Physicochemical characteristics of grease-trap wastewater with different potential mechanisms of FOG solid formation, separation, and accumulation inside grease traps

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Physicochemical characteristics of grease-trap wastewater with different potential mechanisms of FOG solid formation, separation, and accumulation inside grease traps

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ABSTRACT

This work investigates the physicochemical characteristics of grease-trap wastewater discharged from a large community market. It proposes potential mechanisms of fat, oil, and grease (FOG) solid formation, separation, and accumulation inside grease traps. Sixty-four samples, i.e., the floated scum, suspended solid-liquid wastewater, and settled sludge, were collected from the grease-trap inlet and outlet chambers. A lower pH of 5-6 at 25-29 °C inside the grease trap than those reported under the sewer conditions (pH 6-7) was revealed. A significant difference in solid and dissolved constituents was also discovered between the inlet and outlet chambers, indicating that the baffle wall could affect the separation mechanism. The sludge samples had 1.5 times higher total solids (TS) than the scum samples, i.e., 0.225 vs. 0.149 $g\ g^{-1}$ TS, revealing that the sludge amount impacted more significantly the grease trap capacity and operation and maintenance. In contrast, the scum samples had 1.4 times higher volatile solids (VS) than the sludge samples, i.e., 0.134 vs. 0.096 $g\ g^{-1}$ VS, matching with the 64.2 vs. 29.7% of carbon content from CHN analysis. About 2/3 of the free fatty acids (FFAs) with palmitic acids were the primary saturated FFAs, while the remaining 1/3 of unsaturated FFAs were found in the solid and liquid samples. Although up to 0.511 $g\ g^{-1}$ FOG can be extracted from the scum samples, none from the sludge samples. More diverse minerals/metals other than Na, Cl, and Ca were found in the sludge samples than in the scum samples. Grease-trap FOG solids and open drain samples exhibited similar physicochemical properties to those reported in the literature. Four potential mechanisms (crystallization, emulsification, saponification, and baffling) were presented. This work offers insights into the physicochemical properties of grease-trap wastewater that can help explore its FOG solid formation, separation, and accumulation mechanisms inside a grease trap.

1. Introduction

Fat, oil, and grease (FOG) with other waste residues from kitchen wastewater can form FOG solids and accumulate over time after entering public sewer networks (Husain et al., 2014). It costs millions of dollars yearly for many cities worldwide to remove these solids from clogged sewerage pipelines (Ducoste et al., 2009, Williams et al., 2012). Therefore, municipalities in Singapore and Malaysia mandate installing

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What is fat-oil-grease (FOG)?

Food preparation

Cleaning

Grease traps (HDPE)

@Stutong Community Market

Kitchen wastewater generated from our **daily food preparation and cleaning** contains high concentrations of fat, oil, and grease (FOG) [Husain et al., 2014].

I. A. Husain, a. F. A. Ma, M. S. Jammi, M. E. Mirghani, Z. B. Zainudin, and A. Hoda, "Problems, control, and treatment of fat, oil, and grease (FOG): a review," J. Oleo Sci., vol. 63, no. 8, pp. 747-752, 2014.

What is grease trap?

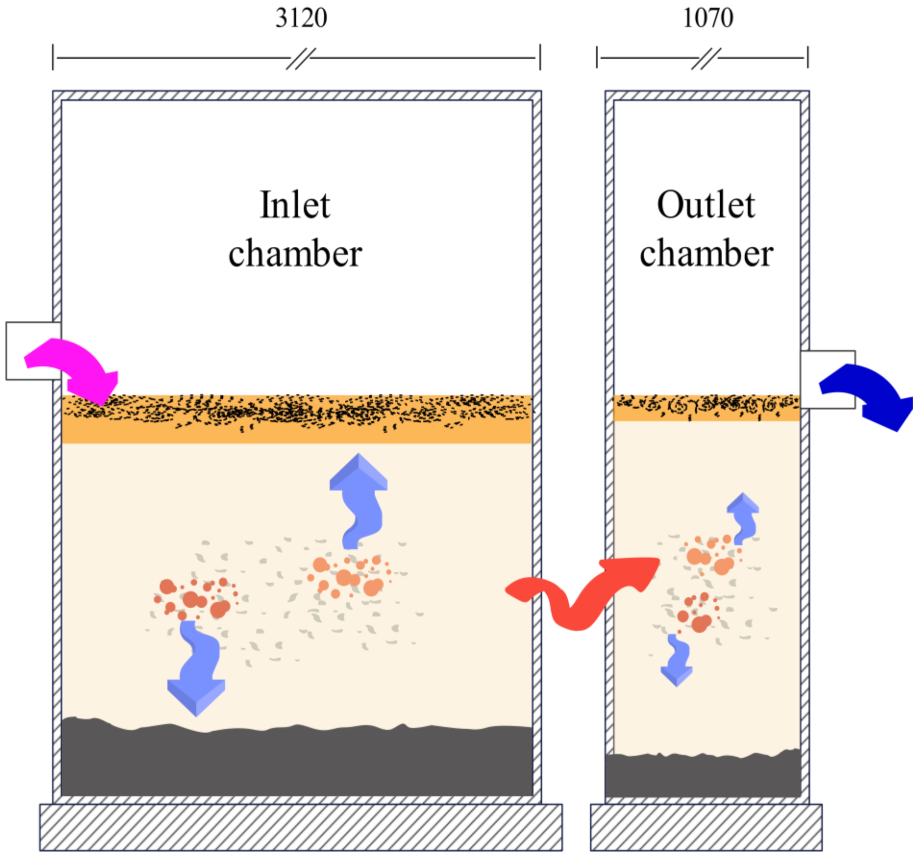

Fig. 1. Flow of grease trap wastewater from inlet to outlet chamber, with the illustration of the layer separation and the FOG solids formation and accumulation.

- Grease traps typically adopt the gravity separation principle to **separate FOG from grease trap wastewater** within a specific hydraulic retention time (HRT).
- They allow the separating of grease trap wastewater into floated scum, suspended liquid, and settled sludge at the top, middle, and bottom layers, respectively (Tang et al., 2024, Suto et al., 2006)

However, the **FOG solids formation, separation, and accumulation mechanisms** in these three layers inside grease traps are still unclear.

L. Y. Tang et al., "Physicochemical characteristics of grease-trap wastewater with different potential mechanisms of FOG solid formation, separation, and accumulation inside grease traps," Water Res., vol. 256, p. 121607, 2024/06/01/ 2024, doi: https://doi.org/10.1016/j.watres.2024.121607.
P. Suto, D. Gray, E. Larsen, and J. Hake, "Innovative anaerobic digestion investigation of fats, oils, and grease," Proc. Water Environ. Fed., vol. 22, pp. 858-879, 01/01 2006, doi: 10.2175/193864706783796853.

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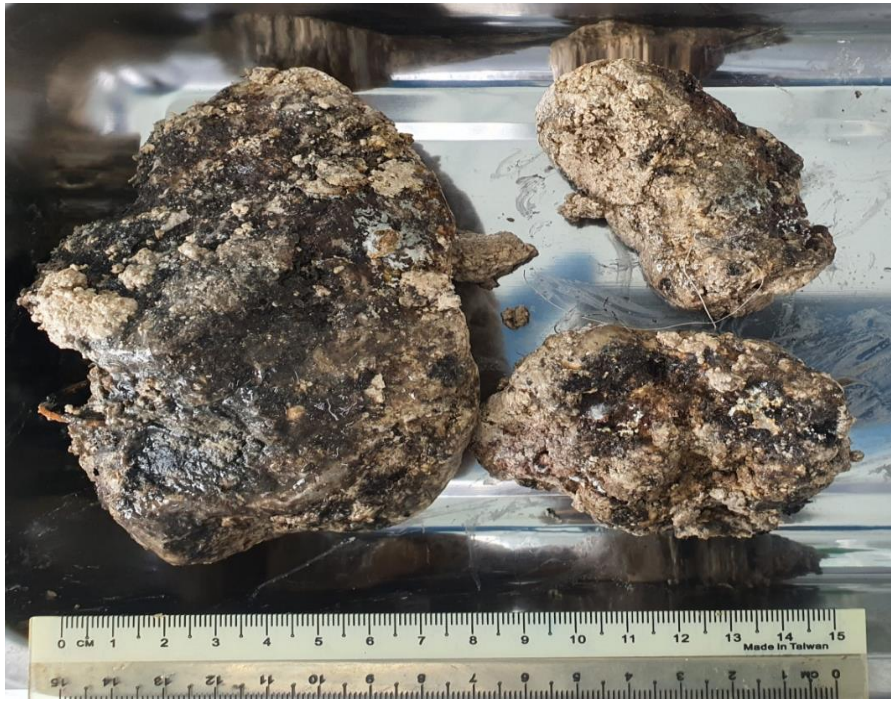
Excessive FOG in sewer resulting in FOG solids accumulation



FOG solids samples found in Kuching Kopitiam

Fatberg causes severe damage in London sewer

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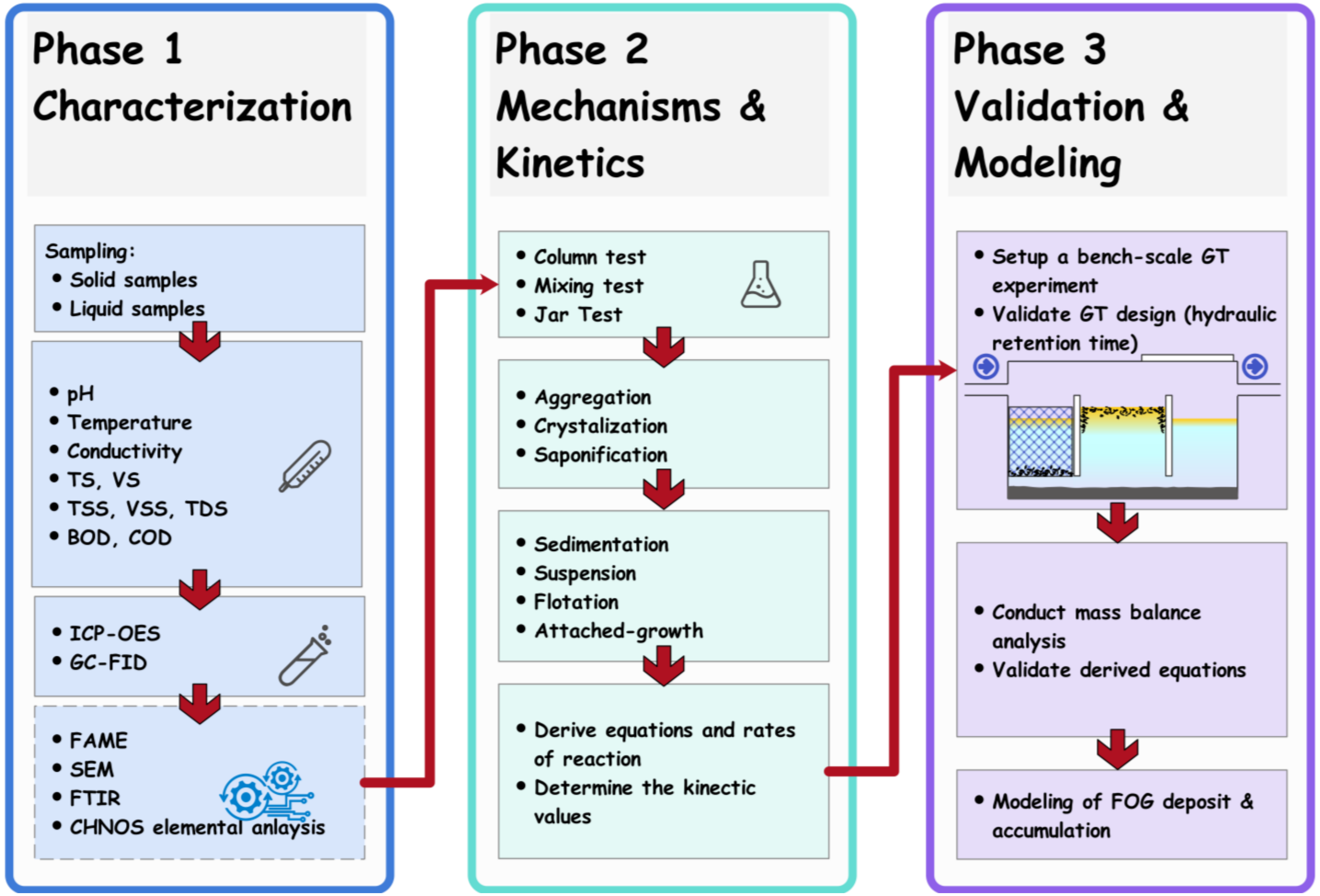
Aim & Objectives

Aim: To provide a fundamental understanding of the <u>formation, separation, and accumulation of FOG deposits and sludge</u> inside the grease traps.

Phase 1: To characterize the field grease trap wastewater, including both <u>solid and liquid samples</u>, for their physicochemical properties.

Phase 2: To conduct lab experiments to <u>investigate the formation and mechanisms</u> in the grease trap using synthetic grease trap wastewater, particularly the FOG content

Phase 3: To develop the model of the aforementioned formation and accumulation mechanisms that validated using a <u>bench-scale grease-trap setup</u>.



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Materials and methods

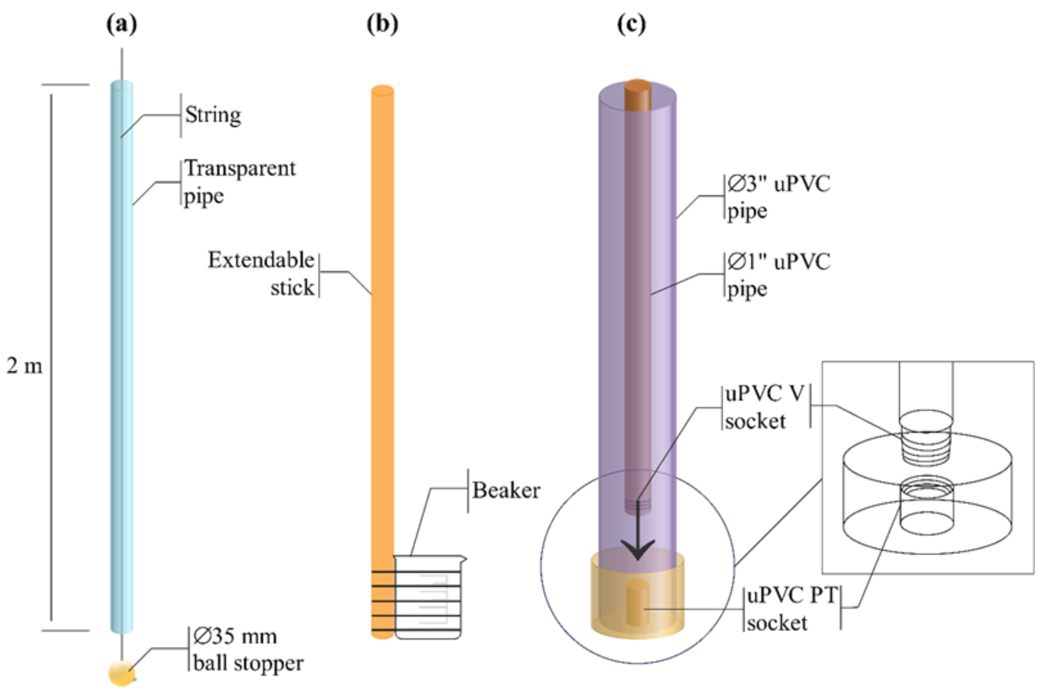


Fig. 2. Three custom-made samplers: (a) Sampler A for profiling the depths of different layers formation inside the grease traps, (b) Sampler B for collecting the floated scum samples at the top layer; (c) Sampler C for collecting the suspended solid-liquid wastewater and settled sludge samples at the middle and bottom layers, respectively.

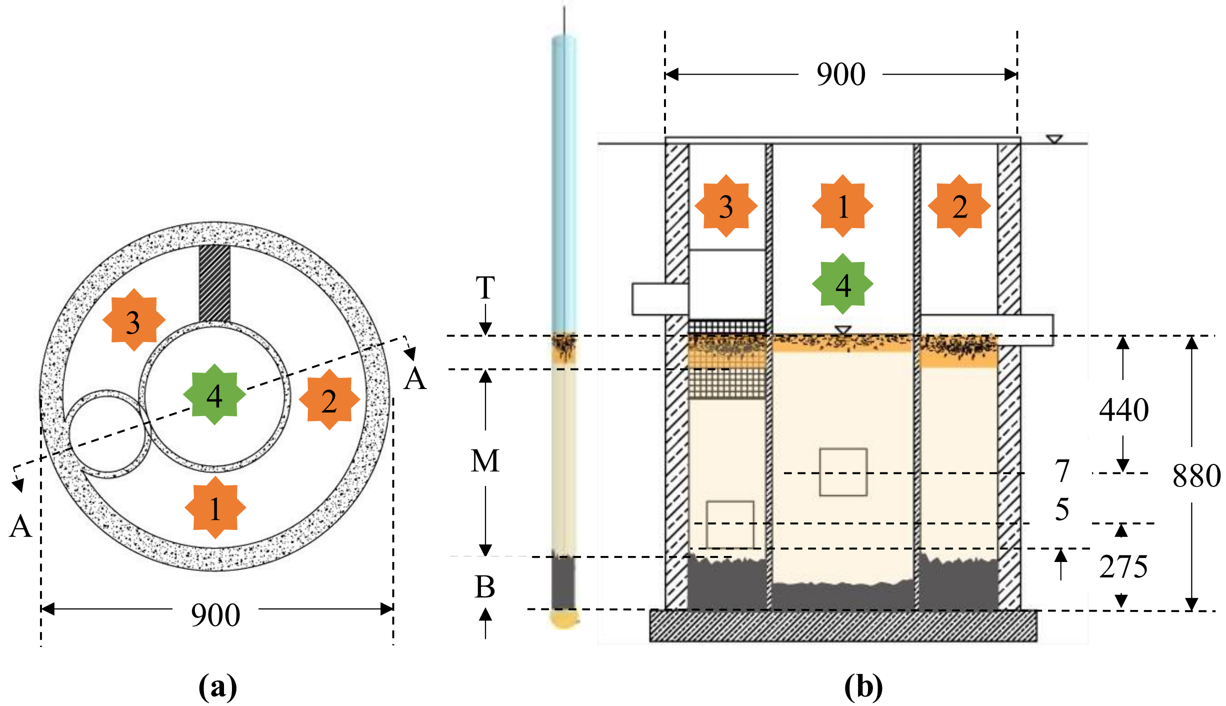


Fig. 3. Schematic diagrams illustrating (a) the Plan and (b) Section A-A views of the four chosen spots at the inlet and outlet chambers for daily monitoring and sampling using different samplers. All dimensions labeled are in mm.

Materials and methods

(a) (b) (c) (d) (e)

Fig. 4. Photographs of site investigation, including (a, b) daily monitoring and (c, d, e) sampling of grease trap wastewater.

Results and discussion

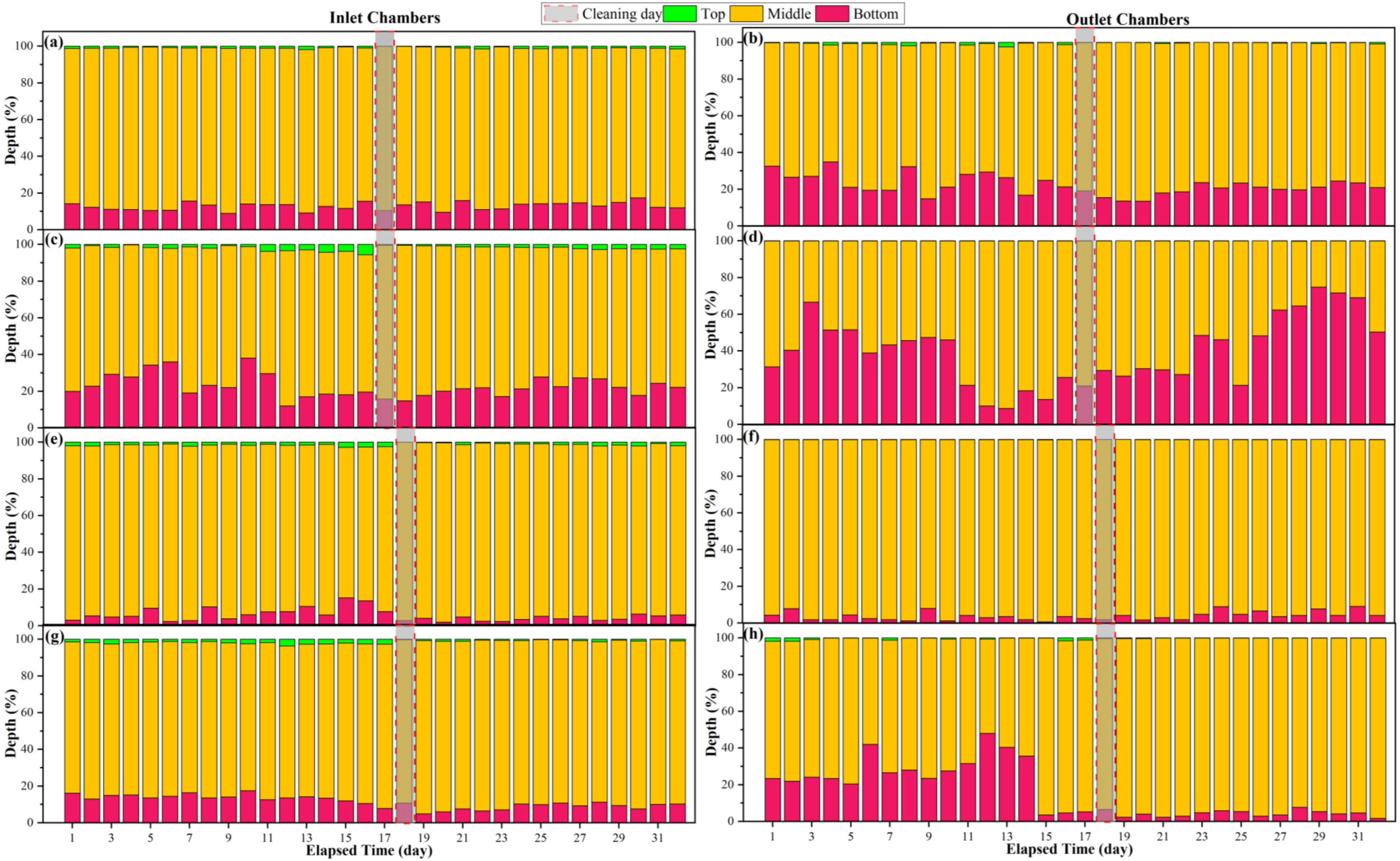
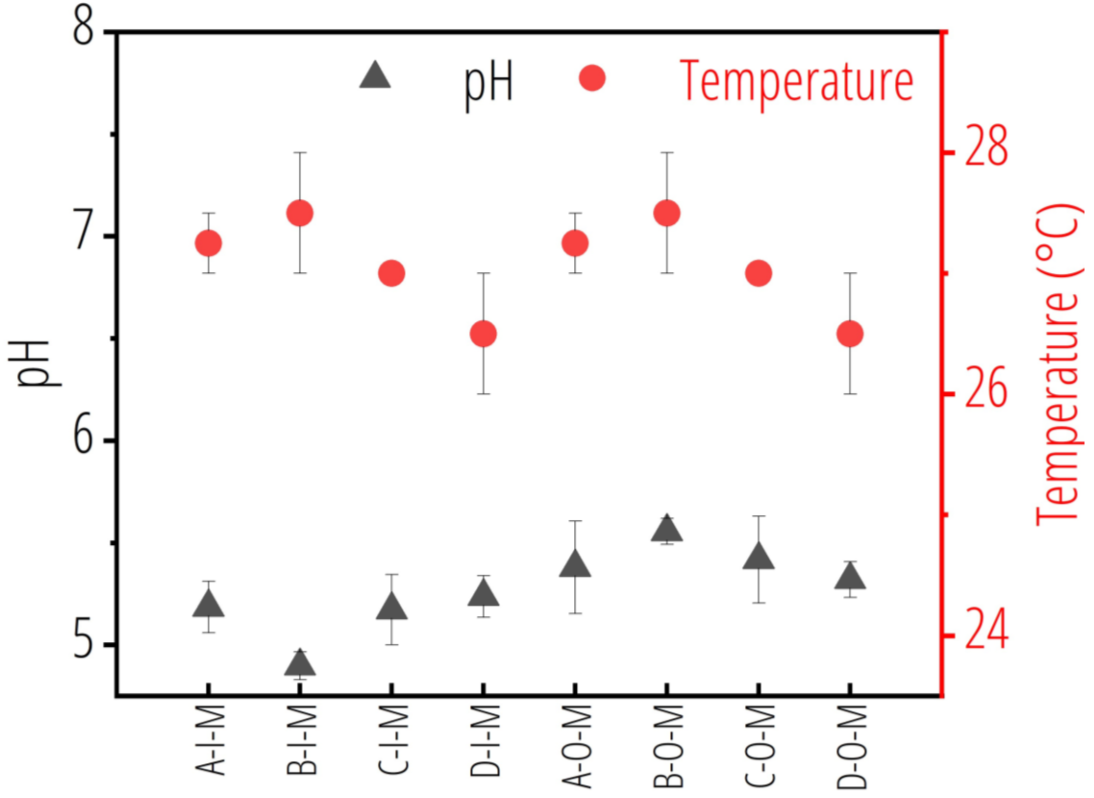


Fig. 5.
Depth composition (%) of the T, M, and B layers for Grease Traps (a,b) A, (c,d) B, (e,f) C, and (g,h) D, including those inside the inlet (I) and outlet (O) chambers and showing their cleaning days on Day 17 or 18.

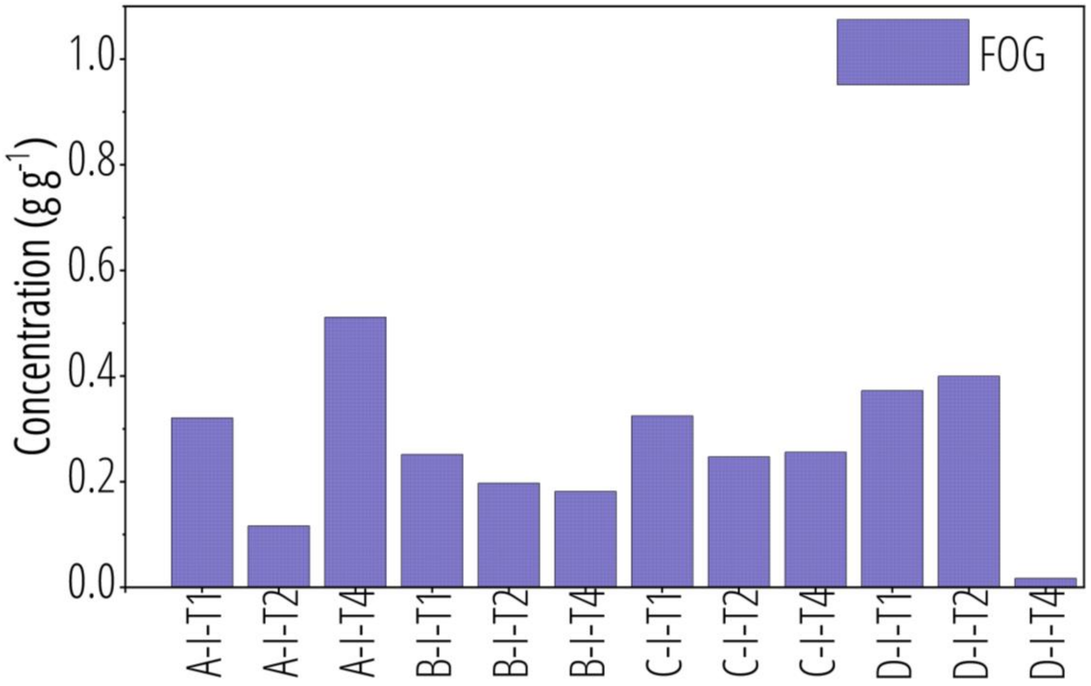
Results and discussion

(1) pH



Acidic condition (**pH 5-6** at **25-29 °C**)

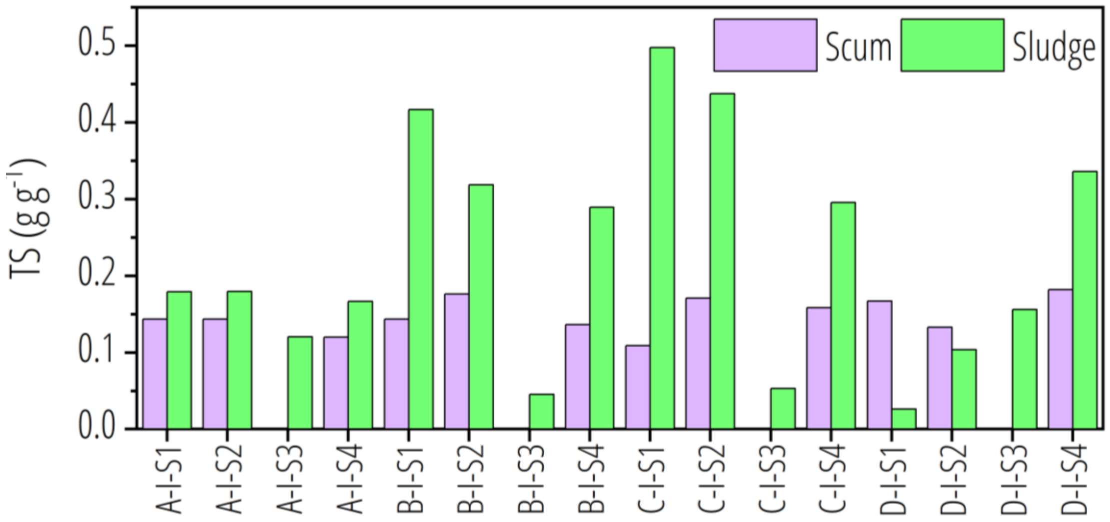
(2) FOG extraction



0.511 g g^{-1} of **FOG** can be extracted from the **top scum samples**, with an average of 0.266 g g^{-1}, but none can be extracted from the bottom sludge.

Results and discussion

(3) Total solids



<u>Bottom sludge</u> samples had **1.5 times higher solids** than the <u>top scum</u> samples, i.e., 0.225 *vs*. 0.149 g g^{-1} TS.

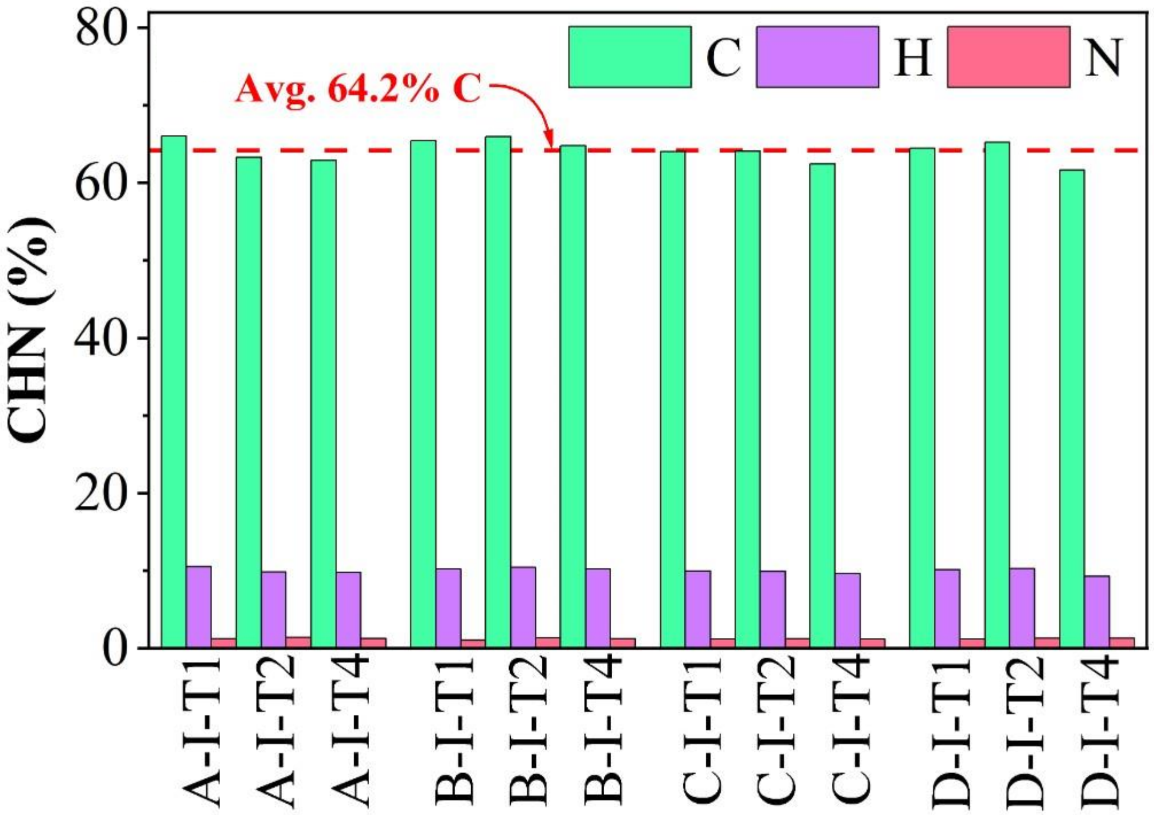
(4) Organic constituents

Parameter	Floated scum	Settled sludge
Total solids (TS), (g g^{-1})	**0.149**	0.225
Volatile solids (VS), (g g^{-1})	0.134	**0.096**
VS/TS ratio (%)	90.1	**61.9**
FOG, (g g^{-1})	0.266	**0**

<u>Bottom sludge</u> samples exhibited **1.4 times lower organic constituents**, including FOG, FOG solids, and other waste residues, <u>than the top scum samples</u>, i.e., 0.096 *vs*. 0.134 g g^{-1} VS, matching with the 61.9 *vs*. 90.1% VS/TS ratios.

Results and discussion

(5) CHN analysis

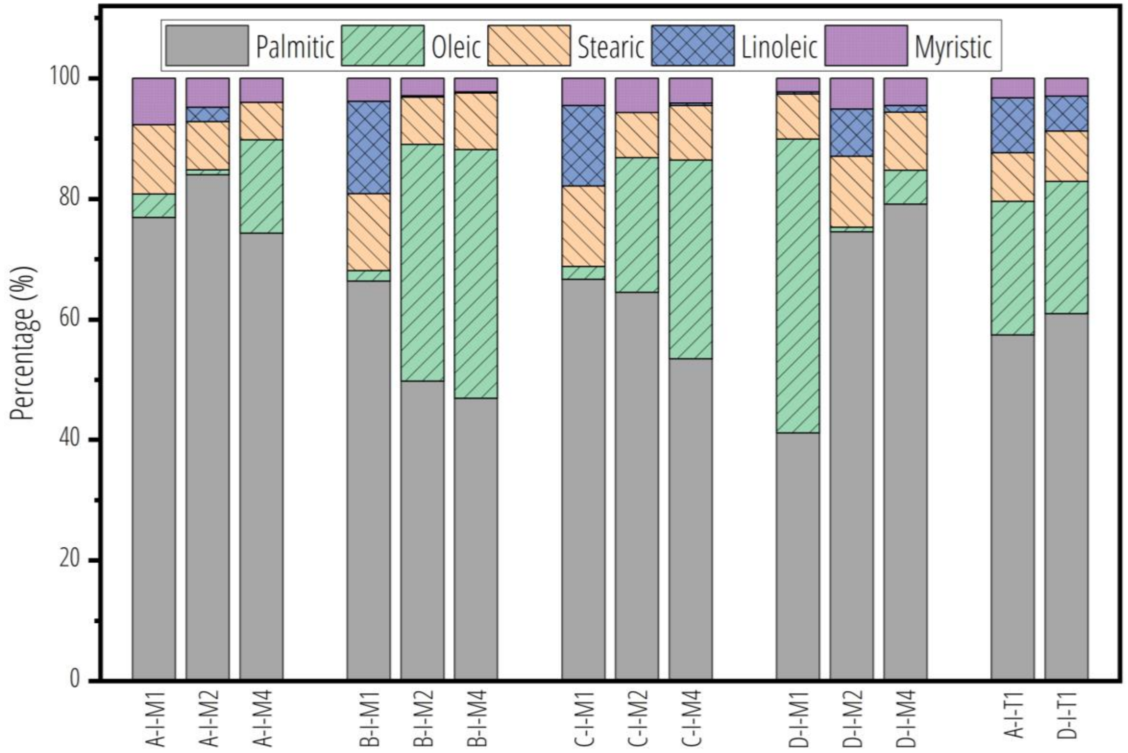


<u>Top scum</u> samples had **higher carbon (C)** with the content up to 66.1% (**64.2%** average).

Aligned with **higher organic content** in <u>top scum</u> samples with **VS/TS ratios** up to an average of **90.1%.**

Results and discussion

(6) Free fatty acids



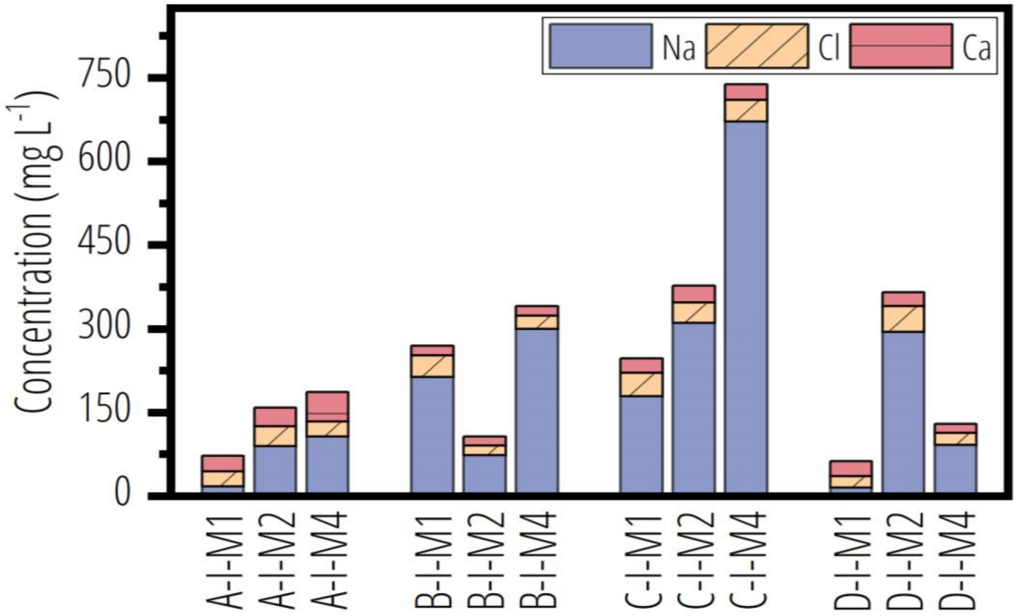
Free fatty acids	Floated scum	Suspended liquid
Oleic (%)	22	17.9
Linoleic (%)	7.45	3.44
Palmitic (%)	**59.2**	**64.8**
Stearic (%)	8.22	9.53
Saturated FFA (%)	70.5	78.6
Unsaturated FFA (%)	29.5	21.4

Saturated FFA: Palmitic and stearic acids
Unsaturated FFA: Oleic and linoleic acids

More saturated (70-80%) than unsaturated (20-30%) FFAs were found inside grease traps, with palmitic acid as the dominant FFA, comprising 59-65% of the total FFAs.

Results and discussion

(7) Metal and mineral ions



Metals and minerals	Floated scum (wt%)	Suspended liquid (wt%)	Settled sludge (wt%)
Sodium	--	**68**	--
Calcium	0.24	12	2.02
Aluminum	0.21	<1	1.59
Silica	**0.31**	--	1.54
Iron	0.02	3	**2.46**
Chloride	--	13	--

Sodium (Na, 68 wt.%), **chloride** (Cl, 13 wt.%), and **calcium** (Ca, 12 wt.%) were found to be significant ions in the suspended liquid samples, but more diverse elements (Al, Si, and Fe) were found from the settled sludge samples.

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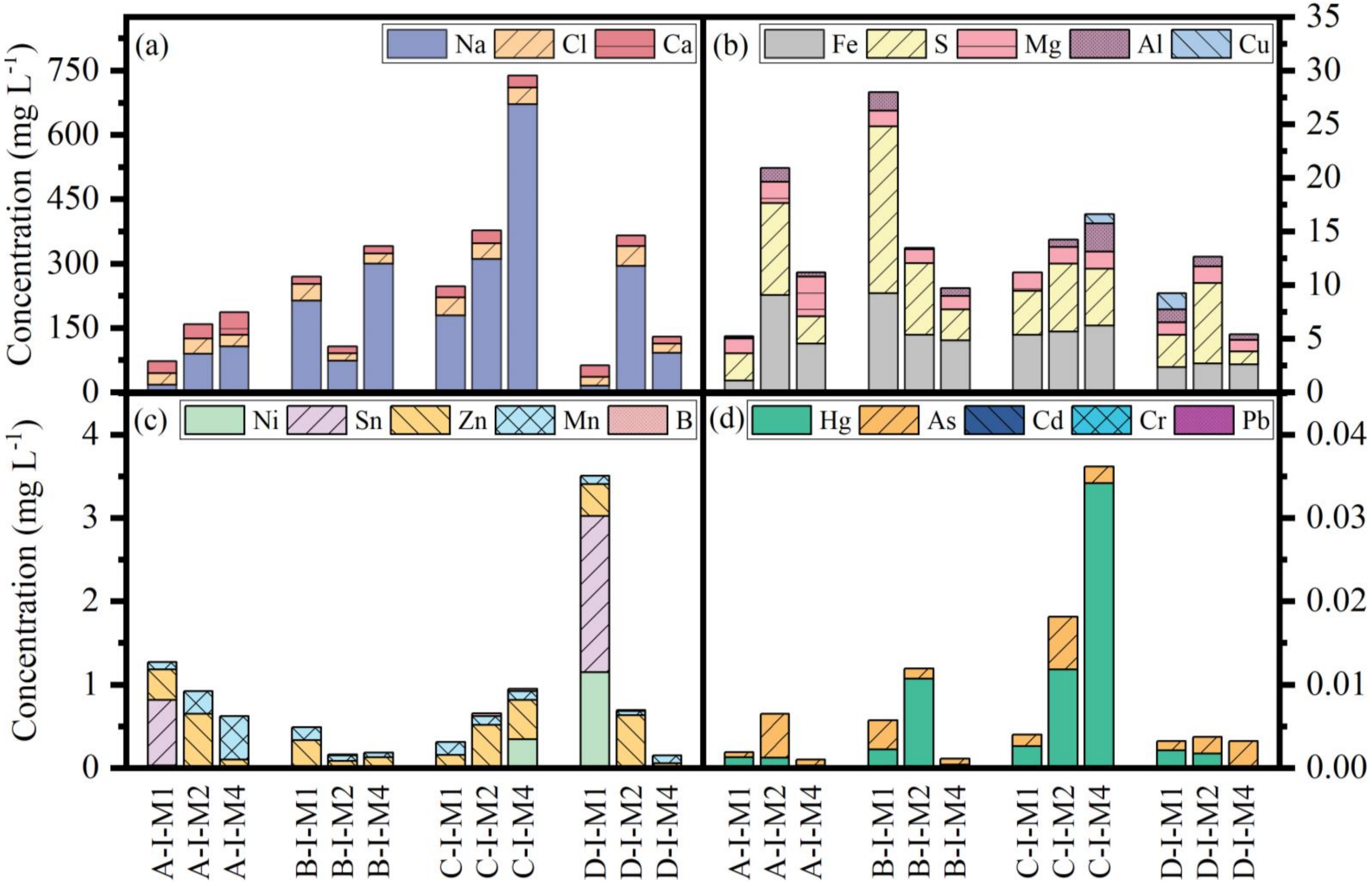
Results and discussion

(7) Metal and mineral ions (cont.)

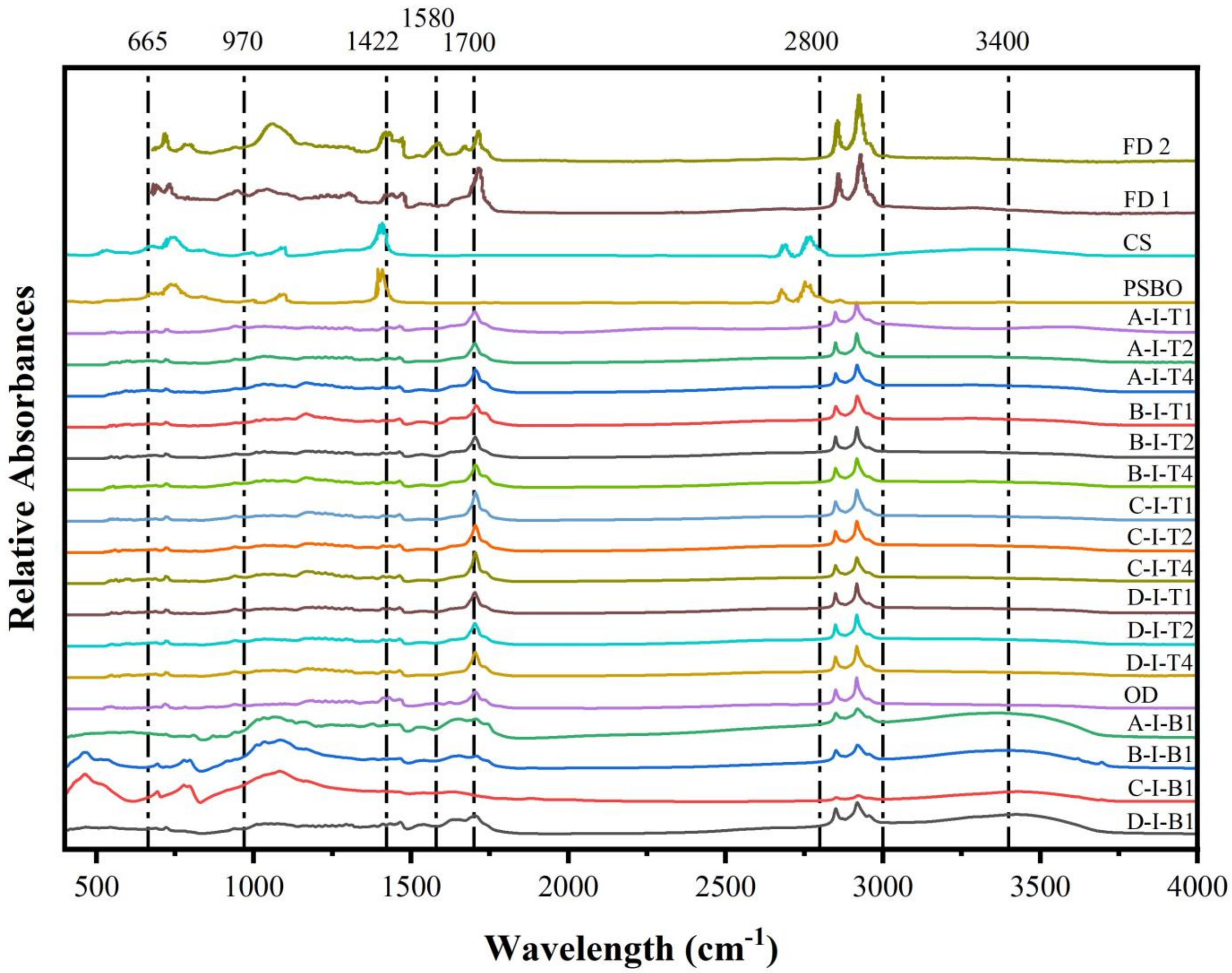
Fig. 6. Composition and concentration of primary and secondary minerals and heavy metals for the collected middle (M) layer samples from Grease Traps A to D inlet (I) chambers.



Results and discussion

(8) FTIR spectrum

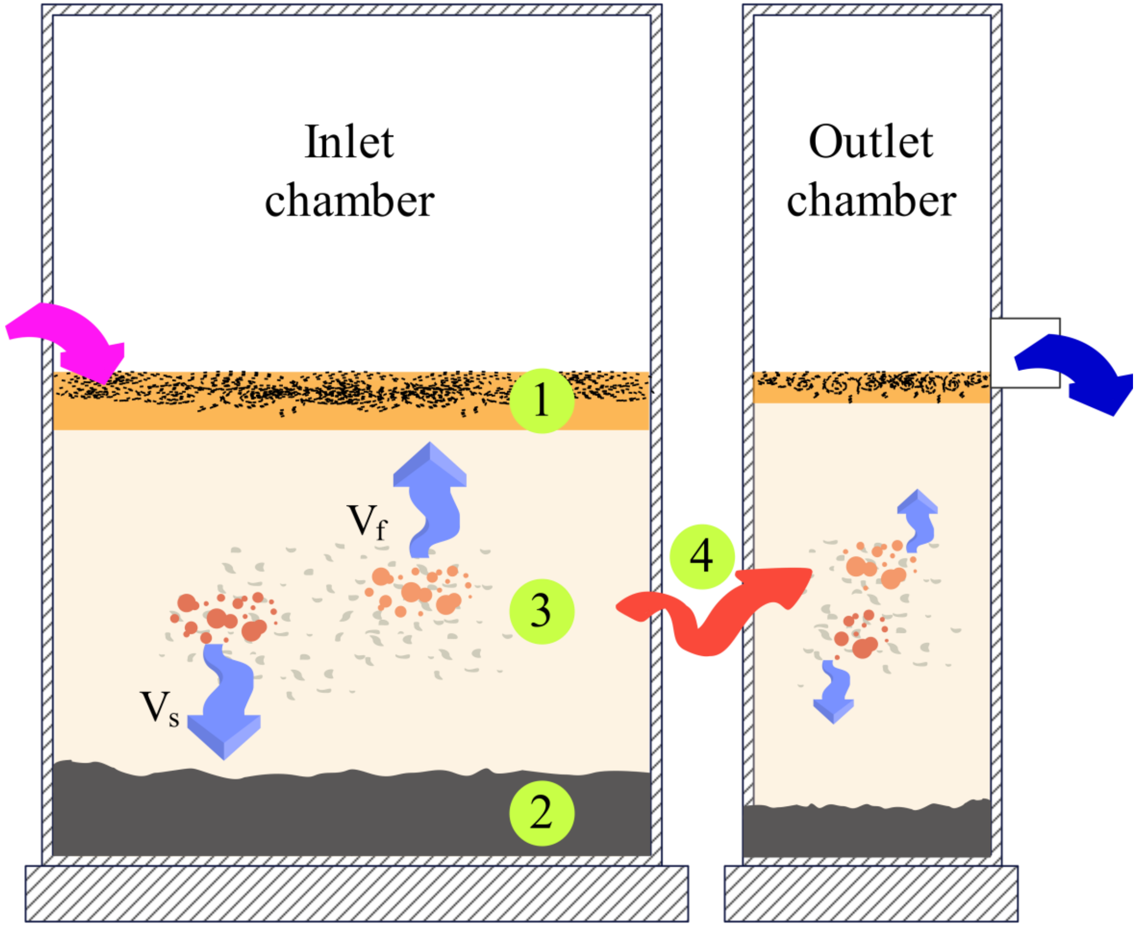
Fig. 7. FTIR spectra of the collected scum, OD, and sludge samples from Grease Traps A to D, compared to samples of FOG deposits (FD 1, FD 2), calcium soap (CS),
and pure soybean oil (PSBO) in the literature (Shin et al., 2015, He et al., 2013).



Shin, H., Han, S., Hwang, H., 2015. Analysis of the characteristics of fat, oil, and grease (FOG) deposits in sewerage systems in the case of Korea. Desalin. Water Treat. 54 (4-5), 1318–1326. https://doi.org/10.1080/19443994.2014.910141, 2015/05/01.
He, X., de los Reyes, F.L., Leming, M.L., Dean, L.O., Lappi, S.E., Ducoste, J.J., 2013. Mechanisms of Fat, Oil and Grease (FOG) deposit formation in sewer lines. Water Res 47 (13), 4451–4459. https://doi.org/10.1016/j.watres.2013.05.002, 2013/09/01/.

Results and discussion

(9) Possible mechanisms



(1) Crystallization

- Excessive FOG and FFA produces the FOG solids (scum) at the top layer

(2) Saponification

- Saponification with more minerals than FFA might have occurred at the bottom layer

(3) Emulsification

- FFA emulsification with surfactant and other colloidal particles generated during the food preparation and cleaning process yields a relatively stable suspended solid liquid wastewater in the middle layer

(4) Baffling

- Baffle walls aids in separating and retaining the scum, suspended wastewater, and sludge, preventing a significant amount of FOG, FOG solids, minerals, and other waste residues from escaping the grease trap

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Conclusion

- Kitchen wastewater is **separated into three layers inside grease traps** (i.e., floated scum, suspended solid-liquid wastewater, and settled sludge) with **different physicochemical properties**.
- Sludge samples had **1.5 times more solids** than the scum samples (i.e., 0.225 *vs.* 0.149 g g^{-1} TS), resulting in more significant impacts on the grease trap capacity (i.e., working volume and hydraulic retention time or HRT).
- **Palmitic (70 to 80% saturated)** and **oleic (20 to 30% unsaturated) acids** were the primary free fatty acids inside grease traps.
- **Sodium** (Na, 68 wt.%), **chloride** (Cl, 13 wt.%), and **calcium** (Ca, 12 wt.%) were found to be significant ions in the liquid samples, but more diverse elements (Al, Si, and Fe) were found in the sludge samples.
- **Four** potential FOG solid formation, separation, and accumulation **mechanisms** inside the grease traps were proposed, i.e., **crystallization, saponification, emulsification,** and **baffling**.

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Any questions?

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