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Orinal Article

The Assessment of the Physiochemical Treatment Systems for Confectionary Industrial Wastewater

Omama Ahmed Hussein KAMALELDIN[1]*, Mohamed ElHosseiny EL-NADI[1], Mahmoud Mohammed ABDELMOMEN[1], Amira Mohamed NAGY[1]

[1]*Department of Public Works Civil Engineering, Faculty of Engineering, Ain Shams University, Egypt.*

**Corresponding Author : omama.ahmed@yahoo.com*

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Abstract *- This study presents a comparative analysis of three physicochemical treatment units-Chemical Enhanced Sedimentation, Chemical Enhanced Flotation, and Chemical Enhanced Sand Filtration-designed for treating the highly polluted effluent from a sweets factory in the industrial zone of Cairo, Egypt. This effluent, characterized by high concentrations of sugars, organics, and suspended solids, poses significant challenges for meeting stringent national wastewater discharge standards. The treatment units were systematically evaluated using* $FeCl_3$ *at an optimal dose of 160 ppm, determined through jar testing of the target wastewater. The units were scaled to reflect the capacities of actual factory installations, ensuring practical relevance. Their performance was assessed based on the removal efficiencies of Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Chemical Oxygen Demand (COD). Among the tested units, the Chemical Enhanced Sand Filtration unit demonstrated superior performance, achieving removal efficiencies of 90.7% for TDS, 31.2% for TSS, and 61.1% for COD. These results position the Sand Filtration unit as a promising solution for confectionery wastewater treatment, enabling compliance with environmental regulations and supporting potential water reuse applications such as cleaning, cooling, or irrigation. The findings offer a practical framework for similar industries seeking sustainable and efficient wastewater management solutions.*

Keywords *- Chemical filtration, Chemical flotation, Chemical sedimentation, Sweets industry, Sweets industry sewage.*

1. Introduction

Over the past hundred years, increasing population and industrial expansion have significantly impacted ecosystems essential for human survival. Regarding the health of oceans and rivers, pollution mainly stems from the release of insufficiently treated industrial and municipal wastewater [1]. Water contamination occurs through various sources, with industrial wastewater-such as effluent from sweets manufacturing-being a significant contributor. Industrial discharge plays a major role in declining water quality in urban regions. As reported by the Food and Agriculture Organization (FAO), global freshwater withdrawals amount to 3,928 km² per year. Large-scale industries, including food and textile production, generate substantial wastewater that leads to pollution.

The release of untreated wastewater into the environment poses severe health risks, potentially causing life-threatening diseases throughout the food chain [2]. It can contaminate drinking water sources, leading to severe health issues such as gastrointestinal diseases, neurological disorders, and even cancer. According to the World Health Organization (WHO), waterborne diseases caused by contaminated water result in millions of deaths annually, highlighting the critical need for effective wastewater treatment [3].

Regulatory compliance is a critical driver for wastewater treatment to control such hazards. Many countries have stringent regulations governing the discharge of industrial effluents. Non-compliance can result in hefty fines and legal actions, which can be financially crippling for businesses [4].

Reusing wastewater presents a promising solution for preserving and enhancing existing water resources. It can serve multiple purposes, such as agricultural irrigation, aquaculture, landscaping, industrial operations, urban applications, recreational activities, environmental conservation, and groundwater replenishment. In theory, treated wastewater can substitute fresh water for nearly all uses, provided it undergoes adequate treatment or alternative safety measures [5].

The confectionery industry, which produces various sweets such as chocolate, chewing gum, and gumdrops, is both widespread and significant globally. Key raw materials for this sector include sugar, water, and other ingredients like milk, flavourings, nuts, and cereals.

Confectionery plants generate substantial volumes of wastewater that are high in readily biodegradable organic materials but low in nutrients. This wastewater can quickly deplete dissolved oxygen and harm aquatic ecosystems due to its high organic matter content when discharged into surface waters. Therefore, effective treatment technologies are essential before releasing this wastewater into the environment [6].

The sugar confectionery market in Egypt, encompassing products such as hard-boiled sweets, mints, caramels, toffees, gums, jellies, marshmallows, fudges, and medicated throat lozenges, experienced a positive Compound Annual Growth Rate (CAGR) of 13.25% from 2015 to 2020. In 2020, the market's sales value reached EGP 4,215.36 million, reflecting a 2.82% increase from 2019. Revenue in the Confectionery market amounts to US$3.02bn in 2024. The sector saw its highest growth rate of 24.05% in 2017. In the Confectionery market, volume is expected to amount to 653.10m kg by 2029. The Confectionery market is expected to show a volume growth of 2.6% in 2025.

According to Central Agency for Public Mobilization and Statistics (CAPMAS) data from 1997, derived from the 1996 census, the total number of facilities recorded was 18,842. The statistics indicate that 94% of these facilities operate with fewer than 10 employees, while only 0.9% employ more than 40 workers [7].

Recently, Egypt has taken serious steps towards regulating discharges from industrial facilities. These regulations protect the surrounding environment and population health and manage the available water resources. Our study focuses on one of the most complicated industrial effluents that result from food-related industries. Sweet factories normally use enormous amounts of sugars, chocolates and other food additives.

Table 1. Maximum allowable levels for various Parameters for wastewater disposal to sewage network [8]

Parameter	Law 48/82 Discharge into Sewer System as per Decree 44/2000
BOD5 (5 days.20 degrees) [mg/l]	<600
COD [mg/l]	<1100
pH	6-9
Total Suspended Solids (TSS) [mg/l]	60
Total Dissolved Solids (TDS) [mg/l]	2000

The Egyptian Environmental Agency issued Article 14 of Decree 44/2000 of the acceptable effluent limits for disposal to sewage network. Table 1 shows the maximum allowable levels for various Parameters for wastewater disposal to sewage network [8].

The available technologies adopted in similar studies are mostly technically complicated options installed mainly in big factories or research centers. It can be found that in 2022, Fayza A. Nasr studied the management of wastewater generated from a confectionery factory located in El Obour City, Egypt. The factory produces confectionery products and chocolates. The effluent wastewater had a high pollution load with an average COD of 5396 mg/L, BOD5 of 2526 mg/L and TSS of 908 mg/L. Conventional activated sludge and UASB were separately investigated as treatment technologies. Continuous activated sludge operated at 9.3kg COD/m^3.d and a temperature range of 20-35 ºC showed good effluent quality with removal efficiencies of 96%, 96% and 98% for COD, BOD5 and TSS, respectively.

The two-stage UASB reactor working at a COD loading rate of 4.7 kg COD/m^3.d and the same temperature range, showed averages of removal of 82%, 81% and 95% of COD, BOD and TSS and, respectively, produced effluent complying with regulatory standards [9]. This example shows that the high quality of the treated effluent is associated with a highly technological solution that is not the most economically effective solution for other small-scale factories like the one featured in this study.

Also, in 2000, G. El Diwani designed, constructed, and installed a pilot plant for the continuous treatment in the National Research Center of 250 liters per day of wastewater originating from a gum and confectionery factory. The plant featured primary components, including an equalization tank, chemical mixing tank, aerator, clarifier, disinfectant tank, and sand filter, along with supporting equipment such as centrifugal and dosing pumps, an air blower, and a pH controller. An industrial-scale unit was developed to manage 50 m^3/day of combined industrial and municipal wastewater containing high concentrations of organic and biologically resistant pollutants. The influent to the pilot scale had an average COD, BOD, and TSS of 5000, 3200, and 5563 mg/L, respectively. On the other hand, the industrial scale had COD, BOD, and TSS of 5000, 3500, and 200, respectively [10]. The removal efficiencies of both the pilot and industrial scales are shown in Table 2.

Table 2. The pilot and industrial scale removal efficiencies [10]

Scale	BOD (%)	COD (%)	TSS (%)
Pilot plant scale	97.8	98.9	89.2
Industrial scale	99.17	98.6	95.0

Multiple studies were done on an international scale. It can be found in a study by Vanterkar [11] that various coagulants, including lime, alum, ferrous sulfate, and ferric chloride, were tested alongside different polyelectrolytes in sweets industry wastewater treatment.

The combinations examined were lime at 200 mg/L with the anionic synthetic polyelectrolyte Magnafloc E-207, lime at 200 mg/L with the nonionic synthetic polyelectrolyte Zetag 7650, and lime at 300 mg/L with the cationic synthetic polyelectrolyte Oxyfloc FL-11. The results revealed that using 0.3 mg/L Magnafloc E-207 with an optimal lime dosage of 200 mg/L was particularly effective, achieving reductions in COD by 67.6% and BOD by 71.0%.

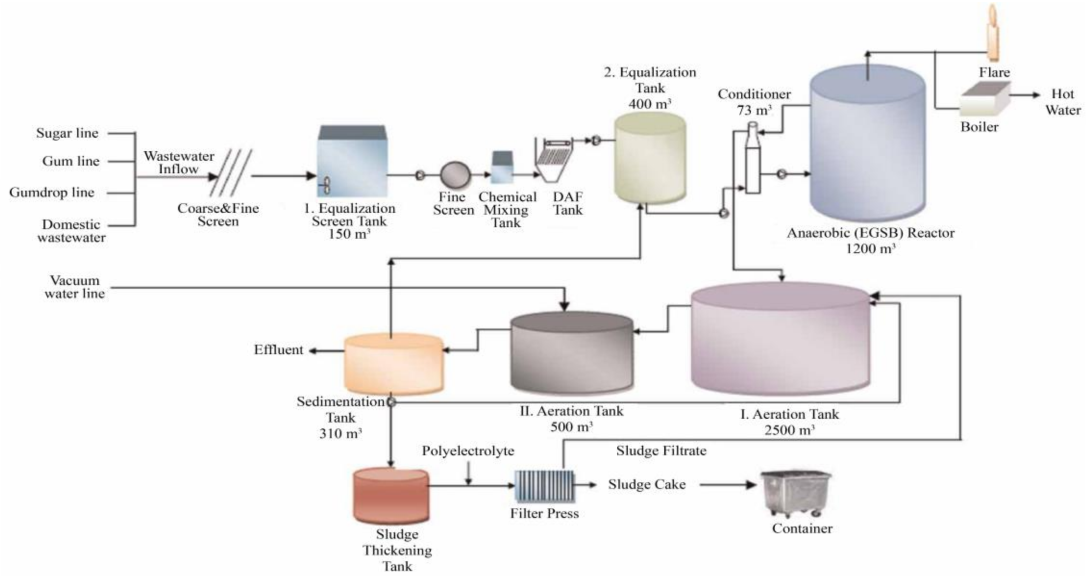

Fig. 1 Flow line of the main wastewater streams in the treatment layout [6]

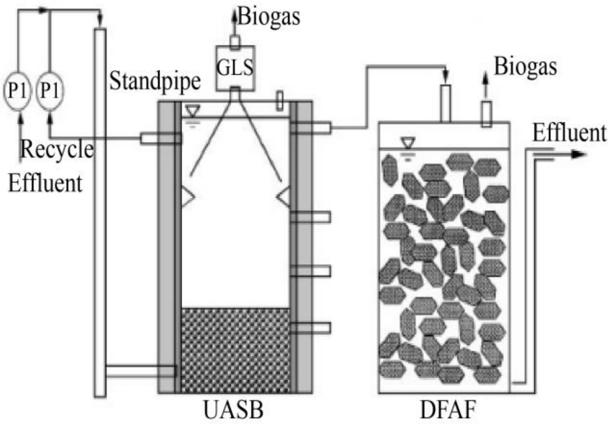

Fig. 2 Schematic of the experimental system [12]

In 2012, a highly polluted wastewater from the Mondelez factory in Turkey that produces chocolate, chewing gums and gumdrops was treated by H. Ozgun with two-step treatment where Anaerobic Expanded Granular Sludge Bed (EGSB) was used as pretreatment, then conventional aerobic activated sludge unit. The factory that generates nearly 170,000 m3/year faced nutrient deficiency in the wastewater influent, which led to the introduction of H_3PO_4 as an external nutrient. The figure below shows the process flow diagram of the implemented treatment units. The results showed COD removal efficiency in EGSB that reached 98% at HRT= 6.2 day, organic loading rate= 10-30 Kg COD/m^3.d. The activated sludge unit with F/M ratio = 0.07 Kg BOD5/KgVss.d, HRT= 4.9 days and SRT= 22 days showed 95% COD removal efficiency with overall 97% COD removal efficiency of the total treatment facility [6].

Lastly, Lara J. Beal and D. Raj investigated a bench scale, two reactors, and a sequential anaerobic treatment system to treat confectionary wastewater. The reactor consists of a 20l Up-flow Anaerobic Sludge Blanket (UASB) with HRT= 1.6 days that operates at 35^0C, with 30% of the reactor volume being granular bacteria from another operating UASB reactor to make the treatment come in line easily. This was followed by a 25l Down Flow Anaerobic Filter (DFAF) with HRT= 0.8 day and operates at 25^0C. Figure 2 shows the process flow diagram of the proposed bench-scale reactor.

The system with HRT=2.4 days showed overall COD removal efficiency of 99%, where UASB treated 98% of the 12.5 kg/m3/d organic loading rate, and 50% COD removal efficiency accounted for the DFAF unit. The system was able to reduce COD from 30 to 0.3 g/l. While not yet dischargeable, this 0.3 g/l waste would be far more amenable to aerobic treatment than the raw wastewater. Although the previous national and international studies showed very promising results regarding treatment efficiencies, they mostly neglect the economic and operational factors, especially when it comes to small-scale factories that lack the technically aware labor and the financial capability of such complicated treatment systems [12].

Therefore, neglecting research into wastewater treatment for the confectionery industry, especially for small to medium factories that represent the higher percentage when we speak about food-related industries, has critical health, environmental, social, and economic implications. On the one hand, health risks include waterborne diseases caused by contaminants in untreated wastewater infiltrating drinking water sources [13]. On the other hand, environmentally, wastewater discharge contributes to eutrophication and biodiversity loss, while persistent pollutants degrade soil and groundwater quality [14]. Finally, Socially, nearby communities face deteriorating living conditions due to odor and water pollution, eroding trust in industrial operations [15]. Economically, untreated wastewater leads to regulatory fines, higher operational costs, and missed opportunities for resource recovery, such as water reuse or biogas production. The following Table shows a comparison of different treatment technologies [5].

Table 3. Advantages and disadvantages of different treatment technologies to be used in sweets factories wastewater [16, 17, 18]

Treatment Technology	Advantages	Disadvantages
Biological Aerobic	- Highly effective for degrading organic pollutants. - Produces stable sludge with lower volumes. - Well-established and cost-effective for treating high BOD/COD effluent. - Lower operational cost per unit volume compared to some advanced processes.	- Requires significant energy consumption for aeration, leading to high operational costs. - Sensitive to fluctuations in wastewater composition, requiring skilled operators. - Long retention times required, increasing the space and infrastructure needs.
Biological Anaerobic	- Lower energy requirements compared to aerobic processes, reducing operational costs. - Produces biogas (methane) as a by-product, which can be used for energy recovery. - More effective for high-strength organic wastewater.	- Slow reaction times, requiring long retention periods. - Ineffective for removing nitrogen and phosphorus. - Requires stable temperature and pH conditions, requiring additional monitoring and control systems. - High capital costs for reactor construction and system maintenance.
Physiochemical Processes	Effective for removing suspended solids, oils, fats, and fine particles (e.g., through filtration, sedimentation, flotation). - Can be used as a pretreatment to reduce load on biological systems, enhancing overall system efficiency. - Simple to operate with relatively low maintenance compared to biological systems. -In treatments such as Filtration, different straining actions help increase efficiency. 1. Mechanical straining traps larger particles, 2. Interception captures particles close to filter grains. 3. Sedimentation allows denser particles to settle due to gravity. Diffusion captures very small particles through random motion. 4. Adhesion sees colloidal particles sticking to sand grains, improving filtration quality. 5. Electrolytic action enhances attachment due to opposite electrical charges on particles and sand grains. 6. Lastly, biological activities involve microorganisms consuming suspended and dissolved organic matter, reducing COD [17]. These mechanisms collectively ensure high TSS removal, moderate TDS removal, and substantial COD reduction, aligning with theoretical expectations and previous experiences.	- High chemical costs, particularly for coagulants and flocculants used in flotation, leading to increased operational costs. - May not remove dissolved organic pollutants or nutrients, requiring additional treatments. -May Require energy consumption for mixing, leading to an increase in the operational costs.

The selection of physicochemical treatment systems, such as filtration, sedimentation, and flotation, for this research, was based on their ease of operation, simplicity, cost-effectiveness, and minimal need for skilled labor. These processes are straightforward to manage, requiring less technical expertise compared to biological systems, as they rely on simple mechanisms like gravity or physical separation. Additionally, physicochemical treatments are more cost-effective, with lower capital and operational costs than advanced biological methods. Their simplicity allows for operation with basic training, reducing the need for highly skilled labor. Given these advantages, physicochemical treatments are considered an ideal choice for wastewater treatment in industries like confectionery, where cost-efficiency and ease of use are essential [18].

Conducting research enables the development of optimized treatment processes that mitigate these risks. Effective methods safeguard public health by reducing waterborne diseases and improving drinking water quality [13]. Environmentally, treatment minimizes pollution and protects aquatic ecosystems and biodiversity [19]. Socially, it enhances community well-being, fostering trust and collaboration between industries and nearby populations. Economically, advancements in treatment technology reduce costs and improve sustainability, supporting. industrial competitiveness while achieving compliance with global water management goals [19].

The pilot units were designed and constructed to improve the existing treatment plant at the factory under study. Laboratory-scale reactors were developed to simulate various physio-chemical processes for treating wastewater from confectionery factories. The objective was to identify the most effective treatment approach based on the required effluent quality, ensuring compliance with national regulations for safe discharge.

2. Materials and Methods

The pilot was located at the sanitary and environmental engineering laboratory of the engineering faculty at Ain Shams University. Each unit is designed in accordance with the Egyptian Code for Design of Wastewater Treatment Plants and other international references [20]. The wastewater used in this study was collected from El-Horria Sweets Factory, 10th of Ramadan City, Cairo, Egypt. The collection process was from the main wastewater sump, and it was done at the end of the shift during the cleaning process to ensure where the highest organics and suspended solids load.

A jar test for the ferric chloride optimum dosing was made, where a solution was prepared from a liquid ferric chloride of 40% purity. Different doses were added to a pH-adjusted water sample, followed by flash mixing for 1 minute at 200 rpm and gentle mixing for 10 minutes. After a 5-minute sedimentation period, samples for each jar were tested for TSS removal efficiency. The results showed that a dose of 160 mg/l is the optimum dose for such wastewater.

The setting up of the Pilots consists of one common chemical preparation where a $FeCl_3$ dose of 160 mg/l was added and flash mixing with a float valve to ensure constant head and triple connection to the three treatment units, each with a control valve to adjust the flow to the connected unit. The Floatation unit was designed on 10 l/s, with a retention time of 20 minutes, and was 7.6 cm in diameter and 25 cm in depth. Figure 3 shows the Floatation unit with inlet and outlet pipe arrangement and dimensions.

The Sedimentation unit was designed on 5 l/s with a retention time of 3.2 hours, 10 cm diameter, and 25 cm depth. Figure 4 shows the sedimentation unit with inlet and outlet pipes arrangement and dimensions. The Sand Filtration unit was designed to operate at a flow rate of 15 L/s, with a diameter of 7.6 cm and a depth of 100 cm, functioning for 8 hours daily. Figure 5 illustrates the filtration unit, including the arrangement of inlet and outlet pipes, material layers, and dimensions. The sand used in the filter has an effective particle size of 0.25–0.35 mm, as specified by the Egyptian Code, ensuring efficient filtration. Additionally, gravel with particle sizes ranging from 3 to 60 mm is a support layer, preventing sand from being washed out with the treated effluent.

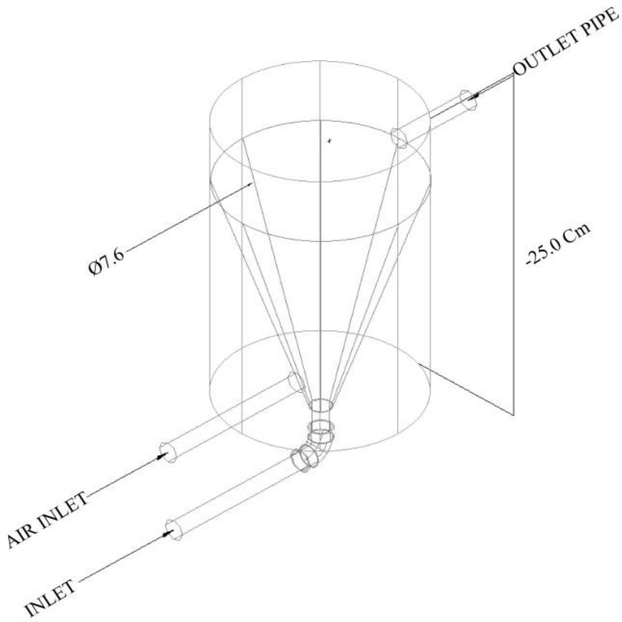

Fig. 3 Floatation unit arrangement and dimensions

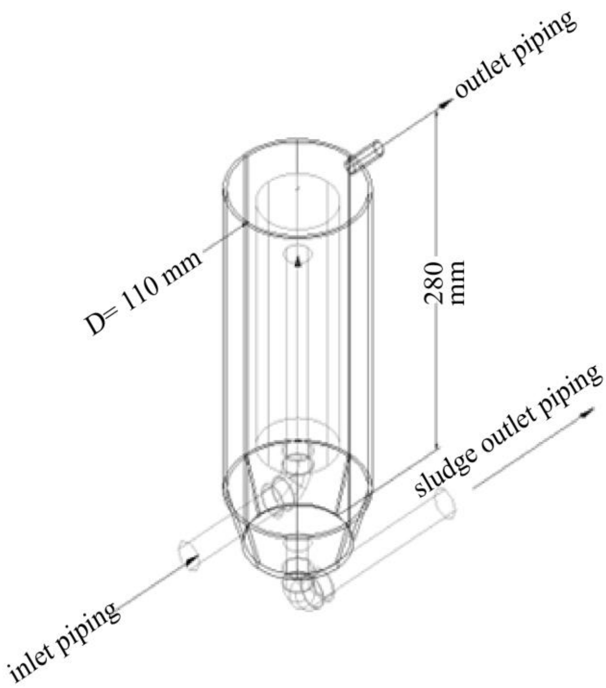

Fig. 4 Sedimentation unit arrangement and dimensions

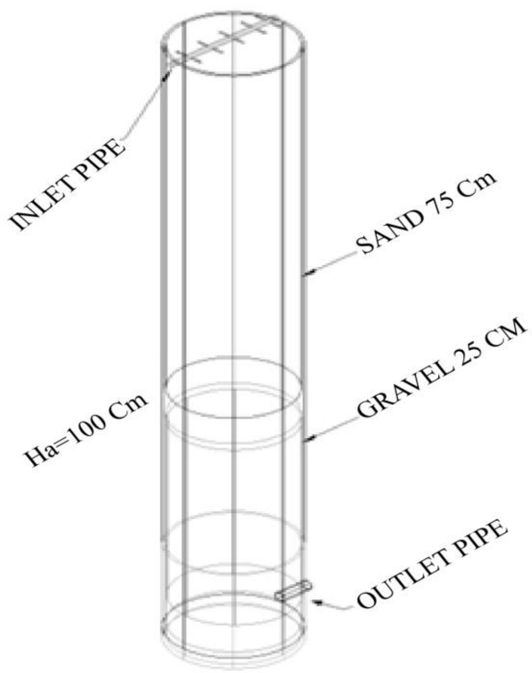

Fig. 5 Filtration unit arrangement and dimensions

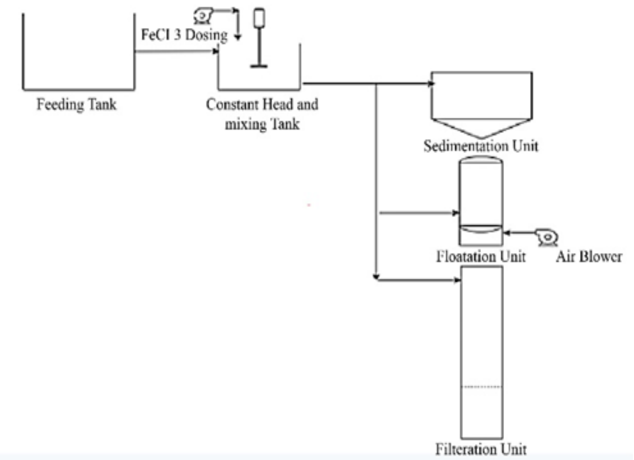

Fig. 6 Process flow diagram of the Treatment Units with the supporting units

Fig. 7 The three treatment units with the supporting units

Figures 6 and 7 show the whole experiment with the three pilots:

1. Floatation,
2. Sedimentation,
3. Filtration, along with supporting units,
4. Constant Head and Chemical Mixing Tank, and
5. Feeding Tank.

The experimental work took three weeks. The operating Physicochemical units with the raw wastewater had a continuous flow operation scheme where each unit operated as a single treatment line; all three units ran simultaneously and with the same influent wastewater. This work is targeted to determine the removal efficiency of each type of treatment against the studied raw sweets industry wastewater. The feeding tank is adjusted to distribute the flow to the coagulation and flocculation unit, and then the flow is divided into the three physical treatment lines.

Samples were taken with a frequency of 4 days per week from Sunday to Wednesday, and it was collected and analyzed directly at the faculty laboratory. Measurements and calculations for the water quality analysis are done for each sample for the following parameters: Dissolved Oxygen (DO), pH value, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD). The sampling location for each unit is at the inlet and the outlet of the unit. All measurements were measured according to the standard method for examination of water and wastewater [21] at the central laboratory of the Holding company for water and wastewater.

3. Results and Discussion

The raw water was analyzed after being freshly collected from the factory mentioned in the study at the beginning of each working week to be used in the study experiment to determine the treatment effectiveness. The results of each week’s raw water are reported in Table 4. The experiment run lasts 3 weeks for each treatment unit, all in parallel. The experimental results for each treatment unit are illustrated in Tables 5 to 7.

3.1. TSS Results Discussion

Table 5 and Figure 8 present the results of the removal ratio of TSS of each unit as follows: Floatation, Sedimentation and Filtration, respectively.

The flotation units demonstrated a TSS removal efficiency ranging from 44.4% to 66.3%. The lab scale setup’s low height-to-area ratio resulted in higher turbulence, impacting the flotation process efficiency, yet it managed an average TSS removal of 52.5%. In comparison, the sedimentation units showed a higher TSS removal efficiency, ranging from 57.9% to 81.1%, averaging 69.5%.

This improved performance can be attributed to the chemically assisted sedimentation process, which enhances particle size and facilitates precipitation. The filtration units outperformed both, with a TSS removal efficiency ranging from 72.9% to 91.8%, thanks to multiple filtration mechanisms, including mechanical straining and biological activities, which collectively resulted in superior TSS removal.

Table 4. Raw water quality

Date		Parameters				
		pH	**TSS [mg/l]**	**TDS [mg/l]**	**COD [mg/l]**	**DO [mg/l]**
Week 1	Day 1	2.44	380	2230	5086	1.1
Week 2	Day 5	3.35	460	2320	7850	0.7
Week 3	Day 9	3.21	410	2290	7680	0.7

Table 5. Removal efficiencies for TSS run one

Date		Floatation	Sedimentation	Filtration
Week 1	Day 1	49.5	55.3	88.2
	Day 2	60.8	57.4	93.3
	Day 3	65.8	60.3	92.4
	Day 4	66.8	63.4	93.7
Week 2	Day 5	54.1	73.7	87.4
	Day 6	49.8	74.1	89.8
	Day 7	45.2	75.4	90.9
	Day 8	46.7	75.7	90.7
Week 3	Day 9	42.2	75.4	87.8
	Day 10	46.3	76.1	90.2
	Day 11	48.8	78.0	90.7
	Day 12	50.2	78.5	91.7
Average		**52.2**	**70.3**	**90.6**
Avg. last week		**46.9**	**70.3**	**90.1**

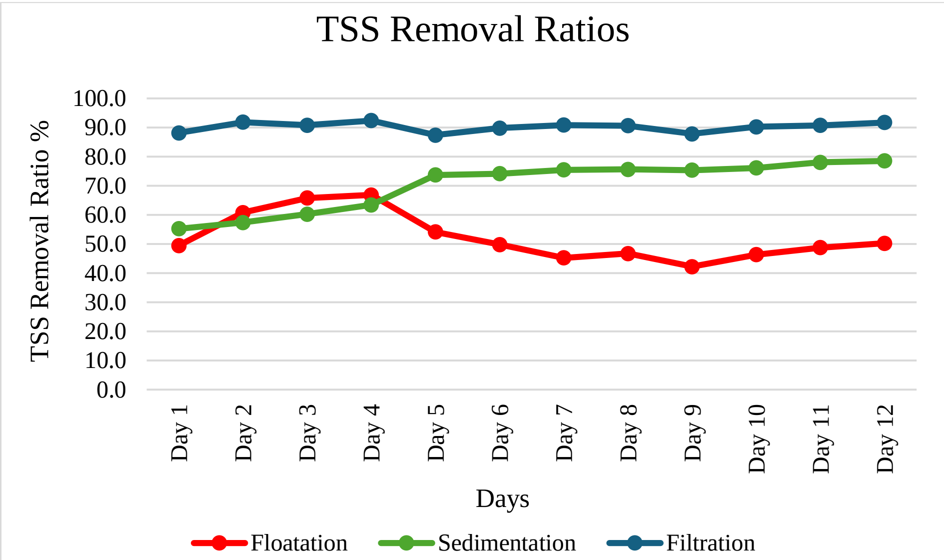

Fig. 8 TSS removal efficiency for Run One

While variation in values for TSS removal in the Floatation unit was high in the first week and then decreased in last 2 weeks, in contrast, the Sedimentation unit variation was opposite, and this can be interpreted as the effect of pH and DO changes of each wastewater patch at high pH the formed particles from the chemical reaction with $FeCl_3$ tend to be more settable than floatable, this is why sedimentation unit removal is better in last two weeks while floatation unit is better in first week.

The Filtration unit is not affected by the nature of the particles, whether settleable or floatable, as all particles get trapped by different straining actions of the filtration unit. The filtration unit results can be compared to El-Diwani [10]. Studies results with 89.25 TSS removal ensuring the effectiveness of our system although it is much simpler technically and operationally compared to El Diwani's system.

3.2. TDS Results Discussion

Table 6 and Figure 9 present the results of the removal ratio of TDS of each phase one unit as follows: Floatation, Sedimentation and Filtration, respectively.Regarding TDS removal, flotation units exhibited low efficiency, with removal rates ranging from 11.7% to 64%, averaging 23.4%. This lower efficiency is due to the lab scale setup's design limitations and turbulence. Sedimentation units showed slightly better performance, with TDS removal efficiencies ranging from 13.7% to 44.23%, averaging 29.0%. The chemically assisted sedimentation process and using $FeCl_3$ helped oxidise part of the dissolved solids, thus improving TDS removal. Filtration units displayed a moderate range of TDS removal efficiency from 17.3% to 64.1%, benefiting from various filtration mechanisms that help reduce dissolved solids to an average of 40.7%, making it the most effective among the three treatment units for TDS removal.

Table 6. Removal Efficiencies for TDS Run One

Date		Floatation	Sedimentation	Filtration
Week 1	Day 1	11.7	13.7	17.3
	Day 2	30.0	30.8	37.9
	Day 3	36.3	40.8	45.7
	Day 4	40.6	44.2	51.6
Week 2	Day 5	13.4	20.2	22.8
	Day 6	21.9	24.8	27.8
	Day 7	24.1	28.4	31.3
	Day 8	27.6	32.2	32.5
Week 3	Day 9	12.7	21.8	31.0
	Day 10	13.2	21.4	31.8
	Day 11	15.2	24.2	33.6
	Day 12	17.1	26.2	35.9
Average		**22.0**	**27.4**	**33.3**
Avg. last week		**14.6**	**23.4**	**33.1**

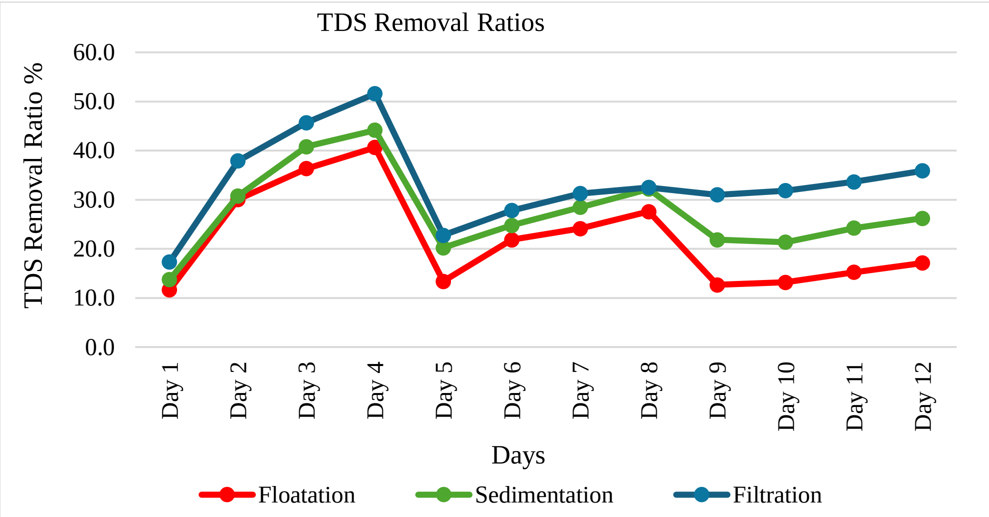

Fig. 9 TDS removal efficiency for run one

Table 7. Removal efficiencies for COD run one

Date		Floatation	Sedimentation	Filtration
Week 1	Day 1	39.6	40.9	89.1
	Day 2	53.8	47.3	90.4
	Day 3	57.8	52.4	86.5
	Day 4	62.4	59.3	85.9
Week 2	Day 5	39.0	55.3	82.9
	Day 6	42.4	57.2	84.2
	Day 7	42.6	60.2	85.4
	Day 8	52.3	66.9	84.0
Week 3	Day 9	38.7	53.0	85.1
	Day 10	40.8	56.3	84.6
	Day 11	40.0	60.1	85.3
	Day 12	40.2	60.2	86.0
Average		**45.8**	**55.7**	**85.8**
Avg. last week		**39.9**	**57.4**	**85.3**

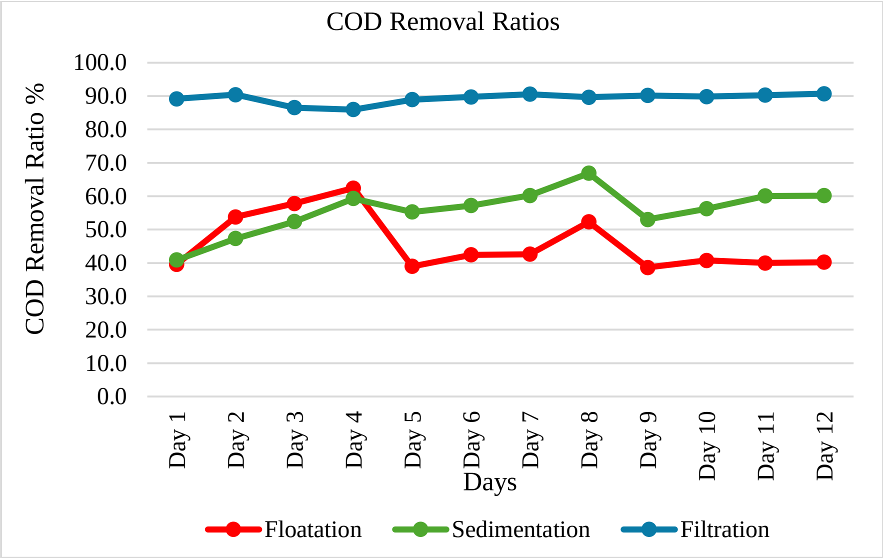

Fig. 10 COD removal efficiency for run one

3.3. COD Results Discussion

Table 7 and Figure 10 present the results of the removal ratio of TDS of each phase one unit as follows: Floatation, Sedimentation and Filtration, respectively. Regarding COD removal, flotation units achieved efficiencies ranging from 38.7% to 85.7%, averaging 51.6%. The addition of ferric chloride aided in the oxidation of soluble organics and the removal of particulate COD fractions, enhancing the overall COD removal. Sedimentation units performed better, with COD removal efficiencies ranging from 55.2% to 88.7%, averaging 72.0%. This higher efficiency is due to the effective coagulation and sedimentation processes facilitated by $FeCl_3$. Filtration units, with a COD removal efficiency range of 53.3% to 82%, averaged 67.6%, leveraging various filtration mechanisms and biological activities to reduce organic matter, thus performing comparably to the sedimentation units in COD removal. The results from the sedimentation unit quite a match Vanterkar studies results from [11] results in COD removal, while the Filtration unit exceeds it by nearly 20%.While variation in values for COD removal in the Floatation unit was high in the first week and then decreased in the last 2 weeks, in contrast, the Sedimentation unit variation was the opposite, and this can be interpreted as effect of pH and DO changes of each wastewater patch at high pH the formed particles from the chemical reaction with $FeCl_3$ tend to be more settable than floatable, this is why sedimentation unit removal is better in last two weeks while floatation unit is better in first week. The filtration unit is not affected by this action due to the nature of this unit.

4. Conclusion

In general, the filtration unit demonstrated significantly the highest efficiency among the three physico-chemical units regarding TSS removal. The sedimentation unit ranked second in performance, while the flotation unit exhibited the lowest efficiency. Compared to the other two units, the results from the chemically enhanced flotation unit were influenced by the operational conditions and the nature of the solids generated due to ferric chloride addition. The generated solids for this industry’s wastewater effluent tended to settle rather than float, resulting in the overall lower performance of the flotation unit. Conversely, the filtration unit outperformed the sedimentation unit due to its small pore size, allowing superior TSS removal. Additionally, the coagulant enhanced the settling characteristics of suspended and colloidal particles in the sedimentation unit, resulting in comparably good removal efficiencies for TSS and COD. The results of this study were promising when compared to larger, higher-cost systems, as demonstrated by Vanterkar et al. [11] for COD removal and El-Diwani [10] for TSS removal. While other systems are designed to achieve higher treatment levels that facilitate reuse or discharge into surface water, typically implemented in large-scale factories with substantial waste volumes, this study focuses on simple, cost-effective solutions for small-scale sweets factories. These solutions enable compliance with environmental regulations and allow safe effluent disposal into local sewer networks, requiring minimal costs and technical expertise.

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