Development of an Irish Grease Management Strategy and Evaluation of Biological In-Situ Digestion

by

Stephen Carter

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Project Supervisor: Mr. Noel Connaughton

Abstract

This document evaluates Ireland's management of fats, oils and greases (FOGs) and examines the role of in-situ bacterial treatment in Grease Retention Units (GRUs). The study includes a sixteen-week bacterial dosing evaluation and culminates in a proposed national Grease Management Strategy.

There are clearly identifiable political, legal, social, economic and environmental drivers for a national strategy. The Department of Environment and Local Government is in an ideal position to draw it up, prior to Local Authorities tailoring it to suit their own functional areas.

The bacterial digestion study found that dosed units experienced a reduction in retained grease of between 2% and 81%. Three of the units experienced significant rises in BOD discharges (up to 372%) and all experienced rises in ammonia (up to 1180%). This may have been due to oxidation and reduction of FOG or merely from the degradation of other organic and proteinaceous compounds. There was no evidence to suggest that bacterial dosing elevated emulsified fats, oils or grease in discharges.

Bacterial digestion will have a role to play in a Grease Management Strategy, but recovery of major sources of FOG for alternative energy production is the preferred long-term option. In the shorter term, thermal oxidisation, anaerobic digestion and composting also have a significant role to play. Any strategy must promote public awareness in order to reduce domestic FOG discharges.

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1.0 Introduction

Fats, oils and grease (FOG) create operational difficulties for wastewater treatment systems and at an international level there have been a number of studies undertaken. Current published research tends to be region specific or focuses on specific aspects of grease management.

As population growth, urbanisation and legislative requirements affects Ireland, there is a need to examine the availability of management options for FOG in the country.

1.1 Objectives

The main objectives of this study are:

- To examine the significance of FOG in sewerage networks internationally and to undertake an evaluation of the Irish experience.
- To identify the legal, social and political drivers that may influence an Irish FOG management strategy.
- To document the basic chemical composition of fat; this facilitates a more complete understanding of the management techniques available to manage the FOG issue.
- To document all available FOG arresting equipment along with the various treatment and disposal methods available locally and internationally.
- To evaluate an on-site study of GRU bacterial treatment in Limerick over an extended period time, to confirm / refute the results of published bacterial dosing trials.
- To develop a draft national grease management strategy for Ireland.

2 Methodology of this Study

2.0 Introduction

This section addresses the methodology utilised in this study to acquire further information. It details site visits, meetings, telephone conversations and on-site testing undertaken to paint a complete GRU management picture in this country. The study is based on five main sections:

1. **Literature Review**
2. **Data Collection and Test Programme**
3. **Results of Research**
4. **Discussion Section**
5. **Conclusion**

2.1 Literature Review

The literature review assesses current information available in the public domain that has a bearing on grease management. An evaluation of the increasing focus on FOG treatment, nationally and internationally, assists in the identification of Irish FOG policy drivers in terms of their regulatory, social, economic and political importance. The literature review continues by addressing best international management practices, including the design of Grease Retention Units (GRUs), in conjunction with are evaluated in conjunction with recommended cleaning regimes. The section concludes with a review of the technologies available to manage collected FOG; both in-situ and ex-situ.

2.2 Data Collection and Test Programme

In order to support the literature review, further data had to be collected in the field. All communications entered into with key stakeholders are documented. These were the individuals and organisations that were identified as being the drivers of GRU policy in Ireland.

A number of Local Authorities were contacted and the overall response was that Limerick, Wicklow and Dublin City Council had a particular interest in Grease Management. These were contacted and gave information in relation to a number of independent consultants and contacts in the Department of Environment and Local Government (DoELG). After undertaking meetings and telephone conversations with these parties, a message was posted on the international newsgroup (alt.wastewater), calling for submissions from interested wastewater professionals worldwide. This provided an international dimension to the issue.

To gather information on the ground, visits were made to GRU installations throughout Ireland and all companies advertising "Grease Disposal" in the Irish telephone directory were contacted. A number of these organisations were subsequently visited. This yielded information on FOG disposal operations and on organisations and individuals undertaking bacterial, enzyme and chemical dosing.

Part of this study evaluates the effectiveness of bacterial dosing in four GRUs in Ireland. In order to secure access to test-sites, a number of existing GRU management companies were approached. Positive feedback was offered, culminating in an approach by one particular Irish drain company; Dyno-Rod Ireland. The company provided a bacterial dosing service and had been approached by Limerick County Council to undertake research on the effectiveness of their GRU dosing strategy. At a meeting with Limerick Council, Punch and Partners Engineers and Dyno-Rod, it was suggested that this study could evaluate four different GRUs around Limerick City that represented different sizes and types of GRUs and kitchen wastes. It was made clear that this study was to be part of an independent academic effort and that a number of competing bacterial products were to be blended to provide an overall view of bacterial GRU dosing in this country. As it was seen to lend more weight to the study, this was agreed with all parties. A larger sample size was also suggested, but the cost of testing was deemed prohibitive due to the test requirements that all GRU contents were to be removed by vacuum-tanker at eight week intervals.

Specific names and positions of key personnel contacted in all of the organisations are listed in the main Data Collection and Test Programme section.

2.3 Results of Research

The results of all investigations and tests that were undertaken are presented in this section. Preliminary analysis of the data is undertaken and is presented in a meaningful way for the discussion section.

2.4 Discussion Section

All results of the research are compared and contrasted with that information which was derived in the literature review. When the data is analysed, it provides the platform for a suggested National Grease Management Strategy.

2.5 Conclusion

The final section is the Conclusion. This section briefly outlines the key findings, recommendations, limitations and areas of further research suggested.

3 Literature Review

3.0 Introduction

This section documents the available literature pertaining to grease management. A wide range of issues are covered, commencing with the significance of fats, oils and grease (FOG) in Ireland at present. Various drivers are identified that suggest a strategy is required and then examples of other models are examined.

An evaluation of FOG properties is undertaken prior to an assessment being made on grease retention units (GRUs), which are currently available at a local and international level. This leads to a review of cleaning methods/ treatments and disposal options.

3.1.0 The Growing Significance of FOG in Sewers

Being of a sticky nature, FOG tends to clog drains and sewers, causing an odour nuisance and leading to the corrosion of sewer lines under anaerobic conditions (Lemus et al, 2002). When reaching a wastewater plant, FOG floats as a layer on the surface and adhere to activated sludge (Mc Ghee, 1991). This blinds the air-water interface and reduces oxygen transfer rates. Since oils and grease are persistent throughout the treatment process, they then remain in the final sludge, causing dewatering and handling difficulties. This leaves the final sludge as a viscous and waxy material (Stoll et al, 1997).

The fate of oil and fat from restaurants and other commercial kitchens is probably one of the most forgotten, yet critical issues in waste management. Oil and grease are not biologically decomposed with any great deal of success. Furthermore, other conventional treatment processes are hindered due to the consistency and nature of the compounds (Stoll et al, 1997).

Lefebvre et al (1998) demonstrate that FOG accounts for an excess of 25% of all Chemical Oxygen Demand (COD) in domestic wastewater. In untreated primary sludge, grease can account for up to 35% of solids and up to 12% of solids in untreated activated sludge (Metcalf and Eddie, 1991). In Mobile town, Alabama, FOGs are the leading cause of Sanitary Sewer Overflows (SSOs). This is caused by food service facilities discharging grease-laden effluent that cools and solidifies to cause significant flow restrictions (Mobile Area Water System Authority, 2004).

There are many other examples available on the detrimental affects of FOGs. In its public information programme, North Carolina authorities note that in 1999, more than 30% of all SSOs were from grease blockages (North Carolina Environmental Authority web page, accessed 12-11-2004). Since then, Mc Rae (2002) explains that 23-28% of all SSOs in North Carolina have been caused by grease. The Tennessee Drainage Authority (2002) grease control guidance document explains that problems relating to FOGs have been historically downplayed and the current figure for grease related blockages stands at around 50%.

3.1.1 The Irish Experience

By the end of 2003, there were 44,521 registered food production and service establishments in the country. There was also a rising trend in "Food to Go" cuisine provided by retail and catering outlets (Food Safety Authority of Ireland, 2003).

In Galway, it is reported that thousands of gallons of FOGs are clogging the drains leading to the Mutton Island sewage plant, posing both a serious environmental and economic issue that will cost the city vast amounts of money (Galway Advertiser, 21-04-05).

3.1.2 The Eastern Region

In their study "Strategic Review and Outlook for Waste Management Capacity and the Impact on the Irish Economy", Bacon et al (2002) highlight the current deficit in infrastructure for dealing with existing waste in Ireland. In the greater Dublin area including Kildare, Wicklow and Meath, two thirds of all Irish waste is produced. Bacon blames Local Authorities for a reluctance to identify their planned waste disposal facilities and reports on an assumption that there will be a timely provision of thermal treatment. This leaves a gap in the infrastructure to treat sludges and biowaste categories to which collected FOG belongs.

3.1.3 Grease Management in Dublin

Dublin has expanded rapidly in recent years and a new wastewater treatment plant has been built at Ringsend to accommodate this. The plant is the largest Sequential Batch Reactor (SBR) plant in the world, initially constructed to cater for 1.7 million people (Dublin City Council, 2004). Anglian Water constructed the plant and identified the significant volumes of grease that enter the Dublin sewerage network. In order to counteract this, specified separate grease removal units were required at the head of the plant (Dublin City Council, 2004). In the south of the city, Dunlaoghaire-Rathdown Council (2005) believes FOGs are becoming an increasingly common problem in the operation and maintenance of the local sewer network.

Compliance Consulting Inc. (2004) undertook a study of FOGs in Dublin and concluded that the Local Authority exercised almost no management over what their food service establishments put down their drains. They also found that inadequate grease trapping equipment combined with population and business growth has rendered the burden on waste infrastructure unbearable.

Plate 1. Grease "balling" in a Final Clarifier

Source: Personal Collection

3.2.0 Legal, Social and Economic Drivers of a Grease Management Strategy

3.2.1 Legislation.

At a national level, the Irish Government can pass an Act of the Oireachtas. This Act can then be used to make secondary legislation such as Regulations and Orders. At EU level, Directives are passed that oblige Member States to incorporate them into national legislation. This is achieved by the introduction of an Act, Regulation or Ministerial order. The majority of Irish environmental legislation originates from EU Directives.

3.2.2 Water Legislation

There are a number of important Acts and Regulations that have strengthened Irish environmental legislation and forced public and private polluters to ensure previously untreated discharges are now legally compliant or face prosecution.

The Local Government (Water Pollution) Acts, 1977 and 1990 are the main framework for the prevention of water pollution in this country. They prohibit pollution and contain provisions on the licensing of discharges to waters and sewers. In 1992, the Environmental Protection Agency Act was introduced to establish the Irish Environmental Protection Agency (EPA). Under Section 61(3), the EPA is required to report on the quality of effluents being discharged from treatment plants, sewers or drainage pipes which are vested in, controlled or used by Sanitary Authorities.

The Urban Waste Water Treatment Consolidated Regulations, 1994-2004 builds on the Urban Wastewater and Water Framework Directives. Their aim is to reduce pollution caused to surface waters by municipal wastewater and ensure proper collection and treatment before discharge to estuaries or coastal waters. A responsibility is placed on Local Authorities to provide treatment of urban wastewater, to monitor discharges from agglomerations and to transmit the results of such monitoring to the EPA.

The European Commission published the Water Framework Directive in 2000. This represents a major revision of EU water policy and will provide the basis of all future Community water legislation addressing both quality and quantity issues. Its aim is to ensure the quality of EU waters by 2010, with the annexes containing quality standards and limits for certain substances in waters and point source discharges. The

Directive further establishes a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. The concept of "River Basin Management Plans" is introduced, specifying that a Competent Authority be designated for each river basin district (RBD). The legislation further requires that the price of water reflect its true cost by 2010 with no cross-subsidies between industry, agriculture and households.

3.2.3 Waste Legislation

The Waste Management Acts of 1996 and 2001 heralded the introduction of a legislative framework to underpin future waste management progress. It assigned new powers and functions to public authorities, while acknowledging a role for the private sector in waste management. Specific obligations were placed on a person to take all reasonable steps to prevent or minimise the production of waste arising from any agricultural, commercial or industrial product or activity. A system of licenses and permits was also introduced, deeming it an offence to dispose of waste through a non-permitted or licensed channel. In order to give the Act enforceability, fines of up to €12.7 million and/or ten years imprisonment were introduced. The Act stipulated that each Local Authority draw up a waste management plan (based on a hierarchical approach) detailing the infrastructure required for their administrative regions. There were 7 regional groupings:

1. Dublin.
2. North East.
3. Midlands.
4. Connaught.
5. Limerick/Clare/Kerry.
6. Cork.
7. South East.

- Kildare, Wicklow and Donegal had separate plans.

In 1999, the Landfill Directive was published, imposing a gradual phasing out of certain materials, including biodegradable wastes from landfills. It called for biodegradable waste to be treated as a resource that could substitute primary raw materials and reduce natural resources consumption. Biodegradable waste was defined as "waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, paper and cardboard". This clearly covers FOGs.

The first deadline is 2006, by which time biodegradable municipal waste (BMW) to landfill is to be reduced to 75% of the amount generated in 1995. This is to drop to 50% in 2009 and to 35% by 2016. Unfortunately these figures were set in 1995 and predated our "Celtic Tiger" expansion. Thus, our original forecast of the waste recycling infrastructure is now well short of the larger quantities of waste now generated. Ireland must create a biological treatment capacity of 351,539 tonnes per annum by 2009 (DoELG, 2004).

The Department of Communications, Marine and Natural Resources (web page accessed 12-02-05) also regards industrial and municipal waste as a potential source of biomass. This has a significant impact on future disposal options for FOG, as it could be exploited for its renewable energy potential.

3.2.4 Other Legislation Relevant to FOG Processing

3.2.4.1 Directive 2003/30/EC on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport

The Directive requires Ireland to report to the Commission before 1st July each year on specific measures taken to promote biofuels and biomass and to indicate targets for their market penetration. Ireland was required to report on its national indicative targets for the first phase by the 1st October 2004. Ireland must indicate the second phase national indicative targets by 2006, which can be based on the following elements:

a) Objective factors such as the limited national potential for production of biofuels from biomass.

b) The amount of resources allocated to the production of biomass for energy uses (other than transport and the specific technical or climatic characteristics of the national market for transport fuels).

c) National policies allocating comparable resources to the production of other transport fuels based on renewable energy sources and consistent with the objectives of this Directive.

3.2.4.2 Proposed Biowaste Directive

There is a proposal for an EU Directive on the Treatment of Biowaste and the EPA has already adopted the technical standards to achieve the requirements of the Directive (DoELG, 2004). Biological treatment of BMW was to be carried out in tandem with other waste streams such as "organic industrial wastes, fisheries residues etc". Co-treatment is seen to offer economies of scale and grease treatment would fit in with this ethos.

3.2.5 National Initiatives and Strategies

In order to drive the changes required to meet national legislative requirements, Irish Government agencies undertook a number of initiatives and strategies as part of their overall waste management strategy. These have been evaluated as part of this study and those pertaining to FOG management are set out in this section.

3.2.5.1 The Concept of Public-Private Partnership

The enormous changes in waste infrastructure requirements have required vast sums of capital spending. A large portion of the waste infrastructure that is in place has been funded by Public Private Partnerships (PPPs). This operates when a Local Authority puts the design, building and operation (DBO) of a facility or service out to public tender. A private firm is then awarded the tender and manages the contract for an annual fee over a specified period. Any increased requirements that incur extra running costs are passed on to the Local Authority. Hence, there is great pressure to minimise loadings and maximise revenues from domestic and commercial waste generators.

Major parts of the National Development Plan (NDP) are carried out using the PPP approach. The current NDP (2000 – 2006) involves €5.4bn of new investment in urban wastewater infrastructure and water services. The plan provides for 735 water and sewerage schemes (EPA, 2004).

3.2.5.2 Changing Our Ways (DoELG 1998)

This document set targets for waste management by 2013:

1. 50% of overall household waste to be diverted from landfill
2. 65% reduction in BMW from landfill
3. Biological treatment capacity of 300,000 tonnes per annum
4. Recycling of 35% MSW
5. The rationalisation of landfills to 20 state of the art facilities.
6. Reduction of CH_4 emissions from landfill by 80%

3.2.5.3 Green Paper on Sustainable Energy (DOPE 1999)

The paper established a policy framework for energy efficiency and the use of renewable energy sources. It also set up Sustainable Energy Ireland (SEI). SEI is responsible for the promotion and assistance of environmentally and economically sustainable energy production across all sectors of the economy. Its targets are to improve energy efficiency and renewable energy and assist in the implementation of the Green Paper on Sustainable Energy and the National Climate Change Strategy. As part of this, it promotes research, development and demonstration of renewable energy technologies and alternative fuels.

3.2.5.4 National Climate Change Strategy (DoELG 2000)

This strategy sets out the Government's ten-year framework to ensure Ireland meets its Kyoto target. It addresses greenhouse gas (GHG) emissions from all sectors of the economy including CH_4, Nitrous Oxides and CO_2. Waste management was said to represent 2.5% of global GHGs and 12% of all CH_4 emissions. A reduction of 40% in waste emissions was requested; suggestions to achieve this included obtaining energy from slurry in conjunction with food waste. A target of reducing GHG emissions by 2.67m tonnes in the transport sector was to be achieved by encouraging alternative and more CO_2 efficient fuels.

3.2.5.5 Delivering Change - Preventing and Recycling Waste 2002

Designed to introduce a more inclusive approach to waste management, "Delivering Change" strives to involve the general public in assisting public and private waste management bodies (DoELG 2004). It further looks to business and industry to create products that facilitate waste minimisation and recycling. In order to accelerate the pace of change in our society, it took a number of measures:

1. Establishment of a National Waste Management Board to coordinate, review and advise on waste management policy
2. Establishment of a National Waste Prevention Programme to be driven by a new core prevention team within the EPA
3. The establishment of a recycling consultative forum and market development group to lead the expansion of waste derived materials

3.2.5.6 Race Against Waste Initiative 2003

The Department of Environment and Local Government (DoELG 2003) launched this initiative to drive home the message that there was a waste management crisis in Ireland. It featured initiatives and practical measures that could be taken to help deal with biodegradable waste. This was promoted by a large national advertising campaign.

3.2.5.7 National Waste Prevention Programme and Market Development Group 2004

In April 2004, The Irish Government established a National Waste Prevention Programme to deliver waste minimisation across all waste streams. The programme is based in the Environmental Protection Agency Office and provides a comprehensive range of initiatives. Addressing education, awareness, technical training and financial assistance, the programme was allocated a grant of €2m. A market development group was subsequently set up in 2004 and allocated €1m to find markets for recycled and recovered products.

3.2.5.8 Draft Discussion Document on Biowaste and Sludges

The discussion paper sets out European strategy on biowaste disposal (European Commission Directorate General, 2004). It promotes the return of biowaste to land where practical and recommends treatment technologies to achieve this. A suggestion is put forward that the requirement to recycle resources responsibly underpins the sustainable development of society. Recommendations are made to incorporate all aspects of recycling and recovery into product lifecycle analysis at design stage. Biowaste recycling is shown to offer the agricultural sector a secure, long-term supply of nutrients to compensate for losses through mineralization, uptake of crops, leakages into groundwater etc.

"Continuous cropping and monoculture reinforce the need of nutrient and organic matter recycling. Sludge and biowaste serve these purposes."

The application of well-stabilised biowaste to land is seen as an important component of the overall life cycle of organic consumables. It is explained that composting mimics the natural decay process where organics are not fully destroyed, but significantly transformed into a slowly decaying storage of humus. This contrasts with mineral based alternatives that increase the global nutrient pool within the agricultural and urban environment, which is already problematically large in much of the EU. The authors acknowledge that compost may contain heavy metals, but argue that there are strict quality controls in place and that mineral phosphorous fertilisers actually contain cadmium impurities.

3.2.5.9 Waste Management-Taking Stock and Moving Forward, April 2004

The DoELG (2004) reviewed the national waste strategy and drew up a number of conclusions and recommendations, making it invaluable to any business thinking of collecting and treating grease in an economic environment. It concluded that:

1. There is a need for more biological treatment in waste management plans (WMPs). Current provisions will not meet our national targets.

2. Multiple WMPs provide barriers to large private waste contractors. A national plan would provide better economies of scale and hence better value for customers.

3. There is a failure on the part of planners to address economies of scale with planning permission only being granted for smaller facilities treating local waste. The EPA is not satisfied that the regional and national requirements are being met under this practice.

4. The waste hierarchy is not properly addressed. Ireland places too much emphasis on recycling, but little on the higher-ranking levels of prevention /minimisation and little focus on items below, such as landfilling (which will always be required for residuals).

5. The private waste industry is now seen as a €1bn per annum business. Due to the enlarged scale of the sector and the number of mergers and takeovers, economies of scale are now emerging. This has resulted in the full allocation of €26m of grants for private industry being rescinded.

6. Local Authorities are confused as to the provision of commercial waste collection. They have no statutory obligation and need guidance in relation to the private collection and treatment of such wastes.

7. Private companies have been awarded waste collection contracts by the Local Authorities in the absence of any tendering process. The transparency and competitiveness of this practice is questioned.

8. A system of trans-national waste permits is recommended. Since the waste business is now consolidated, it is unreasonable for pan-national companies to have a number of waste permits with varying requirement for each region.

3.2.5.10 National Strategy on Biodegradable Waste- Draft Strategy. (DoELG April 2004)

The purpose of the report is to outline the government policy for the diversion of BMW from landfill. The report documents that 65% of municipal waste is biodegradable; the principal biodegradable components being paper, cardboard, food and garden waste. It reminds us that the EPA National Waste database 2001 highlighted 578,158 tonnes of BMW available, of which landfill accounted for 555,926 tonnes and a mere 22,233 tonnes was recovered. Indeed from 1995-2001, our overall municipal waste generation increased by 46%. This amounts to 690 kg per person per annum. The draft report is aimed at building on the previous strategies of Changing Our Ways 1998 and Delivering Change-Preventing and Recycling Waste, 2002.

3.2.6 Economic Measures Affecting Grease Management

3.2.6.1 Finance Acts 1999 and 2004

This relates the possible use of recovered FOGs as a biofuel source. Section 98 of the Finance Act 1999, as amended by Section 50, Finance Act 2004, enabled the Minister for Finance to apply a relief from mineral oil tax (Department of Communications, Marine and Natural Resources, web page accessed 12-02-05). This was for all pilot projects to produce or test the technical viability of biofuel as a motor fuel.

3.2.6.2 European Regional Development Fund (ERDF)

The ERDF finances a number of cohesion programmes, of which INTERREG is an example. INTERREG III (2000-06) is designed to strengthen economic and social cohesion throughout the EU, promoting cross-border, trans-national and interregional cooperation. Under Measure 2.3, funding of €5.1m in ERDF aid is available for cross border renewable energy/energy efficiency proposals. In 2003, €50,000 was allocated to Donegal Farm Relief Services towards the cost of a proposed anaerobic digestion plant to be located at Castlefin, Co Donegal (Department of Communications, Marine and Natural Resources, web page accessed 12-02-05).

3.2.6.3 EU LEADER Programme

LEADER is the EU Community Initiative for Rural Development that provides approved Local Action Groups with public funding to implement business plans for the development of their own areas. LEADER + is the current phase and runs from 2001-2006. Biomass projects have been allocated €44,589 to date (Department of Communications, Marine and Natural Resources, web page accessed 12-02-05).

3.2.6.4 EU LIFE Programme

The EU LIFE programme contributes to the development of innovative technology by co-financing environmental demonstration projects. This includes environmental impact reduction of economic activities, products and waste management.

3.3.0 Existing Lifecycle Assessment (LCA) Models for the Waste Industry

There are a number of examples of LCAs that have been undertaken on various waste management activities. While they are naturally diverse in their content, they follow the same "cradle to grave" approach in their respective waste activities. There is often a difficulty in LCAs when it comes to cost comparisons between competing technologies. ECOTEC (2002) explain that throughout Europe, waste technologies are all at different economic stages in their development. An example is given of incineration, where the cost of a modern incinerator may be far higher than an older incinerator licensed to operate at less stringent Emission Limit Values. Indeed, this difficulty is compounded when competing waste processing technologies are often trans-national and external costs vary widely between various sites. Nonetheless, there are a number of LCA models available for the waste industry that can be examined.

Skordilis (2004) states that the selection of priorities regarding waste management has direct economic and environmental impacts. He puts forward the argument that a waste strategy should not be based on the cost benefit analysis (CBA) approach as it does not account for the possibility of waste reuse as a secondary raw material, nor does it address the external benefits of increased employment and improvements in society as a whole. He puts forward Worth Benefit Utility Analysis (WBUA) as being a more complete method and concludes that governments, Local Authorities, consultants and waste companies could successfully use WBUA in their future policy strategies.

Lundie et al (2004) used a LCA model to compare the impact of food macerators against solid waste disposal methods. They demonstrated that all food waste management strategies should examine the environmental principles associated with a product, process or service from "cradle to grave". This would promote a holistic approach to ecologically sustainable decision-making.

3.3.1 Grease Management Model for Bangkok

Stoll et al (1997) presented a LCA model specifically on grease, the only working example that is available. It focussed on maximum recovery and reuse of FOG in Bangkok and designed a three-tier grease disposal and management strategy:

1. Small to medium restaurants: Passive traps were suggested with waste FOG being collected for use as low-grade lubricants and fuels post smelting.

2. Medium sized restaurants: The option was given of having a grease trap or mechanical separator with periodic emptying to a centralised waste treatment facility.

3. Large restaurants: It was recommended that due to the larger volumes of grease, it would be desirable to have daily collection of grease from mechanical separators. This would avoid rancidity and create a greater potential for reuse of the oils in cosmetics and possibly foods. Further downstream, large passive traps would collect the remainder of the grease and it would be transported to a central treatment facility. All trappings arriving at the central facility would then undergo anaerobic digestion for energy recovery. Final residues were then to go to incineration or landfill.

It is interesting to note that no bacterial additions to grease retention units were mentioned. This may be due to their unavailability in the region or that they were deemed ineffective. The latter is most unlikely, as the practice was not actually dismissed as unsatisfactory.

3.3.2 Further Examples of Grease Management Strategies

While GRU lifecycle assessment models are not common, there are a number of grease reduction programmes in operation. The USEPA Region 4 and Water Environment Federation developed a grease management-training programme for Local Authorities (Florida Department of Environmental Protection, 2000). The programme emphasised the flexibility of various approaches and demonstrated that many proactive strategies can be tailored to suit. In essence, the EPA is open to various programmes as long as they are enforceable, successful and have the necessary teeth to ensure compliance. Advice is given as to the initiation of grease management programmes and they were to be introduced under the aegis of a pre-treatment programme. The USEPA does not allow a Local Authority to rashly adopt a programme; they must first undertake a CMOM (Capacity, Management, Operation and Maintenance) Plan to ensure they have sufficient organisational skills and resources to successfully implement the project. While the overall aim was to remove grease from sewers, it did not address a complete LCA (i.e. fate of removed grease).

However, it did at least allow flexibility in approach, ensuring sufficient planning was undertaken for each Local Authority.

Many of the States in America have grease programmes available and all address reduction at source through training and public participation. In regard to the maintenance and final destination of grease, there is a considerable degree of contradiction from State to State. An example is Tennessee State (2002) where a defined FOG limit in a final discharge is not seen as the most successful methodology for implementing a management programme. It is suggested that policing would be too expensive and that enforcing best management practice may actually provide equally successful results. They further contest that FOG measurement is too narrow a measurement tool in the first instance and if specific limits were to be set, COD would be a broader analytical method. The Tennessee document concludes that FOG specific parameters should be limited to a measurement of discharge effluent temperature as a spot check tool for emulsified materials.

3.4.0 The Definition of Fat

In order to understand the types of FOG that are present in drainage systems, a clear definition of what they are and the properties that they exhibit is important.

3.4.1 Fats and Lipids

Fat can be described as a straightforward glycerol molecule, holding 3 fatty acid molecules by way of an ester bond, commonly known as a triglyceride. There are many possible variations in this basic structure and each type has its own physical, chemical and biological properties. The Institute of Shortening (1999) define lipids as including mono and diglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, fatty acids and fat-soluble vitamins. Lipids have relatively simple C (carbon) - even or odd long chains in the C16-C32 ranges. Lipids contain twice the energy of other organic molecules such as sugar and starch.

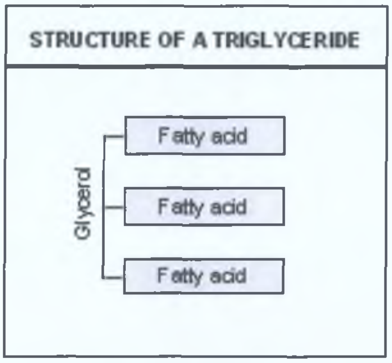
Lemus et al (2002) explain that the main constituents of food based FOGs are of both animal and vegetable sources. They explain that FOGs are triglycerides comprising straight chain fatty acids, attached as esters to glycol. Furthermore, when hydrolysis has taken place, they can produce a combination of free fatty acids and glycerol.

Wakelin (1997) differentiates triglycerides as having considerable differences in their fatty acid composition. This depends on whether they are saturated or unsaturated fatty acids, which in turn affects their physical state at wastewater temperatures. All the elements in lipid residues share the common property of being soluble in various solvents including hexane. Therefore hexane extractable material (HEM) is the measurement for the standard analytical test for grease.

3.4.2 Triglycerides

Triglycerides can be simple (where the 3 fatty acids are identical), or more commonly mixed (where there are 2 or 3 fatty acids present in the molecule). One hundred grams of FOG will yield 95g of fatty acids (The Institute of Shortening 1999). Hence, the physical and chemical properties of the compound are greatly affected by the kinds and proportions of the component fatty acid and the way in which it is positioned on the glycerol molecule. A basic Triglyceride structure is shown in Plate 2.

Plate 2: Triglyceride



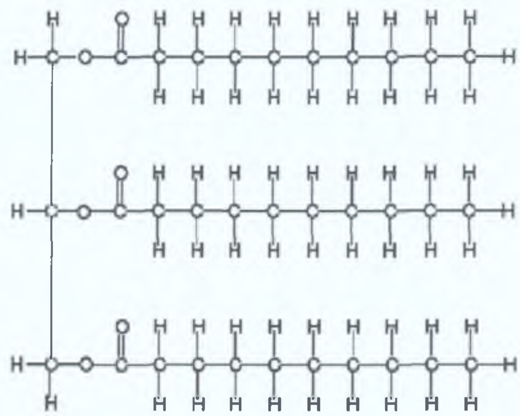
Source: Kscience.co.uk

The predominant fatty acids are saturated and unsaturated carbon chains with an even number of carbon atoms and a single Carboxyl group.

3.4.3 Saturated Fats

Saturated fats are seen as the least chemically reactive, having only a single carbon-carbon bond. This repetitive single carbon bond is shown in Plate 3. Their melting point increases with chain length. Decanoic and longer chain fatty acids are solids at normal room temperatures. Examples of saturated fats are Palmitic and Stearic acid with melting points of 62.9 and 69.6 degrees Celsius respectively.

Plate 3: Saturated Fat

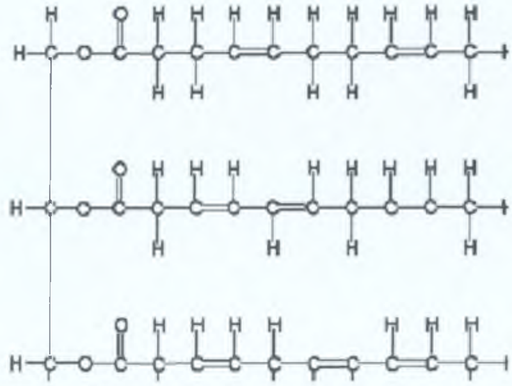


Source: Auburn University

3.4.4 Unsaturated Fats

Unsaturated fatty acids contain one or more carbon-to-carbon double bonds. These bonds are visually represented in Plate 4. The relative abundance of double carbon bonds over the previous plate on saturated fats is clear to see. Oleic acid is the example that occurs most in nature. Where a fatty acid has 1 double bond it is monounsaturated. If it has 2 or more double bonds it is polyunsaturated, an example is Linoleic acid.

Plate 4: Unsaturated Fat

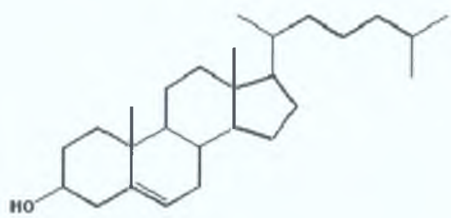


Source: Auburn University

3.4.5 Sterols

Sterols are known as steroidal alcohols; they contain the common steroid nucleus and 8-10 carbon side chains and an alcohol group. Cholesterol is the primary animal fat and is only present in trace amounts in vegetable derived oils. Vegetable oil sterols are collectively known as phytosterols, of which Sitosterol and Stigmasterol are the most commonly known. In Plate 5, the alcohol function of cholesterol can clearly be seen in position 3 of the first ring.

Plate 5 Cholesterol



Source: Oklahoma State University

3.4.6 FOG Content of Various Cuisine Styles

Chen and Yue (2000) list the levels of FOG in restaurant discharges that they studied in Hong Kong. While there is probably a regional difference, it serves the point that different styles of restaurant produce differing effluents.

Table 1: FOG Content of Various Cuisine Types

Style of Cuisine	Typical FOG content (mg/l)
Chinese	120-710
Western	309-332
American Fast Food	355-402
Student Canteen	1090-1500

Source: Chen and Yue (2000)

There is no provision for this variance in the current Irish standards on grease trap sizing, ISEN 1825-2:2001.

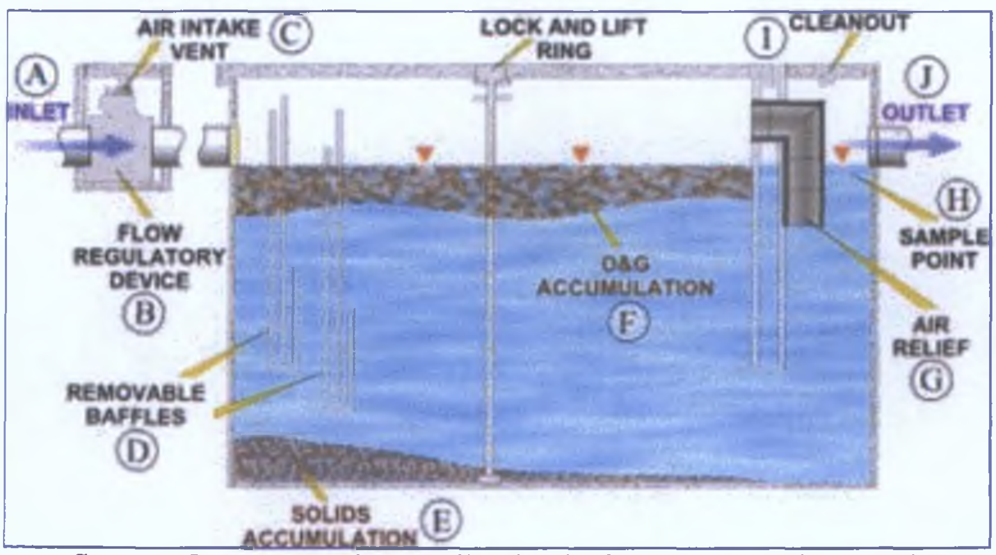
3.5.0 Grease Retention Units (GRUs)

In the waste hierarchy, the predominant strategy is reduction at source. In many cases it is not possible to prevent or even reduce the levels of grease generated. This means that a strategy involving the re-use, recycling or recovery of FOG becomes pertinent. In order to achieve this, FOGs must first be collected. In a grease management strategy, this translates into the provision of grease retention units (GRUs). This is an umbrella definition that includes all grease catching devices such as passive and automatic grease traps and interceptors.

3.5.1 Passive and Automated Traps

The Tennessee Drainage Authority (2002) explains the two basic types of grease trapping unit. The first is passive and works on the principle of specific gravity. Grease enters a baffled box and is trapped behind a weir while clean water flows underneath the weir to the discharge. The second is an automated/ electromechanical device that heats the contents and then skims off grease into a side compartment to await disposal. The terms grease trap and grease interceptor are used interchangeably. However, a grease interceptor refers to a separate device installed indoors or near a kitchen fitting and has a design flow of 50 gallons per minute or less. A grease trap usually refers to an outdoor separation device with a design flow rate of over 50 gallons per minute with a volume exceeding 750 gallons.

Plate 6: Passive Grease Trap



Source: Newport-Beach Council, USA (web page accessed 24-4-05)

In order for the unit to be effective, the Tennessee document (2002) states that the "Three T" rule must be obeyed:

1) Time. The separation device must provide sufficient retention time for emulsified grease and oil to separate and float to the surface.
2) Temperature. The separation device must provide adequate volume to allow the wastewater to cool sufficiently for emulsified grease to separate.
3) Turbulence. Turbulence through the device must be controlled so that grease and solids are not kept in suspension in the wastewater.

3.5.2 Tube Settler Trap

Wei et al (2000) describe how Hong Kong predominantly utilises the standard baffled interceptor. The disadvantage of such a unit is the large footprint that is required to allow sufficient time, temperature and a minimum of turbulence to allow free oils to separate from an emulsion. The smallest oil droplet that can be floated off is 150 micron; however the addition of a tube settler configuration can reduce the standard grease trap footprint down to a mere 20 % of the original size. Interestingly, the testing showed that the best-designed separators under optimal conditions could still only remove 79-89% of non-emulsified grease irrespective of any flow condition. This highlights that gravity separation does not afford total containment.

3.5.3 Enzyme Trap

In New Zealand, Christchurch City Council (web page accessed 12-12-04) allows an "enzyme trap" for the purposes of grease retention. This is a variation of the standard grease trap, where there is a dosing arm built into the trap to dose grease emulsifying enzymes directly onto the grease cap.

3.5.4 ISEN 1825-2:2001.

It was not until recent years that Ireland had adopted any standards for the design of GRUs. In 2001, a prEn document (NSAI 2001) was introduced. This is now adopted as a national standard -ISEN 1825-2:2001 and takes account of design in terms of flow rates and detergent usage. It states that grease separators must be used whenever it is necessary to separate FOGs from wastewater. The document is rather narrow in its focus, as its standard formula does not account for the differing designs that alter separator efficiencies. The maximum flow rate determines the minimum size of the trap. This size is then multiplied by a required factor where a listed variable has detrimental affect on retention. Besides flow rate, there are a number of other variables that are listed:

1. Maximum temperature- over 60°C. a temperature factor of 1.3 is applied.
2. Density of oil- where oil >0.94g/cm^3, a density factor of 1.5 is applied.
3. Detergents- occasional use gives a 1.3 loading.
4. Establishments such as hospitals etc. incur a loading rate of >1.5

Clean out frequencies are stated as being at least once a month and preferably every two weeks. This takes no account of individual circumstances. Indeed, the failure of current Irish legislation to take account of mechanical traps is impinging on the quality of recycling that could be achieved under a successful grease management programme. This is supported by Yates (web page accessed 10-11-04) who states that mechanical traps are an excellent opportunity to recover grease for reuse prior to it being contaminated in a "passive" GRU. He further argues that governmental minimum sizing standards for grease traps should take cognisance of the presence of automated skimmers. Another area of contention is whether dishwashers should be connected into the GRU. ISEN 1825 states that they should be plumbed into a GRU. This is contrasted by Keidal Inc. (2005), who insist that dishwashers should be plumbed separately into their own exclusive GRU and should by-pass the main kitchen grease trap. The reason given is that dishwasher discharge can cause hydraulic overloads.

3.5.5 Electro-Mechanical Separators

In their advertising document on automatic separators, Thermaco (2003) describe their "Big Dipper" as an automated grease removal device designed for smaller kitchens and for specific machines. The unit is shown to reduce a FOG laden waste stream from 634mg/l to 71mg/l. It encompasses a manual or automatic solids removal chamber followed by a central skimming chamber. The unit heats to 115-130 °F. each night prior to the skimming wheel removing FOGs into a collection tray. FM Systems (web page accessed 21-11-2004) market a similar "Grease Guardian" in Ireland.

Plate 7: The Big Dipper

Source "Thermaco (2003)

3.5.6 Corrosion of GRUs

In Texas, the Austin City Authorities (2003) sound a note of caution about free fatty acids corroding baffles, walls and bases. This is reflected in the discharge levels of FOG as the unit degrades over time. All units must be regularly inspected and eventually replaced.

3.5.7 Electro-Coagulation (EC)

Electro-Coagulation (EC) takes place in a tank similar to a GRU. It works by the addition of an anode and cathode of aluminium or ferric. These are supplied as metal rods or discs and need regular replacing. Aluminium electrodes produce a clear effluent, while the iron electrodes produce a waste stream with a rusty brown tinge. Wastewater is passed through an electrostatically charged vessel and a number of sympathetic processes occur. The oxidation of FOGs takes place at the corrodible anode. In addition to this, hydrogen bubbles are released and drive the grease to the surface where it can be concentrated, collected and removed. The metallic ions react with the OH^- ions produced at the cathode during the evolution of the H_2 gas and this yields pollutant-absorbing hydroxides. They assist in coagulation by neutralising negatively charged colloidal particles.

Xinhua et al (2004) describe EC as being in existence since 1906, when the first United States patent was awarded. Indeed, it was practiced throughout the 20th century with limited success and publicity. The process is characterised by the fast rate of pollutant removal, compact size of equipment, simplicity of operation and low capital and operating costs. Xinhua et al conclude that the removal rate is inversely proportional to the distance between the electrodes. The optimal spacing was found to be 10 mm and the pH was irrelevant to operations in the 3-10 range. Removal efficiencies of FOG and COD under normal conditions exceeded 95% and 75% respectively.

Chen and Yue (2000) contend that tight margins force restaurants to be highly efficient with low capital and operating costs. They argue that biological treatment of FOG is not feasible due to the large retention vessels and level of expertise required. Chemical coagulation is also dismissed as inefficient. To demonstrate the merits of EC, they installed a number of units in Hong Kong restaurants, with removal rates of over 90% of all pollutants where initial FOG concentrations exceeded 1500 mg/l. What was significant was that pH, conductivity and the electrical current densities of the wastewaters had no bearing on the treatment quality. Furthermore, the technology acted as a buffering agent, increasing pH of low pH wastewater and decreasing pH in higher pH wastewater.

With the purification of wastewaters came the associated production of sludge. About two thirds floated to the surface while the other third was generated as sediment. The treatment of a wastewater with a COD of 2764 mg/l, FOG 1500mg/l and SS of 574 m/l was undertaken. Under an electrostatic charge loading of 4.97 Faradays/m^3, the amount of sludge produced was 1.93% of the treated wastewater by volume.

Plate 8: An Electro-coagulation Unit

Source: Stormwater Inc. (web page accessed 16-11-04)

3.5.8 Ultra-Filtration (UF) and Micro-Filtration (MF)

These technologies describe fine filtration capable of producing final water purity unattainable through the more conventional means of water treatment.

In their State of the Art report on food manufacturing, the University of Nebraska (1997) explained that oil droplets can form an emulsion when they range in size from between 0.1 microns to 0.5 microns and are a major contributor of high oils in effluent streams. Ultra-filtration (UF) membranes can tackle these and have pore sizes below 0.1 micron. Micro-filtration (MF) uses a larger pore size in excess of 0.5 microns. While the larger pores are reasonably successful at filtering emulsions, there is a risk of breakthrough. Frequent backwashes are required in filtration technology in order to maintain operability. Tubular ultra filtration membranes have been used successfully in removing FOG in salad dressing processing, with a 99% removal rate. The University of Nebraska concludes that UF and MF are successful but long-term reliability to the approach is still unpredictable.

3.5.9 Hydrothermal Separation (HS)

This technology uses the change in physical properties and surface tension of water and FOGs at elevated temperatures. Such a process cracks the emulsion, allowing recovery of separate oil and water streams for reuse or recycling. Operating parameters are 300°C at pressures of 100 atmospheres. The technology is still in the early stages of development with only batch testing completed (University of Nebraska, 1997).

3.6.0 Treatment of Grease Retention Units (GRUs)

3.6.1 Physical Removal of FOGs

This involves the removal of FOG, water and sediments from a GRU. A permit for disposal must be obtained from the Local Authority in whose region the waste is collected. Some premises undertake their own grease removal, this is quite rare in Ireland but common in other countries. There are a large number of drain companies in Ireland currently offering GRU pump out services. Some of these are listed in Irish telephone directories:

- **Accelerated Drains**
- **Action Drain**
- **Advanced Cleaners**
- **Arklow Waste**
- **Dyno Rod**
- **Eagle Environmental**
- **Greenstar**
- **Height for Hire**
- **Tom Hogan Waste**
- **Horizon Environmental**
- **Hydrotec**
- **Ipodec**
- **Irish Waste**
- **Lehanes**
- **McAnulty**
- **Mac Waste**
- **Melodys**
- **Panda Waste**
- **Quick Sharp Drains**
- **Savage Industrial**
- **SITA**
- **Superdrain**
- **Walsh Waste**

There is evidence that restaurant owners would rather sub-contract the cleaning of their GRU. In the USA, Darling Restaurant services explain restaurant owners' dilemma. As well as buying, cooking and selling food in a clean environment, they are expected to be an expert in collection, storage, transport and recycling of old grease.

3.6.2 Pump Out Frequencies

While there are a variety of methods to manage GRUs, most commentators agree that physical emptying is required at some stage. The questions that must be answered are:

1. At what frequency?
2. By what method?

The Plumbing and Drainage Institute of America (1998) highlight that cleaning of their certified interceptors will depend on a wide variety of factors.

1. The type of food served
2. The precise purpose of the interceptor
3. The presence of food grinding macerators.

They also state that in cases where FOG discharge limits are tight, they may require that a trap be cleaned when it reaches a mere 25% of its rated grease retention capacity. The limits for FOG discharges range from 50-600 mg/l in the USA.

Darling Inc. (2003) proposes three pumping programmes:

1. Platinum: providing pump-outs every 4 weeks and two complementary line jettings per year.
2. Gold: giving an 8-week service
3. Silver: providing a quarterly clean out.

In their presentation "The Grease Guzzler", Burbank Incorporated (web page accessed 5/8/04) demonstrates the large volumes of grease that can be collected and reprocessed in Wisconsin USA. They can harvest 4,000 tonnes of FOG per week for reprocessing, using a fleet of 50 trucks. This is a clear example of creating secondary raw materials from waste.

Plate 9: A GRU in Spar Waterford, Taking "Combi-Oven" Condensate

Source: Personal Collection

3.6.3 American Standards for GRU Clean-Outs

The USA has federal and local laws. GRU management is undertaken at local level and local laws apply. San Bernando Council (2004) requires sediment to be cleaned once a week from a trap or more frequently if it has accumulated to more than a 50% level. Loveland City, Colorado (2000) requires weekly cleaning of indoor traps but only require outdoor traps to be inspected monthly. Winston- Salem City (2003) demands a 30-day clean out and specifies that back-flushing, decanting or mobile separation shall not be permitted. Arizona Industrial Waste Monitoring (web page accessed 04-08-04) a division of Flagstaff City Council, Arizona, requires complete emptying of passive traps on a regular basis, including removal of settled solids, grease and water. They argue that passive interceptors are seriously hampered if their working volume is reduced. The Austin City Code (2003) specifies a minimum pump out every 3 months by licensed haulier. The document further states that when the final compartment has accumulated more than 50% fat, this frequency should be reduced to 30-45 days. North Carolina Department of Environment and Natural Resources (1998) sets the pumping frequency for Cary Town at 20% solids level or where a 24-minute retention time is not achieved.

Not all authorities fix set intervals for pump-outs. Los Angeles County Sanitation District (web page accessed 02-08-04) states that cleaning intervals depend on the type of food and the establishment, not on a set criterion. North Carolina (2002) takes a similar approach, not setting frequencies and stating that pump-outs are only one part of the solution. They feel that a broader approach of good management and combined treatment options give the best removal of FOG.

Honolulu State (2002) has a limit of 25% of the rated storage level of grease. It takes the pragmatic view that installation of the largest possible interceptor would then require the least amount of pump-outs. The U.S. Air Force Space Wing (2004) sets a pump-out limit of 20%, by trained personnel only. The discharge limit is set at 100 mg/l FOG. However, the US Navy Facilities Engineering Service Centre (web page accessed 11-05-05) are more liberal, stating that any grease trap waste reduction is best managed by introducing digestive bacteria.

3.6.4 Methodology in GRU Emptying

The Tennessee guidance document (2002) explains the various clean out methodologies available in their jurisdiction. These are common in much of the USA.

Method 1. Pump the Entire Contents. The solids, grease and water are all removed and internal walls, baffles and the floor are inspected for problems. Winston-Salem City (2003) specifies this methodology.

Method 2. Removal of Grease Cap Only. This does not address the solids issue that usually arises at the base of the trap. Solids build-up reduces the hydraulic volume of the trap and also allows organic acids to corrode the walls, floor and baffles.

Method 3. Use of Mobile Interceptor Trucks. The tanker sucks the entire contents of a grease trap into its on-board separator. The displaced liquid from the clarifier section of the truck is then returned to the trap. Hauling costs are lower but a standard truck is not seen to provide the 3 Ts of time, temperature and minimal turbulence. Some states have outlawed these trucks. Advanced vehicles with inspection windows, polymer addition systems and filters can be inspected and licensed by the authorities on an annual basis.

Method 4. This highly illegal method is affectionately known as "Pump and Dump". A tanker is filled with clean water at the start of a shift. Each grease trap is flooded, pushing the grease downstream. Water is then sucked back out, prior to the truck moving to the next job. This process is repeated with the same water on other sites for the remainder of the shift.

The Colorado Bulletin (2002) allows the restaurateur to take a D.I.Y. approach. The owner can clean out the trap, return the baled water containing emulsified grease and place the solids in the waste bin for collection. While this may sound quite lax, the Hong Kong Environmental Protection Department (2004) allows the client to clean their own trap, disposing the FOG as waste or to a central grease trap reception facility.

In Ireland there are no central grease trap reception facilities. However, there are examples of domestic collection bins in materials recycling facilities (MRFs).

Plate 10: Dun Laoghaire- Rathdown Domestic Oil Collection Facilities at Ballyogan MRF.

Source: Personal Collection

Mc Rae (2002) believes that there are too many varying codes of practice for GRU management across America. He states that the restaurant industry wants all operating and sizing parameters to be based on sound information.

3.6.5 Bioaugmentation with Microbes

Novozymes (2000) published an article entitled "Bioaugumentation and Bioremediation, Unlocking the magic of nature". It defines bioaugmentation as the practice of enhancing the performance of indigenous bacterial populations through the addition of commercially prepared bacterial strains with specific catabolic activities. Szymanski and Patterson (2003) describe the evolution of commercial bioaugmentation. They describe how the culturing of "effective micro-organisms" was developed in the 1970s at the University of Ryukyus, Otinawa, Japan. These were to have a number of applications, including agriculture, bioremediation and household uses. The use of bacteria in Europe is covered by the Advisory Committee on Dangerous Pathogens (1995). This divides bacteria, fungi and viruses into classes 1- 4. Class 1 is the safest and Class 4 is the most pathogenic. All bacterial strains used in Europe should be Class 1. This is shown on each material safety data sheet that comes with a product.

Biologically converting FOG to CO_2 and H_20 in a GRU is deemed as a "treatment" option in the hierarchy of waste management. While this option is quite a number of rungs down the environmental ladder, it does effectively reduce the volumes of FOG requiring removal and subsequent off-site treatment and disposal. However, Lowry (web page accessed 04-08/2004) explains that the principle issue is whether microorganisms can completely metabolise oils, or merely convert them into intermediate organic compounds. These compounds could be small enough not to separate out of the water phase of a trap, but large enough to form soaps that clog downstream pipe work.

3.6.6 Scientific basis of Bioaugmentation

Keller (2004) states that bacteria require an energy source to power metabolic activity and require a carbon source to provide the basic building block of cell growth. These compounds can be carbohydrates (sugars and starches) and lipids (fats and grease). Energy is extracted by oxidation and the subsequent utilisation of released electrons while the carbon is provided by enzymatic-mediated catabolism of the same organic compounds. The broken compounds are then introduced into the metabolic pathway where they are converted into glucose. This is in turn converted to pyruvate with a consequential release of energy. Pyruvate is further converted to two-carbon acetyl units that enter the tricarboxylic acid (TCA) cycle and finally the electron transport chain where the majority of energy is released. The triglycerides and free fatty acids can be degraded by a number of documented bacterial strains.

3.6.7 Bacteria and Enzymes in GRU Treatment

Popino (2004) describes a bacterium as a single unique organism. While bacteria often grow in colonies, each cell is independent and reproduces by cell division. Bacteria can reproduce every 20 to 30 minutes, dividing into two identical "daughter cells". If grease is the food source, we can deduce that the bacterial population will reproduce logarithmically until the food source is depleted or an environmental change causes the demise of the population. The precise conditions required for FOG degradation varies from commentator to commentator. Variables include pH and temperature, while the presence of other nutrients and toxins must be factored into the equation.

3.6.8 Merit of Bacteria over Enzymes

Production of the vital enzymes begins as soon as the bacteria begin to grow. Hydrolytic enzymes such as proteases, amylases and cellulases are produced in the range of milligrams per litre to grams per litre. The advantage of using bacterial additives that produce their own enzymes is that bacteria have the ability to digest and degrade free fatty acids instead of allowing them to form a precipitate in the sewers (Dyno-Rod 2004). Naturclean's advertising document (2001) claims that bacteria change their production of enzymes to adapt to various food sources. For protection, they can form colonies, biofilms and spores. The community can adapt to changes in restaurant wastewaters, from cellulose rich to grease rich substrates. When oil concentrations are greater than the respective water concentration, an emulsion can form in which water drops containing bacteria and enzymes can be successfully dispersed throughout the oil.

3.6.9 The Advantage of Aeration

Lowry (web page accessed 04-08-04) compared four grease trap maintenance strategies in Fort Worth. These included pumping out the first trap every two weeks and dosing the second trap with bacteria. He found that there was sufficient retention time in a grease trap environment for bioremediation to be effective, however aeration improved degradation results considerably. Bio-Magic Inc. (2003) agrees with this and recommends the application of their bacteria through fine spray nozzles as an inexpensive form of oxygenation. They state that aerobic digestion is five times faster than anaerobic digestion. However, even with non-aerated traps, Lowry reports that the slower working anaerobic process still had a significant removal rate and was comparable to having a grease trap pumped every two weeks.

3.6.10 Reduction of COD

It is documented that the addition of bacterial strains initiates the breakdown of COD prior to the effluent reaching a wastewater treatment plant. Chen et al (2003) concur with this, they measured the degradation potential of sewer biofilm and discovered that passing organics could be partly degraded. In order to quantify the extent of this, they measured oxygen demand of wastewater upstream and downstream, discovering that sewer biofilm reduces oxygen demand by $32g/m^2/day$. This is close to respiration figures shown for activated sludge. The authors argue that by the utilisation of sewer biofilm, pressure on an overloaded plant can be reduced in the short-term.

Robles (web page accessed 6-9-04) demonstrated a biological pre-treatment unit at the head of the City of Tijuana wastewater plant. While the degradation rate is not considered outstanding compared to capital-intensive solutions, he argued that during the 5 months of dosing, a reasonable effluent was produced at minimal cost.

The Plumbing and Drainage Institute of America (1998) believe that bioremediation does not eliminate the need for monitoring, routine maintenance or inspections; neither does it deal with undigested materials. However, they state that New York City has done an extensive amount of testing using microorganisms for remediation of sewer blockages. The testing shows that this process has merit and the use of bioremediation, in concert with mechanical sewer cleaning, is successful in the treatment of sewer blockages.

3.6.11 Proving the Effectiveness of Bacterial Addition to Grease Retention Units

While it is relatively easy to produce successful pilot plant results, Barden (web page accessed 5-11-04) warns that environmental considerations are never accurately mimicked. This allows enzyme and detergent rich formulations to out-perform "bacteria only" products in such tests. Allowing for this caveat, the following pages offer scientific evidence which demonstrates bacterial addition as being a sound and feasible environmental practice.

Wade (2003) listed 5 key indicators to determine the effectiveness of bacterial GRU treatment. These were:

1. FOG has a consistency similar to thick soup
2. Little or no odour
3. No dry deposit building up on the sides of the GRU
4. No caked deposit floating on the surface of the GRU
5. No grease build-up in downstream drain line

This is an excellent set of parameters for on-site assessment. However, there are no precise measurements given for assessment of success or failure. This is a common problem with product demonstrations. Wellable Limited (2002) tried to address this by combining an evaluation chart with specific analytical data on a grease trap that they tested. These GRU parameters are set out below:

Table 2: GRU Biological Treatment Evaluation Chart

Phase	Timeframe	Waste Consistency	Colour	Odour
Additive introduction	2-3 weeks	Liquification of solids	Reddish brown	Moderate
Peak bacterial performance	3-7 weeks	Absence of solids with a black film on the surface	Dark brown to black	Minimal
Subsidence	8-10 weeks	Foamy or frothy film on surface	Grey	Minimal
Stabilisation	10-12 weeks	Dark water with froth	Grey	None

Source: Wellable 2002

Table 3: Rate of Reduction at the Stabilisation Stage

Indicator	Rate of reduction
COD	30%-50%
FOGS	>80%
Odours	Significant reduction

Source: Wellable 2002

In Wellables' trials on an undersized GRU from a Chinese restaurant, a COD reduction of 36.92% was achieved after week 8 of a 22-week test, increasing to a peak of 61% at week 12.

Taking analysis a stage further, Rivers et al (2002) undertook a detailed pilot scale study of a GRU. They analysed the triglyceride capability and cell density of an engineered bacterial consortium at various pH and temperatures over 28 days. The pH was adjusted to 4, 5, 7 and 9 in parallel model GRUs, each being incubated at temperatures of 8°C, 18°C and 28°C. It was found that bacteria degraded between 50% and 73% of grease at a wide range of temperatures and pH values. In general, the greatest reductions were at lower pH and higher temperatures. A GLM ANOVA (statistical calculation of a deviance table for one or more generalised linear model fits) was calculated to determine the effect of the bacterial addition. When it was nested, the data indicated that there was less than a 0.1% chance that adding bacteria had no effect. This was reinforced when it was found that there was no significant reduction in grease in the control trap. Indeed, results showed that the dosed systems tended to be self-equilibrating and when biological addition ceased, triglyceride degradation rates returned to background levels. This demonstrated that biological addition must be ongoing to prove effective.

Wakelin (1997) produced another pilot study to reaffirm the success of bacterial addition. A number of 250ml conical flasks were inoculated with bacterial products, achieving a 29% degradation of rapeseed oil and 73% reduction of restaurant grease. The most successful strain was Acinetobacter, with a FOG removal rate of 60-65%. However, the best result in this pilot study was achieved using activated sludge and a degradation rate over 90% was achieved without any lag phase. The absence of a lag phase is explained as being due to sludge pre-acclimatisation to the FOG substrate. The test confirms that bacteria are capable of grease degradation in a closed loop system. It also disproves the commonly held notion that grease is not biologically digested but only emulsified. Mongkolthanaruk et al (2002) demonstrated the effect of lag phase in degradation of lipid rich wastewaters, ranging from hours to days. Using Bacillus sp., Acinetobactor calcoaceticus and Pseudomonas aeruginosa, they reduced 35000mg/l FOG to less than 20mg/ l in 12 days. In order to overcome short retention times in a GRU, Davis (Pers. Com. 2004) described how Novozymes had isolated a lipophilic bacterium that attached itself to grease mats and is thus retained in high flow rates.

Lowry (web page accessed 04-08-04) compared four treatment methods for the removal of lipids and food waste in a GRU. He demonstrated that by bacterial addition alone, there was a 77% reduction in BOD from influent to effluent. He also demonstrated that there is a reduction of 56% in NH_3 and 45% in NO_3 from influent to effluent. There was a considerable residual of Dissolved Oxygen in his testing. Where there was a drop in DO, a 7% rise in NH_3 was experienced.

Davis (Pers. Com. 2004) demonstrated the selection methodology for suitable GRU bacterial additives. All strains were rigorously tested for successful application before being placed on the market. Davis describes how a number of strains were tested in six Plexiglas reactors (10 gallons each). The bacterial strain SB3112 was tested on short and long chain fatty acids by respirometry (where oxygen uptake was taken as a measurement of the bacterial ability to utilise the grease). Success was achieved from Stearic acid at C18 (1.74 mg/hr) to Acetic acid C2 (1.70 mg/hr). This conclusively proves at a laboratory scale level that bacterial addition to grease traps is successful. Analysis of the effluent from the control and the test reactors showed no FOG in either sample, confirming that no grease was emulsified. The maximum degradation of FOG in the closed reactor system was 42%. This result was replicated at pH ranges of 4.5-8.0.

3.6.12 Bioaugmentation with Enzymes

Enzymes are protein compounds that act as catalysts for biochemical reactions.
There are two views on the effects of enzymes in grease traps. Some believe that they are a complete solution to grease degradation, while others say they only do a part of the job.

3.6.13 History of Enzyme Purification

Barbaree et al (1995) tell us that the first enzyme to be purified into a crystalline form was urease; extracted by Doctor James Sumner of Cornell University in 1926. There was an increased awareness of the natural action of microbes and enzymes in the 1970s. Barbaree et al (1995) explain that enzymes are termed "biological catalysts". These are chemicals (mainly proteins) that bind with another chemical (referred to as the substrate), which are then broken down. Factors that influence enzyme action are pH, temperature and substrate solubilisation. Snellman et al (2002) found that the presence of calcium improved lipase performance. This was probably as the calcium precipitated the free fatty acids that were released in the reaction.

Further industrial applications for lipases are documented by Pandey et al (web page accessed 27-10-2004). They describe how fat splitting in industry has been completely revolutionised by the introduction of lipases. These lipases have found a wide array of industrial applications such as detergents, oils, fats and dairy products.

3.6.14 Definition of Lipases

Snellman et al (2002) define lipases as glycerol ester hydrolases that catalyse the hydrolysis of triacyglycerols to free fatty acids and glycerol. They resemble esterases in catalytic activity, but differ in that their substrates are water-insoluble fats containing medium to long chain fatty acyl chains. They are further distinguished from esterases in that they are activated at the substrate-water interface.

3.6.15 Measurement of Enzyme Activity

Lipase activity is determined by measuring the rate of release of free fatty acids from triacylglycerides using a pH stat titrator. NaOH is automatically added to maintain a constant pH of 7.0. The amount of alkali added is used to determine the milli-equivalents of free fatty acid formed. This is demonstrated by Meyers et al (1996).

3.6.16 Simplistic Description of Enzyme Operation

Gary et al (1999) highlight that enzymes are designed to reduce FOG, thus reducing waste pumping and transportation costs. They sound a note of caution that enzymes facilitate reactions, but bacteria must be present to use the reaction by-products. This is explained in a simplified analogy: Think of a fly as a bacterium. When it lands on a slice of bread, it secretes a solution to dissolve and emulsify the food into smaller constituents. The liquid has enzymes that do the dissolving. After this enzymatic activity, the fly can partake of the food. Enzymes are thus seen as the "silverware" for the bugs to cut their "steak" into smaller pieces.

3.6.17 Lipase in GRU treatment

There are a variety of lipases required to produce a successful GRU product. Saxena et al. (web page accessed 12-8-2004) outline how differing lipases can be regio-specific to fatty acids at either the 1 2, or 3 fatty acid positions on the glycerol molecule. Hence, complete degradation can only take place when the remaining fatty acid(s) move into a carbon position through random acyl migration. The possibility of providing a "one size fits all" product that is universally effective is unlikely. Novozymes (2001) address this by using a genetically modified (GM) enzyme ("Lipolase 100T") that promotes the hydrolysis of a range of different fats and oils. Many commercial enzymes are GM, as natural ones are expressed in tiny amounts by microorganisms and can be mixed up with other enzymes. Novozymes (2001) document the genetic modification from Thermomyces lanuginosus fungi and Aspergillus oryzae microorganisms. The process involves taking the relevant gene from the microorganism that naturally produces a particular enzyme (donor) and inserting it into another microorganism that will produce the enzyme more efficiently (host).

3.6.18 The Argument against Enzymes

In their comparison of "Enzymes vs. Microbial products", Bio Systems S.A. (2003) argued that enzyme dosing is futile. This non-technical document describes their being thousands of separate enzyme systems operating and emerging naturally in a biological system. It contests that the addition of one or two more is useless and that their hydraulic residence time, which may be only a few hours can have no beneficial effect. In essence, they state that enzymes have a "half-life" and are not self-reproducing.

When an enzyme is added to a drain, it is short-lived due to its fragile nature in those conditions. Barbaree et al (1995) attest that this limited lifespan is useless unless the enzyme can work on a readily soluble compound. Hence they encourage the practice of adding emulsification agents. This is contradicted by Gary et al (1999). They demonstrated that by dosing an enzyme, discharges of FOG could be kept below 100mg/l. However, co-dosing with an emulsifier allowed FOG discharges to regularly exceed the 100mg/l limits as set by many Local Authorities.

3.6.19 Lipase Stabilisation.

A disadvantage of lipase-based products is their instability in a water-based medium. Gupta and Roy (2004) note that less than a monolayer of water is needed for an enzyme molecule to start showing biological activity. Beyond this, the addition of more water molecules increases biological activity. The only way to stabilise an enzyme in water is to stabilise it in a glycerol/ water mix. Since this is what we are trying to degrade in the first place, it is akin to bringing an apple to an orchard. Indeed, Saxena et al (web site accessed 12-8-2004) suggest that the introduction of more glycerol could increase the lipid levels under biological action; the exact opposite of the desired affect. This phenomenon of lipases creating fat problems in sewers is often commented on but an explanation is rarely offered. Saxena et al explain that lipases catalyse the hydrolysis of ester bonds at the interface between insoluble substrate phase and the aqueous phase in which the enzyme is dissolved. However, in experimental conditions, such as the absence of water, they are actually capable of reversing this reaction. This leads to re-esterification and formation of glycerides from fatty acids and glycerol.

3.6.20 Lipase derived Secondary Raw Materials

Haba et al (2000) believe that the feeding of waste grease to animals is a waste of a valuable resource. They used lipase to convert low-grade waste oils into higher-grade secondary raw materials and see this as “green technology”. Meyers et al (1996) agree with this. Through their testing of lipase production by lactic acid bacteria, they note that lactic acid producing bacteria are poor lipase producers, but are safer than conventional bacterial and fungal lipases for reintroduction of lipids into the food chain.

3.7.0 Treatment, Disposal and Reuse of Removed Grease

While it is agreed that GRUs must be manually pumped on occasion, few disposal options are promoted in Ireland. This study now addresses the appropriate treatment and disposal methodologies currently available.

3.7.1 Aerobic Grease Digestion Options.

This involves the oxidation of FOG by microorganisms in an oxygen rich environment. There are a number of technologies available, all of which cater for the hydrophobic and sticky nature of FOG.

3.7.1.1 Aerobic Treatment of DAF waste

Lefebvre et al (1998) describe how FOG can have a negative impact on a wastewater treatment plant. Dissolved Air Flotation (DAF) is recommended as a pre-treatment with the collected scum and sludge being sent to a biological aerobic digester. The end products are CO_2, H_2O and a residual of biomass. This is achieved in a two-step process:

Step 1. Extracellular lipidic enzymes break FOG into glycerol and fatty acids, then hydrolyse the glyceride.

Step 2. Fatty acids are transported to a cell where they are submitted to successive breaks in their carbon chain (beta-oxidation) with the formation of molecules of acetyl CoA. These molecules are finally broken into CO_2 and H_2O in the TCA cycle.

3.7.1.2 Saponification in Aerobic Treatment

Saponification is defined by Mortimer (1986) as:

"The process in which a triglyceride or a mixture of triglycerides is heated with an aqueous solution of a base to yield glycerol and the salts of fatty soaps".

Lefebvre et al (1998) undertook a saponification study on stored grease in Toulouse municipal treatment plant in France. They demonstrated that grease degraded 3-4 times faster when saponified, saving time and energy. However, changing surface tensions caused foaming of up to 70% of the residual liquid volume. The disappearance of foam correlated with the rate of fatty acid consumption.

3.7.4 Aerobic Treatment in a Package Plant

Hoage et al. (web page accessed 3-12-04) addressed the breakdown of FOG in small package plants. A site study on Lone Star Charlie's restaurant showed that the plant "crashed" every 30-40 days due to the high grease loading rates. This resulted in tankering away of the plant contents and the subsequent re-seeding of sludge. By installing vacuum micro bubble aerators, the extra aeration was sufficient to reduce the accumulating greases to a minimum. Upon revisiting the site 5 months after the retrofit, there was no odour, a clear effluent and the plant had not required pumping.

3.7.1.3 Thermophilic Aerobic Systems

Rozichm et al (2002) underlines that thermophilic aerobic systems offer unique advantages for the treatment of high strength organic waste streams, slurries and sludges. The process combines the benefits of both aerobic and anaerobic systems, notably rapid biodegradation kinetics and low biological solids production. The process can result in economic benefits by minimising residuals processing and their subsequent disposal costs. A thermophilic system comprises a self heating, completely mixed thermophilic (45°-65°C) reactor. Effluent from the tank is processed through a solids separator such as a DAF or an ultra filter. A portion of the solids is returned to the reactor and the remainder goes to a chemical treatment unit prior to being returned to the reactor for further digestion. The authors conclude that off-site treatment in public or private disposal facilities is the preferred treatment route of high strength organics and sludges. Incineration is too expensive and faces strong public opposition, while chemical treatment options produce large volumes of sludge. The use of thermophilic aerobic treatment allows an influent of 10,000 mg/l COD to be reduced by 94% with no sludge production.

3.7.1.4 Thermal Aerobic Treatment of FOG

Becker et al (1999) described aerobic thermophilic treatment as excellent for olive oil and wool fat degradation. Wool fat has traditionally been one of the hardest compounds to degrade in the lipid range with high sterol levels. However, at 65°C in a continuously operated laboratory scale reactor, degradation rates of 900 mg/l per hour were achieved.

3.7.1.5 Acid Cracking Prior to Aerobic Treatment

In another approach, Azbar et al (2004) found that acid cracking of FOG was successful prior to biological degradation. By pre-dosing aluminium sulphate and ferric chloride, they facilitated subsequent biological FOG removal rates of 93-95%. Their vegetable oil wastewater had a BOD:COD ratio of 0.2 instead of a standard wastewater ratio of 0.6. This demonstrated that much of the carbon bound in FOG is unavailable for bacterial utilisation, thus underlining the difficulties in degrading FOG in GRU environments.

3.8.0 Anaerobic Digestion

Anaerobic digestion is defined by the Oregon State Environmental Department (web site accessed 4-2-05) as a biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other by-products.

3.8.1 Secondary Raw Material Production

Anaerobic digestion is a technology that can recycle nutrients from a GRU, with the added bonus of harvesting biogas for green energy production. It works by hydrolysis, acetogenesis and methanogenesis. The production of biogas energy and its subsequent combustion is classified as "Renewable Energy" under Directive

2001/77/EC and the digestate can be spread on land. This technology can be used to meet national targets for the Renewables Directive. Mouneimne et al (2003) highlight biogas as a carbon source for denitrification or for the biological removal of phosphorous. This can then act as a coagulant replacement and reduce chemical dosing requirements.

3.8.2 Toxicity of High Strength FOG

Anaerobic digestion of a single substrate is often difficult. Spreece (1995) describes how ice cream, chips and milk waste can poison digesters through their high FOG content. Volatile Fatty Acid (VFA) formation is rapid and can poison the sensitive acetogenic and methanogenic bacterial populations. Gallert et al (2003) show how the accumulation of H_2 and acetate can suppress the synthrophic propionde and butyrate metabolism, eventually leading to a complete failure of methanogenesis. They overcame this by accurately predicting the maximum digestion capability of full-scale digesters using small laboratory sized plant and real substrates.

3.8.3 Solution 1-Adding Protein and Carbohydrate

Kuang (2002) explains the two main difficulties to overcome:

1. The inhibition of methanogenic and acetogenic bacteria by Long Chain Fatty Acids (LCFAs).
2. Washout of biomass as it adheres to floating greases.

Kuang (2002) found that the addition of protein and carbohydrate increased the bacterial growth and actually countered the biomass loss. He further demonstrated that the presence of glucose could enhance methanogenic, acidific and acetate producing bacteria and hence offset the inhibition of LCFAs.

3.8.4 Solution 2-Engineering

Buyukkamaci et al (2004) agree that VFAs are capable of poisoning a digester at high concentrations. They found that the toxic concentrations increase from the top to the bottom of a reactor. If an engineering solution was adopted, higher VFA production could be allowable.

3.8.5 Solution 3 –Co-digestion with Municipal Solid Waste

Fernandez et al (2004) studied co-digestion of grease and the organic fraction of municipal solid waste (MSW). At 28% grease (by weight) in the influent, a pilot plant digested 91.2% of total FOG and resulted in the production of $0.39m^3CH_4/kg$ total volatile solids (TVS). The biogas composition was a respectable 61.9% CH_4 and the study concluded that co-digestion provided attractive energy recovery techniques.

3.8.6 Solution 4-Saponification

As the aerobic digestion process is accelerated by saponification, the same holds true for its anaerobic competitor. Mouneimne et al (2003) show that the addition of alkalinity is recommended for saponification purposes in anaerobic digestion. Only 10% of hexane extractable material is degraded at a pH of 6.5, while 40% is degraded at pH 8.5. They also demonstrated that KOH is far superior to NaOH. At pH 8.5, the extent of acidification of greases using KOH is double that of NaOH. Three possible reasons are put forward.

1. The lipid fraction conditioned by NaOH is only partly converted to VFA.
2. The Na^+ cation affects biological activity
3. The saponification leads to the formation of toxic molecules

3.8.7 International Case Study of FOG Digestion by Anaerobic Digestion

Cockrel et al (2004) commissioned an aerobic digestion plant in Watsonville, USA specifically for grease digestion. The plant capacity was 6000 gallons of grease per day with an 11,000-gallon holding tank feeding forward to a 1.5 MG digester. The capital cost of the project was $214,000 in 2002. Based on natural gas savings through co-generation of power, it had a payback of 3.6 years. Heating the reactor tanks was not necessary and where activated carbon filters were installed to remove odour, they were undersized.

3.8.8 Proposed Animal By-Products Directive

In the EU, grease trap waste falls under the scope of the impending Animal By-Products Directive (ABPD). It has a European Waste Catalogue (EPA, 2002) code of 20-01-08 (Organic compostable kitchen waste including frying oil and kitchen waste from canteens and restaurants). IEA Biotechnology (2003) explain that all animal by-products are to be divided into three categories:

Category 1: Materials of the highest risk to public health, animals or the environment. This includes specified risk material (SRM) such as brains and nervous systems where BSE originates.

Category 2: Includes all animal by-products that can be neither classified as category 1 or 3. Examples include manure or digestive tract content or animals not fit for human consumption.

Category 3: Includes all animal by-products that are fit for human consumption but for commercial reasons are not intended for human consumption.

Under the ABPD, biogas plants that process catering waste are to be approved under individual national legislation. This is being implemented by the Irish Department of Agriculture and Food Guidelines (2004). Catering waste is classified as category 2, which specifically includes "grease trappings". Each plant must now demonstrate that the digestate is held for at least 1 hour at a temperature in excess of 60°C. The Fourth recital of the ABPD stated that the regulation should not affect the application of existing environmental legislation or hinder the development of new rules on environmental protection, particularly as regards biodegradable waste. The EU Commission gave a commitment that a Directive on Biowaste (including catering waste) was to be implemented by the end of 2004. However, this has not yet occurred.

Thus, the future of anaerobic digestion in Ireland is in question until the draft regulations have been adopted and any modifications to assist anaerobic digestion are made.

3.8.9 Anaerobic Digestion Vs Aerobic Digestion

Spreece (1995) describes the merits of anaerobic digestion over conventional aerobic treatment. However, he explains that there is a limiting anaerobic generation time of 3.2 days at 35°C for lipid degradation due to biomass concentrations. The merits of anaerobic digestion over aerobic digestion are identified as:

1. Volumetrically, organic loading rates are 5-10 times higher
2. Biomass synthesis rates are a mere 5-10% of conventional aerobic technology
3. Anaerobic biomass can be preserved for months without deterioration in activity

4. There are no aeration requirements verses 500-2000kw hours of energy per 100 kg of oxygen transfer requirements in aerobic processes
5. Methane production of 12,000BTU per 100kg COD destroyed

3.9.0 Composting

The Composting Association of Ireland (web page accessed 23-05-05) defines composting as the breakdown of organic material, such as kitchen or garden waste, by organisms in a controlled environment. Bacteria, fungi, worms and beetles all play a role in the process.

3.9.1 The Four Phases of Composting

Bitton (1999) explains that there are 4 distinct phases in composting:

1. Mesophilic (20-40°C)- bacteria and thermotolerent fungi dominate
2. Initial thermophilic phase (40-60°C)- thermophilic bacteria (e.g. Bacillus), actinomycetes (e.g. Streptomyces) and fungi (e.g. Aspergillus) predominate.
3. Thermophilic phase (60-80 °C)- Thermophilic spore formers, sulphur and hydrogen oxidising autotrophs (e.g. Hydrogenobacter) and heterotrophic non-spore formers (e.g. Thermus spp.) predominate.
4. Cooling and maturation.

Bitton notes that the carbon: nitrogen ratio should be in the region of 25:1.

3.9.2 Current Composting Situation in Ireland

Currently there are 17 commercial composting facilities in Ireland processing in excess of 500 tonnes per annum. Kelly (Pers. Comm.) describes the state of composting in Ireland as of Spring 2005. There is a national installed capacity of 95,000 tonnes per annum and 60% of these units are on existing or previous waste management facility sites. The 17 existing commercial sites are broken into the following categories:

Table 4: Categories of Compost Sites in Ireland

Compost Technology	Number of Units in Operation
In-Vessel	6
Static Aerated Pile	5
Windrow	4
Vermi-Composting Unit	2

Windrow technology is no longer possible for food waste under the ABPD. The National Strategy on Biodegradable Waste Draft Strategy Report (DoELG, 2004) states that facilities are near maximum working capacity, with several new facilities in the process of getting authorisation. The national composting feedstock is currently 40% green, 33% commercial organic and 26% household organic. The end use of compost is now 60:40 horticultural : landfill.

3.9.3 Composting FOG

Gea et al (2004) describe fat as being sticky, rancid and hydrophobic. They explain that it has poor porosity and solubility with low water content and biodegradability. However, Joshua et al (1994) demonstrated that grease trap waste could be successfully composted within 5-11 days, with no further oxygen demand or reheating potential thereafter.

3.9.4 Compost as a Secondary Resource

Peterson et al (2003) explain that organic waste materials represent an inexpensive nutrient source and soil conditioner. They are quite clear in the potential risks of heavy metal accumulations and the risk of organic by-products from the decomposition of plastics and surfactants. However, the Danish believe that there is definitely a potential for the land spreading of composted municipal organic wastes.

3.9.5 Co-Composting with Sewage Sludge

In order to address the difficulties of digesting grease, Gea et al (2004) proposed co-composting with sewage sludge. Their trials showed a maximum degradation rate of 49.3% over thirteen days at a fat concentration of 20%. The maximum fat concentration viable was 40% over fourteen days, having a degradation rate of 40.7%.

Notwithstanding this, the majority of fat was degraded by the end of the 21-day trial period.

3.9.6 Thermophilic Composting

Lemus et al (2002) tested thermophilic composting of FOG. Their pilot plant achieved 79% grease removal with an impressive 70°C being reached within 10 days. The cumulative heat was 1.7-3.4 MJ per kg for the thermophilic runs- 1 order of magnitude greater than their mesophilic runs of 0.07-0.17MJ. The test concluded that the generated heat allowed faster reaction times, leading to shorter residence, increased throughput and a better pathogen kill.

3.9.7 Addition of Ash

Koivula et al (2004) describe how composting in Finland processes most of the country's catering waste. Adding ash increases the porosity of the compost, allowing more oxygen penetration and greater heat retention. One could assume that this increased heat could assist in the melting of saturated fats. The ash also raised pH, which would buffer free fatty acid (FFA) release. Ash suppressed odours as it had a similar structure to activated carbon.

3.9.8 Composting versus Anaerobic Digestion

The European Commission Directorate General Report (2004) examines which form of FOG treatment is more appropriate. It surmises that wastes containing high moisture and fats are more suitable for anaerobic digestion, while composting should be utilized where high lignin wastes are present. This is because methanogenic bacteria are unable to degrade lignin. The higher costs and more problematic nature of the anaerobic digestion process are seen as a downside to FOG processing.

Another parameter in the consideration of both technologies is the volumes of wastes that arise at the end of the process. Anaerobic digestion produces larges volume of effluent that requires disposal. Composting can usually recycle this water back into the process but requires bulking agents and fillers. Thus, composting produces significantly more solid waste at the end of the process, requiring a larger footprint than the more compact anaerobic digestion alternative.

3.10.0 Rendering

The USEPA (1995) defines rendering as processing of animal by-product materials for the production of tallow, grease and high protein meat and bone meal (MBM). The House of Commons BSE Report (2000) defines the process as crushing animal by-products (e.g. fat, bones and internal organs), heating them to drive off water content and then separating the residue into fat (called Tallow) and solids (called Greaves). MBM is then defined as meal exclusively produced from red meat animals, not poultry.

The main derivatives of tallow are fatty acids, fatty esters and soaps. These are produced by the oleochemical industry. There are three basic processes:

1. Hydrolysis
2. Trans-esterification
3. Saponification

3.10.1 Hydrolysis

This produces glycerol and fatty acids. The tallow is combined with water at high temperatures (220-250^{0}C) for between 90 minutes and 10 hours. A crude fatty acid and dilute crude glycerol result. These are then reprocessed under various temperatures and pressures and are made into fatty alcohols, metallic soaps, fatty amines, fatty acid esters and fatty amides.

3.10.2 Trans-esterification

The engineering department of Iowa State University (web page accessed 10-06-05) defines trans-esterification as the removal of the glyceride molecule from long chain fatty acids by a reaction with alcohol and a catalyst. Common catalysts are potassium hydroxide, sodium hydroxide, and sodium methoxide. The reaction produces fatty monoesters and free glycerine.

3.10.3 Saponification

In rendering, saponification can occur in one of two ways:

The first method is continuous saponification; the tallow is heated with sodium hydroxide at temperatures up to 105^{0}C. It is then sent through a saponification reaction column and mixed with a more concentrated sodium hydroxide at about

140^{0}C, under 2 atmospheres pressure for 8 minutes. This produces soap and glycerol, which can be washed out of the soap mass (USEPA 1995).

The second method is batch saponification. The tallow is placed in a pan with concentrated sodium hydroxide at about 95^{0}C for 3 hours. The soap and glycerol that results is then kept for a further 5 days to complete the washing process.

3.10.4 Wet and Dry Rendering as a Batch or Continuous Process

There are two processes for inedible rendering; the wet process and the dry process. Wet rendering separates fat from raw materials by boiling in water. Dry rendering is the industrial norm. This is a batch or continuous process that dehydrates raw material in order to release the fat. Following dehydration in batch or continuous cookers, the melted fat and protein solids are separated (USEPA 1995).

The batch or continuous rendering process takes waste and crushes it to particles of 2.5- 5 centimetres so that it can be thoroughly cooked. It is then heated to 121^{0}C-135^{0}C, at a typical pressures ranging from 40-50 psig (pounds per square inch gauge). Following the cooking cycle, the contents are discharged to a percolator drain pan. The percolator drain pan has a screen that separates the liquid fat from the protein solids. These solids still contain some fat, so they are then pressed to further reduce the overall fat content from 25% down to 20%.

3.10.5 Rendering and FOG

The composition of grease trap waste is predominantly grey water. Even in neat used restaurant grease, the moisture content can be 25%, with 10% protein solids and 65% tallow/grease by weight. Grease trap waste may actually be <1% tallow unless it is concentrated up. It is possible to blend grease trap waste with recovered waste cooking fat oil. There are two options for a renderer to deal with FOG:

1. Recover it as a secondary raw material
2. Use it as a biofuel in the rendering process

3.10.6 Recovery as a Secondary Raw Material

USEPA (1995) explains that grease should be injected directly into a dedicated grease processing system. Their recommended system is that melted grease is screened to remove coarse solids and then heated to 93^{0}C in vertical processing tanks. The material is stored in that tank for 36-48 hours to allow for gravity separation into 4 phases: grease, emulsion, solids, and water. The emulsion layer is centrifuged to recover the solids and oils. The final grease is then processed.

3.11.0 Biodiesel

The Canadian Renewable Fuels Association (web site accessed on 10-08-04) defines biodiesel as a renewable, biodegradable, alternative fuel or fuel additive for diesel engines. It can be used in its pure form or it can be mixed with a petroleum-based diesel. Biodiesel can be made from a variety of products, including animal fats and virgin and recycled vegetable oils derived from crops such as soybeans, canola, corn and sunflowers.

Montgomery (2004) argues that the dramatic increase in biotechnological activity comes with an obligation to reuse and recover our waste materials. This is to be achieved by increasing the capacity and sophistication of waste management systems. In looking for uses of collected grease, pressure not to reintroduce grease into the food chain makes biofuel a possible end use for FOG.

Biofuel production was traditionally focussed on the generation of hydrogen and methane from anaerobic digestion or thermal energy from composting, but the production of biodiesel as a marketable fuel is a more recent option. Another biodiesel use was suggested by Zhang et al (1995) who introduce the concept of co-metabolic biodegradation. They describe microorganisms using a second substrate (readily degradable) as the carbon (energy) source to degrade the primary substrate, which would not otherwise be attacked as the sole carbon source. This means that biodiesel would promote and accelerate the biodegradation of petroleum-based diesel oil and oil tanker spillages.

3.11.1 The Advent of Biodiesel

BLT Weiselburg (2004) describes how a working group on biodiesel was formed within the Austrian Standards Institute. By 1991 this group published the world's first standard for Rape Oil Methyl Ester (ONORM C1190). Lia et al (2000) write that as early as 1900, the idea of using biodiesel as a substitute for mineral based fuel was put forward by Rudolph Diesel himself. Since this time, animal and vegetable oils have been widely tested as such a fuel alternative. Argent Energy (2005) estimates that the market potential for biodiesel in the UK is 414,000 tonnes in 2005 and will increase to 1,478,000 tonnes by 2010 in order to meet UK targets for the Biofuel Directive. Argent makes the salient point that mineral diesel cannot be produced without the production of petroleum and demand for petroleum in the UK has dropped from 5.4 MT in the second quarter of 2001 to 4.7 MT in Q2 of 2003. Diesel demand has increased 0.7 MT in the same period. Argent has invested in biodiesel production to help offset the difference in supply and demand.

3.11.2 Environmental Impacts of Biodiesel

Environmentally, biodiesel is seen as preferable to mineral diesel. It produces less carbon monoxide, hydrocarbons, smoke and particulate emissions and has higher cetane numbers (the higher the cetane number the easier the fuel ignites when injected into an engine). It is biodegradable and has the added benefit of being non-toxic. However, it has low volatility that allows incomplete combustion and can produce elevated nitrous oxide compounds (NO_x). In order to maximise the positive and minimise the negative points of both fuels, a blending process is the preferred approach. The most commonly used blend is 20 percent by volume biodiesel with 80 percent by volume mineral diesel and is referred to as the B-20 blend. This imparts the desired reduction in emissions, while addressing the power reduction associated with the lower energy content of the bio-fraction. An article in the Local Authority Waste & Environment Magazine in September 2004 highlighted how biodiesel can be easily blended with mineral diesel without any need to modify engines. Indeed, at a 5% blend rate, it still complies with BS EN 590:2000 "Automotive Fuels: Diesel Requirements and Test Methods."

3.11.3 Trans-Esterification

The use of intact triglycerides creates serious issues with high viscosity and fuel injector fouling. Processing the raw oils using trans-esterification can quite easily overcome this. Fat is made up of one glycerol molecule attached to three fatty acids by way of an ester bond. By using methanol, one can transfer these 3 fatty acids on to a methanol and simply recover and recycle the old glycerol molecule. The end result is fatty acid methyl esters (FAME) and glycerol. Ethanol could also be used instead of methanol. Ethyl esters are less toxic and ethanol itself can be produced from grain, creating a totally bio-based fuel source. The most commonly used catalysts for the trans-esterification process are alkali hydroxides and alcoholates.

Plate 11: An example of localised Biodiesel schemes

Source: Personal Collection

3.11.4 Problems with Free Fatty Acids

As one could expect, the biodiesel production cost is prohibitive. The Sunday Herald of the UK (15 March 2005) stated that rapeseed oil costs up to £373 per tonne to buy. Thus, research has been carried out using lower waste greases from industry, with used cooking oil at just £175 sterling per tonne. To obtain this secondary raw material, Stoll et al (1997) highlighted the need for frequent removal of fats from restaurants to protect it from impending rancidity. This rancidity liberates free fatty acids (FFAs) that reduce biodiesel yields.

Plate 12: An example of Used Vegetable Oil Collection in Ireland

Source: Personal Collection

3.11.5 Acid-Catalysed Esterification

When a restaurant wastewater has high FFAs, some operators merely add excess alkali and subsequently remove the FFA portion as insoluble soap (this soap stock is thought of as an underused by-product with industrial potential). However, this reduces the final ester volumes and consumes alkali. An alternative is the acid-catalysed esterification, which simultaneously achieves trans-esterification of the glyceride and esterification of the FFA. It has the drawback of requiring higher temperatures and longer reaction times than the simper alkali catalysed method.

3.11.6 Acid-Base Catalysed Esterification

Montgomery (2004) shows how FFA of up to 40% can be used in biodiesel production. He demonstrates a two-step strategy. First, acid catalysed esterification converts FFA to esters. When FFAs are below 0.5%, a second base catalysed reaction is undertaken on the oil portion.

3.11.7 Enzyme Based Esterification

An alternative catalysation pathway is by using a specific enzyme known as ethyl greasate. This is an option for low-grade grease utilisation. The high FFA (>8%) and the glyceride-linked fatty acids are effectively converted into simple alkyl esters under enzyme action. Full conversion of FFA and glycerides is vital. Low residual amounts reduce the handling and performance characteristics of the fuel.

3.11.8 The Potential for Biodiesel derived from FOG in Ireland.

There are a number of studies on the potential to operate a viable biodiesel plant in Ireland. The studies address three main issues:

1. Is there sufficient scale for a viable production facility?
2. Is it possible to use recovered vegetable oil and animal fat?
3. Is it safe for human health and the engines that run on it?

3.11.9 Evaluating the Existing Potential

Walsh (1998) describes how there is no liquid biofuel industry in Ireland, but two Altener projects have been successfully undertaken on Local Authority vehicles, buses and other light transport vehicles. The organisation sees the potential for all set-aside land to be converted to rapeseed production. This is seen as

"A means of producing an environmentally benign, indigenous liquid fuel while simultaneously maintaining employment in rural areas."

However, there are annual changes in set-aside requirements and this generates uncertainty about sufficient future supply to achieve a scale of production required to run a cost efficient plant. Currently, there is a base area of less than 5000 hectares, with yields of 2.5-3.2 tonnes per hectare. This is an insufficient volume for a biodiesel plant to be economically viable operating solely on rapeseed. With the demise of sugar beet production in Ireland, it may free up more land in the coming years for rapeseed. According to SEI (2003), there is a pressing need to grow more to meet the national Biofuel Directive targets.

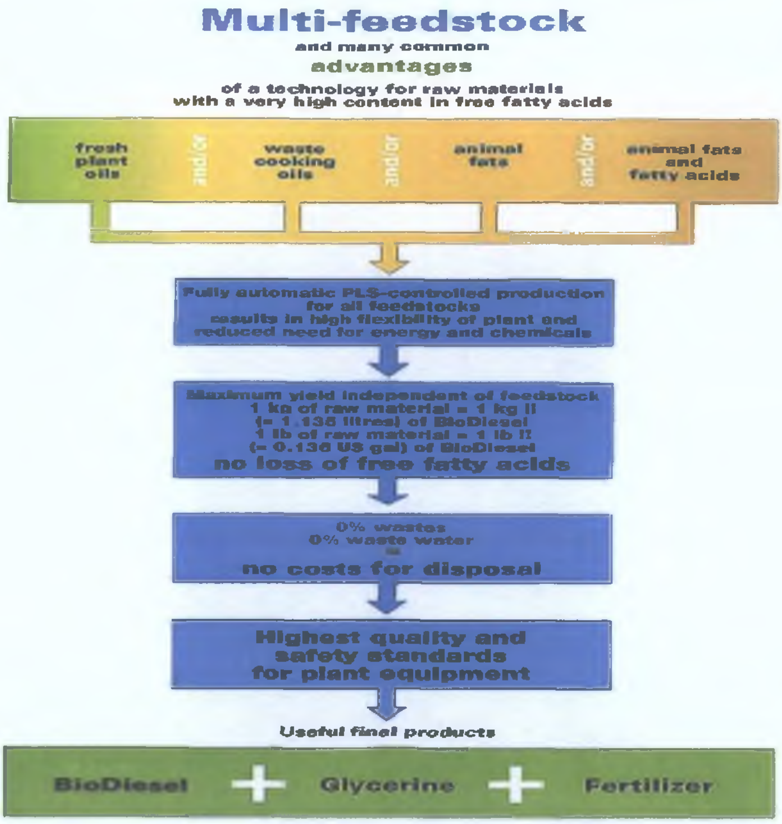
3.11.10 Potential for Recovered Oils and Grease.

In order to fulfil the Biofuel Directive targets with indigenously produced biomass, part of agricultural productive land that is currently used for feed would have to be diverted towards biofuels. This would, in turn, induce additional feed imports. Rice (2004) suggests that recovered vegetable oil (RVO) and tallow could offset this to meet the minimum production level of 20,000tpa that is required for a viable biodiesel plant. He further identifies potential raw materials as RVO, SRM tallow and "clean" tallow. RVO is given two potential uses; biodiesel and combined heat and power (CHP). Rice explains that the RVO has a high degree of commercial uptake in Australia in the biodiesel sector. There are a number of caveats mentioned. Biodiesel production requires economies of scale, with minimum requirements for glycerol refining, quality checks and safety precautions for methanol processing. For high FFA, which grease trappings contain, a more sophisticated plant would be required, involving FFA removal or two-stage esterification.

3.11.11 Biodiesel in Scotland

In Spring 2005, a major biodiesel plant was opened by Argent (2005) in Motherwell, Scotland. Its annual capacity of 50 million litres will provide nearly 5% of Scotland's diesel needs. This is capable of processing grease trappings, used frying oil, yellow grease, animal, chicken and leather fat. The process flow diagram for the plant is presented in Figure 1.

Figure 1: Schematic of Biodiesel Processing, Inputs and Outputs



Source: Argent 2005

Argent (2005) explains that Member States must set their own targets to implement the EU Directive on Biofuels. In the United Kingdom, this is 2% of all mineral fuels to be replaced by biofuel by 2005 and 5.75% by 2010. This plant can assist in the meeting of these deadlines.

3.12.0 Thermal Treatment

Indavar Ireland (2004) defines incineration as the burning of residual waste at a temperature greater than 850 ° C, leaving an inert ash. The benefits of this are the production of a non-reactive ash and energy for power generation. This study examines the possibility of thermal treatment in the disposal of FOG.

3.12.1 Thermal Treatment in Ireland

Under the Irish Waste Management Act (amended 1996), Local Authorities are required to produce waste management plans. The plans are based on the hierarchical approach and most of the plans contain a thermal option. In the National Hazardous

Waste Management Plan, the EPA endorses this option. Thermal treatment with energy recovery is proposed in six regions for residual municipal waste treatment. It is seen as the least favoured recycling-recovery option and is to be used for residual waste after other recycling methods have been exhausted. According to the DoELG (2004), Ireland does not yet have regional incineration facilities for the treatment of hazardous or non hazardous waste. However, there are already 11 small-scale industrial incinerators in commission. Belfast City Council operates a 25,000 tonne per annum incinerator in the heart of the city, using fluidized bed technology to combust sewage sludge. To date, the DoELG (2004) explain that two proposals for incineration plants in the North East Region at Carranstown (150,000tpa) and the Dublin region (400,000-500,000tpa) have been advanced. A co-incineration plant (municipal and hazardous waste) has been suggested for Cork.

3.12.2 Advantages of Incineration of FOGs

Indaver Ireland (2004) makes the salient point that inappropriate recycling of food waste had caused three man-made catastrophes that would not have occurred if food waste were incinerated:

1. Foot and Mouth Crisis
2. The Belgian dioxin crisis
3. The BSE crisis

Thermal oxidation of waste can provide significant environmental gains. These are described by a number of commentators. Makow (2003) demonstrates that waste incineration reduces environmental concerns in relation to the production and uncontrolled release of greenhouse gasses (GHGs). Furthermore, thermal disposal provides for recovery of chemical energy in MSW as demanded by the Integrated Pollution, Prevention and Control (IPPC) Directive 96/61/EC. The Renewables Directive (2001/77/EC) regards industrial and municipal waste as "Short Rotation Carbon" and therefore a potential "renewable energy source". Indavar (2004) describe incineration as aiding the proximity principle of the EU's Sixth Environmental Action Programme. Its goals are to ensure "waste is treated as closely as possible to where it is generated". Due to a lack of waste processing sites near urban areas, this would favour thermal treatment infrastructure.

3.12.3 Argument against Thermal Treatment

The European Commission Directorate General Report (2004) states that the bulk of MSW energy is derived from high calorific fractions based on crude oil. Hence it is not renewable and the wet fraction of biodegradable waste actually diminishes the overall energy efficiency of the incineration process.

Dijgraaf et al (2004) also claim that the thinking behind the EU hierarchy of waste is flawed. They state that incineration is generally thought to produce few externalities, particularly in the Waste to Energy (WTE) facilities. They argue that such plants do have externalities, such as air emissions and chemical waste residuals. In addition, they are economically expensive to construct.

4. Data Collection and Test Programme

4.0 Introduction

This section describes the methodology utilised to acquire further information in this study. It details site visits, meetings and telephone conversations and on-site testing undertaken to paint a complete GRU management picture in this country.

4.1 Requirements and Drivers of a FOG Strategy

Upon completion of the document review, a number of key organisations were contacted in order to determine the validity of the information gathered. The first stage was to contact a number of Local Authorities and meetings were conducted with the following personnel:

- Dublin City Council- John Collins, John Stack and Dermot Gallagher, (Engineers)
- Dun-Laoghaire-Rathdown Council- Pat Ruddy (Engineer)
- Kilkenny County Council- Eamonn Morissey (Engineer)
- Wicklow County Council- Mary O'Neill (Engineer)
- Members of Fingal County Council Sanitary Services Division, Watery Lane, Swords
- Limerick City Council- Anne Goggins (Engineer)

The following independent consultants and commentators were then canvassed for their input on FOG issues in Ireland:

- Philip Sowden of Compliance Consulting
- Punch and Partners Engineering of Cork
- Todd Redmond, Lecturer of Environmental Health, Dublin Institute of Technology

In order to get an international perspective on FOG issues, the following contacts were made over the internet:

- Wim Van den Broeck of Aquaplus Ltd. Environmental Consultancy, Belgium
- Edmonton Council, WWTP in Canada
- Dustin Harper, WWTP worker in North Bonneville USA

The next step was to evaluate the national perspective by talking with Anthony Cauley and Joanie Burns of the Irish Department of Environment and Local Government.

4.2 Grease Retention Units (GRUs)

Telephone contact was made with the National Standards Authority of Ireland to determine the scope of ISEN 1825-2:2001 (the national grease separator standard). Further enquiries were undertaken to determine the role of Agrement Certification. In order to assess Electro-Coagulation, two sites were discovered in Ireland and both were visited:

- OPW Clonmacnoise Site in Offaly
- Tullyvar Landfill Site, Aughnacloy, County Tyrone

To evaluate mechanical grease separation, contact was also made with the manufacturers of "The Big Dipper" –Thermaco and their Irish agents- Proviro.

4.3 Treatment of Grease Retention Units (GRUs)

In order to determine the current practices in regards to treatment of GRUs in Ireland, a number of contacts and meetings were made with Irish drain companies. These included:

- Drain Doctor, Lucan and Peterborough UK
- Dyno-Rod, Nationwide and Dyno-Rod Cheshire, UK
- Horizon Environmental, Nationwide
- Hydrochem, Dublin

A number of organisations were then contacted that provide bacteria, chemical and enzyme products/systems for the GRU market:

- Aerolife Systems (Aerated Grease Traps)
- Biotal (USA and UK supplier of bacteria and enzymes)
- Caztec Donegal (bacterial treatment provider)
- Frutrarom (UK supplier of terpenes)
- Novozymes International (bacteria and enzyme producers)

4.4 Treatment, Disposal and Reuse of Removed Grease

This involved a number of telephone calls and site visits to determine the infrastructure actually in place at present. It also aimed to highlight any weaknesses in the various disposal routes that may not have been identified in the literature review.

4.5 Site Visits

The following site visits were undertaken:

- Adamstown anaerobic digester, County Wexford
- Ballyogan MRF, Dun Laoghaire-Rathdown Council (Greenstar site with composting and waste vegetable oil collection)
- Camphill Community, Callan anaerobic digester, County Kilkenny
- College Proteins, Nobber, County Meath (renderer with thermal oxidiser)
- De Mulder UK (renderer and researcher of incinerating MSW compost)
- Organic Gold, Wilkinstown, County Meath (compost)
- Western Proteins, Ballyhaunis, County Mayo (renderer without thermal oxidiser)

Finally, Mc Gill Composting (Clonmel) was contacted by telephone.

4.6 Evaluation of the Efficacy of Bacterial Dosing in Grease Retention Units.

The document review highlighted that bacteria addition rather than enzymes may be the most effective biological approach. As part of this study, some on-site tests were carried out to evaluate the potential for bacterial dosing as part of a GRU management strategy.

There were time and resource constraints in establishing a large test sample for this study. This was overcome by drawing on previous tests as documented in the literature review. A comparison approach was taken, comparing a number of results described in the previous studies with the findings of this particular study. On this basis, the study merely agrees or disagrees with previous commentators as to the efficacy of the technology. It was not the intention to categorically prove or disprove such a theory based on such a small sample study.

4.7 Test Protocol

In the summer of 2004, a number of sites managed by Dyno-Rod Ireland (a drain management company) were identified in Limerick. Four sites were chosen that used bacterial dosing in their GRUs. Punch and Partners Consulting Engineers and Dyno-Rod identified them as being broadly representative of GRUs treated in Ireland. While each site had differing flows, grease trap sizes and loading rates, all were identified by their proprietors as having steady flow rates throughout the test period of July-November 2004.

The test was based over a four-month period. The time period was selected to fit into the Dyno-Rod management schedule. This involved dosing 25 litres of bacteria over an eight week period, followed by an inspection and GRU clean-out where required. Each GRU was initially cleaned and operated without bacterial dosing for 8 weeks. Subsequently, the trap was cleaned and a further 8-week study was undertaken in which bacteria were added. The GRU was monitored and results compared to previous tests as documented in the literature review.

4.8 Summary Data Table of Literature Review Findings with On-Site Results

In order to compare the data from the literature review with the results from the Limerick study, it was important to develop a summary data table. This table is presented in the Results Section of the study. The data table was based upon the following questions:

1. **Does bacterial dosing reduce the volume of retained grease in a GRU?**
2. **During bacterial treatment, is there an elevation in FOG levels in the discharge effluent?**

Visual and olfactory testing was required to evaluate documents by Wellable (2002) and Wade (2003). This was incorporated into the Summary Data Chart by means of the following questions:

3. **Was the consistency of GRU similar to thick soup?**
4. **Was there little or no odour?**
5. **Was there dry deposit building up on the sides of the GRU?**
6. **Was there caked deposit floating on the surface of the GRU?**

7. **Was there evidence of grease build-up in the downstream drain line?**
8. **Was there foamy or frothy film on the surface of the water?**
9. **Was there a grey colour to the water?**

In regard to measurement of particular parameters, the following questions were also deemed important:

10. **Was there a variance in results where oxygen is less available?**

This was to encompass the findings of Lowry (web page accessed 04-08-2004) and Bio-magic (2003) that aerobic digestion is faster than anaerobic digestion.

In order to test Chens' (2003) theory of sewer biofilm respiring at $32g/m^2/day$, a measure of COD and BOD was incorporated by asking:

11. **Was there a change in BOD and COD?**

Next, an evaluation was made of Lowry's contention that bacterial addition causes:

- A long term reduction of 56% in NH_3 from influent to effluent.
- A reduction of 45% in NO_3 from influent to effluent.
- An increase of 7% in NH_3 from influent to effluent as a result of reduced oxygen levels.

12. **During dosing, were there changes in total N and NH_3 levels?**

4.9 Analysis

In order to reduce the possibility of analytical error and bias, an independent laboratory was deemed essential. The facility used was Alcontrol-Geochem, which had ILAB accreditation awarded for the full suite of tests that were undertaken. Each sample was split between two laboratory supplied 1000ml containers. These were approved glass amber bottles and were overfilled to ensure free headspace was removed. Each bottle was chilled on site from around 40°C to 5°C using ice packs. The bottles were subsequently stored in a sealed cooler box to ensure that they remained at such a temperature until they arrived in the laboratory. All samples were delivered to Alcontrol-Geochem within 3 hours of sampling and each container was logged on a chain of custody form. Analysis dates were fixed in advance as the second Tuesday of each month.

Table 5: Analysis Dates

Day 1	**15-7-04**
Week 4	**10-8-04**
Week 8	**5-9-04**
Week 12	**12-10-04**
Week 16	**2-11-04**

When determining the parameters to be measured, it was decided that there would be two sets of data. The first set was in-situ data that could not be accurately measured off-site at a later stage. This included parameters such as retained solids, dissolved oxygen and total bacterial counts. Bacterial cell counts were undertaken in-situ using "Bioseekers On-site Easicult TCC slides". TCC is a non-selective agar for the growth of bacteria (Bioseekers, web site accessed 10-06-05). All other data was derived from samples analysed at Alcontrol-Geochem.

Table 6: Analysis Carried Out for On-Site Tests of GRUs

Discharge pipe parameters measured by Alcontrol-Geochem.	On-Site GRU analysis
Biochemical Oxygen Demand	pH inlet
Chemical Oxygen demand	pH outlet
Fats, Oils and Grease	Temperature inlet
Total Phosphorous	Temperature outlet
Total Nitrogen	Dissolved oxygen at outlet
Ammonia	Total viable bacteria counts
Total Kjeildal Nitrogen	

4.10 Selection of Bacterial Strains

In order to ensure that a representative range of bacteria was used, a wide range of bacteria types were obtained from Bio Industries and Bio-Future – the two Irish manufacturers of GRU bacteria. The products were powdered spores and liquid.

Both were blended and split between four 25-litre containers. These were then topped up with sterile water. The drum size used was 25 litres as this was the amount of product dosed into the drains over a two-month period by Dyno-Rod Ireland. The following strains of bacteria were utilised in the tests:

- Acinetobacter species
- Arthrobacter parafinnus and species
- Bacillus subtilus, megaterium, licheniformis and species
- Pseudomonas putida, stutzeri and species

4.11 Schedule of Activities Carried Out for On-Site Test of the GRUs

A schedule was drawn up which set out the timetable to be followed throughout the test period:

Table 7: Schedule of Activities Carried Out for On-Site Test of the GRUs

Day 1	• Measured each GRU and cleaned them out using a Jet-Vac (Vacuum Tanker). This ensured that no residual grease or bacteria remained that could interfere with the test • Attached a 25-litre placebo drum (food grade dye and water) to a peristaltic pump and set dose to 416ml per night (Existing Dyno-Rod standard dose rate)
Week 4	• Visited each GRU • Removed samples for Alcontrol-Geochem • Undertook in-situ analysis
Week 8	• Visited each GRU • Removed samples for Alcontrol-Geochem • Undertook in-situ analysis • Measured free oil and solid grease build-up in each trap • Vacuum tankered GRU and installed 25-litre drum of pre-manufactured bacterial treatment
Week 12	• Visited each GRU • Removed samples for Alcontrol-Geochem • Undertook in-situ analysis
Week 16	• Visited each GRU • Removed samples for Alcontrol-Geochem • Undertook in-situ analysis • Measured free oil and solid grease build-up in each trap • Vacuum tankered GRU

5. Results of Research

5.0 Introduction

This section documents the results gathered in the Data Collection and Test Programme section and expands on information generated in the literature review; thus facilitating the discussion in the next section.

5.1.0 Requirements and Drivers of a FOG Strategy

All commentators contacted agreed that there was a pressing need for a broad grease management strategy. Dublin City Council and Wicklow County Council had already undertaken FOG studies with the aid of Compliance Consulting. There was a clear misunderstanding on bacteria, enzyme and chemical dosing and all parties were negative in relation to dosing any product. The organisations interviewed were unaware of any research being undertaken on options for grease once removed. However, they commented that this would be required as part of an integrated national strategy.

In regard to the Dublin issue, Dermot Gallagher of Dublin City Council said that 6-7 tonnes of grease are removed from Ringsend WWTP each day, leaving residual FOG concentrations of between 7 and 14mg/l in the influent. This residual grease passes through the SBR system, affecting the dewatering and drying of sludge.

John Stack of Dublin City Council put the annual budget for sanitary sewer overflows at €2m in the administrative area, a large proportion of which was spent on alleviating FOG blockages. There is no cost identified for decay of the drainage system from anaerobic conditions that lead to the generation of corrosive H_2S and H_2SO_4.

In talking to council officials from Fingal, it is clear that FOG in lift stations are their main difficulties. Grease floats on the water and does not get pumped onwards, slowly accumulating. A grease mat then forms and engulfs the float, thereby triggering the pump to activate, which causes it to burn out unless manually reset.

A common complaint from the private sector was that Local Authorities attributed some instances of sewer damage completely to FOG, while dismissing other contributory factors.

5.1.1 Grease Retention Units (GRUs)

In relation to mechanical grease separators, Proviro (an electro-mechanical separator supplier) contended that their technology would protect Lift-Stations from large levels of grease influx. They described how enzyme treatment had contributed to the blocking of a lift-station at a supermarket in Wexford and how the subsequent installation of a "Big-Dipper" had alleviated this problem. However, Dyno-Rod and Bio-Future cited cases and showed photographs of passive GRUs blocked with grease downstream of a mechanical grease separator in Dublin and in Cork. While the exact cause of these blockages is unclear, it does demonstrate that no one technology can provide a universal answer to all operational circumstances that are encountered in the field.

No GRUs incorporating electro-coagulation were identified locally. However, a unit installed at the Duchas site at Clonmacnoise (County Offaly) for phosphorous removal was only deemed a partial success. Tullyvara landfill site (County Tyrone) is evaluating E-C to treat leachate, but results are inconclusive at present.

Many parties highlighted the impact of "Combi-Ovens" on GRUs. These steam ovens are now installed in many convenience stores and petrol stations nationwide. They cook food by steam recirculation. Condensate is then discharged into the sewer through a drainpipe. This generates substantial volumes of FOG that are disposed of "inappropriately" into a GRU.

5.1.2 Treatment of Grease Retention Units (GRUs)

From discussions with various drain cleaning companies and product suppliers, typical charges were ascertained from around the country. The clean-out charges for GRUs ranged from €300-€1500 per visit, while the cost of product dosing ranged between €700 and €3500 per year. There are in excess of 1500 sites in Ireland paying in excess of €1000 per annum on management of some description.

5.1.3 Treatment, Disposal and Reuse of Removed Grease

There are currently two centralised anaerobic digesters operating in the Republic of Ireland, with a third being operated in County Fermanagh. The two Irish plants are operated under waste permits at Ballymacarbery, Co. Waterford and Camphill

Community in Kilkenny. Camphill can process 1000 tonnes of FOG per annum and co-digest it with farm waste. Ballymacarbery has been performing trials on both MSW and commercial/ industrial wastes and is permitted to process 2,500 tonnes of waste per annum. The Callan operation experiences VFA poisoning and improvements in operating efficiencies are required.

Plate 13: GRU Waste and Soft Drink Syrup being loaded into the Camphill Digester

Source: Personal Collection

Plate 14: Slurry being delivered to Camphill Digester

Source: Personal Collection

The future of anaerobic digestion plants is in question due to the proposed animal by-product regulations (ABPR). Under the ABPR, a system of management must be introduced to ensure that animal pathogens are unable to be reintroduced back in to the food chain and there must be no way of non-processed waste coming into contact with animals. Thus, anaerobic digesters treating FOG are not permitted on farms containing livestock, leading to the recent closure of a plant in Adamstown, County Wexford.

Plate 15: The Disused Adamstown Plant

Source: Personal Collection

The Camphill Community anaerobic digester in Callan (which processes large amounts of FOG) is also facing closure. The plant co-digests cattle slurry and FOG and while horticultural and arable land spreading is permitted, local farmers require the return of their slurry to their pastures. This is not acceptable under ABPR.

5.1.4 Composting

The literature review indicated that anaerobic digestion was favoured over composting for FOG treatment in Ireland. However, In-Vessel compost technology and a drier output allow compost to be utilised as landfill cover and roadside landscaping. This outlet is not available for anaerobic digester effluent.

Plate 16: Dun Laoghaire-Rathdown Composting Facility for MSW.

Source: Personal Collection

5.1.5 Rendering In Ireland

There are a number of rendering plants in this country. The two main types of rendering are edible and inedible. Edible rendering plants process fatty animal tissue into edible fats and proteins. These are Class 3 plants and are usually operated as an integrated rendering plant. This means that they process specific waste from specific factories. The independent rendering plants collect from various sources and hence are Class 1 and 2 (refer to section 3.8.8). Category 1 and 2 plants are the only plants that can accept GRU waste. The four main Category 1 and 2 plants in Ireland are:

1. AIBP, County Waterford.
2. College Proteins, County Meath
3. Monery By-Products, County Cavan
4. Premier Proteins, County Galway

5.1.6 Use as a Biofuel in the Rendering Process

Due to the BSE crisis, Ireland had vast stockpiles of tallow stored for a number of years with no commercial outlet. In the depths of the crisis, IAWS (a food and agri-business group) investigated the production of biofuel. The group owned Monery By-Products (a tallow producer) and Fish Industries (a fish processor in Donegal). IAWS converted their Heavy Fuel Oil (HFO) evaporators in Fish Industries to run on tallow to reduce their stockpiles and save on their conventional fuel consumption. This was a successful project and is now copied in other rendering plants.

5.1.7 Thermal Oxidisers

In the last number of years, the rendering industry has come under immense pressure to meet ammonia standards in their final effluent. In order to counteract this, a number of plants have installed thermal oxidisation systems to burn off protein rich condensate. The steam from the cookers is fed into the thermal oxidiser. Fuel and excess oxygen is pumped into the oxidiser to ensure that the steam and vapours are oxidised for a minimum of 2 seconds at 850°C. The vapour is released to atmosphere and the excess heat is used to run an economiser. In an interview with Mr. Michael Condra of College Proteins, it was demonstrated that grease trappings could be evaporated in this way, allowing the concentrated grease to be used at a later stage to fuel the thermal oxidiser along with tallow and heavy fuel oil. It was demonstrated that the energy costs would make this economically expensive. One hundred kilos of HFO would be required to evaporate 1000 litres of water in the Babcock Wilcox oxidiser on this site. However, it is a disposal route with no solid residuals.

Plate 17 : Thermal Oxidiser

Source: PCC Sterling Limited (web page accessed 15-03-05)

5.1.8 Evaluation of the Efficacy of Bacterial Dosing in Grease Retention Units

The first stage of the on-site study was to determine the GRU infrastructure present and the daily loading rate at each site. This was undertaken and is presented below:

Table 8: GRU Capacity and Loading Rates

Site Name	GRU size in litres	Average number of meals served per day
Crescent Shopping Centre	4500	600
Saint Johns	920	100
Milford Hospice	1350	800-1000
University of Limerick	200	300

5.1.9 Site Descriptions

5.1.10 The Crescent Shopping Centre, Limerick City

The Crescent Shopping Centre had a large triple chamber interceptor taking the kitchen waste from a number of restaurants and butchers. The unit was less than two years old and was supplied by Carlow Pre-Cast Concrete Limited. It is deemed to be correctly sized and retained large volumes of solids and grease.

Plate 18: GRU at Crescent Shopping Centre

Source: Personal Collection

5.1.11 Saint Johns Castle, Limerick City

This GRU serviced the wastewater from a public house that served soup and sandwiches in Saint Johns Castle. The GRU was an older model supplied by Richmond Trading of Tipperary. Upon first appearance, it looked to be slightly corroded and sub-standard.

Plate 19: Saint Johns Castle, Day 1

Source: Personal Collection

5.1.12 Milford Hospice, Limerick City

This was an older GRU also supplied by Richmond Trading. The trap was corroded, undersized and contained high levels of saturated fats from a combi oven. The manager of the site explained that the hospice experienced high numbers of visitors at weekends and that the kitchens were extremely busy at those periods. It was not envisaged that there was sufficient infrastructure in place to retain the volumes of grease that would emanate from the GRU.

Plate 20: Milford Hospice Grease Trap, Day 1

Source: Personal Collection

5.1.13 University of Limerick, Limerick City

This GRU was installed in the last 3 years to cater for bar waste. It was anticipated that there would be a constant loading between term and holiday time as it catered for members of the adjacent leisure centre. The trap contained large amounts of organic debris, with small levels of free-floating oils.

Plate 21: University of Limerick Grease Trap

Source: Personal Collection

5.1.14 Summary Data on GRUs in On-Site Tests

In order to facilitate a comparison between this study and previous studies, a summary data table was prepared as presented in Table 9:

Table 9: Summary Data on GRUs in On-Site Tests

Site Name :	Crescent	St. Johns	Milford	U.L.
Change in volume of retained grease in GRU (week 8 to 16)	81% reduction	33% reduction	2% reduction	74% reduction
Final effluent FOG (Dublin City limit 100 mg/l)	78 mg/l	1 mg/l	418 mg/l	1 mg/l
Is consistency of GRU contents similar to thick soup? (y/n)	Y	Y	N	Y
Observed reduction in odour? (y/n)	N	Y	Y	Y
Dry deposit building up on its sides? (y/n)	Y	N	N	N
Caked deposit floating on the surface? (y/n)	Y	N	N	Y
Grease build-up in downstream drain line? (y/n)	N	N	N	N
Frothy film on surface? (y/n)	Y	Y	N	Y
Is the water greyish (y/n)	Y	Y	Y	Y
Change in D.O?	**reduced**	**reduced**	**same**	**increased**
COD comparison between treated and non-treated GRUs	**-75%**	**-43%**	**+145%**	**+580%**
BOD comparison between treated and non-treated GRUs	**+133%**	**+391%**	**+372%**	**-8%**
NH_3 comparison between treated and non-treated GRUs	**+1160%**	**+500%**	**+700%**	**+611%**
Change in bacteria levels between treated and non-treated GRUs	**reduced**	**reduced**	**reduced**	**reduced**

5.1.15 Supplementary On-Site Analysis

Further analysis was also undertaken on site to highlight any trends that would not have been obvious from visual observation or laboratory results. This is tabulated below:

Table 10: On-Site Results for Test Period

Site Name	Parameter	Week 4	Week 8	Week 12	Week 16
Crescent Shopping Centre	pH Inlet	4.5	5	5	4.5
	pH Outlet	5	4.5-5	4.5	5
	Temperature Inlet ^{0}C.	25	32	35	38
	Temperature Outlet ^{0}C.	29	32	38	31
	DO Outlet (mg/l)	1.3	1.3	1.1	1.1
	Total Viable Count final chamber 10 $^{(n)}$	7	7	5	2
Saint Johns	pH Inlet	5	5	6	5
	pH Outlet	4.5-5	5	6	6
	Temperature Inlet ^{0}C.	38	33	28	29
	Temperature Outlet ^{0}C.	35	31	28	25
	DO Outlet (mg/l)	1.3	1.3	1.2	1.1
	Total Viable Count final chamber 10 $^{(n)}$	6	6	6	2
Milford Hospice	pH Inlet	6.8	4	5	4.5
	pH Outlet	4.5	7	7	5
	Temperature Inlet ^{0}C.	35	42	38	43

Table 10 (continued): On-Site Results for Test Period

Site Name	Parameter	Week 4	Week 8	Week 12	Week 16
	Temperature Outlet ^{0}C.	46	43	42	40
	DO Outlet (mg/l)	1	1	0.7	1
	Total Viable Count final chamber 10 $^{(n)}$	4	4	4	3
University of Limerick	pH Inlet	5.5	5	5	5
	pH Outlet	5.5	5.5	5	5
	Temperature Inlet ^{0}C.	43	38	35	36
	Temperature Outlet ^{0}C.	41	38	41	36
	DO Outlet (mg/l)	0.7	0.7	1.5	2.9
	Total Viable Count final chamber 10 $^{(n)}$	5	5	5	4

Table11: Alcontrol-Geochem Discharge Analysis

Crescent Shopping Centre

Parameter	Week 4	Week 8	Week 12	Week 16
BOD (mg/l)	464	1859	2285	2477
COD (mg/l)	3052	3210	4338	2592
FOG (mg/l)	14	42	24	78
Total P (mg/l)	5.3	4.93	6.79	9.94
Total N (mg/l)	52	30	73	58
Ammonia (mg/l)	0.3	0.5	5.7	5.8
TKN (mg/l)	50	30	73	58

Table 12: Alcontrol-Geochem Discharge Analysis

Saint Johns Castle

Parameter	Week 4	Week 8	Week 12	Week 16
BOD (mg/l)	475	701	82	2741
COD (mg/l)	979	1313	252	574
FOG (mg/l)	110	209	31	1
Total P (mg/l)	5.44	4.93	4.13	3.17
Total N (mg/l)	35	14	38	10
Ammonia (mg/l)	0.3	0.2	0.2	1
TKN (mg/l)	35	14	38	10

Table 13: Alcontrol-Geochem Discharge Analysis

Milford Hospice

Parameter	Week 4	Week 8	Week 12	Week 16
BOD (mg/l)	2186	442	2447	1643
COD (mg/l)	4249	860	3311	1248
FOG (mg/l)	57	16	59	418
Total P (mg/l)	13.97	4.76	10.4	5.96
Total N (mg/l)	45	19	79	31
Ammonia (mg/l)	0.6	0.2	3	1.4
TKN (mg/l)	45	19	79	31

Table 14: Alcontrol-Geochem Discharge Analysis

University of Limerick

Parameter	Week 4	Week 8	Week 12	Week 16
BOD (mg/l)	85	222	93	204
COD (mg/l)	510	803	288	4656
FOG (mg/l)	22	22	15	1
Total P (mg/l)	3.16	2.17	1.04	63.4
Total N (mg/l)	53	16	34	235
Ammonia (mg/l)	0.8	0.9	0.2	5.5
TKN (mg/l)	50	16	34	235

5.1.16 Reduction of FOGs

All GRUs experienced a reduction in retained grease when treated with bacteria. This reduction ranged between 2% and 81% in the four systems. The greatest reduction was in the Crescent (the largest GRU) and the least was Milford Hospice (the most overloaded GRU).

Figure 2: Quantities of Retained Grease at the Four Trial Sites

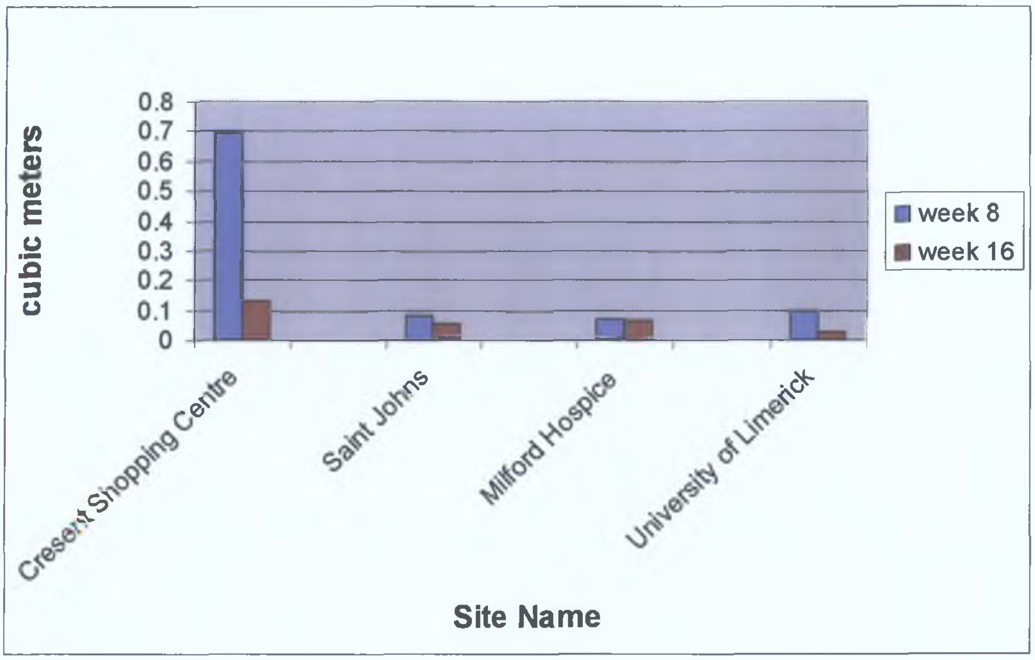


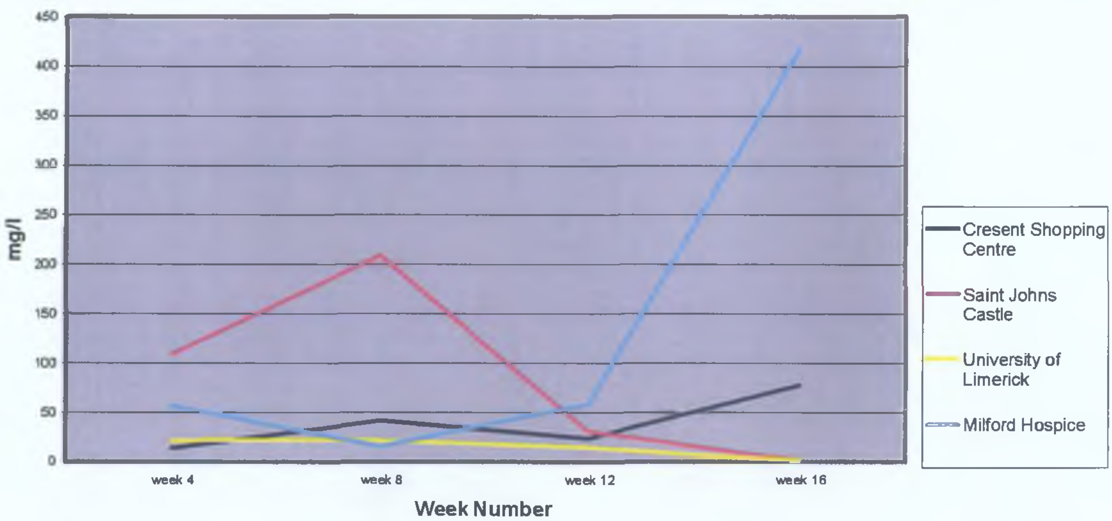
Figure 3: Reduction of Retained Grease with Bacterial Treatment

After eight weeks with no bacterial addition, floating matter accounted for 15.3% of GRU capacity at the Crescent and 50 % at UL. After 8 weeks of dosing, solids were reduced by 81% in the Crescent and 74% in UL.

5.1.17 Final Effluent Results

The results from Alcontrol-Geochem demonstrate that there were considerable fluctuations in the discharge levels of FOG. These are shown below:

Figure 4: FOG in Discharge



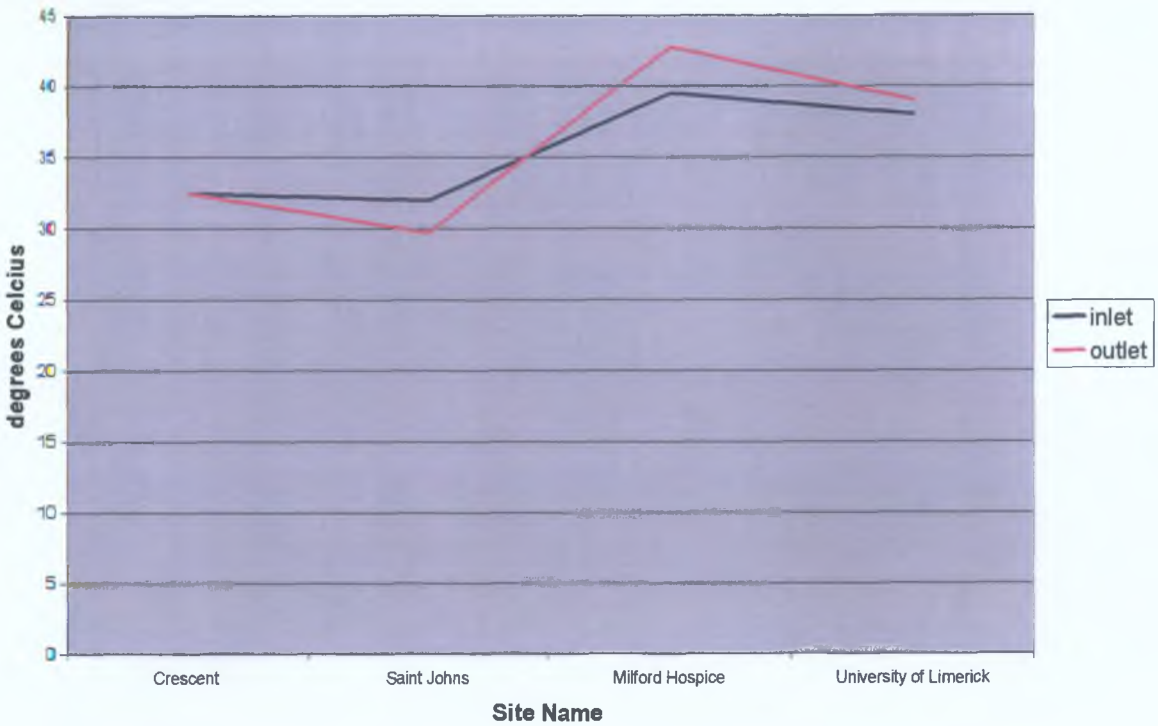
The standard FOG limit set in planning permissions and discharge licences is 100 mg/l. Dublin City Council has further proposed that a 100 mg/litre FOG in commercial discharges should be applied. Therefore, for the purpose of this study, any discharge below 100 mg/litre is deemed allowable and acceptable.

On the basis of the results obtained, success can clearly be demonstrated in 3 out of the 4 sites. Discharged FOG in Saint Johns Castle and University of Limerick was reduced. The Crescent Shopping Centre saw a slight rise, but was still below the 100-mg/litre limit. Milford Hospice discharges broke the 100-mg/l limit and it was clear from the outset that the disrepair and the temperature of the trap were contributory factors.

5.1.18 Temperature

The poor retention of FOG at the Milford Hospice can partly be blamed on the elevated temperatures that prevailed throughout the test period. This failed the principles of the 3Ts of grease separation: time, temperature and lack of turbulence. The temperatures are shown in figure 5.

Figure 5: Mean GRU Temperatures, Week 4-16



5.1.19 Changes in BOD and COD.

After bacterial addition, three of the units experienced significant BOD rises in their discharges. This rise reflects an incomplete breakdown of organics due to some degradation limiting factor. The BOD increase was not translated into a rise in FOG in the final discharge. The COD results decreased in the Crescent Shopping Centre and Saint Johns Public house. This may be due to their lower temperatures facilitating the floatation of FOG, allowing it to be more effectively retained.

Figure 6: Change in COD Levels from Week 8 to Week 16

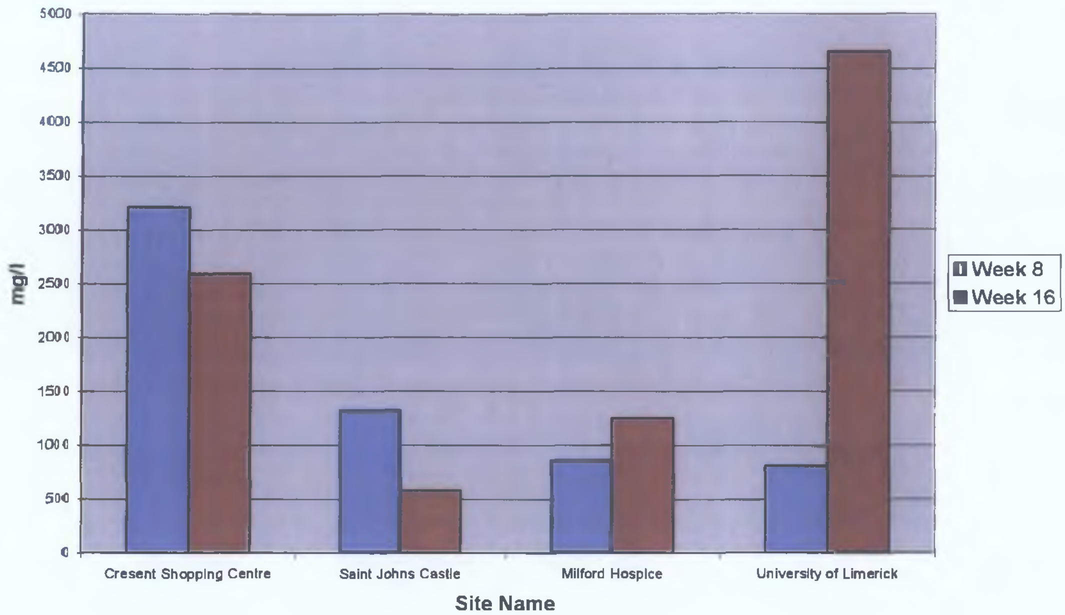


Figure 7: Percentage Change in BOD, Week 8 to Week 16

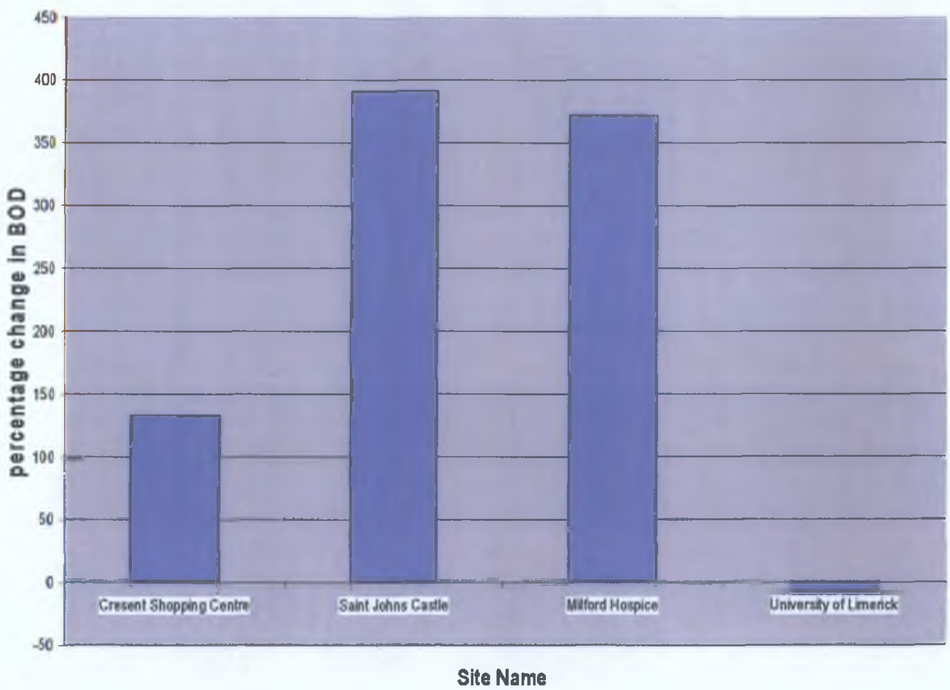
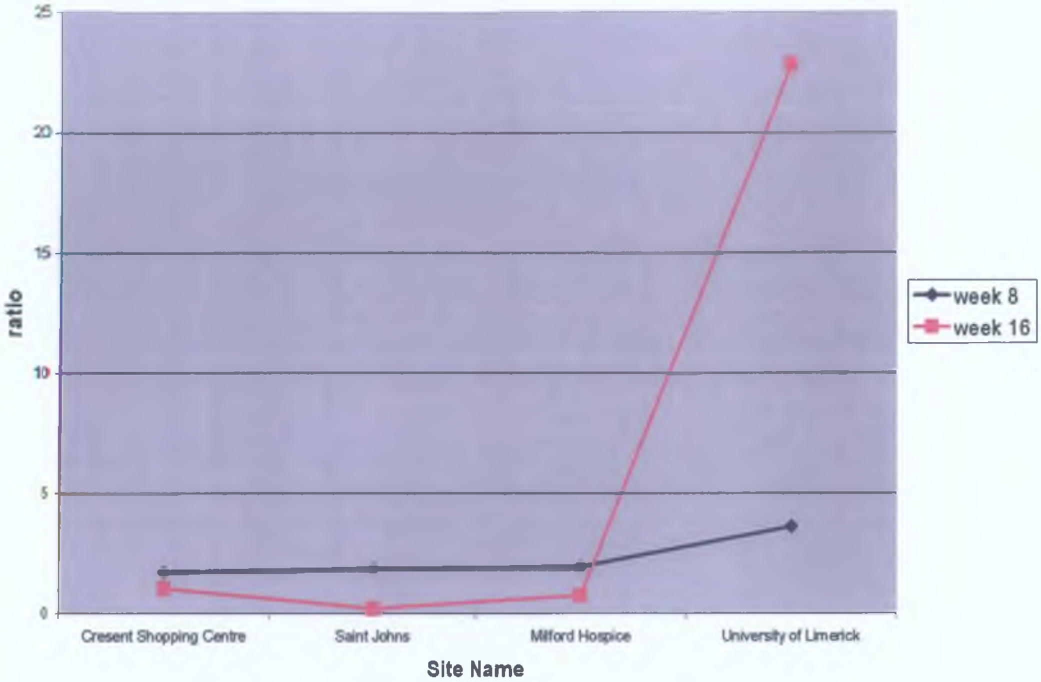


Figure 8: Mean COD:BOD Ratio on all Four Sites

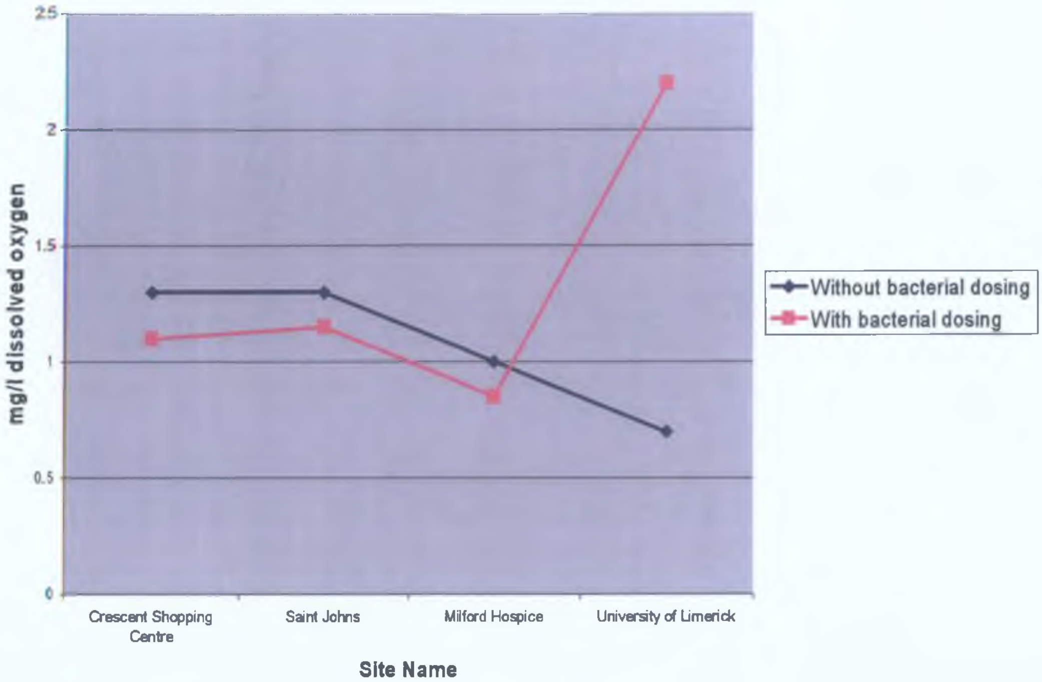


The ratio of COD to BOD decreased in three sites throughout the trial. This reflects the degradation of the less refractory compounds in the GRU. The exception is the GRU at the University of Limerick. It is unlikely that partly degraded FOGs were responsible for this dramatic rise as there would also be a sharp increase in BOD under such circumstances.

5.1.20 Oxygen Levels

There was a slight trend for the mean oxygen levels to decrease during the times when bacteria were dosed.

Figure 9: Mean Dissolved Oxygen in Discharge

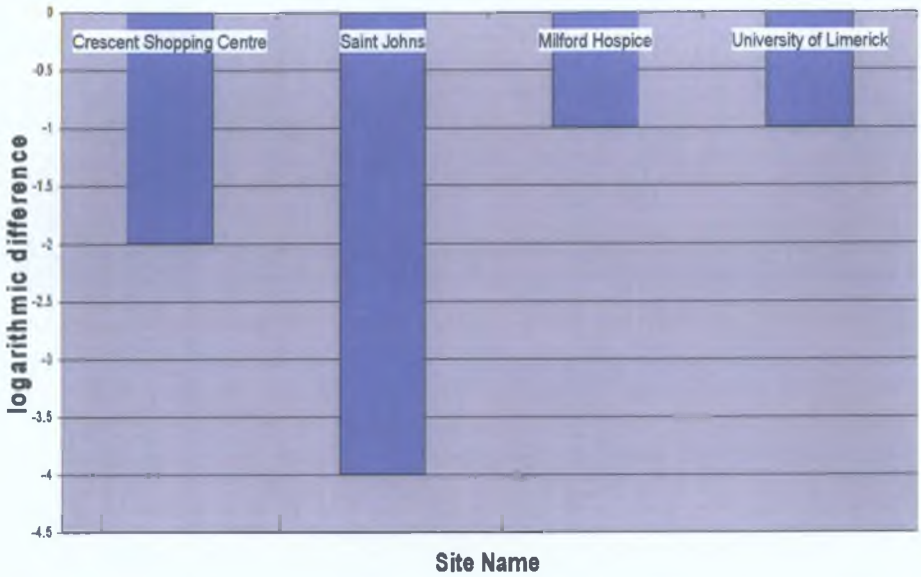


The oxygen measurements were taken at 20 cm below surface level to overcome possible surface aeration. The interesting point is that that there was always a small residual of oxygen. This does not take account of the anaerobic sludge that would collect at the base of the GRU but does allow for some aerobic activity in other areas of the unit.

5.1.21 Bacterial Cell Counts

There was a marked reduction in the amount of biological life in the GRUs during the biological addition phase. Bacteria in the Crescent Shopping Centre GRU reduced from 10^7 Colony Forming Units (CFU) per ml to a mere 10^2 CFU. Saint Johns decreased from 10^6 CFU to 10^2 CFU. It is interesting to note that the greatest decrease in bacteria was in the biggest GRU, with a low temperature and the largest reduction of FOG. Therefore, the amount of bacteria present cannot be used as indicator of the success of bacterial dosing.

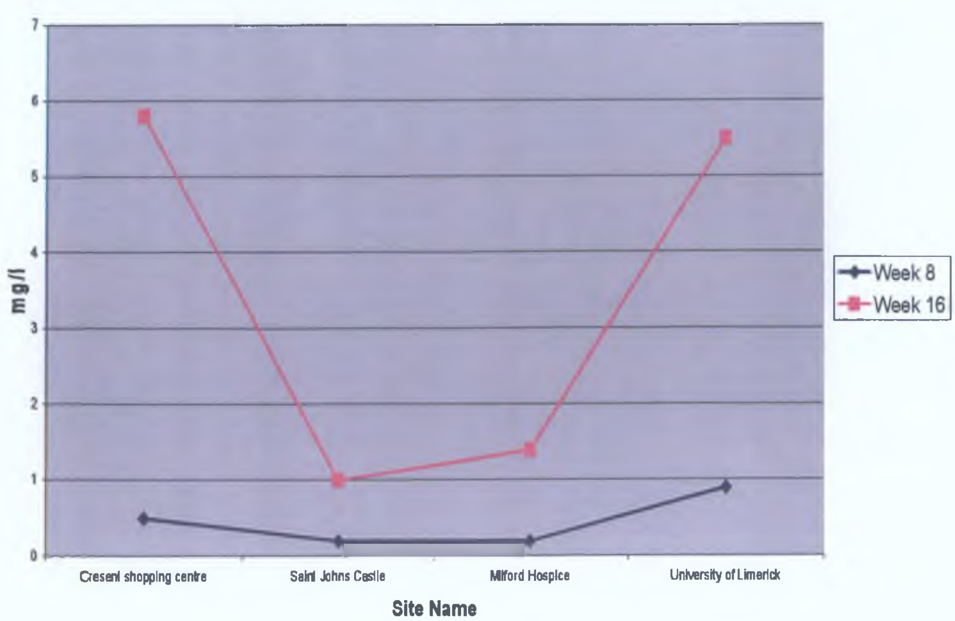
Figure 10: Logarithmic Change in Colony Forming Units, Week 8 to Week 16



5.1.22 Ammonia

There was a significant rise in effluent ammonia concentrations on all sites. The greatest level of ammonia was found in the discharges from the Crescent Shopping Centre GRU.

Figure 11: Ammonia in Discharge, Week 8 to Week 16



6. Discussion

6.0 Introduction

This section is divided into two parts. The first evaluates the data from the on-site testing of biological treatment. The second part evaluates the data that originates in the literature review.

6.1.0 Part 1 Discussion of the Bacteria Dosing Trial

The aim of the trial was to evaluate a "real-life" bacterial dosing system against data found in the literature review. After undertaking this test, it became apparent that there were variances between site results, but a number of trends and conclusions were possible to identify:

- There are many reasons why grease accumulates at differing rates prior to bacterial addition. The two most obvious reasons are the actual presence of grease in the influent and the correct sizing of the unit to provide for the 3 Ts of time, temperature and lack of turbulence. Further reasons are demonstrated in the NSAI standard. Examples include lipid type and presence or absence of detergents.

- The GRUs dosed with bacteria experienced a reduction in retained grease of between 2% and 81%. However, it is not possible to determine a degradation rate based on data as exact as first-order kinetics. Each GRU has its own size, flow rates and organic matter composition. Bacterial dosing is more successful when there are larger volumes of grease retained in the first instance; facilitating greater bacterial degradation.

- Previous studies appear to have relied on somewhat subjective opinions as to the merits of the technology

- There is no possibility of achieving a complete breakdown of FOG in-situ due to limiting factors such as retention and aeration. It is impractical and uneconomic to correct this by increasing aeration, further bacterial addition or GRU size. Further aeration and bacterial colonies will only accelerate decomposition rates to their current end point. As this partial decomposition level is achieved, fat is converted from its hydrophobic and lighter state to organic matter that sinks to render the triple chamber configuration ineffective. This maximum digestion end point was demonstrated when the same volume of bacteria was dosed into different sized GRUs. This meant that all dose rates were proportionally different, yet there was no clear relationship between the dosage and degradation rates. Indeed, the Crescent had the least proportional dose and achieved the best results in solids reduction, while the University of Limerick GRU came second best in solids reduction, even though it was the smallest unit. There was an increase in the percentage of FOGs digested where larger grease mats were retained at the Crescent and the University of Limerick. It is hard to quantify to what level, as it is hard to draw a conclusion on such a small test sample. What is clear is that dose-rate response, residual DO and surface areas of grease exposed do not allow accurate prediction of the discharge quality. In order to achieve complete FOG digestion, a much larger dedicated reactor vessel is required. This would require extended aeration for at least a number of days. This is possible for large industrial users, but not for the average restaurant or hotel.

- Unlike previous studies that found reductions in ammonia, this study saw a significant increase in all cases (ammonia increased by up to 1160%). This is due to increased biological breakdown of proteins in low DO conditions and limited alkalinity. This is because the nitrifying bacteria of Nitrosomonas, Nitrobactor and Nitrosoccus require excess alkalinity and high residual DO to survive. The oxygen required to oxidize one gram of ammonia to nitrate is 4.57 g (University of California, 2004).

- BOD of treated GRU effluent was elevated (up to 372%) compared to the untreated effluent. The by-products of incomplete degradation include triglycerides, mono and diglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, fatty acids and fat-soluble vitamins. These all exert oxygen demands and in all discharges as it takes 1.42 g oxygen to oxidize 1 g of BOD_5 (University of California, 2004). However, the results demonstrate that in 3 out of 4 cases, these organics did not comprise excessive grease.

- There was no way of determining if the increases in BOD and ammonia were due to FOG degradation, or merely due to the oxidation or reduction of other organic and proteinaceous compounds.

- There was a marked reduction in the amount of biological life in the GRUs during the biological addition phase. The reason could be that the environment in which the indigenous bacteria were surviving changed in favour of more grease competitive bacterial colonies. These find their niche and the population stabilises for some reason. It could be that free fatty acids become toxic at a certain level of activity or that a substrate is depleted and becomes a limiting factor. It could also be a function of reduced oxygen in the sediments of the GRU.

- These small-scale on-site tests agreed with previous research that FOG can be broken down in GRUs. Bacterial dosing appears to be better than doing nothing at all. It will reduce grease in the network and the partial decomposition of organics will reduce oxygen requirements in a wastewater plant at a later stage. However, subsequent anaerobic discharges can corrode a sewer network and there may be a possibility of fatty acids binding to carbonates in calcium rich regions. This causes a soap-like deposit that can cause blockages downstream. The precipitation of free fatty acids and glycerol by calcium and magnesium also occurred in Osberstown WWTP, County Kildare when calcium stearate was formed from FOG in limestone rich wastewater.

Where there are large volumes of grease, it is clear that removal at source would be a better treatment option. Indeed, any management strategy would require that FOG be recovered and put to some better use.

There are two areas in which bacterial dosing can play a positive role:

1. In dosing GRUs that do not collect sufficient FOG to warrant collection on a frequent basis.

2. In dosing the discharge line downstream of a GRU to digest the significant levels of FOG between 0.1 microns to 0.5 microns that escape all GRUs (University of Nebraska, 1997).

This study agrees with previous research that bacterial addition could have a positive function in certain circumstances and may be considered as part of a national grease management plan.

6.1.1 Limitations to On-Site Testing

A number of the results obtained during the trial appeared to lack consistency. The short time-frame and site access restrictions meant that grab sampling was the methodology employed, resulting in "snap-shot" data. While the trends on all four sites were broadly similar, there were certain unexpected results which require further comment:

- Milford Hospice had elevated outlet pH levels in weeks 8 and 12 (Table 10). This pH of 7 may be due to the influent composition at the time, or may be due to sampling error. This GRU had high levels of liquid phase FOG which may have interfered with the pH probe and the Whatman pH testing papers.

- Saint Johns Castle showed a BOD result over four times higher than the equivalent COD result (Table 12). Alcontrol-Geochem (laboratory analysts) was contacted to explain this result. They replied that while the BOD test was undertaken on an unfiltered sample, the COD test was undertaken on a settled sample. However, this does not correlate with the other sites which underwent the same analysis. It can be concluded that analytical error may have been a contributory factor.

- Many of the results for the University of Limerick were elevated on week 16 (Table 12). The phosphates were 63.4mg/l, while the three previous results ranged from 1.04mg/l-3.16mg/l. The TKN was 235mg/l, elevated from previous results of 16mg/l-50mg/l. The relatively high solids content and the low FOG levels in the effluent suggest that biodegradation and subsequent mineralization of general food matter generated these results. However, this calls all results into question, as one cannot distinguish between the FOG and general food contribution to TKN and phosphorous. This is emphasised in figure 7, where elevations in BOD are displayed, but the relative contributions of FOG and general food matter are not distinguished.

- Milford Hospice shows an alarming rise in FOG in its effluent in week 16 (figure 4). This is probably due to the poor state of repair of the GRU and gross overloading. However, a similar result may well have been expected in week 8. Since this was not the case, one must ask whether there was a substantial increase in loadings or whether bacteria had a role to play in the process.

Therefore, this small study raises a number of questions that require further examination. The issues identified were grab sampling, possible sampling error, restricted site access and a lack of facilities to continuously measure flows and loadings. However, this study could lay the foundations for a more in-depth study at a later stage.

6.2 Part 2 Discussion of the Literature Review

There are 44,521 registered food production and service establishments in Ireland and yet there is no national strategy for grease treatment. As a number of parties currently play a role in the FOG sector, it is pertinent to discuss their current position.

6.2.1 Local Authorities

Local Authorities do not exercise a great degree of FOG management in their functional areas. If the Local Authority really wanted to protect the sewer they could have introduced permits and licenses many years ago. Indeed, it appears that a potential revenue stream has been overlooked. FOG contributes a significant loading on wastewater infrastructure and there should be an obligation to ensure that proper resources are allocated to minimise its impact.

The failure to licence food outlets may be due to their rapid expansion or the limited resources available for drainage, sanitary services and environmental departments. In terms of enforcement, the levels of action appear to reflect local political circumstances. It is either undertaken with great zeal or ignored altogether.

A lack of knowledge about grease residue treatment is noticeable and grease policies vary from county to county. Many blockages attributed to FOG are actually contributed to by damaged sewers, failing pumps and high rainfall. There is a perception that Local Authorities may blame the symptoms on grease, passing back emergency works costs to the discharger and not accepting their share of the liability.

No serious attempt has been made by Local Authorities to find a suitable treatment and disposal option for collected waste grease and oils. It is not unreasonable to ask that Local Authorities provide treatment facilities on their wastewater sites for locally collected grease. This is not undertaken partly due to malodours already experienced in municipal anaerobic digesters. However, there must be a responsibility to treat FOG residues generated in their functional areas. Indeed, this study has identified numerous successful treatment methodologies, many producing renewable energy at a profit.

6.2.2 Government Agencies

6.2.2.1 The Role of the National Standards Authority of Ireland (NSAI)

The only document specifically related to grease in Ireland is ISEN 1825-2:2001. The scope of this document is so limited that it is often unworkable. The standard formula used for sizing of GRUs does not account for the differing designs that alter separator efficiencies. Furthermore, it makes no reference to mechanical grease separation, proper location of units, biological treatment or plumbing of ancillary devices such as macerators and dishwashers. Many premises in urban areas are too small to accommodate a grease trap and since nothing else is suggested under the standard, dischargees are offered no statutory guidance. According to members of Dublin City Council, 40% of food outlets in Temple Bar have no grease collection infrastructure, as space is not available. Where pre-treatment devices are utilised, some Local Authorities are still insisting that existing GRUs be removed and larger units installed to meet ISEN 1825-2:2001.

The NSAI also control Agrément certification. This is designed specifically for new building products and processes for which published national standards do not yet exist. Since an unsatisfactory standard does exist, the NSAI will allow Agrément certification of any improved product or service in future. The NSAI cannot use the Agrément certification to approve chemicals, enzymes or bacterial products. However, they can issue certificates for processes that utilise them.

6.2.2.2 Role of the Department of Environment and Local Government

There is no public provision of industrial FOG treatment. This is exacerbated by the Department of Environment and Local Government (DoELG) abolishing the full €26 m of waste infrastructure grants for private industry. GRU processing must compete for investors with more lucrative waste management opportunities. The DoELG have a number of papers and working groups looking at environmental issues. There are areas where a FOG strategy can complement their implementation and this should be addressed.

6.2.2.3 Role of the Department of Agriculture and Food (DAF)

Any provision of biological waste management is now under further pressure from the Department of Agriculture and Food (DAF). The implementation of the Animal By-products regulations is forcing high capital investment onto composting and anaerobic digester operations. It is also limiting the lands that residuals can be spread on and is in conflict with the DoELG document "Positive Aspects of Sludge and Biowaste Recycling to Soils 2004". The implementation of the Nitrates Directive and the limiting of phosphorus on land are also closing agricultural outlets for compost, anaerobically digested sludge and sludge residuals.

6.2.2.4 The Role of the EPA

The EPA role is as a watchdog and consequently, they have little to do with "day to day" management of waste strategies. However, they are responsible for the overall waste strategy and Ireland does lag behind many other EU countries in waste management implementation. This is demonstrated by the EU in prosecuting Ireland for breaches of the directives pertaining to nitrates and phosphates. The failure to implement the licensing of incinerators is not directly the fault of the EPA, but their failure to clearly define FOG waste processing strategies in the past has starved alternative grease treatment technologies of investment. This lack of FOG infrastructure is due to the threat of an incinerator being licensed at a future date. A thermal treatment operation could "buy the market" by offering significant discounts for processing all combustible wastes in their licence category. This could render other technologies somewhat obsolete and close down FOG processors overnight. Therefore, in an indirect way and by acts of omission, the EPA impacts on business plans which are critical to new investment.

6.2.2.5 Role of the Department of Communications, Marine and Natural Resources

The department administers Alternative Energy Renewable (AER) licences. Under the AER scheme, winning bidders are entitled to a 15-year power purchase agreement (PPA) with the ESB. A quota is set for the amount of electricity to be sourced from each technology, e.g. wind, hydro, and biomass/waste. Biowaste is not the most economic and therefore secures a smaller quota. Today, generators owned by Eco-Beo (a private Irish AD firm) lie idle and gas is flared off due to lack of PPAs. Even where applicants are successful, the 15-year agreement is not sufficient collateral for finance agencies where borrowing is required. Thus, there is great room for the department to revise their policy on biowaste PPAs.

6.2.3 Role of Private Drain Management Contractors

Public sector failures in grease management led to the void being filled by private operators. With no national management strategy, dedicated infrastructure or clear local government policies, the route is open for any person to provide a FOG management service. As is often the case, the cheapest management route has been popular. This involves illegal and semi-legal disposal of FOG on land and the application of emulsification products directly into drains. Cheap emulsified products are also undermining the drain companies that offer service contracts. Furthermore, drain companies have the added burden of applying for waste permits with insufficient treatment or disposal routes available. This has led to the introduction of mobile interceptor trucks. These operate with no regulation and there is no current way of ensuring that discharges are under FOG threshold limits.

6.2.4 Role of Product Sales Companies

There are numerous companies promoting FOG solvents blended with bacteria or enzymes and packaged as biological products. Currently, deodourised kerosene, terpenes and surfactants are available and offer "wonder-solutions" to restaurants and catering establishments. This practice has not been checked and there is no product approval system by Local Authorities. This inaction has sent out the wrong message and caused many reputable biological products to be forced out of the market place. This study has demonstrated that bacterial products can be effective but in reality, emulsifiers consistently outsell them. A Local Authority system of product approvals could be established to prevent emulsification products being utilised.

6.2.5 Role of Proprietors of Food Producing Outlets

The food production sector has faced great changes in recent years. Profits have been eroded by:

- Rises in labour, electricity and gas costs
- Expense in implementing HACCP programmes
- Increases in "Pay by Weight" waste disposal charges
- Recent packaging regulations bringing large pubs and restaurants into the REPAK recycling scheme
- Smoking ban in public places

Furthermore, there has been a growth of hot food counters in garages and convenience shops and a trend for pubs to serve cooked meals. Significant financial pressures now face this sector and grease management is a further cost that the sector can possibly ill afford. At present, many sites have GRUs in place, but they are usually undersized, poorly maintained and in disrepair. While some management is undertaken, it usually falls short of what is required. Staff turnover is also high, causing difficulties in training staff on the importance of GRU systems.

6.3 FOG Strategy and Implementation -Who and Why?

If a system were introduced via 30 individual local licensing/permit programmes, it would recreate the barriers and concerns identified in "Taking Stock and Moving Forward" (2004). Therefore, it is important that a central body should have an overall governing role. If the DoELG formulated a Grease Management Strategy, they would be in an excellent position to select various options that meet their requirements on the Biowaste Directive, Renewables Directive and the Biofuels Directive. Furthermore, the policy could feed directly into the various state sponsored strategies such as the National Climate Change Strategy (2000), Delivering Change - Preventing and Recycling Waste (2002), Race Against Waste Initiative (2003), Waste Management-Taking Stock and Moving Forward (2004) and the National Strategy on Biodegradable Waste - Draft Strategy Report (2004).

6.4. Treatment and Disposal Options- Availability and Capability

In order for a FOG strategy to part fulfil the DoELG aims and policy objectives, it is important to review the availability and capability of technologies described in the literature review section. The choice of which route to take is ultimately up to the DoELG in the achievement of their own priorities. A list of available technologies is set out in Table 15:

Table 15: Availability of GRU Treatment Technologies

Option	Aerobic	Anaerobic	Compost	Rendering	Biofuel	Thermal	In-Situ
Not Available	☑				☑	☑	
Limited Capacity		☑					
Available			☑	☑			☑

There is no definite time-scale for the provision of a biofuel plant or thermal treatment in Ireland.

6.4.1 Aerobic Treatments

Aerobic treatment of grease is not available in Ireland, even though it is a relatively inexpensive technology. This technology is capable of providing a final disposal source for residual FOG and its provision has a short lead-time.

6.4.2 Anaerobic Digestion

Anaerobic digestion of grease trappings is currently undertaken in Ireland. Current availability can only be maintained if biogas plants can demonstrate that they meet legislative requirements. Low throughputs due to VFA poisoning and washout of biomass also restrict processing capabilities.

6.4.3 Composting

Composting of grease is carried out at present and the technology is progressing rapidly in Ireland. Currently there are 17 commercial composting facilities, each processing in excess of 500 tonnes per annum. While not all of these facilities currently process FOG, Mc. Gill Environmental currently compost grease trappings in Tipperary and there are many international composting technologies specifically configured to process FOG.

6.4.4 Rendering Plants

A market for rendered FOG may be available in the oleochemical industry. However, the purity of the product may have to be addressed in order for this option to be feasible. This purity issue is overcome by Gupta et al (1997) in their FOG model in Bangkok. They document the feeding of "trash fish" with rendered FOG. These fish are then harvested for their more refined oils and proteins. Meanwhile, thermal oxidisation is currently available in Ireland and leaves no liquid or solid residues. Class 1 and 2 rendering plants can process grease trappings. The treatment technology is immediately available with open-ended capacity and a gate fee of around €100 - €120 per tonne.

6.4.5 Biodiesel

There is virtually no biodiesel production in Ireland presently. It can be produced from a variety of products including recycled vegetable oils. The capability of such a biodiesel plant was demonstrated in Scotland. With increasing energy prices, a European Biodiesel Directive and aid under the Finance Act, a national grease management strategy could quite conceivably incorporate biodiesel production into it in the medium term.

6.4.6 Thermal Treatment

Thermal treatment with energy recovery is proposed in six regions of Ireland for residual municipal waste treatment after other recycling methods have been exhausted. However, with no infrastructure present, it is unlikely that it will play any role in the short-term management of FOG residues. Even if there was an incinerator, it is documented that unrefined FOG has undesirable moisture content and high levels of acids.

6.4.7 Biological In-Situ Treatment of GRUs

This study has demonstrated that bacterial products are available and are capable of breaking down grease where infrastructure is suitable. However, the technology is susceptible to various limiting factors in all cases. In the short term, the volume of grease to be managed requires some form of continued bacterial treatment. This is due to two reasons:

1. Not enough outlets to process FOG in the immediate term
2. Switching off existing units may result in less in-situ FOG breakdown, filling GRUs faster and pushing more FOG into the sewerage network.

In the longer term, licensees should be entitled to meet their permit limits by the most appropriate method. It is recommended that some form of "Product Approval Certificate" be issued prior to bacterial dosing so that emulsification agents are phased out.

For industrial premises, it may be viable to build a reactor vessel to pre-treat FOG and dispose of organic sludge separately. Such methodologies are described in the aerobic and anaerobic treatment sections in the literature review section.

6.5 Proposed Grease Management Strategy

A proposed management strategy is outlined below and a number of treatment and disposal scenarios are suggested.

6.5.1 Step 1 Regulatory Framework

The DoELG should set up a working committee. This committee should determine which regulatory framework is most suitable to implement a FOG management system. It is preferable to provide a single regulation instead of a multiplicity of bye-laws. It is also important to ensure the legislation is compatible with the Water Framework Directive (WFD).

6.5.2 Step 2 Managing the Sources of Grease

Prior to selecting the appropriate treatment and disposal options, the first part of the DoELG strategy must be to manage the grease source. Ireland currently fails here as there is no licensing or permitting of restaurant effluents. It is up to the DoELG to choose between licensing and permits. The strengths and weaknesses are described below:

6.5.3 Licensing

The most comprehensive action would be to licence all commercial discharges and charge them accordingly using a calculation similar to the Mogden formula (Pers. Comm. John Stack, Dublin City Council). This is already practiced in industry and takes account of volume, suspended solids and COD. There would be no room for licence holders to manoeuvre and it would demonstrate a true concept of "polluter pays" as required by the WFD. The financial burden of monitoring 44,521 outlets would be prohibitive. Such a system would include monthly sampling and entail large administration and legal costs.

6.5.4 Permits

Cork and Wicklow County Councils are reviewing this option in order to meet a shortfall in new wastewater treatment works funds. Direct DoELG payment is only for the domestic proportion of the wastewater load. Local Authorities are to cover the trade effluent component by levying charges. This may lead to permits being issued and charged on a volumetric basis. Under such a system, wastewater bills will be calculated from water charge meters, provided effluent is below certain contaminant thresholds. This only requires an annual test based on BOD, suspended solids and FOG. Such a permit system is cheaper to introduce but has a number of drawbacks:

- A system based on pass/fail methodology provides little incentive to improve results any further.

- In situations where there were large accumulations of FOG, it could promote the inappropriate use of bacterial treatment, thereby causing BOD, ammonia and suspended solids increases.

- Permit sampling would probably be less frequent than licence sampling. This would allow more scope for deliberate discharges of FOG when inspectors are not present.

- It still does not address the domestic contribution to FOG.

- It fails to address the treatment and disposal options for collected FOG.

6.5.5 Step 3 Set Parameters in Licenses/Permits

The DoELG could set broad guidelines for the pass/fail system of the permit or introduce licensing schedules and charges. These would be communicated to Local Authorities who could then set Emission Limit Values (ELVs) in their own local FOG programme. Parameters may vary depending on local circumstances such as population thresholds, alkalinity, etc.

6.5.6 Step 4 Quantification of Available FOG

As part of a local FOG plan, it is suggested that each Local Authority could undertake a specific quantification of FOG in their functional area. This would be undertaken after the DoELG completes a preliminary study to ensure capacity is available for any strategy chosen. With 44,521 licensed premises, a rough calculation of liquid in GRUs can be undertaken. Studies are required to estimate the precise number of GRUs. If the average premises required one 1000 litre capacity GRU and monthly clean-outs were specified, it would represent approximately 530,000 tonnes of grease per annum. To quantify the amount of pure FOG in this 530,000 tonnes of GRU contents is more complex. If the average GRU capacity was smaller or mobile separator technologies utilised, this figure could be reduced somewhat. One can also make use of the data collated in the Limerick study. The mean collection of FOG was roughly .22 tonnes every two months, corresponding to 1.3 tonnes per annum. This would put national FOG solids at a very approximate figure of 58,000 tonnes per annum. (with wide-scale use of bacteria addition to GRUs, the national figure would be substantially less at approximately 16,500 tonnes per annum). Thus, approximate quantification calculations could be very inaccurate and accurate national prediction models are required. The prediction model must also take account of demographic trends; Dermot O'Leary of Goodbody Financial Services forecasts a population growth of 23% over the next 20 years (reaching 5.08m). The DoELG must relate this to the Landfill Directive, which requires an annual biological treatment capacity of 351,539 tonnes by 2009.

6.5.7 Step 5 - Promotion of Public Education and Training

It is possible that most grease enters the sewer network from domestic sources in this country. Any management strategy that does not promote education and awareness to the general public will be fundamentally flawed. There should be a DoELG public education and training programme to encourage domestic users to collect waste vegetable oils and recycle them. Advertisements and publicity material specifically relating to FOG should be distributed through as many channels as possible.

6.5.8 Step 6. - Treatment and Disposal of Collected Grease

If the DoELG decided to implement a GRU strategy immediately, there are only four possible outlets. These could give sufficient capacity to facilitate a speedy implementation of a strategy. The DoELG could develop these interim routes to generate a steady waste stream. In a future, other technologies could process the FOG in a manner more conducive to meeting national policy and legislative requirements.

The DoELG could ignore short-term capacity and rank the technologies on their position in the waste hierarchy. This would delay implementation but would provide a later, more organised start-up. As a simple hierarchy guide, the various technologies are ranked as to the strategy they represent.

Table 16: Waste Treatment ranked by Waste Hierarchy Level

Option	Prevent	Reduce	Reuse/ Recycle	Recover	Treat	Dispose
Aerobic Treatment					☑	
Anaerobic Digestion			☑	☑		
Composting			☑	☑		
Rendering Plants				☑		
Biofuel				☑		
Thermal Treatment				☑		
In-Situ Biological Treatment					☑	

The preferred options must be reuse and recovery by AD and composting. From the discussion section, it is clear that current capacity is available but in the longer term, these disposal outlets may be uncertain due to future changes in legislation. Under the EU precautionary principle, cognisance must be paid to the fact that AD, composting and In-Situ treatment technologies could provide incomplete treatment and allow residuals to impact negatively at a later stage. On a positive side, these options facilitate the Landfill Directive implementation and fit with the European strategy on biowaste disposal. Biogas can also be used to meet requirements under the Renewable Directive and the Green Paper on Sustainable Energy 1999. In-situ bacterial treatment comes in low on the waste hierarchy. However, early treatment must have some advantage as it reduces the volumes of FOG that require to be removed off-site for subsequent treatment and disposal. Therefore, it should have a role to play in any management strategy.

Under economic considerations, it is possible that the world energy shortage may demand the longer-term development of a biodiesel plant to address the biofuel Directive. This would require significant investment but an indigenous fuel source would impact significantly on balance of trade and would assist in many of the green energy requirements of the State. It may also provide the stimulus for the development of rape as an energy crop and thereby assist in Common Agricultural Policy reforms too.

This document has shown the capacity and capability of each treatment option. It is up to the DoELG to prioritise their requirements and select a suitable treatment route for the first phase of the programme.

6.5.9 Step 7 - Implementation at Local Authority Level

After the DoELG has undertaken a national evaluation of FOG and set the overall policy, it will then be up to the Local Authorities to tailor the programme to their own areas. This may be done on a county-by-county basis, or as part of a regional grouping to achieve economies of scale. The programme should be implemented under a local strategy similar to the Capacity, Management, Operations and Maintenance Plans (CMOM) under section 5 of the Clean Water Act, USA.

It should take the following steps:

1. Obtain a list of all licensed food outlets from the Food Safety Authority of Ireland.
2. Visit and audit each site for the presence and suitability of GRU infrastructure. The requirements of a permit system should be communicated to the owner or occupier. Data should be collected on the volumes of grease removed in the last year. Levels of products and services purchased and certificates of disposal should be collected. This information will provide proof that FOGs are being collected and disposed of in a legally compliant manner.
3. Calculate total grease volumes to be collected in the county.
4. Identify, select and name the most desirable treatment options and disposal sites.
5. Calculate of the total costs of the strategy.
6. Calculate the charges in each Local Authority area, allowing no cross-subsidies.
7. Set permit charges by size or turnover of operator.
8. Draw up long-term plans for investments in infrastructure so that sufficient capacity is maintained.
9. Develop asset management procedures. This facilitates the generation of records that can document damage caused by FOGs to infrastructure over time.
10. Share all of this information with stakeholders in the form of a policy statement on FOG management.

When these steps have been undertaken, the programme should then be reviewed and audited periodically to ensure that it is operating successfully. This should be done to an agreed timetable to ensure no slippage in management strategy.

7. CONCLUSIONS

7.0 Introduction

This section documents the key findings and recommendations of the study. It also evaluates areas where further research is required and highlights any difficulties that were encountered while researching the topic.

7.1 Key Findings and Recommendations

There is a clear requirement for a national grease management strategy. This is based on clearly identifiable political, legal, social, economic and environmental conditions. There are a number of areas that must be addressed in any proposed national strategy. These are:

- The identification and publication of all GRU devices that are deemed acceptable on a national basis.
- The identification and publication of all acceptable in-situ treatment and FOG removal methodologies.
- The identification and publication of all acceptable treatment and disposal routes for the collected FOGs.
- The introduction of a public awareness programme.

With their current management role, a clear body to co-ordinate such a strategy is the DoELG. The strategy that they may opt for could be:

- Introduction of permits for all food production outlets.
- Physical removal of FOG from large GRUs.
- Bacterial treatment of drains post GRUs
- Bacterial treatment directly into GRUs that do not accumulate sufficient FOG to warrant regular de-sludging.
- Public education and training programme.
- Short-term disposal through thermal oxidisation.
- Medium-term recovery by anaerobic digestion and composting when proposed Animal By-Product Regulation position is clarified.

- Facilitating longer term biodiesel production.

Subsequent to the DoELG undertaking a broad national evaluation of FOG, it should then be up to the Local Authorities to tailor the programme to their own areas. This may be done on a county-by-county basis, or as part of a regional grouping to achieve economies of scale.

7.2 Difficulties Encountered

It was not possible to quantify the amount of FOG generated in Ireland as no national audit has been undertaken. This was overcome by a preliminary estimation using average GRU volumes and also averages for FOG build-up in GRUs in Limerick. This put the national figure at approximately 530,000 tonnes per annum of liquid containing FOG, which would contain in the region of 16,500-58,000 tonnes per annum of solid FOG.

The site evaluation of biological treatment also posed some difficulties. It was limited by:

- Available resources
- Access to historic data
- Access to flow rates
- Limited time-frame

This was overcome by accepting that any conclusions were merely indicative of previous studies. This resulted in the study merely agreeing/disagreeing with the more scientific studies that were evaluated in the literature review section.

Further Research

During the course of the study, a large volume of data was evaluated. The study aimed to address most issues but the scope was narrowed to the focus on the Irish experience of FOG management. There were a number of points that could impact on future Irish FOG strategies. These are outlined as possible subjects for further research:

- The dosing of GRUs with bacteria caused an elevation of COD and BOD in discharges. This may have implications for the upgrading and redesign of wastewater treatment plants. Recently, Dublin City Council announced that the Ringsend plant had prematurely met its design life criteria. Henze et al (1997) put forward the theory that the standard population equivalent (PE) of 0.2 m^3 and 60g BOD per day should be revised upwards in cases where there is a prognosis of increased population growth or industrialisation. There is an opportunity to study whether areas prone to high FOG should increase the PE design specification to cater for this. Examples in Ireland are the major tourist and gourmet centres.

- Further analysis on the possible levels of FOG requiring removal from the sewerage network should be evaluated by each local authority. This data could then play an important role in the development of future waste management plans. Analysis of seasonal variations in FOG generation could also be studied for tourism areas such as Cork, Kerry and Galway.

- There must be a reason why biodiesel production has not already been undertaken in Ireland. This study failed to find it and further research is recommended as to the positive and negative aspects of such technologies. It is illogical that Ireland has not acted during a global mineral oil shortage with rising prices while importing all its mineral oils. There is a proven biodiesel technology in Europe and globally, and there is also the added incentive of an EU Biodiesel Directive and EU CAP reforms.

- In terms of licensing and permits, is it fairer to set discharge limits in terms of COD or BOD and abolish FOG parameters? This would have a negative impact on bacterial addition where FOG is reduced at the expense of COD/BOD.

- Bacterial digestion studies have not taken account of the presence of other organic matter in the previous GRU studies evaluated. Perhaps this has a significant bearing on digestion rates and could be evaluated.

- Wellable (2002) demonstrated that optimum bacterial treatment results occurred after twelve weeks. The possibility of an extended dosing period was not available for this test but could be examined in a future study. It is suggested that this could be undertaken over a three to six month period and take account of limitations documented in section 6.1.1.

- Should "Combi Ovens" be plumbed directly into drain lines or into another collection mechanism that is more easily emptied by restaurant staff?

- The precipitation of free fatty acids and glycerol by calcium and magnesium in hard water areas should be studied. This occurred in Limerick in the study and also occurred in Osberstown WWTP, County Kildare when calcium stearate was formed from FOG in limestone rich wastewater.

- The impact of BSE and the Animal By-Products Directive on rendering should be assessed. This appears to have prevented most FOG use as a "secondary raw material" indefinitely.

- Research into co-composting FOGs and other wastes with inert incinerator ash should be evaluated in an Irish context prior to the commissioning of an incinerator. This would almost certainly remove some of the ash from landfill and use it as a secondary resource.

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8.2 Appendices

Table 17. Biodiesel International Standards

Biodiesel	Unit	Austrian Standard C1190 Feb. 91 [1)]	DIN 51606 Sept 1997	U.S. Quality Specification NBB/ASTM	Euro Standard EN 14214
Density at 15°C	g/cm3	0.86 - 0.90	0.875 - 0.90	/	0.86 - 0.90
Viscosity at 40°C	mm^2/s	6.5 - 9.0 (20°C)	3.5 - 5.0	1.9 - 6.0	3.50 - 5.00
Flash point	°C (°F)	min. 55 (131)	min. 110 (230)	min. 100 (212)	min. 120 (248)
CFPP	°C (°F) summer winter	max. 0 (32) max. -8 (17.6)	max. 0 (32) max. -20 (-4)	/	[2)]
Total sulphur	mg/kg	max. 200	max. 100	max. 500	max. 10.0
Conradson (CCR) at 100% at 10%	% mass	max. 0.1 /	max. 0.05 /	max. 0.05 /	/ max. 0.30
Cetane number	-	min. 48	min. 49	min. 40	min. 51
Sulfated ash content	% mass	max. 0.02	max. 0.03	max. 0.02	max. 0.02
Water content	mg/kg	free of deposited water	max. 300	/	max. 500
Water & sediment	vol. %	/	/	max. 0.05	/
Total contamination	mg/kg	/	max. 20	/	max. 24
Copper corrosion (3 hs, 50°C)	degree of Corrosion	/	1	No. 3b max.	1
Neutralisation value	mg	max. 1	max. 0.5	max. 0.8	max. 0.50

Table 17 (Continued) Biodiesel International Standards

Oxidation stability	h	/	/	/	min. 6.0
Methanol content	% mass	max. 0.30	max. 0.3	max. 0.2	max. 0.20
Ester content	% mass	/	/	/	min 96.5
Monoglycerides	% mass	/	max. 0.8	/	max. 0.80
Diglycerides	% mass	/	max. 0.4	/	max. 0.20
Triglycerides	% mass	/	max. 0.4	/	max. 0.20
Free glycerine	% mass	max. 0.03	max. 0.02	max. 0.02	max. 0.02
Total glycerine	% mass	max. 0.25	max. 0.25	max. 0.24	max. 0.25
Iodine value		/	max. 115	/	max. 120
Linolenic acid ME	% mass	/	/	/	max. 12.0
Polyunsaturated (>=4db)	% mass	/	/	/	max. 1
Phosphorus content	mg/kg	/	max. 10	/	max. 10.0
Alkaline content (Na+K)	mg/kg	/	max. 5	/	max. 5.0
Alkaline earth metals (Ca + Mg)	mg/kg	/	/	/	max. 5.0

1) The world's first Biodiesel standard, ÖNORM C1190 (Feb 1991)

2) depending on the national appendix to EN 14214

Source: Biodiesel International, 2005