FATS, OILS AND GREASES IN EFFLUENT STREAMS FROM SHOPPING CENTRES

THUTO MOSHOLI & CHRISTIAAN E. CLOETE
University of Pretoria, South Africa

ABSTRACT

Fats, oils and greases (FOG) are an urban conundrum creating severe problems to municipal sewer infrastructures. FOG emanates from food service establishments or catering operations when cooking with plant or animal based oils or fats. However, its rise to becoming a globally recognised contaminant emanating from kitchen based wastewater is associated with the shift from rural to urbanized lifestyles, and the corresponding changing eating habits of city dwellers. The management, prevention and handling of FOG costs cause an exorbitant burden on municipalities, cities and countries. The scale and severity of FOG contamination has not been previously explored in South Africa. The cumulative effect of urbanisation, large scale shopping centre developments plus a fast-growing local fast food industry supports the view that a FOG problem should exist in shopping centres locally. The study explores this problem within the shopping centre industry by means of comprehensive questionnaires, site visits, telephone interviews, interviews with subject matter experts and online surveys at 38 shopping centres in the Gauteng province in South Africa. An index was developed to measure the number of food service establishments (FSEs) per shopping centre size. The results show that FOG is a real and imminent problem in shopping centres. Of the shopping centres surveyed, 88% confirmed experiencing FOG related problems. Based upon frequency of occurrence of sewer blockages, 12 of the 38 centres were categorised as experiencing severe problems. Five of the shopping centres surveyed installed external grease trap devices. The propensity of FOG deposition in sewer lines is dependent on the strength of the kitchen wastewater or FOG organics loading. The strength of FSE wastewater is affected by the operations and configuration of the catering business. The cuisine type or menu served has the highest impact on FOG loading.

Keywords: fats, oil and grease, food service establishment, fat trap, shopping centres, sewer line blockage.

1 INTRODUCTION

The fat, oil and grease (FOG) problem can be described as the 21st Century's 'perfect storm': an outcome of urbanisation, population and economic growth, the issue is compounded by changing weather patterns causing inundation of the sewerage infrastructure capacity, of which FOG is known to reduce by coating sewer walls with FOG compound [1]–[3].

FOG are an urban problem creating severe problems to municipal sewer infrastructure. FOG emanates from food service establishment or catering operations when cooking with plant or animal based oils or fats [4], [5]. The management, prevention and handling FOG costs cause an exorbitant burden on municipalities, cities and countries. FOG presents hygienic issues, cost and operational disruption in food service establishments (FSE). Increasing levels of FOG are found due to gradual changes in eating habits as a result of urbanization and economic growth [6]. When considering the growing urban population and rising expenditure in food service establishments, the number of sources and quantity of FOG are projected to continue to increase [7].

The scale and severity of FOG contamination has not been explored in South Africa. The study explores the extent of the problem within the shopping centre industry in the Gauteng Province, South Africa.

The link between urbanisation and changing eating habits is well documented in the research done for the International Food Policy Research [8]. The South Australian Water

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Corporation, in their 2040 future planning report, identified urbanisation as one of the major megatrends that would significantly affect the water utility sector in the future [9].

Urbanisation and rapid economic growth are the main change agents causing the significant rise in FOGs, as urbanisation is accompanied by a change in eating habits and increased consumption of fast foods. Densification of residential and business areas leads to stressed sewer lines as well. All these factors combined make FOGs in effluent streams an important problem to address urgently and systematically in South Africa.

The rise of a new South African middle class coincided with the increased growth of the major retailers locally. The middle class continued to grow, as poorer households gained access to more services [10]. The fast food industry has grown significantly locally and has attracted many new overseas brands. South Africa's food service industry showed exceptional growth throughout 2016 [11]. Restaurants which offer cheaper options (such as KFC) are doing exceptionally good business in South Africa. Chicken continues to represent the largest fast food category, accounting for nearly 50% of total fast food market, followed by burgers, pizza and fish [12]. The growth of the fast food industry has also been catalysed by the retail development of new shopping centres. These factors, in addition to the increased generation of kitchen based wastewater, rich in fats, oils and greases (FOG) result in the emergence and significant growth of a 'new' type of wastewater problem generated.

The very limited research on the FOG problem in South Africa [13] does not negate the existence of the problem. South Africa is a water scarce country. Large quantities of water bodies are continuously threatened by excessive pollution emanating from various sources, some directly from dysfunctional wastewater treatment works, some from direct contact with highly polluted streams and some through human activity. The FOG issue is a serious but hidden problem affecting the quality of water resources. It puts a huge maintenance burden on the already struggling wastewater treatment works. Fats, oils and greases pose a triple threat; an infrastructural danger, a health and hygiene problem and a severe maintenance burden to the local municipality and property owners. FOG increases the loading at waste water treatment works, an additional treatment burden to the already poorly maintained plants.

South Africa has a generally good legal and regulatory framework for effluent wastewater quality management. Its weakness is in compliance monitoring and enforcement. Apart from national standards [14]–[16], each municipality has Water and Sanitation Bylaws in terms of Section 1 of [17]. These empower the municipality to enforce strict quality conditions and penalties on effluent discharged by a business into the municipal sewer lines. The Act details the limits of concentration of substances that may be discharged to the Municipal Sanitation system. Each metropolitan district has municipal bylaws that enforce penalties and tariffs.

2 METHODOLOGY

The main objective was to explore the prevalence of the FOG problem in shopping centres, by attempting to establish a correlation between food service establishments and the severity of the FOG problem. The research surveys were carried out over a period of three months in 2017. The assumption was that the data and reports collected from the majority of shopping centres in Gauteng are representative of shopping centres in South Africa. The study focussed only on shopping centres in the Gauteng province. FOG problems are not limited to shopping centres, however, but occur everywhere in catering facilities located in different localities and districts.

The study explored this problem within the shopping centre industry by means of comprehensive questionnaires, site visits, telephone interviews, interviews with subject matter experts at 38 shopping centres in the Gauteng province in South Africa, as well as

online surveys of the shopping centre operations managers and fat or grease maintenance companies. More than 100 respondents who were either shopping centre operation managers, facilities managers or centre managers were surveyed.

As can be seen from Table 1, the best response yields were from site visits and telephone interviews.

Shopping centres of different sizes were surveyed. Most were in the size range 60,000–100,000 m^2, followed by the 40,000–60,000 m^2 range (Fig. 1).

3 SHOPPING CENTRE FSE DENSITY (SCFD) INDEX

Given the wide variation in the size of shopping centres surveyed, a benchmarking tool was developed to express the ratio of the number of FSEs per centre to the size of the centre per 10,000 m^2. The objective of the proposed shopping centre FSE density (SCFD) index was to establish a correlation between the numbers of FSEs per centre in relation to the reported

Table 1: Individual surveys response yields.

Survey instrument	Responses	Number	Percentage
Comprehensive questionnaire	5	30	16.7
Site visits	16	30	53.3
Telephone interviews	20	25	80.0
Online survey to shopping centres	4	83	4.8
Online survey to fat trap companies	2	41	4.9

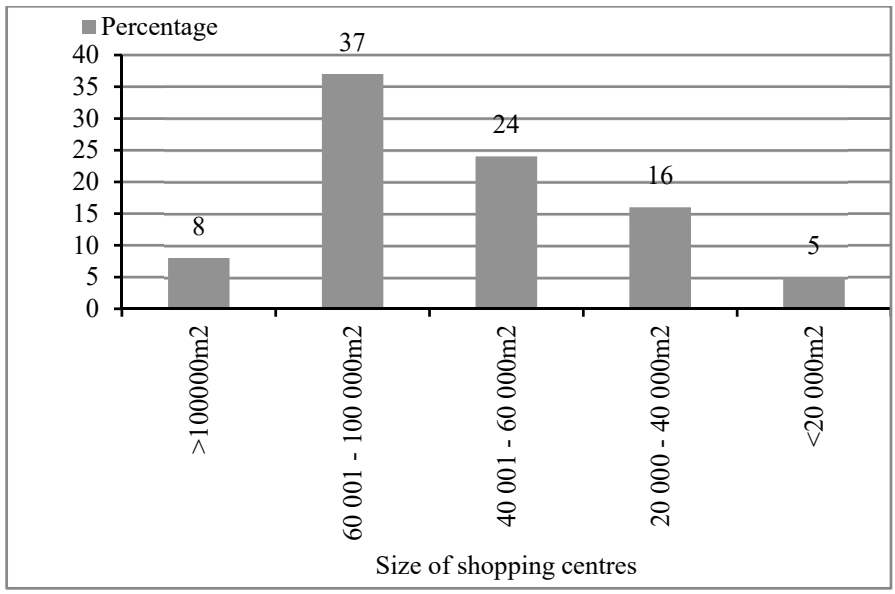

Figure 1: Size distribution of shopping centres surveyed.

frequency of FOG related blockages. The power of this index is that it can used for benchmarking across shopping centres of different sizes. This index compares the number of FSEs to the centre size. The ratio is able to show which centres have a high ratio of FSEs compared to others. The effect of the number of food service establishments per shopping centre was studied in relation to the severity of FOG related problems observed per centre. The data is shown in Table 2. No references have been found where this index has been used before.

The index can be used to determine the relationship between FSE concentration in a centre to the frequency of FOG related problems in the centre (Fig. 2). Theoretically there should be a clear correlation between these two variables.

Fig. 3 shows the relationship between the number of FSEs and size of the corresponding shopping centre. This shows that larger centres generally have proportionally higher number of FSEs. The largest shopping centres (above 100,000 m^2) have the highest number of FSEs, mostly above 30 FSEs per centre. The vast majority of centres' indices vary between two and four FSEs/10,000 m^2.

From Table 2, of the total 38 centres surveyed the frequency of FOG reported occurrences was as follows; six (6) centres none, fourteen (14) centres were low frequency, eight (8) were medium and ten (10) were high. The average SCFD index was 2.9 FSEs per 10,000 m^2. The highest measured ratios were 12 and 8.5 FSEs per 10,000 m^2. In these two centres FOG induced sewer blockages occurred at high and medium frequencies respectively.

In all the 10 reported high frequency FOG occurrences, five were below the average of 2.9 and five were above the average. This does not suggest an outright correlation between the density and high FOG related problems in this range. The same was observed for low frequency FOG problems observations. Theoretically it is expected that all low frequency FOG problems will be in the shopping centres whose SCFD index is below average. However it was noted that of the 14 low frequency FOG related problem observations, four were above the average and 10 below the average. This is slightly a better correlation than the high frequency data.

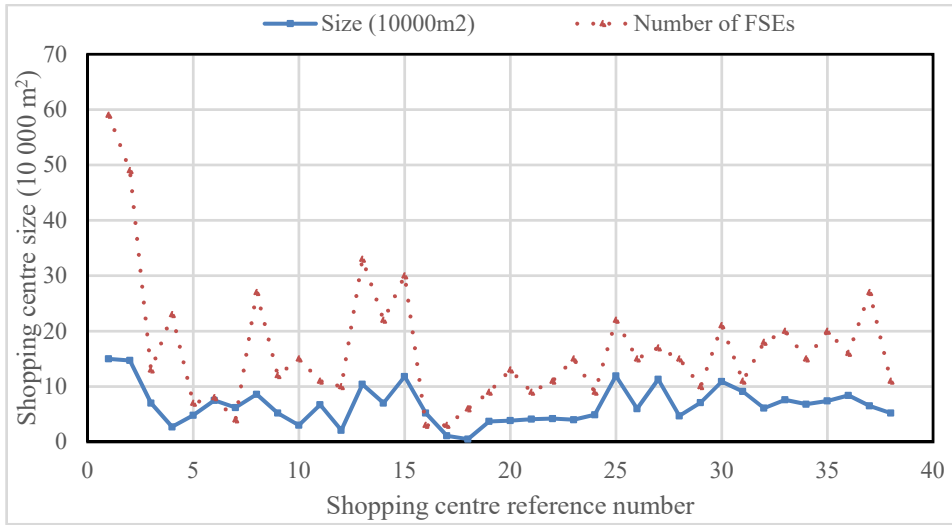

Figure 2: Number of FSEs per shopping centre size.

Table 2: Summary table with number of FSEs per centre.

Centre	Size (m^2)	Size (10,000 x m^2)	FOG problem	No. of FSEs	Density (FSE/10,000 m^2)	Frequency of blockages
1	150,000	15.0	Y	59	3.93	Low
2	147,000	14.7	Y	49	3.33	Medium
3	70,000	7.0	N	13	1.86	None
4	27,000	2.7	Y	23	8.52	Medium
5	48,000	4.8	Y	7	1.46	Low
6	75,000	7.5	Y	8	1.07	High
7	62,000	6.2	N	4	0.65	None
8	86,000	8.6	Y	27	3.14	High
9	52,000	5.2	Y	12	2.31	High
10	30,000	3.0	Y	15	5.00	Low
11	67,000	6.7	Y	11	1.64	Low
12	21,000	2.1	Y	10	4.76	High
13	104,000	10.4	Y	33	3.17	Medium
14	70,000	7.0	Y	22	3.14	Medium
15	118,000	11.8	Y	30	2.54	Medium
16	52,000	5.2	N	3	0.58	None
17	11,000	1.1	N	3	2.73	None
18	5,000	0.5	Y	6	12.00	High
19	37,000	3.7	Y	9	2.43	Low
20	38,500	3.9	Y	13	3.38	Low
21	41,000	4.1	Y	9	2.20	Low
22	42,000	4.2	Y	11	2.62	Low
23	40,000	4.0	Y	15	3.75	Low
24	49,000	4.9	Y	9	1.84	Low
25	119,000	11.9	N	22	1.85	None
26	60,000	6.0	Y	15	2.50	Low
27	113,000	11.3	Y	17	1.50	High
28	47,000	4.7	Y	15	3.19	High
29	71,000	7.1	Y	10	1.41	Medium
30	109,000	10.9	Y	21	1.93	High
31	91,000	9.1	Y	11	1.21	Medium
32	61,000	6.1	Y	18	2.95	Medium
33	76,000	7.6	Y	20	2.63	High
34	68,000	6.8	Y	15	2.21	Low
35	74,000	7.4	N	20	2.70	Low
36	84,000	8.4	Y	16	1.90	Low
37	65,000	6.5	Y	27	4.15	High
38	52,000	5.2	N	11	2.12	None

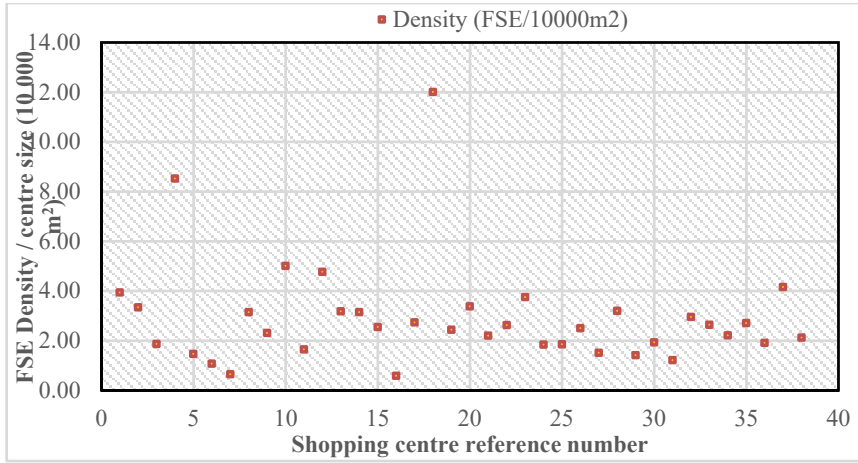

Figure 3: FSE density per shopping centre size.

Fig. 4 indicates the expected and actual correlation. The FOG blockage occurrence rates were classified as none = 0, low = 1, medium = 2 and high = 3. These are then plotted against the centre's measured SCFD index. Theoretically when there are no FSEs (zero SCFD) there should be no (zero) blockages due to FOG, the same applies for a high number of FSEs (higher SCFD) the frequency of observed FOG related blockages must high at three.

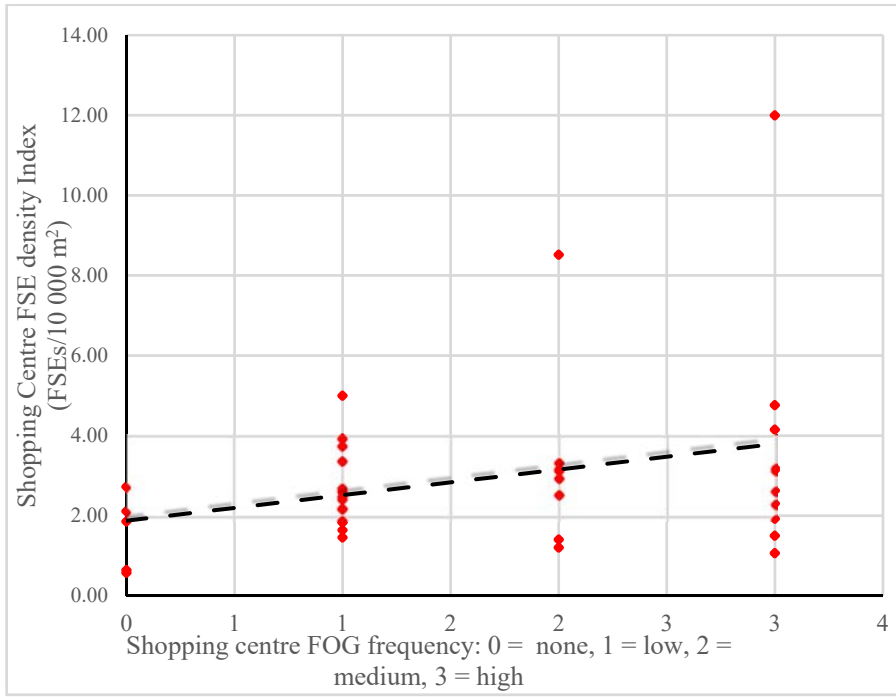

Figure 4: SCFD index versus shopping centre FOG frequency.

Generally, a poor correlation was found, especially on 1 (low) and 3 (high) blocking occurrences. It was theoretically expected that the data points at low (1) will be associated with a lower SCFD index and at high (3) to be associated with a high SCFD index. There is scope for further study and research in exploring the relationship between the SCFD index and severity of FOG related problems per shopping centre. This will require doing more site visits to shopping centres and scrutinizing the data provided by maintenance managers.

4 FINDINGS AND DISCUSSION

More than 100 respondents who were shopping centre operation managers, facilities managers or centre managers in a total of 38 shopping centres in Gauteng were surveyed. The overwhelming majority (88%) confirmed the occurrence of FOG related problems in their shopping centres.

The severity of FOG problems in the shopping centres was graded according to the frequency of occurrence of FOG related sewer blockages. Weekly or bi-weekly are classified as high severity, greater than monthly to quarterly as medium severity, and low severity as FOG related sewer blockages only once to twice yearly. The overall picture is depicted in Fig. 5. There is overwhelming evidence that FOGs are a real problem in the majority of shopping centres surveyed, with 30% reporting the problem to be severe.

The findings are summarised below per topic.

4.1.1 Is FOG a high maintenance problem?

A few shopping centre managers considered FOG a high risk problem and rate it very high among their severe maintenance problems. A critical observation is that four of the respondents surveyed indicated that the FOG problem is increasing or getting worse progressively.

4.1.2 Fat traps and grease traps

All shopping centres surveyed rely on the kitchen based internal fat trap device as a first line of defence in the elimination of FOG from kitchen based wastewater. The majority of maintenance managers believe that fat traps are sufficient in dealing with the FOG problem.

Literature shows that the real measured performance of these devices is generally lower than that reported by the manufacturer plus these devices are sensitive to many variables which may vary during the operation of the restaurant such as type of detergents used, the

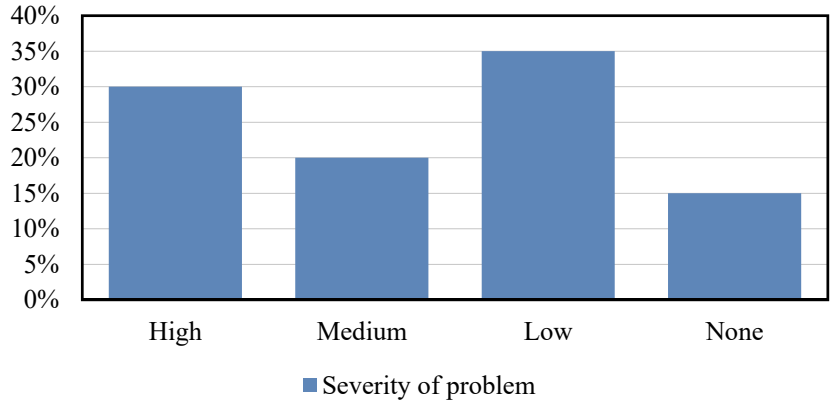

Figure 5: Frequency of FOG problems across centres surveyed.

liquid loading to the device, fluid temperature, etc. In general scientific literature casts a doubt on the sufficiency of fat traps in eliminating FOG.

4.1.3 Fat trap maintenance
The efficiency of a fat trap device can be greatly improved with regular cleaning and maintenance. FSE operators were found to rely on fat trap contractors more than on internal staff to do regular fat trap maintenance. A very common procedure applied by centre managers to ensure proper fat trap cleaning and maintenance is to request submission of service reports and waste disposal certificates. This is a good practice, the problem is that there is no professional body or association that is responsible for accrediting and approving fat trap cleaning companies to ensure that their work is standardised.

4.1.4 External grease traps
Five of the 38 shopping centres surveyed had external grease traps. Inspection of these devices during site visits showed that they are effective in trapping substantial amounts of FOG that have escaped the FSEs fat traps. This confirms the low efficiency of internal fat trap devices.

4.1.5 Bypass of fat trap device
A recurring concern by maintenance and operation managers is the deliberate bypassing of fat traps and dumping of FOG waste down the kitchen floor drains by kitchen staff. This issue was highlighted several times in interviews and surveys as it caused severe blockages and frustration among centre maintenance managers. The culprit FSE operator, by failing to clean and maintain their own fat trap, passes the problem to the shopping centre.

4.1.6 Inspections of FSE operators
The majority of shopping centres reported the practice of regular scheduled and random inspections of FSE fat traps and kitchen operation to avoid poor kitchen practices. The inspections help ensure that the FSE operator consistently operates their facility properly to the landlord's requirements.

4.1.7 High pressure cleaning
In order to address frequent sewer line blockages the majority of shopping centre maintenance departments implement pre-emptive scheduled cleaning of sewer lines by high pressure water jetting. This is a costly exercise which has always been carried by the centre, but now a few shopping centres have taken punitive steps of charging these costs directly to the FSEs implicated. This policy was successfully applied by a few centres, about five in the 38 centres surveyed.

4.1.8 Penalising FSE operators
FOG related sewer problems remain a consistent burden to the shopping centres, however there is a shift in attitude in addressing the problem, a few centres are now implementing penalties direct to responsible tenants. Several respondents confirmed that they have policies or procedures in place that dictate penalties to be charged directly to FSE operators proportional to the cost of sewer lines unblocking and cleanup.

4.1.9 Maintenance staff, insourcing and outsourcing
The majority of centres with severe FOG problems relied on internal maintenance staff and use own high pressure cleaning tools and equipment. These teams also conduct regular pre-

emptive cleaning. Insourcing is therefore the preferred method of handling maintenance related to FOG.

4.1.10 Damage to pump station and WWTW
Further down the sanitary sewer lines network, FOG causes catastrophic problems at pump stations. The effects of FOG at wastewater treatment plants have been reported in many literature studies and are acknowledged by local operators.

4.1.11 Compliance and enforcement
The South African legal framework was considered sufficient by those who responded but there is little enforcement, especially among FSEs in shopping centre. There is a lot frustration from shopping centre maintenance managers caused by negligent behaviour by FSE operators when it comes to handling FOG.

4.1.12 The use of bio-additives
The use of bio-additives for FOG treatment is widely marketed however in the surveys few respondents commended them. Bio-additives are mixtures of bacterial cultures with nutrients plus lipase enzyme. Reports on the efficacy of bio-additives are not consistent, even in literature.

4.1.13 Sewer system design
The sharing of a common sewer line by several FSEs exacerbates the sewer blockage frequency, thus some centre have modified their lines to reduce the load by reducing the number of FSEs per line, in some cases to even having a separate line per outlet. Thus sewer system design can impact sewer lines blockages.

4.1.14 Type of FSEs influencing FOG
Regarding which FSE type were prone to creating more FOG related problems, most maintenance managers pointed to fried chicken, burgers, fish and chips and Indian cuisine type restaurants. These FSEs produce a relatively higher loading of FOG rich wastewater than others. According to the international literature it is mostly Chinese, Mexican, Indian type FSEs that produced kitchen wastewater with a higher FOG concentration.

4.1.15 Challenges reported by fat trap companies
Fat trap serving companies suggested that government support though enforcing compliance on fat trap inspections and maintenance will help. Another concern was the negligence and poor understanding of fat trap devices by FSEs.

4.1.16 Solutions proposed by respondents
It was firstly recommended that education and training campaigns should be launched to FSE operators and shopping centre maintenance staff on FOG and best management practices. Secondly, tight control on fat trap maintenance compliance, through regular inspections and monitoring of service records. Lastly, intervention by relevant government departments is required to enforce the compliance of waste policies in shopping centres to FSE operators. More specifically, it was recommended that the waste generator must be responsible for disposal and downstream effects of their waste.

5 CONCLUSIONS

FOG is a real and imminent problem in shopping centres. Of the shopping centres surveyed, an overwhelming majority (88%) confirmed to currently experiencing FOG related problems

in their shopping centres. This is sufficient evidence that fats, oils and greases are a real problem in the majority of shopping centres surveyed.

FOG emanate from FSEs and catering establishments. An increase in the number of FSEs in a shopping centre would result in a higher FOG loading and directionally more FOG problems in sewer lines. This hypothesis was tested using the SCFD (shopping centre FSE density) index which measures the number of FSE per 10,000 m^2 of shopping centre floor area. However using the data for 38 shopping centres, there was no clear correlation in the data to support the hypothesis. Further studies are required to additional data.

In terms of addressing FOG within their facilities, shopping centre management is still heavily reliant on the presence of fat traps to remove FOG. Internal or kitchen based fat traps are effective when operated under proper care and maintenance as recommended by the manufacturer. The successful use of external grease traps downstream of internal fat traps is proof of the insufficiency of internal kitchen based fat traps to address FOG contamination effectively.

The FOG concentration in FSE effluent is mainly affected by the operations and configuration of the catering business. Cuisine type has the highest impact on FOG loading. Co-digestion of wastewater sludge with FOG waste to generate biogas in an anaerobic reactor is the best and most economic manner for treating FOG waste.

6 RECOMMENDATIONS

Based upon the findings, the following recommendations are suggested:

- Shopping centre management should enforce the implementation of standardised Best Management Practices (BMP) for handling of FOG by FSEs. Shopping centres should lobby for BMPs to be included in wastewater bylaws.
- The most effective strategy in the battle against FOG contamination is though waste treatment and reduction at source. The restaurant or catering facility where FOG is generated is the best place to address the problem.
- Shopping centre management must ensure that proper fat trap sizing is done for existing and new FSE tenants in the property.
- Fat trap maintenance contractors should be verified, trained, certified and graded by an independent body to ensure the consistent excellent service standards to industry.
- A voluntary membership association for fat or grease traps manufacturers and maintenance companies should be established to setup operating guidelines and code of conducts for members. The association must help in holding members to a high quality standard.
- Stringent monitoring of FSE operations by landlords must be done regularly with penalties applied for transgressions.
- External grease traps must be a compulsory feature for shopping centres above 30,000 m^2 with minimum three FSEs. This should be based on the size of centre and number of FSEs.
- Any FSE within the shopping centre with a fat trap must hold a trade effluent discharge license with a guiding set of conditions based on BMPs and supported by relevant policies and bylaws. Penalties should be levied for non-compliance.
- A FOG forum should be established under the Department of Water and Sanitation similar to other forums such as Rivers and Catchments Forums or the Acid Mine Drainage (AMD) focused study group. This must provide regular interaction with stakeholders on FOG issues and promotion of advancement in addressing the problem.

- Shopping centre management should provide regular training and awareness on the general effects of FOG and on maintenance and operation of grease abatement devices

A shopping centre performance matrix should be developed which monitors and measures environmental sustainability issues among centres covering innovation in waste reduction and treatment. Shopping centre facilities managers' key performance indicators (KPIs) should include a focus on efficient FSEs operations and effluent management. Local municipality environmental monitoring and compliance teams should be trained to inspect and monitor the quality and volume of effluent released from shopping centres into the municipal main sewer line.

Funding is required for further studies on the following areas:

- Detailed study on FOG loading and variations across different types of FSEs.
- Additional data, more site visits to shopping centres for in depth surveys.
- Benchmarking study on the shopping centre FSE Density index in South Africa.
- Quantifying the additional operating costs of treating FOG rich wastewater at WWTW.
- Test runs on biogas production from co-digestion of wastewater sludge with FOG.
- Testing of fat traps to compare design efficiency against actual performance.
- Testing dissolved air flotation (DAF) for efficacy in separation of FOG wastewater.

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