Management and Recovery of FOG (fats, oils and greases)

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Executive Summary

Background to research

There are approximately 200,000 sewer blockages throughout the UK every year. It is estimated around 75% are caused by FOG (Mills, 2010). Problems caused by FOG in the sewer system not only affect the performance of the sewer system and waste water treatment works (WWTW) but may also reduce asset life and increase maintenance costs. This will have an economic impact on the responsible water authorities and will ultimately be reflected in increased prices for customers. In addition, FOG related blockages can result in sewer overflows either as a result of reduced capacity or burst sewer pipes.

Objectives of research

This report outlines the current state of knowledge regarding best practice for FOG management at UK and international level. In addition, opportunities for reuse of recovered FOG are explored.

Key findings and recommendations

Residential and commercial properties both contribute significantly to FOG in the waste water system. Case studies show that an active programme of education, licensing, inspection and enforcement can result in significant reductions in FOG related blockage and sewer overflows.

Identification of hot spots of deposition and blockage and the corresponding potential sources of FOG is a fundamental first step towards its management. An effective FOG management programme requires a combination of source control and operation and maintenance measures.

While fats, oils and greases in the waste water system are a major problem, there is an opportunity to recover these materials and use them beneficially in processes that will improve both the environment and the efficiency of waste water treatment. Key to this is educating and encouraging communities and businesses to think of fats, oil and grease as a valuable commodity rather than waste.

Collection at source appears to be the most cost effective option for FOG recovery. Anaerobic digestion of recovered FOG in combination with other materials and conversion to biodiesel both present opportunities for reducing the cost of operating waste water treatment works while reducing landfill load.

Key words

Fats, oils and greases; FOG; sewers; best management practice

1.0 INTRODUCTION

1.1. Why are fats, oils and greases (FOG) a problem?

In overview, FOG entering the wastewater system causes a number of problems:

- They clog the system by restricting capacity, blocking and damaging pipes. This increases both the time and money required for cleaning and maintenance.
- If not fully removed and treated, the FOG can deplete oxygen in receiving waters.
- Additional capacity and energy is required at wastewater treatment works to handle excess FOG entering the system.

There are approximately 200,000 sewer blockages throughout the UK every year. It is estimated around 75% are caused by FOG (Mills, 2010). An extreme example of FOG related blockage was recently reported by Thames Water (Thames Water, 2013), who discovered a single length of sewer almost completely clogged with over 15 tonnes of fat. This had reduced the sewer to 5% of its original capacity. Problems caused by FOG in the sewer system not only affect the performance of the sewer system and waste water treatment works (WWTW) but may also reduce asset life and increase maintenance costs. This will have an economic impact on the responsible water authorities and will ultimately be reflected in increased prices for customers. In addition, FOG related blockages can result in sewer overflows either as a result of reduced capacity or burst sewer pipes. In response to the discovery of a large fat deposit, Thames Water (2013) reported that "If we hadn't discovered it in time, raw sewage could have started spurting out of manholes". Sewer overflows can have significant environmental consequences, including risks to public health because of the exposure to pathogens such as E. coli, which are present in sewage. They can result in reductions of water quality in streams, rivers and lochs and may pollute groundwater. There may also be significant social and economic impacts on individuals and businesses if properties become flooded. If properties have been flooded with sewer water, cleaning up will be unpleasant and costly. In addition, flood from sewers rich in fats can lead to significant land contamination and may result in the need to remove and replace areas of soil.

The potential environmental impact of FOG also needs to be taken into consideration during any processing and ultimate disposal.

1.2. Aim of this report

This report outlines the current state of knowledge regarding best practice for FOG management at UK and international level. In addition, opportunities for reuse of recovered FOG are explored.

2.0 SOURCES OF FATS, OILS AND GREASE

FOG entering the sewer system comes from a variety of different sources that can be broadly grouped into three categories: domestic, commercial and industrial.

2.1. Domestic sources of FOG

The biggest problems resulting from FOG within sewers are generally located in areas where commercial premises dominate. Domestic sources are still significant however, particularly at certain times of the year such as Christmas and other occasions where food forms a major part of festival celebrations. In Scotland, Scottish Water (2012) report that 55% of sewer blockages are caused by people disposing of cooking fat down their sink. Significant problems with domestic sources of FOG were also reported by the Capital Regional District (CRD), an area of British Columbia, Canada. The

CRD estimates that almost 1,000,000 kg of fats, oils and grease from residential sources (an estimated 176,993 households and population of 382,250 in 2013 (CRD, 2008)) enter the wastewater system annually: 60% of all FOG entering the system (CRD, 2013).

2.2. Commercial sources of FOG

Commercial properties appear to be major contributors to FOG in the sewer. For example, the City of Dublin drainage maintenance records indicate that "FOG is a serious problem in areas where there are concentrations of Food Service Establishments (FSE) such as pubs, restaurants, hotels, takeaways, convenience stores" (Dublin City Council, 2013). Estimates of average annual FOG production by different types of businesses in Dublin include 624 litres by public houses, 906 litres by fast food outlets and 2353 litres by hospitals; no details are available of the sources of FOG within the different businesses (O'Dwyer, 2012).

2.3. Industrial sources of FOG

Industrial sources include abattoirs, rendering plants, and food processors and manufacturers. Although the content of any effluent produced is generally controlled through licensing and legislation. Many industrial sources already have processes in place to collect the bulk of material produced. However they are still a potential source of FOG that may enter the sewer system.

3.0 PROBLEMS IN THE SEWER AND AT WASTE WATER TREATMENT WORKS

3.1. How and where are FOG deposits formed?

3.1.1. Deposit formation

FOG can accumulate on sewer pipe walls as a result of a chemical reaction or a physical aggregation process. Within a sewer these deposits tend to form above the water line (Keener et al., 2008). This can result in extensive build up due to changing water levels. He et al (2013) suggest this is due to the preferential accumulation of FOG deposit precursors at the water surface. Their study found four major components contributing to deposit formation on sewer pipe walls; calcium, free fatty acids (FFAs), FOG, and water. Oils were found to act primarily as a transporter but also as a minor source of FFAs. They suggest that all four components are required and "FOG deposits will likely not form on concrete in the absence of any of the four components". This experimental study focused on concrete structures and the applicability of their findings to sewers constructed from other materials was not assessed. However, it is likely that deposits will form on any surface if there is a source of Calcium, for example Calcium could leach from mortar in brick built sewers.

Little research is available detailing the processes involved in FOG deposit formation. One study by Williams et al (2012) suggests that two mechanisms are involved in the transformation of cooking oils released from kitchens into sewer FOG deposits. First, the biodegradation of the oil content associated with a transformation from unsaturated to saturated fatty acids. Secondly, a process linked to water hardness which affects the physical characteristics of FOG. Williams et al (2012) suggest that the biodegradation may be related to 'age' of the deposit or linked to bacterial transformations and note that "…further understanding of these mechanisms may allow more accurate targeting of bio-augmentation strategies to manage FOG deposits". Their study also proposes a link between water hardness and the physical properties of FOG deposits. The deposits in harder water areas tended to be firmer, have higher melting points, and possibly had more cohesion. However other studies (e.g. Keener, 2008) did not find a link between water hardness and deposit characteristics. Within Scotland, water is generally soft or moderately soft therefore further research of this potential link and identification of other links between water properties and FOG formation would be beneficial. As noted by Williams et al (2012), this may allow programmes of interventions, such as physically jetting deposits, to be developed and adjusted for particular types of deposits depending on the local water environment.

3.1.2. Blockage 'hot spots'

Within any sewer system, some locations are more prone to blockage by FOG than others. A number of factors may contribute to why these locations have become blockage 'hot spots'. These include: the location of the sewer in relation to residential, commercial and industrial areas; characteristics of the individual sewer pipe (e.g. diameter, material, joins); characteristics of the sewer network (bends, sags, number of inflows, effluent volume); and existing maintenance and cleaning programmes. Shaffer (2009) suggests that blockage 'hot spots' can be grouped into three categories by the main underlying influencing factor:

1. grease loading;
2. design or structural issues; and
3. sewer cleaning effectiveness.

Shaffer (2009) suggests that taking different management approaches for each category would offer the most cost effective solution. FOG source control measures such as grease interceptors, FSE inspections and education would be most effective for type 1 'hot spots'. For type 2, he suggests that asset repairs or replacement, or a change in cleaning practices may be more effective at reducing blockage at that point. For type 3, where ineffective cleaning is found to be the main cause of the problem, a different cleaning technique or increased cleaning frequency may help. However, while maintenance and cleaning may offer a cost effective solution to reducing blockages at particular 'hot spots', unless source control measures are in place they will not reduce the overall FOG load in the sewer system. They may result in higher loads reaching 'hot spots' further downstream or greater FOG accumulation at the WWTW.

Identifying the location of 'hot spots' is recognised as being an important first step in any FOG management programme. In addition to the advantages of being able to target maintenance and cleaning programmes, an understanding of where repeated FOG related blockages occur may be beneficial in promoting the need to reduce FOG input into the sewer system. "FOG sources, such as FSEs, will better understand the importance of controlling their FOG discharges through the use of kitchen Best Management Practices or grease removal equipment, if they understand how their FOG discharges are contributing to a sewer line blockage at a specific hot spot"(EEC, 2003). However, this assumes a link can be readily made between the blockage and the source location which may be difficult. FOG may travel some distance through the sewer system before it is deposited and the distance may vary depending on a number of factors such as water temperature, water volume, total FOG loading, and the location of potential type 2 or type 3 'hot spots'.

3.2. What are FOG deposits made of?

The composition of FOG within the sewer network is variable. A study by Williams et al (2012) found that the physical characteristics and melting point of FOG collected different distances into the sewer system and from sewer works and pumping stations were similar but their moisture content was noticeably different. FOG collected at sewage works had higher moisture content. They also found significant differences in the proportions of oil in the FOG deposit, with pumping stations having a mean of about 18%, sewers 9% and sewage works 1.2%. They reported that the concentrations of potentially toxic metals found in FOG deposits were generally below the EU limits set for application of sewage sludge on agricultural land and the UK Environment Agency Soil Guideline Values for toxic metals. Calcium was found to be the most common metal in the deposits with high levels of Iron and Aluminium also present. Similar findings were reported by He et al. (2011) who found FOG deposits to be mainly composed of Calcium salts of fatty acids. Keener et al. (2008) found high concentrations of fatty acids and Calcium along with high Iron and Aluminium concentrations in sewer FOG deposits collected from 23 cities around the United States. Keener et al. (2008) also reported the presence of Silicon. Iron, Aluminium and Silicon, along with Calcium, are commonly found as a result of concrete corrosion. During an experimental study, He et al (2013) found Calcium leaching from concrete that had been immersed in water or in grease trap effluent. They suggest that the release of Calcium from corroded concrete could be reduced through the use of alternate materials for the construction of grease traps and the application of non-corroding coatings on precast concrete surfaces and that this may lead to a reduction in FOG deposition in sewers.

3.3. Why are FOG deposits a problem?

When sewer pipes get fully or partially blocked to the extent that sewage flow is severely restricted, sewage may overflow into streets and properties, waste processing will be disrupted, there are major impacts on the public and businesses, and sewer operation and maintenance needs are increased which increases costs. Within the UK, over £15 million is spent annually on reactive blockage clearance, along with the additional cost of cleaning up after flooding incidents (Mills, 2010).

FOG deposits on the walls of sewer pipes cause problems by reducing the capacity of the conduit. They also provide a 'catch' point for other materials which can adhere to the FOG deposits and increase the rate of build-up. As these accumulations develop, sections of the deposit can break off and float down the sewer. These floating sections or 'fat bergs' will accumulate at pinch points in the sewer system which may result in sewer blockage.

In addition to the problems of blockage, FOG deposits result in higher corrosion rates of pipework, increase the need for cleaning and maintenance, and significantly increase the volume of solid waste that reaches the WWTW. FOG are not only a problem in the sewer pipes, they can congeal and form deposits on the surface of settling tanks, digesters, pipes, pumps, sensors and any other surface within a WWTW. Also of concern is that grease may partially block screens and trickle filter systems, clog sludge pumps and, in large volumes, inhibit the activity of sludge digesting micro-organisms. This may lead to a reduction in quality of the output from the treatment process (Aymong, 2007). This can significantly reduce performance and potentially cause the WWTW to shut down.

While no reports are available directly linking the presence of FOG deposits to an increase of local vermin activity within the sewer, there is some anecdotal evidence suggesting that rats may use large FOG deposits as refuge, hollowing out areas to use as warm resting places.

3.4. Why are oils that do not solidify a problem?

While many oils solidify and form deposits at low temperatures they are still a problem if they remain in a liquid form, often binding to fat and grease deposits and actively increasing the potential for FOG deposit formation (He et al, 2013). In addition, some oils may move too rapidly through the system to be fully broken down by the treatment process and so remain in the treated water. Droplets of oil may also act to concentrate contaminants.

4.0 MANAGEMENT OF FOG

The collection and re-use of used cooking oils (UCO), sometimes referred to as Yellow Grease, is a well-recognised mechanism for reducing oil input into the sewer and waste systems. A number of companies within the UK currently collect and process used cooking oils. A list of companies that provide this service in Scotland is available on the ZeroWasteScotland website[1]. While approaches for managing UCO and converting it into products such as biodiesel have been reasonably well documented, to-date less attention has been given to the management of other FOG that enter the sewer system. FOG within the sewers or found in grease traps are sometimes referred to as 'Brown Grease'. While the general management practices outlined in this section apply to all FOG, the main focus is on management of Brown Grease.

4.1. Policy and Legislation

Within the UK there are currently a number of legal requirements in place to help prevent fat, oil and grease entering drains and sewers. Within England and Wales these include the Water Industry Act (1991), the Environmental Protection Act (1990), the Building Act (1984), and the Food Safety Act (1990). Within Scotland, the recent Water Resources (Scotland) Act 2013 introduces a new offence of passing fat, oil or grease into the public sewer system which interferes with, or is likely to interfere with, the free flow of the sewer or adversely affects, or is likely to, the sewage treatment and disposal process[2]. In addition, it gives Scottish Water the right to reclaim the costs incurred in investigating, unblocking or repairing any sewer from the owners of commercial premises that allow any fat, oil or grease to be poured into the sewer.

4.2. Waste Licensing

A number of countries have adopted a consent requirement for FOG management as an alternative or supplement to, legislation. These require owners of commercial properties to obtain a trade effluent consent from the relevant water and sewerage company. This specifies the composition of the discharge, including maximum concentrations of FOG within the effluent. A trade waste consent system is currently operated by Scottish Water and a number of Water Authorities in England and Wales covering discharge of particular substances from some types of commercial premises. This approach has been expanded by Dublin City Council as part of their FOG Programme (Dublin City Council, 2013). Every food service establishment is required to apply for a licence to discharge trade effluent under Section 16 of the Local Government (Water Pollution) Act 1977. Further details of the programme are given in the case study in Section 4.5.2.

4.3. Education and awareness

While legislation can put in place mechanisms for limiting FOG discharge into sewers, the effectiveness of these measures will still depend on the level of 'buy in' from both domestic and business users, "…it's not just about regulation and enforcement. We need an attitude change amongst users – whether that's staff working in commercial kitchens or people living in their own homes. So it's got to include education and awareness" (Mills, 2010). The need for education has also been recognised by a number of water authorities within the UK. For example, Anglian Water,

[1] http://www.zerowastescotland.org.uk/BusinessResourceCentre

[2] Water Resources (Scotland) Act 2013 (asp5) Section 35(2)

who estimate that at any one time there is 10,000 tonnes of fat in its network of sewers, have included in their FOG programme mission statement: "We will seek to inform children and young people about the impact of fats in sewers to help educate future generations" (Anglian Water, 2013).

A number of different approaches have been taken to raise public awareness of the problems associated with the disposal of FOG. These fall into two main categories: general campaigns; and targeted campaigns.

4.3.1.General campaigns

A number of water companies within the UK and internationally have developed FOG programmes. These are designed to encourage the public and businesses to properly dispose of fats, oils and grease through increasing awareness of the consequences and damages caused by improper grease disposal. In addition, many also provide educational tools, contacts, and information to help alleviate grease problems. Some examples include:

- UK water companies "Stop and think – not down the sink" campaigns (e.g. Welsh Water, 2013; NI Water, 2013);
- Wessex Waters "Wrap up your Fat" campaign which includes an app for mobile devices that has information and advice, contact details and games (Wessex Water, 2013);
- The Cease the Grease campaign in Dallas, USA (Dallas Water Utilities, 2013);
- CalFOG's "Put a lid on it" campaign in California, USA (Harris, 2009).

4.3.2.Targeted campaigns

In addition to general campaigns, many organisations have set up targeted campaigns designed to raise awareness either through specific events, at particular times of the year, or for particular groups. Some examples include:

- Severn Trent Waters "Trim the fat this Christmas" (Severn Trent Water, 2012);
- Wessex Waters "Christmas Wrap" (Wessex Water, 2012);
- Severn Trent Waters 'National Chip Week' campaign (Severn Trent Water, 2013);
- Fight F.O.G.™ and the FOG Monsters brand which is used by over 30 different utility companies in the USA and includes material specifically targeted at children (GoldStreetDesigns, 2013).

Although the Dallas Water Utilities Cease the Grease campaign won the 2012 Texas Commission on Environmental Quality Environmental Excellence award for Pollution Prevention, there is little readily available documented evidence on the effectiveness of general or targeted campaigns. While they may have delivered a message to a small section of the community many individuals and businesses still appear unaware of issues caused by FOG disposal. However, the general lack of reported beneficial outcomes of these campaigns does not mean they were not successful. The case studies in Sections 4.5.4 and 4.5.5 give details of campaigns which have reported benefits.

4.4. Standards and guidelines

Water UK in collaboration with water and sewerage companies, the Environment Agency, the Chartered Institute of Environmental Health and the Consumer Council for Water, have developed a guidance document – "Disposal of fats, oils, grease and food waste – Best Management Practice for Catering Outlets". This covers the need for staff training, pre-washing preparation, the use of grease traps, the use of food macerators, enzyme dosing for enhanced fat breakdown in the grease trap/sewer system and waste oil storage and collection. This document is advertised as a best practice guide on a number of English Council and water company websites (e.g. Richmond Council, South West Water, Torridge District Council). A version of the same document is promoted by Welsh Water. Similar guides have been produced for domestic use. For example Scottish Water has produced a document focused primarily on domestic customers "Your guide to disposing cooking fats".

The production of Best Management Guides is the most common approach, both nationally and internationally, to managing FOG from business premises. However there is still considerable debate as to what types of business these guides should target. In particular, there is uncertainty around the impact of dairy based fats and whether businesses whose FOG waste is primarily dairy based (e.g. speciality coffee shops, ice-cream, milk shake and dairy smoothie sellers), should be covered by any FOG management programme (Davis, 2011). In addition, the main focus appears to be where food preparation and serving are the main business. However, as noted by O'Dwyer (2012) while reviewing FOG management in Dublin, some of the biggest FOG waste producers were hospitals and hotels. Ensuring best management practice guidelines are available at catering facilities within these types of establishment is essential. Establishments need to be made aware that they do not need to cook food at a site in order to produce FOG-containing wastewater. Cleaning processes and wastewaters produced from serving food can also be an issue.

Some recommendations found in good practice guides but not currently included in the Water UK document include:

- Routinely cleaning kitchen exhaust system filters to prevent accumulation on and around the external vent as this may result in FOG entering the sewer system along with storm water when it rains (Tri-City District, 2013);
- Reducing dishwasher temperature to 70°C or the minimum required by health and safety legislation and ensuring dishwashers are positioned as far as possible from any grease trap to allow the waste water time to cool before reaching the trap (Tri-City District, 2013). Water temperatures greater than 60°C will dissolve grease and are more likely to wash it out of the traps.

The best practice guides often include posters that can be displayed near sinks and food processing areas that highlight essential do's and don'ts. These use simple visual illustrations to show good and bad practice and are often annotated in several languages or are made available in different languages.

An option being considered by a number of water companies is working with local colleges and education providers to ensure that FOG management and details of current best practices are included in courses covering food handing, preparation, serving and management.

4.5. Example case studies

4.5.1. South East Water Limited, Melbourne, Australia (Scoble and Day, 2002)

South East Water Limited, a state-owned company providing water and sewerage services to 1.3 million customers in the south east region of Melbourne, reported that in 1995 it was estimated that approximately 30% of sewer blockages were caused by FOG, and that 80% of the FOG came from commercial premises such as restaurants and fast food outlets. To reduce sewer blockages, South East Water implemented a three phase 'Greasy Waste' Programme. Phase 1 required all commercial premises to have Trade Waste Consents and was implemented over a two year period. Potential FOG contributors were identified by a combination of checking Yellow Pages references and street-to-street surveys. Each identified business was inspected, and if it met the criteria for a greasy waste discharge then it was provided with a Trade Waste Consent application. Details of any fitted grease interceptors were noted during the inspection for assessment during subsequent phases of the programme. Follow up checks were made to ensure the application had been submitted. Businesses refusing to lodge an application were treated as illegal dischargers, with the ultimate penalty being disconnection from the sewer system. Phase 2 ensured all commercial customers had an appropriately sized grease interceptor. A grease interceptor sizing criteria was developed based on the fixtures contributing greasy waste, and the seating capacity of the business with a minimum size set at 250 litres. In the three year period following the completion of the first phase, all businesses requiring new or upgraded grease interceptors were identified, notified and checked for compliance. Phase 3 ensured that all commercial grease interceptors were pumped out at an appropriate frequency, generally every four months. Two years after setting up a monitoring and enforcement programme an average of 110,000 litres of grease waste were being pumped out of the interceptors each month. Six years after initiation, the Greasy Waste Programme resulted in a 50% reduction in sewer blockages caused by FOG.

4.5.2. Dublin City Council (O'Dwyer, 2012)

In January 2008, Dublin City Council (DCC) commenced a programme to control the discharge of FOG to the public sewer system. In order to optimise use of the limited resources available, focus was placed on food based businesses as 80% of FOG related blockages in the sewer system had been found to occur in areas of high concentrations of food service establishments (FSEs). The DCC FOG programme is based on a prevention at source approach. The first phase of the programme involved identifying, locating and surveying all potential FSEs. This included, but was not limited to, fast food restaurants, full service restaurants, drive through restaurants, coffee shops, bakeries, supermarkets, hospitals, nursing homes, school/college/university canteens, club/organization canteens, company/office building canteens, guest houses, hotels, public houses and convenience stores/delicatessens. Investigations identified that only 2% of FSEs had adequate grease traps. Each FSE was then required to apply for a trade effluent licence. Once granted, this required them to comply with conditions which typically included: the installation of an appropriately sized grease trap; regular maintenance of the grease trap; the proper disposal of waste oil; and a limit on the amount of FOG discharged to sewer of 100mg/l (Dublin City Council, 2013). This was followed up by promotion of 'Good Practice' and compliance was monitored and enforced with the cost of implementation borne by the FSEs through license charges and a polluter pays principle. Up to 26/1/2012, 206 prosecutions had been initiated with 10 convictions and 147 out of court settlements. Annual charges for trade effluent licences were initially set as fixed amounts based on the type of establishment but from 2011 an incentive based payment scheme has been implemented. The new payment scheme is risk based with establishments being categorised as high, medium or low risk based on information from monitoring visits and previous compliance and license payment records. Annual charges for 2012 ranged from €315 (£270) for low risk businesses (adequate grease traps; good, well documented maintenance regime; full record of waste disposal) to €1255 (£1080) for high risk businesses (no grease trap, or a grease trap that is inadequately sized or poorly maintained). This incentive based scheme has been well received by the businesses. A review at the end of 2011 indicated that the programme had proven to be extremely effective with an estimated 1,100 tonnes of FOG being prevented from entering the sewage network in 2011. In addition, no sewer blockage requiring manual clearance occurred between March 2010 and the end of 2011.

4.5.3. *Severn Trent Water (Mills, 2010)*

Severn Trent Water spends over £10 million each year cleaning 700 kilometres of sewers which are prone to clogging and clear nearly 22,000 sewer blockages. A major campaign focused on one town, Stourport, which had a history of sewer blockages and odour problems. The main cause of the blockages was a build-up of FOG. As a trial, Severn Trent installed grease traps in several restaurants and takeaways. In the six months after the scheme started there were no blockages in the drains as a result of a build-up of FOG. Mills (2010) reported that “Severn Trent suggests the benefits of installing a fat trap are huge and immediate”. The 40 litre traps are now emptied every two weeks.

4.5.4. *CalFOG’s “Put a lid on it” campaign (Harris, 2009)*

The California Fats, Oils, and Grease work group (CalFOG) consists of wastewater agency, regulator, consulting firm, and restaurant and related industry representatives. It was formed with the aim of preventing, reducing and mitigating grease related sewer blockages and overflows in wastewater collection systems. A public engagement outreach programme was developed to promote the proper disposal of FOG. This included programmes for cities tailored to their individual needs and regional mass media campaigns. The programme targeted FSE’s through the use of recognition programmes, sink stickers and posters; and members of the public through school visits, exhibits, contests, information mailing and give-aways. In addition they worked with local plumbers and plumbing associations to encourage plumbers to educate clients about the problems caused by FOG and to report any FOG related blockage clearances, overflows and illegal dumping. As a result of the campaign, clearance from the pumping station has been reduced from once every six weeks to once every 10 weeks and they report a significant drop in the number of beach closures due to sewer overflows. Results from pre-campaign and post-campaign surveys also suggest increasing awareness of the problems caused by FOG disposal; a rise from 63% of the surveyed population to 82%.

4.5.5. *Cease the Grease, Dallas Water Utilities*[3]

Dallas Water Utilities (DWU) operates and maintains over 4,200 miles of sewer. In 2005 a grease abatement programme was set up with the aim of reducing the number of FOG related blockages in sewers by diverting FOG and finding a suitable use for it. The programme identified ‘hot spots’ for proactive line cleaning, changing city ordinances to comply with State recommendations for FOG management, and developing an educational programme. DWU has reduced FOG blockages in the sewer system by 96% over five years. More recently, a sustainable disposal means for FOG that directly benefits the City and its residents has been piloted and found to be effective. The programme involved a number of activities: preventive maintenance, regulatory enforcement, outreach and education, FOG recycling, regional and national efforts, multimedia campaigns.

A ‘hot spot’ preventative maintenance programme was established and known ‘hot spots’ were cleaned at a higher frequency that other areas. Additionally, direct mailings or door hangers are distributed to addresses in the area around a FOG related sewer overflow within 24 hours of the incident. As well as reinforcing the message that putting FOG down the drain causes these blockages the flyers also give information about alternatives to pouring FOG down the drain and give details of web pages where recycling information can be found.

[3] Details provided by H. Cantril Dulac, Environmental Co-ordinator, Grease Abasement Program, Dallas Water Utilities.

City ordinances for FSEs were changed to adhere to state issued 'Standards for Grease Management' which already required use of grease traps. In addition, staff were employed to monitor cleaning frequencies of grease traps aided by computer based tracking of cleaning frequencies, utilizing technology that DWU helped develop. The additional staff and software helped reduce the amount of FOG entering the sewer which led to more FOG being available for recycling. DWU is now using grease trap waste and injecting it into one of their anaerobic digesters.

An educational program was developed targeting homeowners, apartment complexes, schools and FSEs. DWU also worked with local restaurant associations to develop an educational video and regularly speak at local food handlers training classes to educate FSE staff about grease trap regulations and Best Management Practices for FOG.

DWU measure the success of the project by the reduction in the number of sewer overflows. The two years before the start of the programme averaged 108 annual sewer overflows. In the years since the programme started, the number of incidents has significantly reduced. The number of annual overflows dropped to 42 in 2006/7, and then continued to drop to 39, 15, 8, 8, and 4 over the next five years.

During the programme, an estimated 13.5 million gallons of FOG have been prevented from entering the sewer system. This represents annual savings of $1.3million. A large part of the City's savings come from avoided cost of treating FOG from FSEs. Additionally, the City has saved an average of $40,000/year on avoided FOG-related sewer overflows.

5.0 REMOVAL AND RECOVERY OF FOG

To date, the main research focus on FOG recovery and recycling has been based on UCOs and FOG produced from rendering companies. The understanding of the processes involved in FOG accumulation in grease traps or sewer deposits and recovery and pre-treatment options for further processing is currently limited, with only a few reported studies.

5.1. Removal at source

5.1.1. The use of grease interceptors and traps

One of the most common methods of preventing FOG from entering the sewer system is by installing a grease trap between the sink outlet and the outlet to the public sewer. These devices come in many different forms and sizes and are also referred to as automatic grease recovery units, grease interceptors, grease abatement devices and waste grease units. Grease traps may be fitted internal to or external to the business premises, depending on the size and type required. Indoor grease traps are intended for limited food or drink preparation and are typically found very close to a sink. Outdoor traps, generally referred to as interceptors, have a larger capacity, lower maintenance costs and easier access for waste collection. Under test conditions these externally fitted interceptors were found to be more efficient at FOG removal with rates of up to 80% of FOG removed from effluent. Smaller grease traps showed up to 50% FOG removal (Gallimore et al, 2011).

Three layers are commonly found in the accumulations within grease traps. The top layer contains floatable deposits (primarily FOG), the middle aqueous layer tends to be rich in organic matter and the bottom layer is generally a sludge consisting of food particles and other solids (Suto et al, 2006). The chemical and physical characteristics of grease trap waste can vary greatly depending on the type of restaurant or food service establishment, the grease interceptor or trap design (i.e., size, inlet/outlet piping, number of baffles), and the frequency at which the device is cleared. Studies report that FOG accounts for approximately only 0–15% by volume of the waste, with an average of 2–3% (Long et al., 2013).

The use of grease traps allows FOG to be collected separately from the effluent disposed of in the sewer. The recovered FOG is commonly referred to as 'brown grease'. Separate collection facilitates the further processing of the recovered FOG independent of other waste, providing an opportunity for use in processes such as biodiesel generation or enhancing anaerobic digestion at WWTW. However, at the start of a FOG management programme, the necessary infrastructure and processing capacity may not be available to handle the volumes recovered from grease traps. This should not be considered a reason for delaying a recommendation for use of grease traps. A report outlining a programme for FOG management in California (CalFOG Workgroup, 2004), notes that "…sometimes intermediate steps on the way to a final solution are necessary". It suggests that while sending FOG waste recovered from grease traps to conventional waste disposal facilities is not ideal, it offers a practical option for keeping FOG out of the sewer system until further processing options are fully developed.

5.1.2. Other options for at source management

A trial using a bacterial bio-remediation solution was run by Anglian Water and the Water Research Council in Baddow Road, Chelmsford, a prominent restaurant and take-away area located where there is a history of sewer blockages, overflows and odour problems (WPI, 2009). Following the use of bio-remediation, sewer blockages were found to be down by 50% along with a reduction in the number of odour complaints and pollution incidents. In addition, Anglian Water was able to save £6,000 against the cost of treating blockages (Mills, 2010). Similar findings were reported by Tang et al. (2012) whose study tested the effectiveness of pre-treating restaurant wastewater from a student dining hall at Pennsylvania State University. A bio-additive containing five different strains of bacteria known to degrade FOG was added to grease traps over a three month period. During this time there was a 40% reduction in the amount of FOG deposition in adjacent sewers.

5.2. Removal from within the sewer network

Currently, removal of FOG from locations within the sewer network tends to be reactive after a blockage. Alternatively, collection from known 'hot spots' of high deposition may be an option allowing recovery for further processing. For example, FOG collected from sewer pinch-points in London will be used for fuel production at Beckton power station (See case study in Section 6.5.2). FOG collection from sewers however, perhaps offers the most difficulty in terms of logistics, with potential access problems, a high man-power requirement with the associated health and safety risks, and the difficulties of recovery scheduling due to the variable rate and location of build ups. While this option may offer a potential solution for areas of high volume, high frequency deposition it is unlikely to be cost effective for areas with small volumes or where deposition is more irregular.

5.3. Removal at WWTW

While the option of recovering FOG once it has reached WWTW has the advantage of reduced transport requirements if it is to be processed on site, there are a number of potential issues associated with recovery at this stage. Perhaps most importantly, recovering FOG at WWTW will not reduce the load of FOG within the wastewater system and therefore will have no impact on the problem of FOG deposition in the sewer system. FOG deposits are found on many different surfaces at WWTW which makes automatic FOG removal problematic. A number of devices are available that will remove FOG from the surface of collection tanks although little information is available about the cost and efficiency of these processes. For example, a new wastewater treatment plant in

Peacehaven, East Sussex is using chain and scraper systems to remove fats, oils, grit and grease from collection tanks. While details of the potential benefits of this system to the final effluent discharge are noted, no information is available on how the collected fats, oils, grit and grease are processed.

Another issue with recovering FOG at this late stage in the waste water process is the additional time and sources available for the FOG deposits to become contaminated with other materials. This may lead to a requirement for additional processing if recovered FOG is to be used for purposes such as biodiesel production. This would increase costs and may require additional processing capacity.

6.0 USES FOR RECOVERED FOG

There are a number of options available for the use of recovered FOG including land fill, land application, composting, rendering for manufacturing lubricants or industrial soaps, incineration, anaerobic co-digestion, or biodiesel production. Comparisons between the potential yields and efficiencies of these processes are difficult due to differences in methods and styles of measuring, assessing and reporting. In addition, yield and efficiency was found to vary significantly depending on the specifics of the process and the characteristics of the recovered FOG. A detailed analysis of the performance of available processing options for biodiesel generation and enhanced anaerobic digestion is out with the scope of this report but would be a useful exercise if considering either of these options for re-use of recovered FOG.

6.1. Land application

While the direct application of recovered FOG to the land is potentially one of the cheapest disposal options, this is strictly regulated which will limit its potential for disposing in significant volumes. Although land application has been cited as improving the soil organic carbon content and may prevent nitrogen leaching (Rashid and Voroney, 2004), careful consideration should be given to its use as the high fat content can result in a coat forming around soil particles preventing roots from accessing water.

6.2. Composting

Composting may produce a final product that can be sold for use on the land and will also reduce the potential for methane that would have been produced if the recovered FOG had been landfilled. To date no research has been performed to assess the potential use of recovered FOG for direct-to-land applications such as composting (Long et al, 2012).

6.3. Biodiesel

An increase in environmental awareness, along with concerns about future energy security, has forced the consideration of alternatives to fossil fuels. Biodiesel, defined by EU Directive 2003/30/EC as ‘‘a methyl-ester produced from vegetable oil or animal fats, of diesel quality, to be used as biofuel’’ (EU 2003), is widely regarded as a suitable alternative. It can be produced from renewable sources through simple cost-effective transesterification and it is compatible with existing technology and infrastructures (Ng et al, 2010).

Despite the ease of the process, there are growing concerns about the production of biodiesel from vegetable oils produced directly from crops as the need for fertile lands for non-edible crops reduces the land available for food crops. This has the potential to reduce availability and increase the price of food staples. A recent study looking at the impact of biofuel crops on wildlife suggests that there could be major impacts on habitat conservation as most crops used for biodiesel are grown on land converted from rainforests, peatlands, savannas and grasslands (Fargione et al., 2009). They also note that crop production results in a net carbon debt due mainly to the energy required for plant growth (ploughing, harvesting etc.) therefore biodiesel produced from crops may also not be suitably effective in terms of reducing greenhouse gas emissions. The EU Renewable Energy Directive (EU, 2009) states that with effect from 1 January 2017, in order to comply with national biofuel targets and renewable energy obligations and to be eligible for financial support, the greenhouse gas emission saving from the use of biofuels needs to be at least 50% based on fossil fuel emission. Thamsiriroj and Murphy (2009) calculated an emissions reduction of 28.8% for biodiesel produced from Irish-grown rapeseed.

These concerns have resulted in a search for alternative materials for biodiesel production. A number of studies compared biodiesel production from different source materials (e.g. Canakci & Sanli, 2008; Dorado et al., 2006; Filho & Badr, 2004; Zhang et al., 2003; Bender, 1999). While different approaches and materials were assessed in the studies, the production of biodiesel from waste oils and fats was in general found to offer an economically feasible approach, due mainly to high availability and low acquisition costs. It was found that savings could be made in waste water treatment and waste disposal. Another major advantage of biodiesel derived from FOG is the lack of environmental impacts associated with land use conversion and it has the potential to offset the carbon impact of both fossil fuels and crop-based biofuels (Montefrio et al., 2010).

However, there are potential issues with the use of FOG, and in particular brown grease, to produce biodiesel. It is difficult to standardise the processing due to the variability in composition of the recovered FOG. An assessment of how local waste oil and grease is recycled into biodiesel in California notes that “often times the problem with brown grease is that you are not sure what is in there" (Greer, 2010). Studies have suggested that FOG with particularly high free fatty acid levels may make the conversion of FOG to biodiesel more complex and expensive. In an assessment of options for the recovery and pre-treatment of FOG from grease interceptors for biodiesel production, Montefrio et al (2010) suggest that FFA levels can be minimised by extracting the FOG layer from grease trap waste with the least amount of food residuals and water; conducting the extraction at least every 15 days; and storing the FOG in a dry and sealed holding facility for the least amount of time.

A recent review by Ragauskas et al (2013) offers a reasonably comprehensive assessment of the technology currently available for biodiesel production from FOG.

The majority of research to date has focused on biodiesel production from the fat/grease layer extracted from trap waste. A recent study by Zheng et al (2012) was conducted to assess the potential of secondary biodiesel production from the solid residual fraction of grease trap waste left after typical fat/grease extraction; this residue would normally be disposed of. They found that the residue generally consisted of food particles high in starch, fat, protein and fibre. The residue was fed to black soldier fly larvae and the resulting larval biomass was used for crude grease extraction which was then converted into biodiesel. The volume of biodiesel produced from the secondary process almost matched the primary production. They suggest that the approach offers a mechanism to enhance the efficiency of biodiesel production from restaurant waste and to help reduce the solid residual fraction produced during the processing of biodiesel from grease trap waste. As yet no details are available of how this might be applied at large scale processing plants.

6.4. Anaerobic digestion and biogas production

WWTW generate sludge as a product of the physical, chemical and biological processes used during treatment (e.g. Appels et al., 2008). Anaerobic digestion (AD) of the sewage sludge generated at WWTW is commonly undertaken to reduce the amount of final waste solids and transform the organic sludge contents into biogas which can be collected and used. AD has been used in the UK since the late 1800s, but an increasing number of AD plants are now being built to generate clean renewable energy and help divert waste from landfill. Sewage sludge is generally digested on its own but a number of studies have suggested that co-digestion with other substrates could increase both biogas production and organic matter degradation (e.g. Donoso-Bravo & Fdz-Polanco, 2013; Luostarinen et al., 2009; Davidsson et al., 2008). One potential option is to use FOG waste collected from grease traps, sewers or WWTW as a second feedstock for digestion. Historically FOG waste, once stabilized, has been disposed of in landfills. The use of AD of FOG waste along with the sludge offers a mechanism to potentially reduce the overall volume of waste destined for landfill in addition to increasing the amount of biogas produced. In a comprehensive review of gas production and process limitations Long et al. (2012) report that "FOG collected from the food service industry has been cited to increase biogas production by 30% or more when added directly to the anaerobic digester and may allow wastewater treatment plants to meet over 50% of their electricity demand through on-site generation". They also note that some studies have raised a number of potential operational problems with the co-digestion of FOG and sludge. The most common concern is the inhibition of methane generation when FOG is added at high concentrations or loading rates. A study by Zhu et al. (2011) found a significant improvement in methane production during anaerobic co-digestion when grease trap waste was added as a co-substrate in addition to sludge. A 65% increase was found for a less than 4% (vol/vol) addition of grease trap waste. However, they found the digestion process was inhibited and biogas production was reduced with higher loadings. This suggests that management of load volumes and rates is essential for efficient co-digestion of grease trap waste and waste sludge. One approach to manage load volumes is noted by Kester et al. (2008), who recommend that it is best to process FOG through a holding tank with grinding and mixing pumps before loading it into a digester. Metered volumes of the ground and mixed FOG can then be input into the digester at known and steady rates avoiding a 'slug load' to the digester. Further investigation of the performance of different mixes of FOG and sludge would be beneficial in optimizing the co-digestion process.

FOG co-digestion can be performed under mesophilic (moderate temperatures, between 25°C and 40°C) or thermophilic (temperatures above 50°C) conditions. Suto et al. (2006) recommended thermophilic temperature conditions (55 °C) for FOG co-digestion. This is due to the reactor's increased ability to degrade long chain fatty acids and the formation of a smaller scum layer when compared to a reactor operating in the mesophilic temperature range (35 °C). However, a further study by Lynch and Fitgerald (2009) reported in Long et al (2013) suggests that the limited performance improvements found from thermophilic operation do not always justify the higher cost associated with the increased energy needed for heating.

6.5. Example case studies

6.5.1. Piedmont biofuels, Central North Carolina (Greer, 2010)

The co-founder of Piedmont biofuels, a small renewable energy company in Central North Carolina, USA, that produces biodiesel predominantly from used cooking oils, has recognised that "the future of biodiesel is going to come from deeper in the waste stream" (Greer, 2010). The company has recently started to produce biodiesel from recovered FOG.

6.5.2. Beckton 'fat-fuelled' power station, East London (Raleigh, 2013)

Within the UK, the world's largest 'fat-fuelled' power station is being built at Beckton in East London and is scheduled to be operational in the first quarter of 2015. The plant, developed and run by 2OC, is set to produce 130GWh a year of renewable electricity. It will use leftover, low-grade cooking oil and food fat collected from food service establishments and food manufacturers, and FOG from grease traps in restaurant kitchens and from FOG deposit 'hot spots' around the capital's sewer network. Additional material for the production of biofuel to power the plant will come from waste vegetable oils and tallow (animal fat). Thames Water has agreed to purchase 75 GWh of this output to run Beckton sewage works and the nearby desalination plant. Any remaining power will be sold on to the national energy supply grid. Thames Water will also supply the plant with 30 tonnes a day of FOG that would otherwise clog up London's sewers. Costs for clearing and disposing of this FOG currently run to £1million per month.

6.5.3.Watsonville, California waste water treatment plant (Kester et al, 2008)

A FOG receiving facility was installed in the WWTW in Watsonville in 2003 with the main purpose of increasing gas production in the anaerobic digesters. The FOG is delivered to the WWTW by tanker and pumped from the haulage tank through a basket strainer which removes inorganic solids to a receiving tank where it is recirculated using a chopper pump. From there, controlled volumes are supplied to the suction side of an external high rate digester via a chopper pump. The addition of FOG material to the anaerobic digestion at the WWTW has noticeably increased biogas production. The additional biogas has significantly reduced the need for purchasing natural gas to supplement the digested sludge biogas to fuel a cogeneration engine.

7.0 CONCLUSIONS

7.1. Summary of findings

This report has reviewed the current state of knowledge regarding best practice for FOG management and explored opportunities for reuse of recovered FOG. The main findings are summarised in the following key points:

- Residential and commercial properties both contribute significantly to FOG in the waste water system.
- The processes involved in FOG deposit formation are not well understood but the knowledge base is growing.
- Effective FOG control requires both source control and operation and maintenance measures.
- Education, increasing awareness and public engagement are key to effective source control.
- Identification of hot spots of deposition and blockage and the corresponding potential sources of FOG is a fundamental first step towards FOG management.
- Case studies show that an active programme of education, licensing, inspection and enforcement can result in significant reductions in FOG related blockage and sewer overflows.
- Collection of FOG at source appears to be the most cost effective option for FOG recovery.
- While fats, oils and greases in the waste water system are a major problem, there is an opportunity to recover these materials and use them beneficially in processes that will improve both the environment and the efficiency of waste water treatment. Key to this is educating and encouraging communities and businesses to think of fats, oil and grease as a valuable commodity rather than waste.

7.2. Recommendations

Within Scotland, the problems caused by FOG in the waste water system are generally managed by re-active clearance of sewers as they become blocked. Although best practice guides are available for domestic and business use, monitoring and enforcement is less evident than elsewhere. A FOG management programme that reduces sewer blockage and the volume of waste for landfill has the potential for resulting in significant cost savings through reduced maintenance requirements and reduced incidents of flooding. In addition, use of recovered FOG presents opportunities to offset costs associated with waste water treatment through the generation of biofuels and increased efficiency of anaerobic digestion.

The following recommendations for FOG management are based on effective practices currently in use and have been broken down into three categories: understanding current conditions; education, awareness and engagement; licensing, monitoring and enforcement.

7.2.1.Understanding current conditions

A good understanding of where FOG blockages occur and the corresponding likely sources of the FOG is an important first step. Information on the volume of FOG removed, frequency of blockage, cleaning frequency, and associated incidences of flooding are key metrics that should be recorded. This will enable problem areas to be identified and the progress and effectiveness of any management and control practices implemented to be assessed against these base metrics. This may be critical in justifying continued commitment to a FOG management programme. In addition, recording the location of the blockage will allow investigation of patterns of blockage associated with particular types of residential or commercial areas which will help target future actions.

7.2.2.Education, awareness and engagement

It has been recognised that education and awareness are fundamental to any FOG management approach. Case studies have shown posters, stickers and information packs for FSEs that offer simple graphic instructions for best practice in FOG management are useful tools for reducing FOG discharge. These could initially be issued to FSEs in problem areas identified during investigations to understand current conditions or a particular problem area could be selected as a pilot. Manual delivery of this material by a 'FOG manager' would allow a relationship to be established with the business. This has proven to be effective in other areas as it gives the business a single point of contact. The same visit could be used to assess the premises to see if any grease traps are present.

While educating individual businesses is crucial, educating future employees and employers will give longer term benefits. Engagement with education providers to ensure best management practices for FOG are covered in all catering, food handing and food management courses would be beneficial.

Residential sources of FOG are also of major concern. Targeted campaigns appear to offer the best solution for raising public awareness of problems associated with FOG disposal. A programme of workshops aimed at schools has proven effective in getting messages into homes and may be a useful approach.

7.2.3.Licensing, monitoring and enforcement

While current legislation does not require FSEs to obtain a trade waste consent before discharging FOG waste into the public sewer, case studies have shown this to be an extremely effective measure in controlling FOG. A move towards some form of consent or licensing requirement for all FSEs or all FOG dischargers may be the best approach.

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