland
Cabionteely House
Cabinteely, County Dublin

The Chief Executive Officer
Trees for Ireland
61 Rathgar Road
Dublin 6

The Chief Executive Officer
Trinity Greens
Box 23
Regents House, TCD, Dublin 2

The Chief Executive Officer
Sustainable Community Villages
159 Lower Rathmines Road
Dublin 6

The Chief Executive Officer
UCD Environmental Institute
Richview
Clonskeagh, Dublin 14

The Chief Executive Officer
Vegetarian Society of Ireland
PO Box 3010, Dublin 4

The Chief Executive Officer
VOICE
7 Upper Camden Street, Dublin 2

The Chief Executive Officer
Waste Working Group
c/o VOICE
7 Upper Camden Street, Dublin 2

The Chief Executive Officer
Willing Workers on Organic Farms
Rose O'Brien
Harpoons Town, Drinagh, Co. Wexford

The Chief Executive Officer
Young Reporters for the Environement
An Taisce
Tailor's Hall, Back Lane, Dublin 8

The Chief Executive Officer
Bord Pleanala
64 Malborough Street
Dublin 1

The Chief Executive Officer
Health and Safety Authority
10 Hogan Place, Dublin 2

The Chief Executive Officer
National Parks & Wildlife Service
7 Ely Place
Dublin 2

The Chief Executive Officer
COFORD
Agriculture Building, Belfield, Dublin 4

The Secretary General
Dept of the Env. & Local Government
Custom House
Dublin 1

The Chief Executive Officer
Environmental Protection Agency
PO Box 3000
John Castle Estate, Wexford

The Chief Executive Officer
Office of Director of Consumer Affairs
4-5 Harcourt Road
Dublin 2

The Chief Executive Officer
Bord Bia
Clanwilliam Court
Lower Mount Street, Dublin 2

The Chief Executive Officer
Food Safety Authority of Ireland
Abbey Court
Lower Abbey Street, Dublin 1

The Chief Executive Officer
Forest Service
Johnstown Castle Estate, Co. Wexford

The Chief Executive Officer
Teagasc
19 Sandymount Avenue
Ballsbridge, Dublin 4

The Secretary General
Dept of Agriculture & Food
Kildare Street, Dublin 2

The Secretary General
Department of Health & Children
Hawkins House
Hawkins Street,Dublin 2

The Chief Executive Officer
Health Research Board
73 Lower Baggot Street
Dublin 2

The Chief Executive Officer
Waterways Ireland
17 - 19 Lower Hatch Street
Dublin 2

The Chief Executive Officer
Landfeeds Environmental Ltd
Ballinalacken
Ballyragget
County Kilkenny

The Chief Executive Officer
FBD Insurance
FBD House
Bluebell
Dublin 12

The Chief Executive Officer
Irish Farmers Journal
Irish Farm Centre
Bluebell, Dublin 12

The Chief Executive Officer
Fyffes
1 Beresford Street
Dublin 7

The Chief Executive Officer
Dawn Farm Foods
The Maudlins
Naas
County Kildare

The Chief Executive Officer
Dairygold Coop Society Ltd
Fermoy Road
Mitchelstown
County Cork

The Chief Executive Officer
John Daly Foods Ltd
Claregalway
County Galway

The Chief Executive Officer
La Rousse Foods
31 Park West
Nangor Road, Dublin 12

The Chief Executive Officer
McNally Foods Ltd
32 Spruce Avenue
Stillorgan Industrial Park
Stillorgan, County Dublin

The Chief Executive Officer
O'Briens Irish Sandwich Bar
International Support Office
23 South William Street
Dublin 2

The Chief Executive Officer
Otto's Creative Catering
Dunworley
Butlerstown
Bandon, County Cork

The Chief Executive Officer
Shamrock Foods Ltd
Merrywell Industrial Estate
Dublin 12

The Chief Executive Officer
Swift Fine Foods Ltd
Lough Egish Food Park
Castleblayney, County Monaghan

The Chief Executive Officer
Trio Food Ltd
Ballinode
Sligo

The Chief Executive Officer
Centra Food Market
205A Emmet Road
Inchichore
Dublin 8

The Chief Executive Officer
Superquinn
Sutton Cross
Dublin 13

The Chief Executive Officer
Dunnes Stores Ltd
Beaux Lane House
Off St Stephens Green
Dublin

The Chief Executive Officer
Fertilizer Association of Ireland
151 Thomas Street
Dublin 8

The Chief Executive Officer
Tesco Ireland Ltd
Graham House
Marine Road
Dun Laoghaire, Dublin

The Chief Executive Officer
Londis
1 Lee House
Riverview Business Park
Blackrock, County Cork

The Chief Executive Officer
Goulding Fertilisers
Centre Park Road
Marina
County Cork

Appendix E3

List of Stakeholders Contacted for Selection of Indicators

Environmental Officer
Carlow County Council
Athy Road
Carlow

Senior Engineer (Environment Section)
Cavan County Council
Courthouse, Farnham Street
Cavan

Senior Executive Engineer
Tulla Area Office
Courthouse Tulla
County Clare

Director, Environmental Services
Cork City Council
Floor 3, Norwich Union House
89/90 South Mall, Cork

Senior Executive Engineer (Water Servs)
Shannon Area Office
Town Hall
Shannon County Clare

Senior Executive Engineer (Water Servs), Wexford County Council
County Hall
Wexford

Director, Water & Environment Services
Wicklow County Council
County Buildings
Wicklow

The Administrative Officer
Environment Department
Cork County Council
Floor 3, County Hall, Cork

Waste Regulations Officer (Env Section)
Donegal County Council
Three Rivers Centre
Lifford, County Donegal

Acting Director (Environmental Services)
Level 3, County Hall
Marine Road, Dun Laoghaire

Administrative Officer (Environment Section)
North Tipperary County Council
Machinery Yard, Limerick Road
Nenagh

Senior Engineer (Environmental Services)
Carlow County Council
County Buildings, Athy Road
Carlow

Operations Manager
COFORD
Agricultural Building, Belfield
Dublin 4

Senior Engineer (Environmental Services), Environment Section
Kildare County Council
St Mary's, Naas, County Kildare

APHA
8 Woodbine Park
Blackrock, County Dublin

Landfeeds Environmental Ltd
Unit 16, Hebron Industrial Estate
Kilkenny

Executive Engineer, Water Services
South Tipperary County Council
County Hall, Emmett Street
Clonmel

Chairman
Environmental Health Officers Assoc
39A Main Street, Bray, County
Wicklow

Assistant Agricultural Inspector
Department of Agriculture and Food
Agriculture House, Kildare Street
Dublin 2

Head, Research & Development for
Health
Health Research Board
73 Lower Baggot Street, Dublin 2

Administrator
Demeter Ltd
Watergarden, Thomastown
Co Kilkenny

Director/Environmental Consultant
Clean Technology Centre
Unit 1, Melbourne Business Park
Model Farm Road, Cork

Environmental Auditor
Forest Service
Oliver Plunkett Road
Letterkenny, Co Donegal

Licensing & Guidance
An Taisce
Back Lane, Tailors Hall
Dublin 8

Ag Head of Centre
TEAGASC
Johnstown Castle, Wexford

Environmental Education Officer
The Organic Centre
Rossinver, Co. Leitrim

Chairman
Rural Resettlement Ireland
Killala, Kilrush
County Clare

Certification Manager
Irish Organic Farmers & Growers Assoc
Harbour Building, Harbour Road
Killorgan, Co Westmeath

Coordinator
VOICE
7 Upper Comden Street
Dublin 7

Senior Executive Engineer
Limerick County Council
County Hall, Dooradoyle
County Limerick

Director, Environmental Services
Waterford County Council
Civic Offices, Davitts Quay
Dungarvan, Co Waterford

Environment Section
Waterford City Council
City Hall, The Mall
Waterford City

Deputy Project Engineer (Environment Dept)
Dublin City Council
Wood Quay
Dublin 8

Assistant City Manager (Environmental Department)
Dublin City Council
Wood Quay
Dublin 8

Senior Executive Officer (Env. Servs)
First Floor, County Hall
Main Street, SwordsFingal,
County Dublin

Ag. Director, Environmental Services
Galway County Council
Coubty Building, Prospect Hill
Galway

Senior Executive Engineer (Env. Dept)
Roscommon County Council
West Business Park, Roscommon

Senior Executive (Environment Dept)
Sligo County Council
County Hall, Riverside, Sligo

Environment Section
Sligo Borough Council
City Hall, Quay Street, Sligo

Director, Environment Department
Galway City Council
City Hall, College Road, Galway

Executive Engineer, Env. Services
Kerry County Council
Ruthass, Tralee, County Kerry

Senior Engineer, Water Services
Kildare County Council
St Mary's, Naas, Co Kildare

Senior Engineer, Environmental Services
Meath County Council
County Hall, Navan, Co Meath

Senior Engineer, Env. Services
Monaghan County Council
County Offices
The Glen, Monaghan.

Senior Engineer, Environment Section
Kilkenny County Council
County Hall, John Street
Kilkenny

Director, Env. & Water Services
Laois County Council
Aras an Chontae
Portlaoise

Executive Engineer
Water Services Dept
Leitrim County Council
Carrick-on-Shannon

Senior Engineer, Sanitary & Env. Directorate
Longford County Council
Great Water Street
Longford

Senior Engineer, Env. Department
Louth County Council
County Hall, Millenium Centre
Dundalk

Director of Water Services
Mayo County Council
Second Floor, The Mall
Castlebar

Executive Secretary
Industrial & Environmental Committee
IFA Headquarters
Bluebell, Dublin 12

Chairman, National Industrial & Evnt'l Committee
IFA Headquarters
Bluebell, Dublin 12

Manager, Farm Women Programme
IFA Headquarters
Bluebell, Dublin 12

Environment Correspondent
RTE
Donnybrook
Dublin 4

Environmental Correspondent
Irish Independent
27-32 Talbot Street
Dublin 1

Environmental Correspondent, Irish Times
10-16 D'Olier Street
Dublin 2

Senior Engineer, Environment Section
Westmeath County Council
County Buildings
Mullingar

Environmental Management & Planning Div
Environmental Protection Agency
P.O. Box 3000, Johnstown Castle Estate
Wexford

Appendix E4
Expert and Informants Group

1. Fehily Timoney & Co
2. P.H. McCarthy & Partners;
3. Mc O'Sullivan (Consultants)
4. T. J. O'Connor & Associates.
5. Entec O'Dwyer & Co Ltd
6. Entec and O'Dwyer;
7. Teagasc
8. Jennings O'Donovan & Partners
9. Weston-FTA Ltd

Appendix F

Biosolids Stakeholder Survey: Summary of Responses

Questions Relevant to All Groups

A1. In Ireland, 51 per cent of sewage sludge is presently spread on agricultural land. Do you/does your organisation consider this a good idea?

Yes	**117** (82%)
No	**22** (16%)
Don't know	**2** (1%)

A2. In Ireland, about 33 million tonnes of untreated vegetable and animal wastes are spread on land. Do you/does your organisation think this is a good idea?

Yes	**64** (45%)
No	**56** (40%)
Don't know	**21** (15%)

A3. Do you/does your organisation think untreated waste from the following industries should be spread on agricultural land?

Industry	Yes	No	Don't know
Abattoirs	**33** (23%)	**81** (57%)	**27** (19%)
Dairy processing	**27** (19%)	**93** (66%)	**21** (15%)
Sugar processing	**23** (16%)	**99** (70%)	**19** (13%)
Leather and tannery	**31** (21%)	**95** (67%)	**15** (11%)
Pharmaceutical	**20** (14%)	**97** (69%)	**24** (17%)

A4. Do you/does your organisation have any concerns with the following disposal and recycling routes for biosolids: Please tick (✔).

	Yes	No	Don't know
Disposal to landfill	**97** (69%)	**42** (30%)	**2** (1%)
Use on agricultural land	**71** (50%)	**57** (40%)	**13** (10%)
Use in other green areas with high public access (e.g. golf courses)	**96** (68%)	**39** (28%)	**6** (4%)
Use in other green areas with low public access (e.g. motorway verges)	**89** (63%)	**47** (33%)	**5** (4%)
Incineration	**112** (79%)	**15** (11%)	**14** (10%)
Land reclamation (e.g. disused mine sites)	**56** (40%)	**72** (51%)	**13** (9%)
Use in forestry	**49** (35%)	**85** (60%)	**7** (5%)
Others (please specify)....................................	☐	☐	☐

A5. How familiar are you/is your organisation with the idea of 'sustainable development'?

Very familiar	**37** (26%)
Familiar	**71** (50%)
Not familiar	**33** (23%)

A6. Do you/does your organisation consider sustainable development indicators useful as a tool for the management of biosolids?

Very useful	**83** (59%)
Useful	**31** (22%)
Not useful	**0** (0%)
Don't know	**27** (19%)

A7. Please see Section 7.2 of Chapter 7

Other issues identified by stakeholders

Stakeholders were encouraged in the survey to include comments or other concerns that may have been omitted in the questionnaire. Following are comments and other concerns listed by stakeholders.

- Finding ways to reduce the production of biosolids.
- Public perception of food safety.
- Biosolids are a fact of life – they have to be dealt with. Best practice worldwide must influence policy.
- Lack of resources to monitor compliance with legislation.
- Additional costs incurred by local authorities.

A8. Please see Section 7.3 of Chapter 7

Other actions/information suggested by stakeholders

- Research sludge stabilisation techniques.
- Create register of approved contractors for biosolids reuse.
- Review and update legislation.
- Nutrient management.
- Monitoring of biosolids spread by local authorities.

- The human population is growing worldwide. New (presently unknown) methods must be researched.
- Public clarification of disposal options.
- Finding ways to reduce the production of biosolids.

A9. Please add any additional ideas and opinions in this box

- The only route for disposal of biosolids in Cavan is to spread on agricultural land. There is a general resistance by the public to this practice. Alternative methods of disposal are needed in the medium term (7-10 years).
- It is very important that a sustainable route for the re-use of biosolids is maintained as the landfill capacity reduces and becomes more expensive. As pointed out in the survey, the amount of sludge produced will increase dramatically over the coming years in the country.
- This area is only one of very many issues to tax the mind. Our government shoulc be taking responsibility for the welfare of the people and finding solutions to deal with this problem.
- A full range of economic, social and environmental indicators would be needed towards sustainable sewage management (SSM).
- One body to regulate the use of biosolids.
- A major issue to be resolved is the public/consumer perception of the link between biosolids application to land and food safety. While we feel the treatments and regulations governing biosolids use in agriculture are adequate, we still find it difficult to advise farmers to accept biosolids. If public perception was to change it could have serious implication for farmers who use it. A problem that needs to be addressed is that if the public have a problem with use in agriculture, then they must accept alternative option such as incineration. They can't have it every way!!
- Human values must be paramount in all research leading to policies.
- The use of biosolids is prohibited for organic farming.
- The taxpayer will probably pay either way. If costs are externalized and the environment is regarded as a 'cheaper treatment', the tax payer will pay in degraded water quality and increased water treatment costs, water filtration installation costs and so on.

A10. Please suggest some SDIs that you may want to be included

Title	Issue Addressed	Source of Data	Brief Definition
Back levels of nutrients	Nutrient runoff to surface water		Soil sampling
Background levels of heavy metals	Exceed level of allowable limits		Soil sampling
Quality control	Biosolids quality soil, operator and transport quality		
Generation of organic waste	Organic waste All agriculture	Livestock number through put from abattoirs, dairy	Level of generation of organic (non domestic) waste nationally
Destination of organic waste	Organic waste All agriculture	Livestock number through put from abattoirs, dairy	What happens to waste described above
Heavy metals in ground water	Heavy metal contamination	Water analysis	
Crop yield over time	Impact on crop growth	Yield measurements	
Animal health	Exotic diseases	Monitoring of animal health	
Monitoring	Quality	Regulatory target	
Calorific value	Fuel use	Biosolids analysis	
Carbon dioxide	Digestion/composting	Biosolids analysis	
Farmers' response	Benefit to the land	Teagasc and field data	Crop yields and taste

Additional Questions Relevant to Group I - Regulators

B1. Is there a Biosolids Management Plan in your Local Authority Area?

Yes	**16**	(100%)
No	**0**	(0%)
Don't know	**0**	(0%)

(If 'yes' please enclose a copy when returning your response to this questionnaire)

B2. If 'yes', was the Plan subject to any form of formal public consultation? Please check (✔).

Public participated during development of plan	**0**	(0%)
Plan was presented at public meetings	**0**	(0%)
Plan was subject to Environmental Assessment	**16**	(100%)
Others, please specify....................................	**0**	(0%)
None	**0**	(0%)

B3. Is there a biosolids processing facility in your Local Authority Area?

Yes	**15** (94%)
No	**1** (6%)
Don't know	**0** (0%)

B4. What principal mode of transport is used to deliver the biosolids to the end-use/disposal site?

16 (100%)	**Road**
0 (0%)	**Rail**
0 (0%)	**Water**

B5. Please indicate below whether or not your Local Authority biosolids facility is designed to accept sludge from the following industries?

Industry	Yes	No	Don't know
Abattoirs	**10** (63%)	**6** (37%)	
Dairy processing	**8** (50%)	**8** (50%)	
Sugar processing	**10** (63%)	**6** (37%)	
Leather and tannery if any	**12** (75%)	**4** (25%)	
Pharmaceutical	**6** (37%)	**10** (63%)	

<u>Additional Questions Relevant To Group II & III – Organisations and Individuals</u>

C1. Biosolids are sewage sludge that has been treated (or stabilized) to allow beneficial reuse in farming and other non-agricultural activities. Did you/your organisation know this?

Yes	**112** (91%)
No	**11** (9%)

C2. Have you/has your organisation heard of the following recommended treatment processes for biosolids production? Please tick the appropriate box.

Anaerobic digestion	Yes	**104** (85%)	No	**19** (15%)
Aerobic digestion	Yes	**107** (87%)	No	**16** (13%)
Composting	Yes	**123** (100%)	No	**0** (0%)
Lime treatment	Yes	**108** (88%)	No	**15** (12%)

Thermal drying	Yes	**109** (89%)	No	**14** (11%)

C3. Do you/does your organisation consider the present *regulations/legislations* in respect of biosolids management adequate?

Very adequate	**0** (0%)
Adequate	**33** (27%)
Not adequate	**77** (62%)
Don't know	**13** (11%)

C4. Do you/does your organisation consider the current level of *implementation* of regulations/legislations in respect of biosolids management adequate?

Very adequate	**0** (0%)
Adequate	**14** (11%)
Not adequate	**87** (71%)
Don't know	**22** (18%)

Appendix G1

Cover Letter to Individuals

Biosolids Stakeholder Survey

The Institute of Technology, Sligo in collaboration with the University of Limerick is currently engaged in a project to understand and articulate stakeholder concerns on the recycling and use of biosolids (treated sewage sludge) in Ireland. **This is with a view to developing sustainable development indicators (SDIs) to address these concerns.** You have been identified as one of the major stakeholders and we would be glad to enlist your participation in this process. Please find below details of the study for which your help would be greatly appreciated.

Project Title: Development and Testing of Sustainable Development Indicators for Biosolids Management at Local / Regional Levels

Project Team: Noel Connaughton, Department of Environmental Sciences, Institute of Technology Sligo.
Dr Richard Moles, Centre for Environmental Research, University of Limerick.
Dr John Bartlett, Department of Environmental Sciences, Institute of Technology Sligo.
Dr Bernadette O'Regan, Centre for Environmental Research, University of Limerick.
Magnus Amajirionwu, Centre for Sustainability, Institute of Technology Sligo.

Project Description: Reuse of sewage biosolids, especially in agriculture has been practiced for some years in many European countries including Ireland without notable human health or environmental problems. Nonetheless, some scientists, farm communities and other sectors of the general public have expressed concerns about this practice.

We are therefore obliged to conduct a survey on the disposal and recycling of biosolids to provide stakeholders the opportunity to express their concerns and suggest information and action needed to address these concerns. The information gathered will be used to develop indicators for the sustainable management of biosolids taking into consideration the economic, environmental, social and institutional dimensions.

I am attaching the study questionnaire. Please complete the questionnaire as comprehensively as possible. The detailed survey findings will be discussed at stakeholder meetings to which you are invited.

To maintain the project schedule, I request that completed questionnaires be returned by 31 March 2004. This will allow time for information to be compiled and prepared for presentation to the stakeholder meeting. Your responses will be treated confidentially.

Thanking you for your cooperation and time. Please forward completed questionnaire in the enclosed addressed envelope to:

Magnus Amajirionwu
Centre for Sustainability
Institute of Technology
Ballinode, Sligo

Tel: 071 915 5414 Fax: 071 914 4500
e-mail: Amajirionwu.Magnus@itsligo.ie

Appendix G2

Cover Letter to Organisations

Biosolids Stakeholder Survey

The Institute of Technology, Sligo in collaboration with the University of Limerick is currently engaged in a project to understand and articulate stakeholder concerns on the recycling and use of biosolids (treated sewage sludge) in Ireland. **This is with a view to developing sustainable development indicators (SDIs) to address these concerns.** Your organisation has been identified as one of the major stakeholders and we would be glad to enlist its participation in this process. Please find below details of the study for which your organisation's assistance will be greatly appreciated.

Project Title: Development and Testing of Sustainable Development Indicators for Biosolids Management at Local / Regional Levels

Project Team: Noel Connaughton, Department of Environmental Sciences, Institute of Technology Sligo.
Dr Richard Moles, Centre for Environmental Research, University of Limerick.
Dr John Bartlett, Department of Environmental Sciences, Institute of Technology Sligo.
Dr Bernadette O'Regan, Centre for Environmental Research, University of Limerick.
Magnus Amajirionwu, Centre for Sustainability, Institute of Technology Sligo.

Project Description: Reuse of sewage biosolids, especially in agriculture has been practiced for some years in many European countries including Ireland without notable human health or environmental problems. Nonetheless, some scientists, farm communities and other sectors of the general public have expressed concerns about this practice.

We are therefore obliged to conduct a survey on the disposal and recycling of biosolids to provide stakeholders the opportunity to express their concerns and suggest information and action needed to address these concerns. The information gathered will be used to develop indicators for the sustainable management of biosolids taking into consideration the economic, environmental, social and institutional dimensions.

I am attaching the study questionnaire. Please complete the questionnaire as comprehensively as possible. The detailed survey findings will be discussed at stakeholder meetings to which your organisation is invited.

To maintain the project schedule, I request that completed questionnaires be returned by **Friday, 4 June 2004**. This will allow time for information to be compiled and prepared for presentation to the stakeholder meeting. Your organisation's responses will be treated confidentially.

Thanking you for your cooperation and time. Please forward completed questionnaire in the enclosed addressed envelope (and any queries) to the undersigned.

Magnus Amajirionwu
Centre for Sustainability
Institute of Technology
Ballinode, Sligo

Tel: 071 915 5414
Fax: 071 914 4500
e-mail: Amajirionwu.Magnus@itsligo.ie

Appendix G3

Cover Letter to Local Authorities

Biosolids Stakeholder Survey

The Institute of Technology, Sligo in collaboration with the University of Limerick is currently engaged in a project to understand and articulate stakeholder concerns on the recycling and use of biosolids (treated sewage sludge) in Ireland. **This is with a view to developing sustainable development indicators (SDIs) to address these concerns.** Your Local Authority has been identified as one of the major stakeholders and we would be glad to enlist its participation in this process. Please find below details of the study for which your Local Authority's assistance will be greatly appreciated.

Project Title: Development and Testing of Sustainable Development Indicators for Biosolids Management at Local / Regional Levels

Project Team: Noel Connaughton, Department of Environmental Sciences, Institute of Technology Sligo.
Dr Richard Moles, Centre for Environmental Research, University of Limerick.
Dr John Bartlett, Department of Environmental Sciences, Institute of Technology Sligo.
Dr Bernadette O'Regan, Centre for Environmental Research, University of Limerick.
Magnus Amajirionwu, Centre for Sustainability, Institute of Technology Sligo.

Project Description: Reuse of sewage biosolids, especially in agriculture has been practiced for some years in many European countries including Ireland without notable human health or environmental problems. Nonetheless, some scientists, farm communities and other sectors of the general public have expressed concerns about this practice.

We are therefore obliged to conduct a survey on the disposal and recycling of biosolids to provide stakeholders the opportunity to express their concerns and suggest information and action needed to address these concerns. The information gathered will be used to develop indicators for the sustainable management of biosolids taking into consideration the economic, environmental, social and institutional dimensions.

I am attaching the study questionnaire. Please complete the questionnaire as comprehensively as possible. The detailed survey findings will be discussed at stakeholder meetings to which your Local Authority is invited.

To maintain the project schedule, I request that completed questionnaires be returned by 30 April 2004. This will allow time for information to be compiled and prepared for presentation to the stakeholder meeting. Your Local Authority's responses will be treated confidentially.

Thanking you for your cooperation and time. Please forward completed questionnaire in the enclosed addressed envelope to:

Magnus Amajirionwu
Centre for Sustainability
Institute of Technology
Ballinode, Sligo
Tel: 071 915 5414 Fax: 071 914 4500
e-mail: Amajirionwu.Magnus@itsligo.ie

Appendix H

Data Availability Survey Form
Sligo County Council

S/No	Data Required		Period					
			2000	2001	2002	2003	2004	2005
1	Total annual sewage production (dry weight)	Total						
		Treated						
		Untreated						
2	Number of wastewater treatment plants (Attach list showing population equivalent for each plant)							
3	Quantity of treated sewage sludge recycled							
	(List recycling routes and quantities for each route)	a.						
		b.						
		c.						
		d.						
		e.						
4	Quantity of sewage sludge sent to landfills	Treated						
		Untreated						
5	Number of training courses provided for farmers on the safe use of treated sewage sludge							
6	Number of information packs to educate the general public on the benefits, quality control and level of risk inherent in reusing treated sewage sludge especially in agriculture.							

S/No	Data Required		Period					
			2000	2001	2002	2003	2004	2005
7	Number of public complaints validated as arising from biosolids processing, recycling and disposal							
8	Amount of money spent on researching safe use of treated sewage sludge							
9	Result of stakeholder surveys to gauge public acceptance/rejection of the reuse of treated sewage sludge (attach results)							
10	Number of registered contractors involved in sewage sludge management. Do you have a register?							
11	Number of enforcement notices received in relation to sewage sludge management form the EPA							
12	Level in % of phosphorus and nitrogen removal from sewage sludge							
13	Quantity of treated sewage sludge that did not meet stipulated qualitystandard							
14	Number of people with access to central sewer connection							
15	Number of people without access to central sewer connection							