Egypt. J. Chem. **Vol. 65**, No. 5 pp. 391 - 399 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Cost Effective Management of Confectionery Industrial Wastewater

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Abstract

The goal of this study is the management of wastewater generated from a confectionery factory located at El-Obour Industrial City, Egypt. The factory produces confectionery products, chocolates, eastern and western bakery products. Laboratory analysis of raw wastewater showed high pollution load with an average COD and BOD5 of 5396 mg/L and 2526 mg/L. Most of the organic matter was present in soluble form since TSS was 908 mg/L on average. The raw wastewater showed limited nutrients concentration with average of 55 mgTKN/L and 3.3 mgTP/L. Conventional activated sludge and UASB reactors were separately investigated as treatment technologies. Aerobic sequential batch reactor (SBR) indicated hydraulic retention time (HRT) 12 hr. to produce effluent complying with the regulatory standards. Continuous activated sludge operated at 9.3kg COD/m3.d and temperature range of 20-35 ◦C showed good effluent quality with removal efficiencies of 96%, 96% and 98% for COD, BOD5 and TSS, respectively. Two-stage UASB reactor working at COD loading rate of 4.7 kg COD/m3.d and same temperature's range, showed averages of removal of 82%, 81%, 95%, and 85% of COD, BOD, TSS and oil&grease, respectively to produce effluent complying with the regulatory standards. The activated sludge unit provided better effluent quality than the two-stage UASB reactor. However, the two-stage UASB reactor was selected as a sustainable and cost-effective technology for the treatment.

Keywords: Confectionery; Industrial wastewater; Management; SBR; two-stage UASB system.

1. Introduction

Owing to the population growth and non-sustainable water resource management, Egypt has reached a stage of water poverty, with an annual per capita share of water less than 700 m^3. It is reported that about 16 billion cubic meters of agricultural and industrial wastewater are being dumped annually into the River Nile and irrigation canals, affecting the scarcely available freshwater resources [1]. The sharp deterioration in the quality of freshwater resources severely restricts opportunities for agricultural products to compete in global markets, increases the health risk for the local consumers, and adversely impacts the performance of the water treatment plants. Many municipal wastewater treatment plants suffer dramatic deterioration in the quality of the treated effluent either because of the overload of the treatment plant or the lack of power needed for aeration of the activated sludge which is the most widely used technology in Egypt for sewage treatment. The Egyptian government established a national standard for industrial effluent discharge into the public sewerage networks. Europe has large experience with large-scale implementation of biogas and biomethane production and is the world leader in biogas production with more than 50% of the global production. The learned lessons from the European experience indicated the potential impacts of the system on food supply, economic, environmental, and social issues of sustainability [2]. The characteristics of raw wastewater from the cake shop showed acidic pH and average values of 1966, 1344, 30.4, and 2.5 mg/L for COD, BOD, Total nitrogen (TN), and total phosphorus (TP), respectively [3]. The BOD/COD ratio is the index of wastewater biodegradability and wastewater is considered biodegradable and could be easily treated biologically if BOD/COD is above 50% and will require seed sludge and acclimatization if it is between 30-50% since the process will be relatively low [4, 5]. The industrial wastewater is considered not feasible to be treated biologically if BOD/COD ratio is below 30% [4, 6].Conventional, and non-conventional chemical treatment is not recommended for biodegradable wastewater since they are chemical addition

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Receive Date: 29 December 2021, Revise Date: 13 January 2022, Accept Date: 16 January 2022
DOI: 10.21608/ejchem.2022.113488.5164

processes and increase the total dissolved solids in the final treated effluent [7]. Anaerobic biological treatment has great potential for the treatment of dairy wastewater, soybean wastewater, beverage wastewater, mixed liquid swine manure and brewery wastewater, swine wastewater and sugar industry wastewater [8, 12]. However, the anaerobic treatment is more suitable and environmentally sustainable for biodegradable high-strength industrial wastewater than the aerobic treatment process [13-15]. The anaerobic wastewater treatment is considered sustainable and economically feasible for biodegradable industrial wastewater with a COD value above 1500 mg/L [7, 13]. The activated sludge system receiving potato chips processing wastewater at 8.9 kg BOD/m^3.d, was able to achieve 86% and 84% reduction in BOD and COD while the UASB reactor treating the same wastewater at an organic loading rate of 2.9 kg BOD/m^3.d was able to reduce BOD and COD at 86% and 82% [16]. It has been reported that the UASB reactor is more sustainable for the treatment of potato chips processing wastewater under Egyptian conditions [16]. A pilot-scale submerged MBR with three different setups; suspended activated sludge, integrated suspended and attached activated sludge, and activated sludge with poly aluminium chloride (PAC) were used for the treatment of cake shop wastewater, and reported results indicated that PAC has no significant impact on Organic Loading Rate (11 g COD/L. d) and the only significant effect was on TN and TP removal which increased from 71 to 82% for TN and from 79 to 85% for TP while COD removal rate was the same and achieved 98% in both. On the other hand, integrating suspended and attached activated sludge resulted in a significant increase in OLR to 13.3 g COD/L. d and improved TN and TP removal to reach 82% and 85% respectively [3]. Confectionery wastewater is supposed to have readily soluble fermentable fractions which make the pH of this wastewater acidic in nature. The confectionary wastewater has acidic pH (pH 5) and high strength characteristics with average values of 10470 mg COD/L, 4600 mg BOD/L and 1215 mg/L for volatile suspended solids [17]. These characteristics make it a potential substrate for bio-hydrogen production and the reported results revealed 99% of COD is fermentable and removable with the hydrogen production rate of 204 ml/g COD removed [17]. The wastewater from the confectionery industry is defined as a potential substrate for microbial growth and production of microbial products like xanthan and it is considered economically competitive to the synthetic media for commercial production of xanthan gum [18]. Confectionery wastewater is weak in nutrients and alkalinity, which means an external source of nutrients and alkalinity should be supplemented. An expanded granular sludge bed reactor (EGSBR) was used to treat pre-treated industrial wastewater generated from a confectionery factory. The EGSBR received a wastewater flow rate providing 6.2 days Hydraulic Retention Time (HRT) and an average organic loading rate of 2.9 g/L. d which is considered low compared to the anaerobic reactors. The system provides an average COD removal rate of 88% at 34 ^oC. Post-treatment of the anaerobic effluent in conventional activated sludge system working at 0.07 g BOD/g VSS and 4.9 days HRT achieved 95% reduction in the COD. Both integrated systems; anaerobic and aerobic processes provided a total of 97% COD removal [19]. Treatment of confectionery wastewater using UASB at HRT of 12hr and an OLR of 4.4 kg BOD/m^3.d gave satisfactory results with average COD and BOD removal rates of 92% for both, while application of activated sludge system at a 6 hrs HRT and ORL of 8.4 kg BOD/m^3.d provides percentages removal of 87% and 86% for BOD and COD, respectively. Despite the lower retention time and footprint of the activated sludge system in comparison to the UASB reactor, the latter was more sustainable and economic for the treatment of confectionary wastewater and it provides treated effluent meeting the regulatory standards for effluent discharge into the public sewerage networks [16]. The literature review showed that the UASB reactor is economically more sustainable and technically more effective in treating confectionery wastewater compared to the potato chips processing wastewater [16, 20]. Moreover, anaerobic treatment of the wastewater produced by bakeries which are primarily generated from cleaning of equipment and floor washing is preferable to the electrocoagulation which mostly needs NaCl addition to enhance the electric conductivity of the wastewater and improve the treatment performance. Electrochemical treatment of bakery shop wastewater provided maximum of 37.5% removal for COD while the treatment process increased the total dissolved solids of the final treated effluent which may reduce the chance of agricultural effluent reuse [21, 22]. The main goal of the current study is the management of industrial wastewater from a confectionery factory to meet the regulatory standard for industrial effluent discharge into the public sewerage network.

2. Materials and method

2.1. Site Description, Industrial Process and Sources of Wastewater

The company is located at Obour industrial city, east Cairo, Egypt. The activity is limited to the production of confections, eastern and western pastry, and chocolate. This industry produces wastewater that does not conform to standards stipulated in the Egyptian ministerial decree no. 44/2000 for wastewater discharge into the main sewerage system. The eastern and western confections and bakery industry is characterized by a variety of products and production lines. Design of equipment and production lines is made such that cleaning and sterilization processes can be accomplished in an easy way. This is either throughout the day for some equipment or at least once a day at end of the work for other production lines and main equipment. Water is used in confection factories for the industrial preparation of raw materials and pastes as well as daily cleaning of equipment, tools, and production area. Also, water is used for boilers, human utilization, and plantation as appropriate. The raw material is composed of flour, sugar, cocoa, butter, vegetable oils, milk powder, egg, glucose, fructose, yeast, sodium bicarbonate, ammonium bicarbonate, flavor/odor generator, fruit, and nuts. Industrial processing to produce chocolate, Biscuit, pastry, and cake are presented in Figure (1). Weighing and mixing of raw materials result in spillage and losses of some quantities on the floor. This contributes to wastewater during washing and cleaning of the floor. The homogeneous chocolate mixture may be stored in hot containers until pouring into the molds or poured without storage. Chocolate types differ based on the type and percentage of components and additives. Also, washing and cleaning of the equipment contributed to wastewater generation. As shown in Figure (1), production lines of cake and pastry are similar in many steps; the difference is about the quality and quantity of used raw materials. About 100 m^3 of wastewater is discharged daily into the main sewerage system. As mentioned before, this wastewater is produced from the washing, cleaning, and sterilization process of the equipment. Also, cleaning of the floor in the work area due to spillage of oil, sweet fluids, sugar dust, and flour contributes to wastewater generation.

2.2. Samples Collection and Analyses

Six composite samples were collected during the first shift from the end-of-pipe just before effluent discharge to the public sewerage network. Each sample represents 12 discrete samples with 1.5-L each on one-hour interval time, which means 18-L sample volume was collected for each one. These six samples were used for experimental works. Another 5-L composite sample was collected at the same time from the end-of-pipe. This sample was preserved in Ice Tank, transported to the laboratory, and subjected for laboratory analysis on arrival. All samples were transported to the laboratory of Water Pollution Research, National Research Centre within 1.5 hours. The water analytical parameters include all parameters indicated in Egyptian legislation for food processing industries discharged into the public sewerage network. These parameters include pH, chemical and biological oxygen demand, total suspended solids, total solids, settleable solids at 10 and 30 minutes, total Kjeldahl nitrogen, total phosphorus, soluble sulfides, oil& grease, and phenol. All the analyses were carried out according to the Standard Methods for the Examination of Water and Wastewater [23]. This sampling program with the same sequence was repeated on a weekly basis.

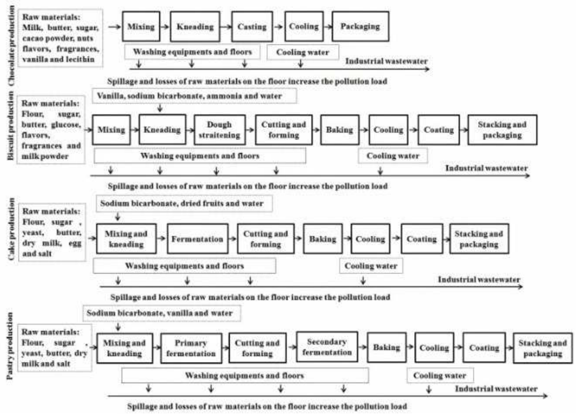

Fig. 1: Industrial processing and production lines with the wastewater sources

2.3. Experimental

The large six samples with 18-L volume each were used for the experimental works. The experimental works cover anaerobic and aerobic wastewater treatment experiments. Before starting the aerobic and anaerobic experiments, a mass balance was carried out between COD, TN, and TP in the raw wastewater to determine the N and P requirements if needed. Scientifically, the ratio of C:N:P for the aerobic bacteria is 100:5:1 while anaerobes need 250:5:1 [7]. Consequently, we decide to balance the ratio of COD:N:P at 250:5:1 for the aerobic sludge and 500:5:1 for the anaerobic sludge. Urea and potassium dihydrogen phosphate were used as a source of nitrogen and phosphorus. A urea solution with 50 mg N/ml and potassium dihydrogen phosphate solution with 2.5 mg P/ml were separately prepared and used to supply N and P requirements. The alkalinity of wastewater is very important and acts as a buffering agent of the biological system either aerobic or anaerobic. The requirement of alkalinity was estimated using the COD of the raw wastewater to have 250 mg alkalinity as $CaCO_3$/500 mg COD. The measured values of COD and total alkalinity were used to estimate the alkalinity requirements. Sodium bicarbonate was used as a source of external alkalinity. 84 mg $NaHCO_3$ equivalent to 100 mg alkalinity ($CaCO_3$) requirement.

2.3.1. Aerobic Sequencing Batch Reactor (SBR)

After two weeks adaptation period, the impact of hydraulic retention time (HRT) on the treatment performance was carried out by starting a new feed at a fixed initial MLSS concentration (2-3 g/L). Dissolved oxygen concentration was adjusted to maintain a minimum concentration of 3 mgO_2/L. Samples of MLSS were collected at 0, 1, 2, 3, 4, 5, 6, 7, 8, 15, and 24 hours of aeration time (reaction time). The samples were left for 60 minutes to settle and clear supernatants were subjected for analysis of COD and TSS while settled sludge was analyzed for MLSS concentrations.

2.3.2. Continuous flow activated sludge system

A treatment unit made of Plexiglas with a 2.7-L aeration compartment and 1-L settling compartment was used (Figure 2). The unit was continuously fed with the nutrients supplemented wastewater at pre-defined HRT from the batch experiment. The sludge residence time (SRT) in the unit was set at 7 days.

2.3.3. Up-flow Anaerobic Sludge Blanket Reactor (UASB)

UASB reactor. Both the first and second reactors are similar in shape and size. Each reactor has a 10 cm inner diameter and 40 cm total height. The reactor has a 3.1 L net volume and 2.9 L effective volume, excluding gas collector. The experiment was performed at a temperature range of 20-35 ^oC with 12 hrs HRT in each. The reactors were seeded with anaerobic sludge collected from anaerobic digester of Gabal El Asfar municipal wastewater treatment plant at 30 gTSS/L. The initial sludge has 55% VSS.

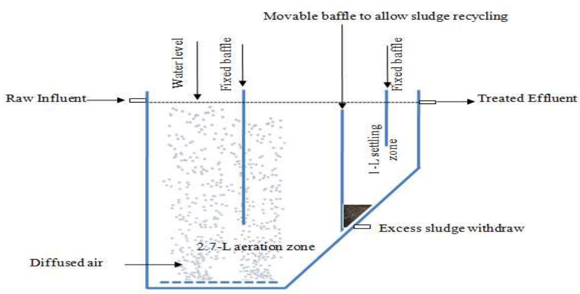

Fig. 2: The model aerobic wastewater treatment plant using activated sludge

3. Results and discussion

Industrial wastewater produced from the production lines of the manufacturing of candy and bakery is characterized by high loads of organic materials, whether soluble (sugars) or insoluble (flour, starch, and some fruit residues) all of which are biodegradable. The results of physicochemical characterization of raw wastewater during the period from November to the end of March are presented in Table (1). Mostly the wastewater is acidic in nature due to the readily biodegradable soluble sugars; see the ratio between TSS and COD in Table (1), which indicates that most of the COD is soluble in nature. This is similar to the other work that is indicating most of the COD of confectionary wastewater is present in soluble form (soluble sugars) which is readily biodegradable and fermentable and making the wastewater acidic in nature [17]. Also, the easily biodegradable characteristic of wastewater generated from the bakery, pastry, and confectionary factories was reported by others [3, 18, 24]. However, the pH was sometimes observed to be above 7 (7.4 and 9.2) which could be attributed to the use of caustic soda and alkaline detergents in cleaning utensils and equipment and washing floors. The raw wastewater has a high load of organic matter with a BOD/COD ratio of 48% on average and ranged between 36% and 69%. This supports the biological treatment of such kind of wastewater either an aerobically or aerobically [7]. Also, the results indicated the colloidal nature of non-soluble particulates which is attributed to the starchy nature of these non-soluble matters. The BOD/COD ratio is the index of wastewater biodegradability and wastewater is considered biodegradable and could be easily treated biologically if BOD/COD is above 50% and will require seed sludge and acclimatization if it is between 30-50% since the process will be relatively low [4, 5]. Industrial wastewater is considered not feasible to be treated biologically if BOD/COD ratio is below 30% [4]. The results of this study showed a BOD/COD ratio of 47% which is considered suitable for biological treatment. However, the results of raw wastewater show a low concentration of nitrogen and phosphorus as compared to COD and BOD. This low concentration of nitrogen and phosphorus may limit optimal growth of anaerobic and/or aerobic sludge and external addition of nitrogen and phosphorus may be needed. Similar results were reported and indicated low nutrients concentration in confectionary wastewaters and their external addition should be carried out to make anaerobic reactor works effectively. Also, it is reported that the confectionary wastewater is sugary with low alkalinity and external alkalinity supplement is needed for anaerobic treatment [19].The choice

Table (1): Physicochemical characterizations of raw wastewater final effluents

Parameters	Unit	Results			Disposal limits*
		Min.	**Max.**	**Av.**	
pH	--	3.7	9.2	6.5	6-9.5
COD	mgO_2/L	3200	7450	5396	1100
BOD	mgO_2/L	1460	3575	2526	600
TSS	mg/L	178	2050	908	800
TDS	mg/L	2044	7202	4074	--
TKN	mg/L	32	105	55	100
TP	mg/L	1.1	4.7	3.3	25
O&G	mg/L	115	530	223	100
H_2S	mg/L	--	--	--	10
Phenol	mg/L	--	--	--	0.05

*Ministerial decree 44/2000for discharge of industrial effluent into public sewerage network

between aerobic and anaerobic treatments depends on the capital cost of the treatment plant, operation and maintenance cost, nitrogen, and phosphorus requirements regarding COD and effluent quality (disposal limits). High disposal limits, low land availability and fewer nutrients' requirements make anaerobic treatment better than the aerobic one. On the other hand, available land and fewer disposal limits make aerobic treatment to be the best choice for the treatment of biodegradable industrial wastewater. Aerobic treatment using activated sludge and anaerobic treatment using two-stage UASB reactor were investigated and compared. The results of raw wastewater indicate phosphorus requirement in case of anaerobic and aerobic treatment while nitrogen is present at enough concentration for the anaerobic treatment but not for the aerobic treatment which needs additional nitrogen from an external source. Also, pH adjustment and alkalinity addition are required before the biological treatment. Also, the variations in the characteristics of raw wastewater before nutrients addition (Figure 3) make it necessary to establish an equalization tank before the biological treatment process to make the influent more homogenous and less variable in concentration. This enables personnel to estimate nutrient requirements and makes it an easy addition process. The presence of the equalization tank before the biological process was recommended for industrial wastewater treatment plants [7].

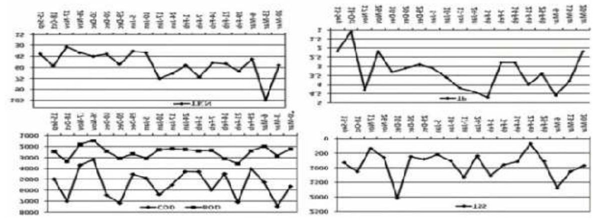

Fig. 3: Variations in the characteristics of raw wastewater before addition of nutrients

3.1. Biological treatment using activated sludge

Biological treatment, particularly the activated sludge and the extended aeration, is one of the most widely used technologies for the treatment of industrial and municipal wastewaters. The results of the aerobic sequential batch reactor depicted in Figure (4). From the data of this experiment, the estimated HRT for the continuous experiment of the activated sludge was extracted as follow:

Required retention time of the first trail = COD to be removed/ (removal rate, mg COD/g MLSS/h × sludge concentration in grams) = (5000-600) / (104.3 × 4) = 10.45 hours. Required retention time of the second trail = COD to be removed/ (removal rate, mg COD/g MLSS/h × sludge concentration in grams) = (5000-600) / (80.2 × 4) = 13.7 hours. The average estimated HRT from each trail is = [10.5 + 13.7]/2 ≈ 12 hours. Also, from this aerobic sequential batch reactor, the data shows excess sludge production at 0.4 g TSS/g COD removed on average. A continuous lab-scale activated sludge system was operated at 12 hrs HRT using raw wastewater supplemented with the required nitrogen, phosphorus, and alkalinity after pH neutralization. The results of the aerobic continuous system are shown in Table (2) and Figure (5). The activated sludge unit operated at OLR of 9.3 kg COD/m^3. d provides treated effluent with residual COD, BOD, TSS, and oil and grease compatible with the disposal limits. These residual values are 172, 79, 35, and 48 mg/L which are far below the disposal limits defined in the Egyptian decree no 44/2000 for disposal of industrial effluent to the main sewerage network. The corresponding percentages removal of COD, BOD, TSS, and oil and grease are 96%, 96%, 98%, and 80%, respectively. The excess sludge production from the continuous experiment indicates 0.58 g TSS/g COD removed. This value is slightly less than the value obtained from the batch experiment which could be attributed to high aeration density in the batch experiment and so more endogenous decay. The performance of the activated sludge unit in this study is comparable to the results reported for a pilot-scale activated sludge MBR system treating cake shop wastewater at 11 kg COD/m^3. d which provides a removal percentage of 98% for COD [3]. In the current study, the continuous activated sludge system provides treated effluent with residual COD and BOD concentration of 172 and 79 mg/L, respectively which is less than the reported values in a lab-scale activated sludge systems treating confectionary wastewater (597 mg COD/L and 312 mg BOD/L) and potato chips processing wastewater (639 mg COD/L and 316 mg BOD/L). However, others applied high COD loading rate for the confectionary wastewater (17.1 kg

COD/m^3.d) and potato chips processing wastewater (19.7 kg COD/m^3.d) [16]. The estimated F/M ration of the previous mentioned work [16] were 4.9 and 5.6 g COD/g TSS. d which is extraordinary for any activated sludge system. The maximum recommended F/M ratio for the conventional, completely mixed, and high rate activated sludge system is 0.5, 1.0, and 1.5, respectively [7].

Table (2): Physicochemical characterizations of raw wastewater and treated effluents from the activated sludge system

Sample		pH	COD	BOD	TSS	O&G
	Minimum	7.1	4460	2220	573	225
Influent wastewater	Maximum	8.1	4860	2592	1433	255
	Average	7.8	4668	2427	1020	238
	Minimum	7.2	128	55	16.8	14.5
Effluent wastewater	Maximum	8.0	202	92	86	95
	Average	7.7	172	79	35	48
% removal	Average	-	96	96	98	80
Disposal limits	Maximum	6-9.5	1100	600	800	100

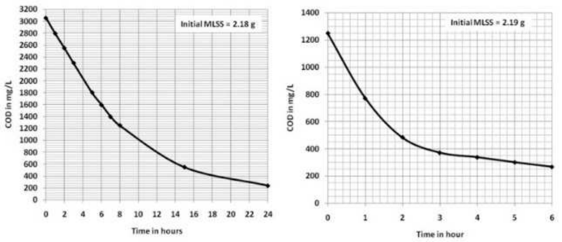

Fig. 4: Residual COD in the SBR experiments

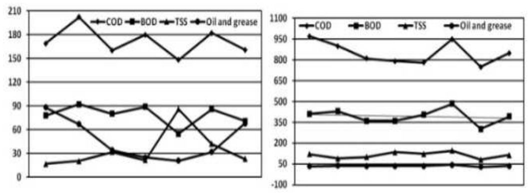

Fig. 5: Concentration of residual contaminants in the aerobic and anaerobic effluent

3.1.1. Sludge characteristics

The results of sludge analysis including sludge volume index (SVI) and microscopic examination indicate good quality. The SVI ranged between 95-140 ml/g, which is comparable to the desired range in well managed activated sludge treatment plant [7, 25-27]. As indicated in Figure (6), the most common species of the sludge are *Opercularia* and *Vorticella* while Rotifera was detected in small numbers. This is mostly attributed to the low sludge residence time (7 days).

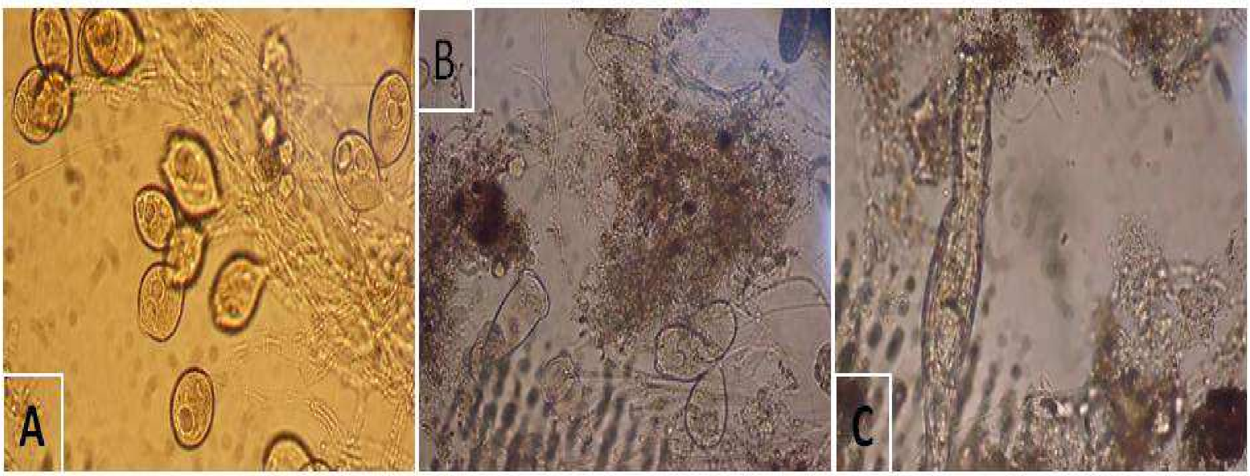

Fig. 6: Most common species of microorganisms in the activated sludge; *Opercularia* (A), *Vorticella* (B) and *Rotifera* sp.(C)

3.2. Biological Treatment Using Two-Stages UASB

Anaerobic digestion of food processing wastewater was carried out in a lab-scale anaerobic filter [24]. Also, treatment of confectionery wastewater using UASB at HRT of 12hr and an OLR of 4.4 kg BOD/m3.d gave satisfactory results under Egyptian environmental conditions [16].The anaerobic treatment was considered sustainable and economically feasible for biodegradable industrial wastewater with a COD value above 1500 mg/L [7]. It is widely confirmed that the anaerobic treatment is more suitable and environmentally sustainable for high-strength industrial wastewater than the aerobic treatment process [8]. For the above-mentioned reasons, utilizing two stages UASB reactor for the treatment of raw wastewater was carried out. After 40 days startup period, the UASB reactor provides effluent quality meeting the permissible limits (Table 3) for effluent discharge into the public sewerage networks. The residual values of COD, BOD, TSS, and oil and grease are 850, 393, 114, and 36 mg/L, respectively. The corresponding percentages removal is 82%, 81%, 95% and 85%, respectively. These recorded values are comparable with the effluent quality of lab-scale anaerobic filter treating food processing wastewater with 530-2620 mg COD/L [24]. Operation of the anaerobic filter at 35^{o}C and receiving food processing wastewater at COD loading rate of 0.4-1.23 kg/m^3.d provides 88% removal for COD removal rate which may be slightly higher than the results of the current study based on the percentage removal but actually our result is better, since the COD loading rate of (4.7 kg COD/m^3.d) is 5 times more than the other one (0.4-1.3 kg/m^3.d) [24]. Also the anaerobic filter was operated at 35^{o}C while the reactor of this study was operated at temperature range of 20-35^{o}C. Furthermore, operation of anaerobic baffled reactor treating high strength Bakery's yeast production wastewater provides higher COD removal (95%) at lower COD loading rate (2.5 kg/m^3. d) comparing to the current study [28].

Table (3): Physicochemical characterizations of raw wastewater and treated effluents from the two-stage UASB reactor

Sample		pH	COD	BOD	TSS	O&G
Influent wastewater	Minimum	7.1	4460	2220	573	225
	Maximum	8.1	4860	2592	1433	255
	Average	7.8	4668	2427	1020	238
Effluent wastewater	Minimum	6.7	780	360	90	34
	Maximum	7.8	970	430	136	37
	Average	7.1	850	393	114	36
% removal	Average	-	82	84	89	85
Disposal limits	Maximum	6-9.5	1100	600	800	100

On the other hand, increasing the COD loading rate to 7.5 kg/m^3.d declines the COD removal to 78% [28], which is less than the current value. The current study presented a broad range of temperature (20-35 ^{o}C) in comparison with mesophilic condition ((30-40 ^{o}C) presented in other studies [29]. An expanded granular sludge bed reactor was used to pre-treat confectionary wastewater [19]at 34 ^{o}C and 2.9 kgCOD/m^3.d and provides 88% COD removal efficiency, which is comparable to the current result. On the other hand, the average percentage of COD removal in the current study is lower than the reported values of the UASB reactor treating confectionary wastewater and UASB reactor treating potato processing wastewater [16].They obtained extraordinary COD% removal in the UASB reactor (92%) treating confectionary wastewater at a COD loading rate of 8.95 kg/m^3. d and the UASB reactor (86%) treating potato processing wastewater at a COD loading rate of 8.76 kg/m^3. d [16]. The COD removal load of the current study is 3.9 kg/m^3.d lies within the range (2.4-5.9 kg COD/m^3. d) reported for the anaerobic baffled reactor treating high strength Bakery's yeast production wastewater [28]. Also, the COD removal load of the current study is much higher than the COD removal load (0.72 kg COD/m^3. d) obtained by [24].The estimated COD removal load of the value of the expanded granular sludge bed reactor treating pretreated confectionary wastewater was 2.6 kg COD/m^3.d which is also less than the current value. On the other hand, COD removal load of 8.2 kg/m^3. d and 7.5 kg/m^3.d was reported for the UASB reactor treating confectionary wastewater and the UASB reactor treating potato processing wastewater, respectively [16]. A mesophilic (37 ^{o}C) UASB reactor treating slaughterhouse wastewater at COD loading rates of 5 kg/m^3.d and 6.5 k COD/m3.d achieved 90% and 60% COD removal rates, respectively which correspond to COD removal loads of 4.5 and 3.9 kg COD/m3.d. These values confirm the results of the current study.

3.3. Cost analysis

To make a cost comparison for both methods, the construction costs were calculated for each system. In the case of the aerobic pathway, the calculations including, digging, tanks, pumps, ventilation blowers, ventilation grilles, sand and gravel media, control board, and other connections, these cost amount to USD 38500. But in the case of the anaerobic path, the calculations including digging tanks and gas-liquid separators which altogether cost an amount of USD 15000. Furthermore, the operating cost was calculated for aerobic and anaerobic treatments including electricity, chemicals, maintenance, and labor.

4. Conclusions

This study includes the management of wastewater generated from a confectionery factory located in Obour industrial city, Egypt. Characteristics of wastewater generated from confectionary factory show high strength wastewater with an average COD and BOD of 5396 mg/L and 2526 mg/L, respectively. The raw wastewaters could be treated aerobically and an aerobically. However, limitations in nitrogen and phosphorus make it necessary to supplement nitrogen and phosphorus from an external source especially in the case of the aerobic system (activated sludge). The aerobic sequential batches indicate hydraulic retention time (HRT) of 12 hours as optimal to provide effluent quality complying with the standards. The continuous flow- activated sludge system operated at a COD loading rate of 9.3 kg COD/m^3. d at 20-35^{o}C showed effluent quality with average residual concentrations of 172 mg COD/L, 79 mg BOD/L, 35 mg TSS/L, 48 mg O&G/L, and corresponding removal efficiencies of 96%, 96%, 98% and 80% respectively. Two-stage UASB reactor working at COD loading rate of 4.7 kg/m^3.d at 20-35 C◦ showed average removal of 82%, 81%, 95% and 85% for COD, BOD, TSS, and O&G respectively. The residual concentrations are 850 mg COD/L, 393 mg BOD/L, 114 mg TSS/L and 36 mg O&G/L. Despite, the activated sludge process provides better effluent the two-stage UASB reactor was selected as a sustainable technology for the treatment process due to less running cost (no aerations and no need for nitrogen addition). In the case of treating 100 m3/d of wastewater; an amount of 11.3 kg urea (commercial fertilizer) and 7.2 kg superphosphate (commercial fertilizer) will be needed for the continuous activated sludge system, while in the case of the two-stage UASB only 3 kg of the superphosphate will be needed. Furthermore, an amount of USD 38500 for the construction of an aerobic system will be required whereas anaerobic UASB construction only costs USD15000.

5. References

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