

Treatment of Effluents from Food Services Establishment (FSEs) by Physico-chemical Processes: A Case Study for Trinidad & Tobago

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Abstract

In Trinidad & Tobago, it is estimated that approximately 231,304 kg/day of unaccounted for FOG-bearing wastewaters from Food Establishments, are released into the environment with no method of viable treatment in the country. This seeks to find a financially viable and optimal physico-chemical processes for the treatment of emulsified FOGs, for subsequent release into the environment. Bench-scale studies analysed the characteristics of FSE's effluents from three popular sources, studied the treatment using Jar Tests experiments, and subsequent pilot plant study. The mean concentration of constituents in the FSEs' samples were FOG (511 mg/l \pm 116 mg/l), Suspended Solids (446 mg/l \pm 146 mg/l), Chemical Oxygen Demand (2229 mg/l \pm 963 mg/l) and pH (6 \pm 0.3). Jar Tests were conducted using Poly-aluminium Chloride (PACl) as coagulant, anionic and cationic polyelectrolytes as flocculant aids with suitable pH adjustments of samples to determine the isoelectric point for the coagulant. FOG removal levels of 99.9% resulted in a final effluent concentration of 0.17 mg/l, which was within the regulatory standard of 20 mg/l. Required conditions were a PACl concentration of 250 mg/l, followed by flocculation aid with 4 mg/l of 0.1% low cationic polyelectrolyte (CP 1154) at pH adjusted to 8, and post-sedimentation for thirty minutes. The Jar test results were used as the basis for the design of a pilot-scale treatment plant. The plant achieved a 97.4% removal of FOG (residual of 16.8 mg/l) using 0.1% medium cationic polyelectrolyte (CP1156) and pre- and post-sedimentation times of 120 minutes, and 360 minutes, respectively.

Introduction

Fats, oil and grease, collectively known as FOG can severely impact the sewerage system and by extension the environment, if not treated and disposed of properly. FOG constitutes substances of petroleum origin, known as brown oil) and those from animal and vegetable origin, known as yellow grease). FOG (yellow and brown), when discharged into the environment in excessive amounts, do not degrade easily resulting in sewer chokes which lead to sewage overflows into the environment. FOG in liquid form appear harmless, however, when it cools it congeals and hardens and attaches to the inner lining of drainage pipes and sewers. Sewer pipes are generally made from hydrophobic and oleophilic materials to which oily substances are naturally attracted. Sewage overflows pose health problems as sewage carries pathogenic organisms including viruses and also cause damage to properties. Moreover, when laden with oil, it causes fire hazards on spillage to environment. In Trinidad, the FSEs are rapidly growing generating more oil and grease to be disposed of. However, the absence of legitimate disposal standards has led to illegal dumping and inappropriate disposal practices.

Subsequent to these chokes additional problems that are encountered include:

- Biological processes used to treat domestic wastewater would be inhibited, resulting in significant expenditure and increase in operations and maintenance costs, to restore them to their effective operational levels. This would include the shutting down of treatment plants and lift stations for servicing and the replacement and repair of equipment damage;

- Costs are incurred by the government and unwarranted inconveniences to the public when rectifications of the problems caused by FOG are needed to the collection system. This is the case as public sewer chokes are very costly and require mobilization of significant amount of resources;
- Operational costs to repair and service wastewater treatment plant where processes have been affected due to excessive inflow of FOG into the wastewater treatment plant.
- Resultant increase in operation and maintenance costs along with loss of revenue due to loss of production in Food Services Establishments (FSEs);
- Reduction of revenue from loss of customers due to the obnoxious odours produced internally to building drains of Commercial Businesses;
- Because of chokes in the sewer line, anaerobic condition is resulted leading to release of hydrogen sulphide which is a fire hazard
- Explosion of rodent and vermin population thereby increasing risks of the transmittance of communicable diseases.

Currently there are many incidences of excessive amounts of FOG entering the public sewer system, causing sewage overflows into the environment in Trinidad and Tobago. It has been reported by the local authorities that most of these grease problems have been caused by absence of adequate pre-treatment systems in some FSEs, either grease traps/interceptors being non-existent, or these are poorly designed and/or ill-maintained. Based on these problems, this paper embarks into treatment of the emulsified layer of FOG-laden FSE effluents by physico-chemical means, viz. pre-sedimentation followed by coagulation-flocculation-sedimentation. The effluents were collected from the traps/interceptors of some FSEs which use baking (M), frying (K), or mixed mode of food preparation (W). The initial study was done with bench-scale experimentation followed by pilot-plant operation.

It shall be noted in determining an optimum treatment for emulsified FOG, a literature survey was conducted. It showed treatment of FOG has been considered by scholars over the last decade. The scope of the problem is wide i.e. type of FOG, and the various aqueous layers. Various methods have been studied to treat the different layers of animal and vegetable grease wastewater. Some articles speak specifically to emulsified and others settables, while most speak in general to FOG. The most consistent and effective results were seen from the physico-chemical treatment processes which are dominated by electro coagulation and flocculation. For those specific to wastewater from FSEs biological methods were explored locally and were found to be unsatisfactory. In international studies, optimum results for effluents from FSEs, were attained via a sophisticated experimental type set up (Qin et al, 2013) that used a pilot plant with the aid of a centralized quadratic program which predetermined the optimum dosage requirement and therefore resulted in zero trade effluent. Based on the aforementioned, an optimum physico-chemical treatment process for the emulsified oil and grease wastewater from FSEs in Trinidad and Tobago would be explored using simple coagulation and flocculation techniques with minimal unit processes or aids which would generate an effluent that meets the permissible level given by the respective authorities to enter sewer systems, making it optimal (effective and within conservative costs).

Experimental Programme

Sampling

Three FSEs with the most popular food processing operations were identified for sampling. They constituted predominantly frying (chicken and chips), predominantly baking (pizzeria) and predominantly cooking of various dishes using combination of all cooking processes. Grab samples were manually collected from the grease traps of the three FSEs, placed in a portable deep freezer and carried to the laboratory within thirty minutes. The collected samples were also composited in proportions which a hauler would have. Sampling for Bench Level Studies and Pilot Scale Studies were done weekly over a two (2) month period each.

Analysis

The first phase of analysis (Bench Level Studies) of the grab samples from individual FSEs effluents, as well as the second phase of analysis of composite samples were analyzed for pH, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and FOG as per Standard Methods [14]. Each extraction of emulsified water to be tested was placed in a 2L beaker and was continuously stirred via submergence of a magnet in the beaker to ensure homogeneity in sample while conducting tests. Once characterization was completed, the Jar test was performed using different dosages of Poly-aluminium Chloride (PACL), variation of pH adjustments and polyelectrolytes. Prior to Jar Test, the sample was allowed to stand to allow separation of the FOG layers before extracting the emulsified layer for treatment. Following the Jar Test (treatment process), the sample was again allowed to stand before testing of the effluent for aforementioned parameters. Details are discussed under sub heading titled "Bench Level Studies – coagulation and flocculation."

At the second phase (Pilot Scale Study) a homogeneously mixed volume of the sample was extracted and placed in beaker using aforementioned test methods for characterization. The remaining sample which was examined, in alignment with the bench level procedures. The initial step of separation was attained by allowing the sample to have a quiescent period in the first tank (pre-sedimentation), following which the emulsified layer was extracted via a transfer pipe with gate valve to the second and third tanks, to initiate the physicochemical treatment. The final tank was used for settling of floc after treatment for a quiescent period, before the final effluent was withdrawn and tested. Details are discussed under sub heading titled "Pilot Scale Studies – coagulation and flocculation." Treatment commenced using the chemical findings from the bench level studies, where further mathematical analysis and subsequent changes in physical and chemical parameters were determined, in order to reproduce efficient results at the pilot scale.

Bench Level Studies - Coagulation and Flocculation

Jar tests were carried out fortnightly to determine the optimum coagulation-flocculation treatment process using various strengths and dosages of poly-aluminium chloride (PACl) and various proprietary

polyelectrolytes (supplied by General Electric). The steps for coagulation-flocculation - settling were as follows:

- a. A 5% Stock of PACl was made up and placed in the volumetric flask.
- b. 0.1% stock of the polyelectrolyte used was made up (based on manufacturer's instructions) and placed in a glass jar.
- c. The sample collected was poured into a 2-L graduated cylinder and left to settle for 30 minutes. The supernatant emulsified water was withdrawn and placed in each of the six 1-L beakers.
- d. Each beaker was placed on the magnetic stirrer with the magnet immersed in the liquid.
- e. A pipette was used to apply drops of the sodium hydroxide until the desired pH of the sample was attained. This was done whilst the pH probe was immersed in the contents thereby monitoring the pH value.
- f. The beakers along with the contents therein were replaced on the platform of the six place flocculator. The paddles were then gently immersed in the liquid.
- g. The respective dosages of PACl were then quickly removed from the volumetric flask through 25 ml pipette and placed in the respective beakers.
- h. Flash mixing (coagulation) continued for 2 minutes @ 100 rpm.
 - i. The requisite polyelectrolyte dosages were then quickly pipetted from the glass jar and placed into the respective 6 beakers and the slow mixing (flocculation) was done for 20 minutes @ 20 rpm.
 - j. Following which the six place flocculator was turned off and the contents left to settle for 30 minutes.
- k. The top layer in each beaker was thrown off and the supernatant was used for analysis of FOG, COD, TSS, pH, and aluminium.
- l. All parameters tested were done in accordance with Standard Methods [14]
- m. The jar tests were repeated until the optimal dosages of PACl as well as polyelectrolyte combination was determined.

Pilot Scale Studies – Coagulation and Flocculation

- a. Prior to treatment the sample was tested for FOG, TSS, COD, pH (to verify characterization).
- b. The sample collected was gently poured into the first tank of the pilot plant and left to settle (to differentiate between layers) for varying times between 30 minutes and 120 minutes.
- c. The Two (2) Cole Palmer Stirrers Propeller Type (Model Numbers 500007-30 and 50002-40), were set up on either side of the length of the coagulation tank, symmetrically positioned to allow homogenous mixing. They were both immersed to a depth of 10% of tank width from the bottom of the tank and at an angle of 10% from the vertical to reduce vortexing.
- d. The gate valve on the overflow pipe from the first chamber (pre-sedimentation) to the second chamber (coagulation tank) was opened (small opening) to allow the emulsified layer to be

- transferred to the coagulation tank with minimal disturbance. As such, this regime was considered non-turbulent mixing, despite Reynold's number not being confirmed in the pipe.
- e. The stirrers were then put on to mix the water while the pH of the sample was adjusted until a value of 8 was attained. This was done via a pipette used to apply drops of the Sodium Hydroxide and pH indicator strips.
 - f. When the desired pH value was attained 250 mg/l of PACl (pre-determined optimum dosage at bench level) was then quickly removed from a glass jar (with previously mixed coagulant) via the $0.025 \times 10^{-3} \text{ m}^3$ pipette and placed in the coagulation tank.
 - g. Coagulation then commenced for two (2) minutes at the required rpm. Note determination of the rpm depended on volume of sample, mixing velocities, tip speed and power of stirrers.
 - h. After the two (2) minutes the mechanical stirrers were slowed down to 0 rpm and the contents in the coagulation tank were allowed to flow via gravity to the flocculation tank via a small opening of the gate valve on the transfer pipe. It should be noted the valve was opened to control the flow to minimise disturbances of the flocs formed while throttling to the contents already in the flocculation tank. As such, this regime was considered non-turbulent mixing, despite Reynold's number not being confirmed in the pipe.
 - i. The two mechanical stirrers were then placed in the same position for the flocculation tank. The polyelectrolyte dosage (previously mixed) were then quickly pipetted from the glass jar into the flocculation tank based on respective dosages.
 - j. Flocculation quickly commenced for twenty (20) minutes at the required rpm. Note determination of the rpm depended on volume of sample, mixing velocities, tip speed and power of stirrers.
 - k. Following which the Two (2) mechanical stirrers were turned off and the contents allowed to transfer to the final tank (settling tank) via small opening of the ball valve on the transfer pipe, so as to minimise disturbances through the pipe and in the receiving tank. The sample was allowed to settle for various times (between 60 and 360 minutes) following which the supernatant was drawn off to be tested.
 - l. Respective tests were then conducted on the effluent (FOG, COD, TSS, pH, Aluminium). It shall be noted that analysis of aluminium in sludge was done via formula.
 - m. This procedure was carried out until verification of the Bench level studies were attained or equally desired results.

Results And Discussion

Characterization of effluents from FSEs

Four pertinent wastewater quality parameters were analysed, viz combined fats, oil and grease (FOG); total suspended solids (TSS); pH; and chemical oxygen demand (COD). It should be noted that a composite sample (C) was also analysed to represent the realistic situation of what any grease hauler

would bring to a wastewater treatment plant for treatment. This sample “C” is the mixture of FSE effluent samples “K” (baking-based), “M” (frying-based) and “W” (mixed-based)

Table 1 summarizes the characteristics of FOG-bearing effluent (emulsified layer) from three FSEs (via composite sample “C”) based on sampling and analyses discussed in the forgoing section.

Parameter	Range of Values	Typical Value (mean)
Fats, Oil and Grease (FOG)	162-1311 mg/l	511 mg/l
Total Suspended Solids (TSS)	260 – 710 mg/l	446 mg/l
pH	5-6	6
Chemical Oxygen Demand (COD)	667-4942 mg/l	2229 mg/l

Table 1: Characteristics of FSE Effluent

It may be noted that the parameter with the highest concentration is COD (average of 2229 mg/l), followed by FOG (average, 511 mg/l) and TSS (average, 446 mg/l). The above results reveal that the combination of samples would be ideal and realistic to be envisaged for its physico – chemical treatment by coagulation-flocculation-sedimentation.

Bench-Scale Study

The physico-chemical treatment selected in this study is conventional coagulation, flocculation and settling via Jar Tests. Poly-aluminium Chloride was used to perform coagulation. The effects of additions of poly-electrolytes (supplied by General Electric) were also examined. Poly-aluminium Chloride ($[Al(OH)_aCl_b]_n$, where $(a + b) = 3$, with $a > 1.05$) (Water New Zealand 2013) [17] is a class of soluble aluminium products where the aluminium chloride has been partially reacted with a base. It contains some of the highly cationic oligomers of aluminium, which makes it an excellent choice for coagulation. Polyelectrolytes are used for floc build up as they bridge between particles and charged aluminium flocs (Eckenfelder Jr. 1966, 280) [24]. They are also absorbable meaning small dosages are effective to encourage floc build up. Colloids of oil and grease are hydrophobic which often retard flocculation and frequently require special treatment to achieve effective coagulation (Eckenfelder Jr. 1966, 280) [24]. Additionally, the vast majority of colloids are negatively charged (with a range of the zeta potential between -12 to -40 mv). Consequently, coagulation is induced by the addition of high valence cations. Optimum coagulation occurs when the zeta potential is zero (isoelectric point – which occurs at a specific pH for the respective chemical), with effective coagulation at +/- (-5) mv (Eckenfelder Jr. 1966, 283).

Figure 1 shows removal rates of FOG at varying dosages (0 mg/l – 650 mg/l) of a 5% Stock Solution of PACl subsequent to coagulation and flocculation of the emulsified sample. Better removal rates were seen for dosages ranging between 150mg/l to 300 mg/l, with a drastic drop in removal for dosages higher than 300 mg/l. 250 mg/l dosage shows the optimum removal (89.90%), indicative of the dose which makes the emulsion most unstable. The 86.7% removal rate for 0 mg/L is indicative of a larger percent of grease being floatables after coagulation and flocculation. pH remained on the higher end of

the characterization range i.e. 6, which is expected as PAC is reacted on the base end of the pH scale even though carrying hydrogen ions (H⁺) which contributes to acidity. The removals of TSS ranged between 11%-65% and that of COD in the range of 52% - 91%.

Figure 2 shows that oil and grease removal rates not only increased with altered pH, but removal rates generally remained above 90 percent over a pH range of 6-10. Optimum removal of 98.98% was achieved for a pH of 8. TSS removal rates (93 % to 99 %) were also in alignment with FOG rates which may be attributed to the increase in destabilisation of colloids. pH range varied between 6 and 8 which is more towards the base end, as expected with the addition of NaOH. On the other hand, the upper range of removal COD dropped to 61%, which is expected with the addition of a chemical (NaOH).

Figure 3 illustrates the effects of the optimum PAC dosage (250 mg/L) and pH adjustment of samples to 8, with addition of low anionic polyelectrolyte dosages to assess its efficacy in the treatment. Figure 3 shows there was no significant change in FOG removals with the addition of the low anionic polyelectrolyte, rather, with increased dosages past 1mg/l, there was a decreased trend in the removal of oil and grease. This is an indication that the probable net charge left after coagulation is negative. TSS removal remained in the 90%, with the exception of the polyelectrolyte dosage of 6mg/l, which gave a removal of 41%. COD removals generally dropped in a range of 40% - 60% with two high removals of 76% and 85% for 0 mg/l and 7 mg/l of polyelectrolyte added respectively. pH went unaffected by the addition of the polyelectrolyte.

Based on the insignificant change by the addition of the anionic polyelectrolyte, a low cationic polyelectrolyte was tried. Figure 4 shows the results.

It is seen that optimum performance regarding the removal of emulsified oil and grease was achieved with a poly-aluminium chloride (PACl) dosage of 250 mg/l for a 5% Stock with the influent sample adjusted to a pH of 8 (seen to be isoelectric point for PACl) and with a low cationic polyelectrolyte dosage of 4 mg/l. This resulted in a removal rate of 99.9% with an FOG residual of 0.17 mg/l. TSS removals remained in a high range (90 percentile range) as anticipated. However, COD removals significantly dropped because of the polymeric organic matters therein; noting the removal rate at 4mg/l was 53 % which is consistent with other results.

In summary, the aforementioned optimum result was obtained following several experiments, where initially the addition of no chemicals were explored, followed by the addition of coagulants only. Upon deriving at the best coagulant dosage, the variation of pH ranges were explored for optimum results. Then under the optimal coagulant dosage and pH range, experiments were conducted to determine the effect on removal levels at various dosages of cationic and anionic polyelectrolytes.

Pilot Scale Study

The pilot scale study was conducted to not only confirm the results at the bench level study but to provide additional data that would aid in scaling up. It should be noted that pilot scale limit is designed and built

so that the process can be better understood. It provides boundary conditions that allow scale up from the prototype to the commercial plant (Whalley 2016) [27]. A pilot plant is meant to be flexible and adaptable so that the researcher can do modifications to test configurations.

The engineering parameters critical for the run of each sample were: wastewater volume, temporal mean velocity gradient (G), tip speed and the resulting rpm for the mechanical agitators. Average volume of samples at the pilot scale was 40 litres, as compared to bench scale level volume of 2 litres. Two agitators were used, namely a Cole Palmer 50000-40 and a Cole Palmer 50000-60, each of propeller type, of diameter 0.0635 m, which were used both in the coagulation and flocculation tanks. In the absence of values for the “ K_t ” constant normally provided by the suppliers of the mechanical agitators, use was made of the literature. As reported for Propeller type agitators with a pitch of two and 3 blades K_t for turbulent and laminar flows are 1 and 43.5, respectively (Tchobanglous, Burton, and Metcalf and Eddy 1991) [22]. Tip speed (TS) and Reynold’s Number were monitored to ensure all parameters remained in correct ranges (as listed in the following paragraph); however, velocity gradient was the parameter controlled. Equations for the aforementioned are as follows:

a) $G = \sqrt{P/(\mu \cdot V)}$

b) $TS = 2R\omega\pi$

c) Power (P) = $K_t/g \cdot v \cdot N^3 \cdot D^5$

d) $Re = (\rho N D^2) / \mu$

The power of the stirrers are 74.5 W with an efficiency of 80% as stated by Cole Palmer. Where ideal parameter ranges are: Coagulation; G 300-1000s⁻¹, Tip Speed $x > 3 \text{ ms}^{-1}$ and RPM < 1500. Flocculation; G 20-60 s⁻¹, Tip Speed $0.15 \text{ ms}^{-1} < x < 0.6 \text{ ms}^{-1}$, RPM $x < 100$ (Tchobanglous, Burton, and Metcalf and Eddy 1991) [22].

All the chemical parameters considered at the bench level study remained at the optimum dosages and strengths (PACl 250 mg/l dosage and 6N Sodium Hydroxide for adjustment of pH at 8) except the polyelectrolytes. Polyelectrolyte dosages and strengths coupled with varying settling times were manipulated in order to attain optimum results based on limitations faced mainly by equipment type and dimensions i.e. agitator type used in flocculation tank. Subsequently, the K_t value and subsequent calculations for mixing were used to determine the necessary rpm to allow optimum bridging of particles, in the flocculation tank. Detention times were also varied in the first tank (Pre-sedimentation tank) to allow a proper representation of emulsified oil and grease to be treated. Time varied between thirty (30) minutes and one hundred and twenty (120) minutes with an average of one hundred and seven (107) minutes. In addition, varying strengths and dosages of the polyelectrolytes were manipulated so as to obtain the optimum results, this aids as increased strength and dosages (strength – increased functional groups /unit grams and increased dosages – number of polymer groups per unit volume of liquid) would

have served by increasing the charge density for agglomeration where the mechanical aspect was insufficient for the same.

Figure 5 illustrates the results at the pilot plant study. With all pre-determined bench level treatment parameters remaining at optimum dosages and strengths, with variation only in the polyelectrolyte dosages and strengths, and the settling times at pre sedimentation and final tanks; optimum results were attained for a dosage of 5mg/l Medium Cationic (0.1% Stock) and a final settling time of six (6) hours respectively. Results yielded 97.4% FOG removal and resultant residual of 16.8 mg/l. This result differs from the dosing strength for the polyelectrolyte that attained optimum results at the bench level study of 4mg/l Low Cationic (0.1% Stock) for a removal rate of 99.9% (0.17 mg/l residual). It is concluded that the residual concentration in the bench level study is significantly below that generated at the pilot plant may be attributed to the limitations of equipment used in the pilot plant study, as discussed above.

The secondary parameters after treatment were as follows; pH consistently remained at 7 after treatment, TSS had over 90 percent removals and residuals ranged between 30 mg/l and 14 mg/l. COD removal rates on the other hand were not significant ranging between - 17% to 45%, as predetermined with the use of the increased strengths and dosages of cationic polyelectrolytes. The effluent had negligible amount of aluminium from operations, recorded at 0.16 mg/l, indicative of most of the aluminium in the process settled out. Formula determined concentration of aluminium in sludge to be 6999mg/l.

Conclusion

FOG effluents from FSEs in Trinidad and Tobago are discharged into the environment and sewers in considerable amounts which causes multifactorial adverse effects. This study was to determine the treatment of the emulsified layer of these effluents, to bring forth a recommendation to safely dispose of these effluents. To do so the characteristics of the effluents were studied and subsequently a treatment method was determined at Bench Level Study, following which a pilot scale study was then conducted for the purpose of scaling up.

The characterization was done based on analyses of samples that were representative of the effluents from three FSEs in Trinidad practicing three popular food process operations, i.e., frying, baking, and combination cooking. The characterization was successfully defined through parameters, viz. FOG, TSS, COD, and pH. It was shown that the proportional mixing of the three samples (representative of what a hauler would have for treatment) gave the typical value for each parameter used for characterization. Typical values were 511mg/l of FOG, 446 mg/l of TSS, 2229 mg/l of COD and 6 of pH. Following characterization, physico-chemical treatment by coagulation-flocculation was pursued at the bench level using 'Jar tests.' It was revealed that optimum performance regarding the removal of emulsified oil and grease was achieved with a poly-aluminium chloride (PACl) dosage of 250 mg/l for a 5% Stock with the influent sample adjusted to a pH of 8 (isoelectric point for PACl) and with a low cationic (CP1154) polyelectrolyte dosage of 4 mg/l. This resulted in a removal rate of 99.9% with a FOG residual of 0.17 mg/l.

The pilot scale study confirmed the primary findings of the bench level study. However, it was revealed that a higher strength and dose of the cationic polyelectrolyte and increased retention times in primary and final tanks were required to attain the desired results as there were equipment limitations in the flocculation tank. This is in alignment with theory where factors critical for agglomeration are equipment type and density charge. With the adjustments the pilot scale attained desirable results with the following parameters; Poly-aluminium chloride (PACl) dosage of 250 mg/l for a 5% Stock with the influent sample adjusted to a pH of 8, a polyelectrolyte dosage of 5mg/l Medium Cationic (0.1% Stock CP1156). Critical was settling times in the pre-sedimentation tank and final tank, which were two (2) hours and six (6) hours respectively. The treatment was shown to be 97.4% FOG removal for with resultant residual of 16.8 mg/l, which is under the permissible limit for discharge into sewer systems which stands at 20 mg/l (Trinidad and Tobago Bureau of Standards for Trade Effluents, TTS 638:2015). Other quality parameters such as aluminium content, TSS and pH met the stipulated aforementioned standards which would allow the treated wastewater to enter into the sewer systems based. However, COD removal was low, due to the polymeric properties therein of the polyelectrolyte and as such a granular activated carbon bed is recommended to reduce the COD levels, before discharge into the sewer system.

The study also showed this pilot plant to be more economical compared to the pilot plant used in the Hong Kong study (Qin et al. 2013) i.e. Electro Coagulation and Electro Flocculation with a stimulus sequencing quadratic program. Estimated cost comparison was done and showed to run one batch (0.04 cubic meters) in each system would cost approximately TTD 18000 vs TTD 61000, for the standard coagulation-flocculation method vs the Electro Coagulation-flocculation system with quadratic programming, respectively i.e. approximately 5 times the cost. Noting the results both meet the permissible level for FOG based on the Trinidad and Tobago Bureau of Standards for Trade Effluents (TTS 638:2015).

An analysis of the sludge arising out of coagulation showed it to be heavily water based and high in aluminium content. As such, it can be disposed of via dewatering or digestion and any further remnants can be disposed of via the Water Utility's Water Treatment Plant Sludge Ponds which has internal methods of disposing of this type of sludge waste. Research on sludge with this concentration of aluminium (6999mg/l) also reveals that it can be used for cement mortar and concrete making (Chakraborty 2005). The literature review has shown the other two layers of FOG i.e. floatables and settleables can be disposed of via acid digestion or based on its property it can be incinerated using controlled mechanisms.

Declarations

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose

DATA AVAILABILITY

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

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Figures

PACl Dosages vs Percentage Removal Rates of FOG

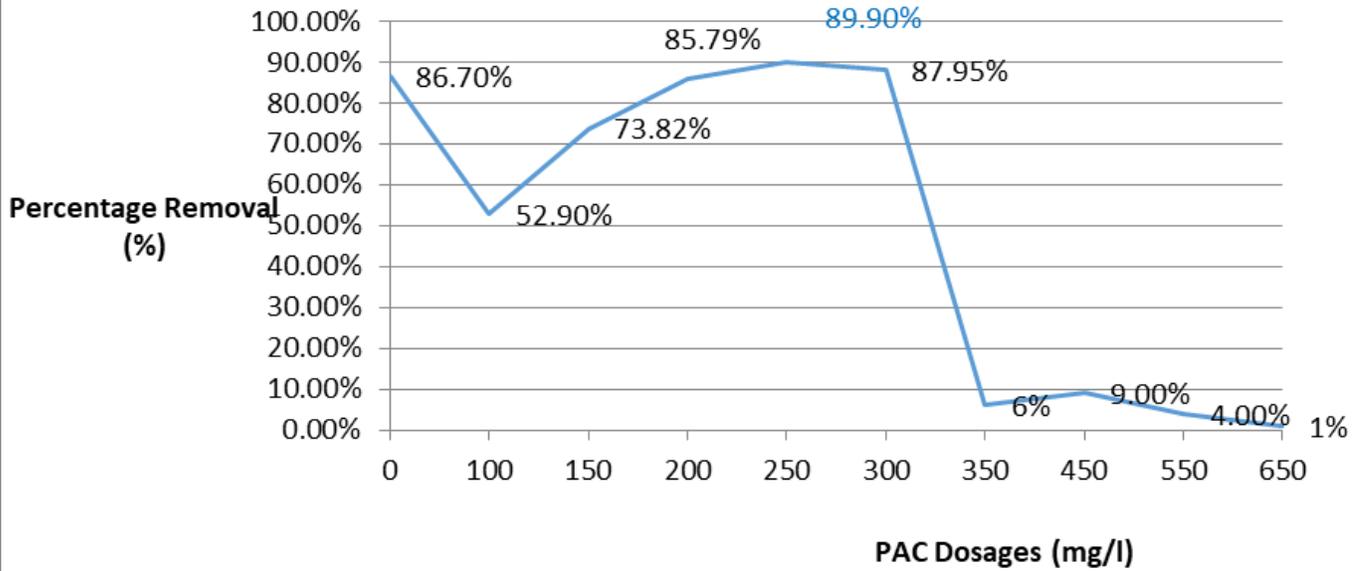


Figure 1

PACl Dosages vs Percentage Removal of FOG

Variation in pH vs Percentage Removal Rates of FOG

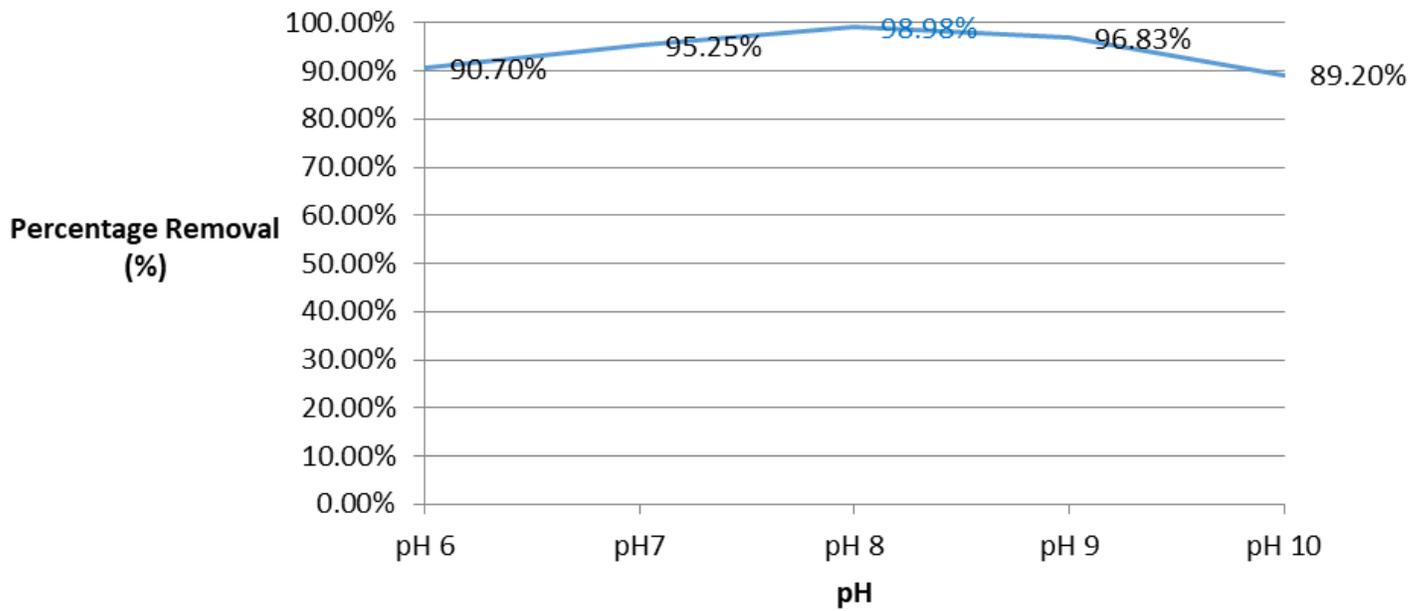


Figure 2

Removal of FOG vs pH at 250mg/l of 5% Stock PACl

Anionic Flocculant Dosages vs Percentage Removal Rates of FOG

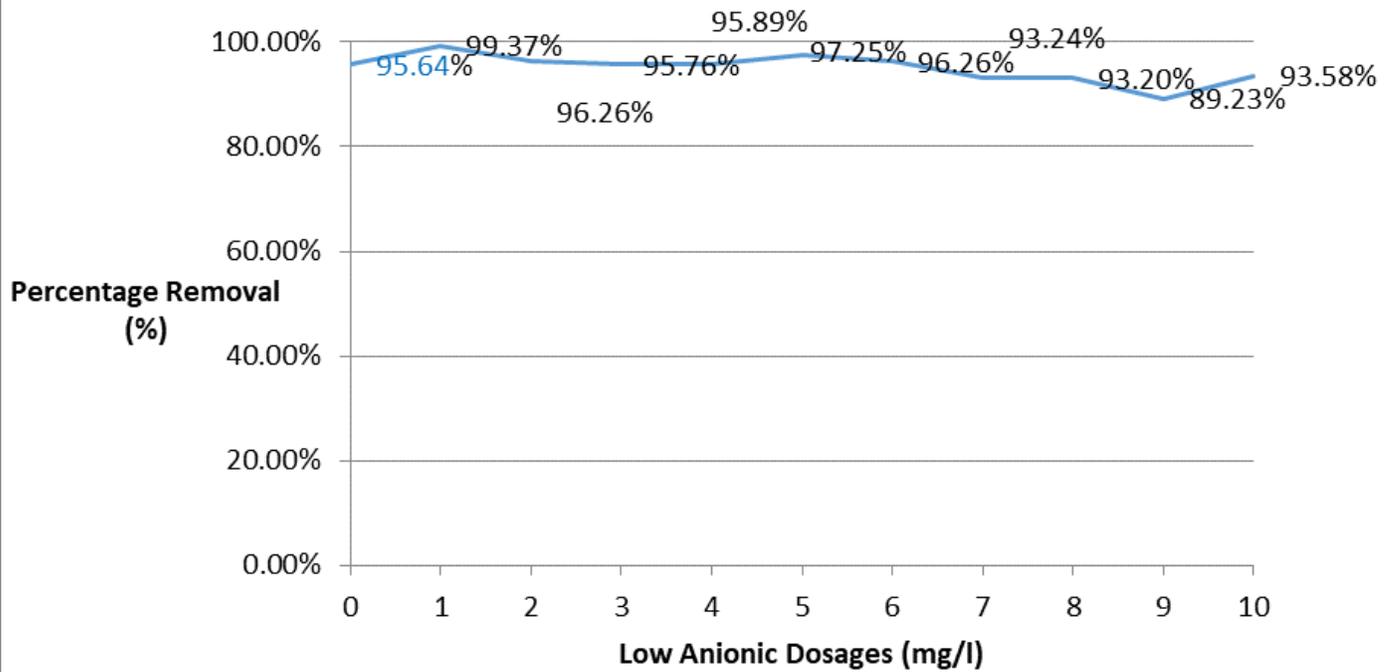


Figure 3

Removal of FOG at various dosages of low anionic polyelectrolyte along with 250mg/L of PACl with pH of sample adjusted to 8

Low Cationic Flocculant vs Percentage Removal Rates of FOG

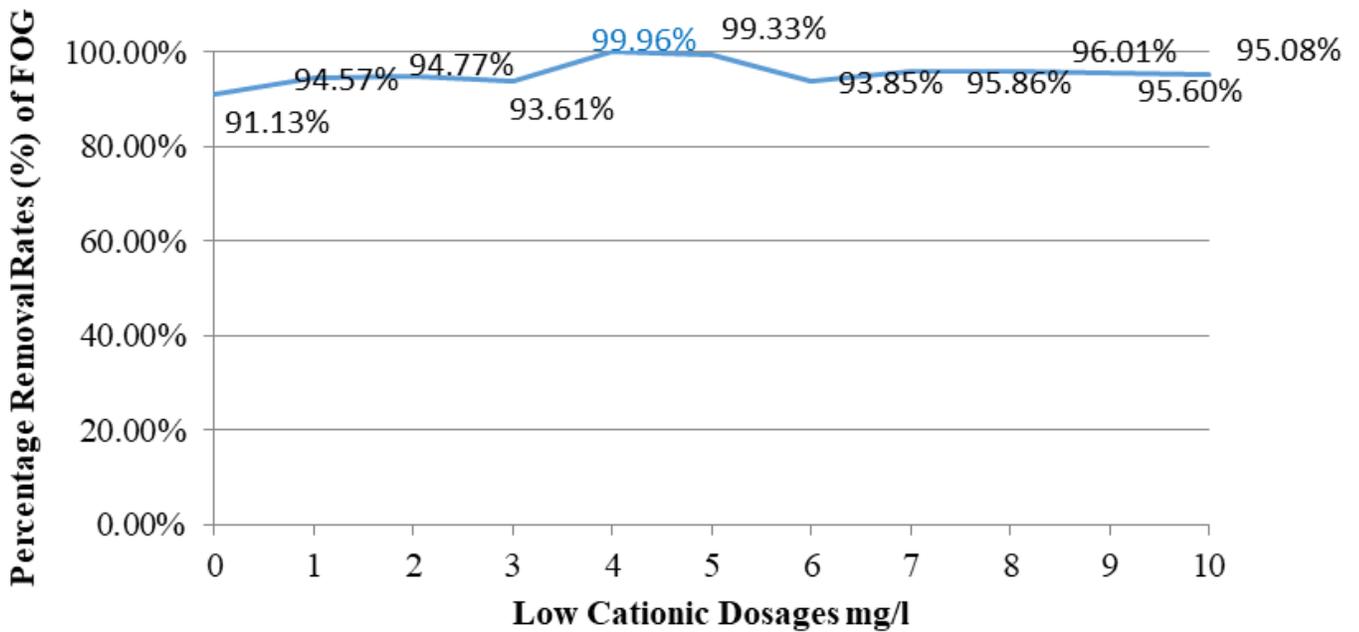


Figure 4

Removal of FOG at various dosages of low cationic polyelectrolyte along with 250mg/L of PAC with pH of sample adjusted to 8

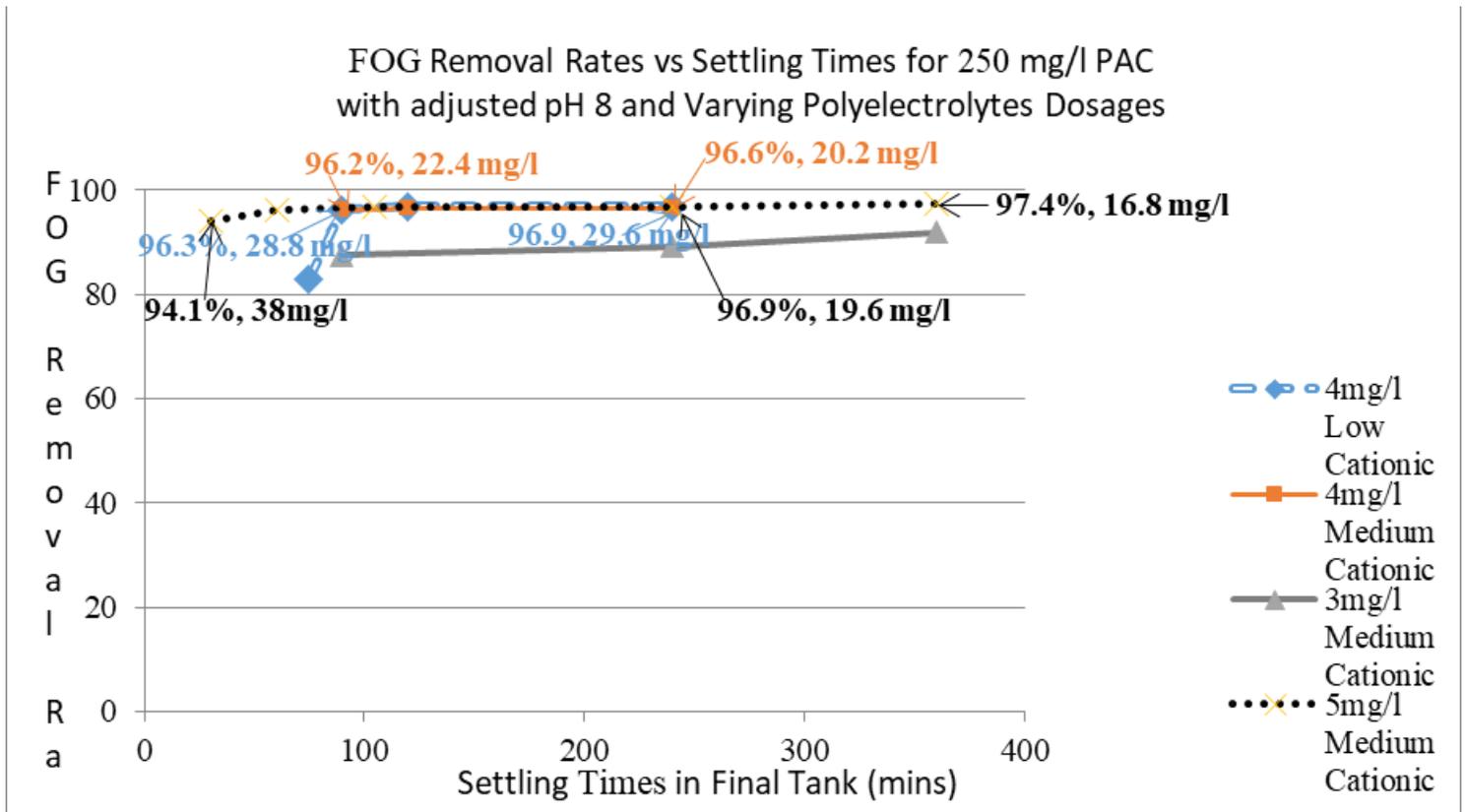


Figure 5

Varying Settling Times in Final Tank with Varying Polyelectrolyte Dosages and Strengths vs % Removal Rates