Evaluating the efficiency of the industrial wastewater treatment unite of edible oil extraction and refining company and reuse for irrigation

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ABSTRACT: The present study focused on evaluation the edible oil wastewater. Water samples were taken from each stage of wastewater treatment for analysis to evaluate the industrial wastewater quality and if can use it for agricultural irrigation. The result showed that the removal of suspended solids was almost consistent and higher than that of BOD5 and COD. It was also affirmed that the removal of sulfates and phosphates from the wastewater was efficient. The physicochemical treatment processes significantly influence the relative biodegradability of the organic compounds in the wastewater. Hence, the effective treatment of edible oil refinery wastewater was about 10 to 100%, but the overall efficiency of wastewater treatment was 74%.
The efficiency of edible oil extraction and refinery wastewater treatment for the present study has less efficiency (concerning the chemical composition, there are some parameters stiles need to efficiently removed such as coliforms (contaminated with Escherichia coli). In the edible oil industry, water reuse is increasingly being considered to reduce fresh water consumption and to minimize treatment costs. The treated wastewater can be used for non-potable applications such as irrigation for agricultural purposes, if the treated water meets safety standards
To ensure the removal of most harmful components from the wastewater of the edible oil industry, we suggest adding a final stage in the treatment, which is the carbon filter. The carbon materials can be useful for removing the most hazard and pollutant materials in wastewater and increases the efficiency of wastewater treatment of edible oil wastewater.
Biochar presents a versatile and effective approach for pollutants removal in wastewater treatment. Continued research into its mechanisms, modifications, and integration strategies will enhance its viability as a sustainable solution for water pollution management.

Keywords: Edible oil, wastewater treatment, Refined soybean oil wastewater, Edible Oil Industry

INTRODUCTION

Wastewater generated from the edible oil extraction and refining processes is characterized by a complex mixture of organic and inorganic pollutants. The composition and characteristics of this wastewater vary significantly depending on the type of oil processed and the specific refining techniques employed.

The sources of edible oil manufacture are soyabean, groundnut, rapeseed, safflower, cotton seed, corn, coconut, mustard, rice bran, neem, mahuwa etc. The refined edible oil manufacturing units generate solid waste (spent earth) and wastewater. The wastewater come out from oil refinery create serious environmental problem such as great threat to aquatic life due to its high organic content. Hence its treatment is essential prior to its disposal. The choice of effluent treatment method depends on the organic content present in the effluent and its discharge conditions.

In the edible oil industry, wastewaters mainly generated from the degumming, deacidification and deodorization and neutralization steps. In the neutralization step, sodium salts of free fatty acid are produced whose splitting through the use of H_2SO_4 generates highly acidic and oily wastewaters. Its characteristics depend largely on the type of oil processed and, on the process, implemented that are high in COD, oil and grease, sulphate and phosphate content, resulting in both high inorganic as well as organic loading of the relevant wastewater treatment works **(Aslan et al., 2009).**

Soybean oil is one of the most widely used edible oils in the world. With the improvement in standards of living and changing diets, the demand for quality edible oil is increasing. Thus, refining crude soybean oil is a necessary step in the production of soybean oils. Large amounts of high-strength organic wastewater are released during the crude soybean oil refining process, which usually includes degumming, deacidification, neutralization, bleaching, and deodorization steps to remove the undesirable components before making the oil available for human consumption **(Rajkumar et al., 2010).** The refined soybean oil wastewater (RSOW) has a high concentration of chemical oxygen demand (COD) and contains large amounts of sodium salts from free fatty acids soap stocks, oil, grease, sulfates, and phosphates **(Dohare and Meshram, 2014).** The harmful effluent discarded in its raw form causes substantial impacts on the environment. RSOW is usually treated by a combination of a pretreatment to dislodge the oil and grease, biological treatment, and advanced treatment, and the removal of COD and oil content can reach more than 90% **(Aslan et al., 2009; Dkhissi et al., 2018).** However, the traditional treatment methods lack economic competition due to the increase in cost and energy. Because of the high concentration of organic materials, RSOW can be further used as a resource. Therefore, the development of an efficient and economical treatment approach for such RSOW is attractive.

Edible oil effluents can be treated either separately or in conjunction by chemical or biological means. The problems with chemical treatment are the increased chemical handling costs and the production of chemical sludge that is difficult to treat and dispose of. Biological treatment methods offer an easy and cost-effective alternative to chemical methods in the treatment of edible oil effluent. Biological treatment of edible oil wastewater could be treated by Conventional Activated Sludge Process and Sequencing Batch Reactor **(Mkhize & Bux, 2001).**

Edible oil industry wastewaters mainly come from the degumming, deacidification, deodorization and neutralization steps **(Rupani et al 2010).** In the neutralization step sodium salts of free fatty acid soap stocks are produced whose splitting through the use of sulfuric acid generates highly acidic and oily wastewaters **(Olafadehan and Jinadu, 2012)**. Its characteristics depend largely on the type of oil processed and, on the process, implemented that are high in COD, oil and grease, sulphate and phosphate content, resulting in both high inorganic as well as organic loading of the relevant wastewater treatment.

Effluent from the vegetable oil industry used to be discharged directly into soil or groundwater. But due to the emergence of environmental consciousness the Pollution Control Boards have become stricter and imposed stringent norms. The studies have shown that fatty materials within waste streams from oil industries are readily biodegradable and it therefore follows that these effluents are amenable to biological treatment.95% of BOD in wastewaters from a soya bean oil refining plant is removed by using an activated sludge process **(Aslan et al 2009).**

During these processes by-products and wastes are formed. The operating conditions and processes carried out influence the amount and characteristics of the byproducts and wastes formed. The wastewater varies both in quantity and characteristics from one oil industry to another. The composition of wastewater from the same industry also varies widely from day to day discussed.

Types of physical, chemical and biological methods used for the oily wastewater treatment. Use of these methods, disposal and waste treatment still remain major challenges in the fats and oils industries **(Chipasa, 2001).**

The present study describes the characteristics of wastewater coming out from oil extraction and refinery before passing to effluent treatment unit and after wastewater treatment and show the efficiency of the industrial wastewater treatment unit.

2. MATERIALS AND METHODS

2.1. Wastewater treatment unit

The wastewater treatment unit of the edible oil extraction and refining company consists of four units as follows:

1. Collection well: There are four primary separation wells for oil and sediments. The oils are separated on the surface and drawn off for use in the acidification unit.
2. Drum Barrel filter: It separates the sediments in the water.
3. Chemical treatment: for removal of oils and fats through:

1. acidification with H_2SO_4 (98%) in stainless steel tank (neutralization)
2. Ferric chloride ($FeCl_2$, 40%) for soap and oil coagulation
4. scraper unit: for removing the sediments and solid waste.
5. DAF unit (Dissolved Air Flotation) for scraping off the sediments on the surface of the water with air stirring.
6. Sodium hydroxide (NaOH) addition for neutralizing the pH
7. Biological treatment: It is carried out by aerobic bacteria that live in an alkaline medium and feed on oils, fats and urea.
1- Feeding phase (fill phase)
2- Regeneration phase (reaction phase)
3- Sedimentation phase
4- Effluent phase (Drain phase)
8. discharge pipes for transfer the treated wastewater to Public Sewerage Network.

Photo (1). Collection pit

Photo (2): Drum Barrel screen filter

Photo (3): Chemical treatment

Photo (4): scraper unit (DAF) (acidic application)

Photo (5) Sodium hydroxide neutralization application

Photo (6): Biological treatment

2.2. Sampling strategy and analytical methods

Four times of wastewater treatment process were selected with one week interval from six stages of working cycle to collect wastewater samples for analysis. Each sample represents one stage of treatment process.

A total of 24 outflow; inlet flow (step 1), barrel filter (stage 2), acidic wastewater outflow (step 3), NaOH (stage 4), scrape wastewater outflow (stage 5), and process wastewater outflow (step 6). Samples were taken before treatment in order to obtain a clear picture of the quality of each influent alone. All samples were analyzed for physico-chemical variables in accordance with the procedure laid down in Standard Methods for the Examination of Water and Wastewater **(APHA, 2017).** The pH and Temperature of all samples were measured in situ.

3. Statistical analysis

All collected data were tabulated and subjected to descriptive analysis using MS Excel Software (MS Office 2019).

3. RESULTS AND DISCUSION

Wastewater samples were collected from edible oil extraction and refinery of Borg Al-Arab for Industry, New Borg Al-Arab City, Alexandria before treatment and then the effluent coming out from the edible oil refinery effluent treatment unit (ETU). These samples were analyzed for different water quality parameters. The results are summarized in Table (1).

Table (1). Characteristics of the wastewater generated from the edible oil refinery unit

Parameters	Before ETU	After ETU	Difference %
pH	5.48	8.03	46.58
EC, µS/cm	2375.75	2083.75	-14.01
TDS, mg/l	1520.48	1333.60	-14.01
TN, %	0.0028	0.0003	-91.07
TOC, %	0.20	0.06	-69.89
Total alkalinity, mg/l	6.97	3.92	-43.83
TH, mg/l	290.38	62.28	-78.55
TSS, mg/l	10.00	55.00	450.00
Na, mg/l	324.30	289.80	-10.64
K, mg/l	140.76	35.19	-75.00
Ca, mg/l	24.00	48.00	100.00
Mg, mg/l	73.86	88.63	20.00
CO_3 +HCO_3	60.00	120.00	100.00
Cl, mg/l	152.65	244.24	60.00
SO_4, mg/l	249.66	224.78	-9.97
PO_4, mg/l	766.13	141.73	-81.50
NO_3, mg/l	52.17	0.00	-100.00
Oil and Grease	150.00	25.00	-83.33
TFM, %	0.65	0.114	-82.54
BOD_5 (20 0C), mg/l	370	42	-88.65
COD, mg/l	2500	92	-96.32
Color	Yellow	clear	
Temperature	43	25	-41.86
Coli forms counts, CFU/100 ml	1100	450	-59.09
Total microbial count, CFU/100 ml	300	280	-6.67

Variation in pH

The wastewater is highly acidic before treatment but after treatment it is maintained the pH of treated wastewater at 8.03. It is increased by 46.58% to reach the standard value of 6.5 – 9.0.

Salinity (Electrical Conductivity) and TDS

The wastewater salinity was 2375.75 µS/cm before treatment but reduced to about 2083.75 µS/cm after treatment. It is reduced by about 12.29%.

Total N (TN) and Total Organic Carbon (TOC) Both TN and TOC of wastewater were decreased after treatment by about 91.07 and 69.89%, respectively.

Total Alkalinity(Alk) and Total Hardness (TH)

After treatment of the edible oil refinery wastewater, the values were reduced by about 43.83 and 78.55%, respectively.

Total Suspended Solid (TSS) Treatment of edible oil refinery wastewater increased the TSS by 450%. High conductivity is due to presence of Ca^{++} and Mg^{++} ions. **(Abhay et al., 2018).**

Soluble Na, K, and SO_4 Soluble Na, K, and SO4 ions were decreased after treatment of edible oil refinery wastewater by about 10.64, 75.00, and 9.97%, respectively.

Soluble Ca, Mg, CO_3+HCO_3, and Cl Soluble Ca, Mg, CO_3+HCO_3, and Cl ions were increased after treatment of edible oil refinery wastewater by about 100, 20, 100, and 60%, respectively. **Soluble PO_4 and NO_3**

Removal of BOD (Biological Oxygen Demand)

Same as removal efficiency of BOD in wastewater from edible oil refinery of ETU. Inadequate mixing of acidic wastewater in alkaline waste water tank So BOD removal efficiency is medium. BOD removal efficiency decreases by about 88.65%.

Removal of Pathogens

Coli forms count and total microbial count were decreased after treatment of edible oil refinery wastewater by about and 59.09 and 6. 67%, respectively but stile contaminated with *Escherichia coli.*

Temperature C°

The temperature of edible oil refinery wastewater was 43 C° before entering the ETU and it is 25 C° after treatment. The values are acceptable.

The standards for industrial wastewater quality are set to protect public health, aquatic ecosystems, and the overall environment. They vary depending on the industry, the receiving environment, and local regulations. Compliance with these standards is enforced through regulations and monitoring, and industries are required to treat wastewater to meet these standards before discharge (Table 2), **US-EPA (2022).**

Soluble PO_4 and NO_3 ions were decreased after treatment of edible oil refinery wastewater by about 81.50 and 100%, respectively.

Removal efficiency of oil & greases

Maximum amount of Oil and grease were removed in ETU. In settling tank removal percentage decreases by aeration. Maximum removal is done by diffuser and frothing of water by about 83.33%

Removal of COD (Chemical Oxygen Demand)

Wastewater from edible oil refinery has high value of COD. In ETU, chemical treatment is done where 96.32 % COD decreases.

Table (2). The standards for industrial wastewater quality (US-EPA, 2022)

Parameter Guideline	Value
Temperature increase, °C	< 30
pH	6 - 9
Total Suspended solids, mg/l	30 - 100
Oil and Grease, mg/l	10 - 100
BOD_5 (20 °C), mg/l	30 -100
COD, mg/l	50 - 250
Total Nitrogen mg/l	10 - 50
Total Phosphorus, mg/l	1 - 5
Coliforms counts, CFU/100 mL	<400
Total microbial count, CFU/100 mL	<200

Metal like of Al, Cd, Co, Cr, Fe, Mn, and Sr are present in wastewater which are removed after ETU by about 9.49 to 83.52%. Also, Zn, Mo, Ni, V, and Pb were also present in wastewater which increased by about 67.45 to 407.22% (Table 3). The standard values were recorded in Table (3). The recorded values of treated wastewater from edible oil refinery were in the acceptable range for discharge in surface water or for agricultural irrigation water **(Abhay et al., 2018, Commonwealth of Australia, 2024**).

Table (3). Element's content of the wastewater generated from the edible oil refinery unit and standard values

Element	Before ETU (mg/l)	After ETU (mg/l)	Difference %	Standard value (mg/l)
Al	0.4925	0.1732	-64.82	5.0
Cd	0.0229	0.0187	-18.54	0.01
Co	0.0295	0.0267	-9.49	0.05
Cr	0.0181	0.0100	-44.83	0.05
Cu	0.0195	0.0172	-11.44	0.2
Fe	5.0323	0.8291	-83.52	5.0
Mn	0.1840	0.0384	-79.12	0.2
Zn	0.0458	0.0767	67.45	2.0
Mo	0.0135	0.0685	407.22	0.01
Ni	0.0077	0.0172	122.73	0.2
Pb	0.0180	0.0441	145.00	5.0
Sr	0.2699	0.0986	-63.47	0.02
V	0.0136	0.0300	120.77	0.1

Edible oil refinery wastewater treatment has been a challenge throughout the years because of influent chemical and physical characteristics and stringent effluent regulation. Effluent characteristics are strongly dependent on the quality of refinery influent and refining method employed for the particular oil type. Edible oil refinery wastewater can be successfully treated using physical, chemical and biological methods. The measured values of elements for treated wastewater from edible oil refinery were in the acceptable range for discharge in surface water or for agricultural irrigation water.

Industrial water quality standards are essential for regulating wastewater discharges to protect the environment, public health, and aquatic life. These standards vary by country and industry, but they generally cover a wide range of pollutants, including organic matter, heavy metals, nutrients, and toxic chemicals. By setting these limits, authorities ensure that industries manage wastewater responsibly and that receiving water bodies remain clean and safe for human and ecological health.

The effectiveness of the treatment process was different for each parameter monitored (BOD_5, COD, suspended solids, sulfates, phosphates, and chlorides). Reduction of one of these parameters does not guarantee that others have been equally affected.

Results show that the removal of suspended solids was almost consistent and higher than that of BOD_5 and COD. It can be affirmed, therefore, that most of the organic contaminants leading to high BOD_5 and COD values are due to soluble and stable emulsified organic matter, which the physicochemical treatment system does not remove from both the acid and technological wastewater. It was also affirmed that the removal of sulfates and phosphates from the acid wastewater was efficient, but poor from the technological wastewater. On the other hand, such processes as coagulation, flocculation and sedimentation are insufficient and produce sludges which are not only difficult to remove, but also a burden to the environment (**Ahmed et al., 2020; Kumar et al., 2020**). The physicochemical treatment processes significantly influence the relative biodegradability of the organic compounds in the wastewater. Hence, for effective treatment of edible oil refinery wastewater, in addition to physicochemical methods, a biological treatment process would probably improve the quality of the final effluent and ensure the reduction in biodegradable organic matter content.

The efficiency of edible oil extraction and refinery wastewater treatment for the present study has less efficiency (concerning the chemical composition, there are some parameters stiles need to efficiently removed such as coliforms (contaminated with *Escherichia coli*).

In the edible oil industry, water reuse is increasingly being considered to reduce fresh water consumption and to minimize treatment costs. The treated wastewater can be used for non-potable applications such as irrigation for agricultural purposes, if the treated water meets safety standards (**Wang, et al., 2023; Zhang, & Wang, 2021)**.

As for the irrigation water quality, the present results (Table 4) show that some calculated parameters (EC and Cl) were not suitable for common crops, but can be used for moderately tolerant plants and can be reclaimed by mixing with fresh water to reduce the salinity.

Table (4). Irrigation water quality for used in agriculture

Parameters	Values after ETU	Standard values	Description	References
pH	8.03	6.5 – 8.4	Safe	Commonwealth of Australia (2024)
EC, µS/cm (Electrical Conductivity)	2083.75	1500-3000	Water that may have adverse effects on many crops, thus requiring careful management practices.	Shahid and Mahmoudi (2014)
Cl, mg/l	244.24	141–350	Moderately tolerant plants usually show slight to substantial injury	Bauder et al.(2011)
SAR (Sodium Adsorption Ratio)	5.73	<10	considered to be a 'low sodium' water class, i.e. the use of the irrigation water with SAR less than 8 is rated as being safe with regard to causing sodicity.	Richards (1954);Zaman et al. (2018)
RSC, meq/l(Residual Sodium Carbonate)	-7.72	<1.25	safe	(Wilcox et al., 1954)
PS, meq/l(Potential Salinity)	9.17	> 5	Non suitable	Richards (1954)
ESP, %(Exchangeable Sodium Percentage)	6.71	< 13	safe	Phocaides (2007)

Efficient wastewater treatment in the edible oil industry requires a combination of physical, chemical, and biological methods tailored to the specific composition of the wastewater. By adopting a comprehensive treatment approach, the industry can minimize environmental impacts, recover valuable resources, and comply with regulatory standards while promoting sustainability (**Gupta et al., 2021)**

Wastewater treatment in the edible oil extraction and refining industry is essential to address the significant environmental impacts associated with the discharge of wastewater containing oils, fats, chemicals, and organic matter. The treatment processes aim to remove pollutants like fats, oils, and greases (FOG), suspended solids, organic matter (BOD and COD), and residual chemicals from refining processes (**Rao et al., 2022)**.

To ensure the removal of most harmful components from the wastewater of the edible oil industry, we suggest adding a final stage in the treatment, which is the carbon filter. The carbon materials can be useful for removing the most hazard and pollutant materials in wastewater **(Hamid et al., 2017& 2019).**

Biochar, a carbon-rich material produced from organic wastes through pyrolysis, has emerged as a promising solution for removing pollutants from wastewater. Its unique properties, including a large surface area, porous structure, and diverse functional groups, enhance its effectiveness as an adsorbent for various contaminants. This write-up explores the mechanisms through which biochar removes pollutants, its modifications to improve efficiency, and the challenges associated with its application in wastewater treatment.

Biochar operates through several mechanisms that facilitate the removal of contaminants from wastewater such as:

Adsorption: Biochar's high surface area allows it to effectively adsorb organic and inorganic pollutants. Studies have shown that biochar can significantly reduce concentrations of heavy metals (**Muoghalu et al., 2023; Dong et al., 2023;**

Ion Exchange: Biochar can exchange ions with dissolved contaminants, particularly in cases involving heavy metals and nutrients like ammonium and phosphate **(Li et al., 2023, Cherian et al., 2024).**

To further improve the efficiency of biochar in wastewater treatment, various modifications have been developed:

1. **Chemical Activation**: Treating biochar with chemicals (e.g., HCl, H_2SO_4, HNO_3) can increase its surface area and functional groups (such as such as carboxyl and phenolic groups), enhancing its adsorption capacity for specific contaminants **(Diaz et al., 2024; Murtaza et al., 2024; Muoghalu et al., 2023; Wang et al., 2020).**
2. **Magnetic Biochar**: Incorporating magnetic materials into biochar allows for easy separation from treated water using magnetic fields, thus facilitating reuse and reducing waste **(Li et al., 2023).**
3. **Activation Techniques**: Methods such as steam activation or CO_2 activation increase the surface area and porosity of biochar. For instance, CO_2 activation has been reported to enhance the specific surface area by more than ten times, significantly improving adsorption capacities for heavy metals **(Diaz et al., 2024).**

Despite its potential, several challenges remain in the application of biochar for wastewater treatment:

1. Variability in Performance: The effectiveness of biochar can vary significantly based on feedstock type, production conditions, and the nature of the contaminants present in wastewater. This necessitates further research to standardize production methods and optimize performance across different contexts (**Vlasova, 2021; Cherian et al., 2024**).
2. Environmental Concerns: The safety of using biochar must be thoroughly evaluated to prevent any adverse effects on ecosystems or human health. Future studies should focus on assessing potential risks associated with biochar application in various environmental settings **(Wang et al., 2020; Vlasova, 2021).**

In conclusion, biochar presents a versatile and effective approach for pollutant removal in wastewater treatment. Continued research into its mechanisms, modifications, and integration strategies will enhance its viability as a sustainable solution for water pollution management.

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الملخص العربي

تقييم كفاءة وحدة معالجة مياه الصرف الصناعي لشركة استخلاص وتكرير الزيوت النباتية في الري لإعادة استخدامها

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ركزت الدراسة الحالية على تقييم مياه الصرف الناتجة عن استخراج وتنقية الزيوت النباتية. تم أخذ عينات من المياه من كل مرحلة من مراحل معالجة مياه الصرف الصناعي للتحليل وتقييم جودة مياه الصرف الصناعي وما إذا كان يمكن استخدامها في الري الزراعي. تُظهر النتائج أن إزالة المواد الصلبة العالقة كانت شبه متسقة وأعلى من إزالة BOD5 و .COD كما تم التأكيد على أن إزالة الكبريتات والفوسفات من مياه الصرف كانت فعالة. تؤثر عمليات المعالجة الفيزيائية والكيميائية بشكل كبير على التحلل الحيوي النسبي للمركبات العضوية في مياه الصرف الصناعي. لذلك، كانت المعالجة الفعالة لمياه الصرف من مصافي زيت الطعام تتراوح بين 10 إلى 100%، ولكن الكفاءة الكلية لمعالجة مياه الصرف كانت 74 .%.

كفاءة استخراج الزيت الصالح للأكل ومعالجة مياه الصرف من المصافي للدراسة الحالية أقل كفاءة (بالنظر إلى التركيب الكيميائي، هناك بعض المعايير التي لا تزال بحاجة إلى إزالة فعالة مثل الكوليفورمات) .(Contaminated with Escherichia coli) . في صناعة الزيوت الصالحة للأكل، يتم النظر بشكل متزايد في إعادة استخدام المياه لتقليل استهلاك المياه العذبة وتقليل تكاليف المعالجة. يمكن استخدام مياه الصرف الصناعي المعالجة في التطبيقات غير الصالحة للشرب مثل الري للأغراض الزراعية، إذا كانت المياه المعالجة تفي بمعايير السلامة .

لضمان إزالة معظم المكونات الضارة من مياه الصرف لصناعة زيت الطعام، نقترح إضافة مرحلة نهائية في المعالجة، وهي فلتر الكربون. يمكن أن تكون المواد الكربونية مفيدة لإزالة المواد الأكثر خطورة وتلوثًا في مياه الصرف وزيادة كفاءة معالجة مياه الصرف .

يقدم الفحم الحيوي نهجًا متعدد الاستخدامات وفعالًا لإزالة الملوثات في معالجة مياه الصرف الصناعي. ستعزز الأبحاث المستمرة في آلياته وتعديلاته واستراتيجيات دمجه من جدواه كحل مستدام لإدارة تلوث المياه .