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Application of Building and Aquatic Wastes within a Cage as fixed bio-reactor beside micro-sand Technology to reuse the Pepsi industrial Wastewater for Irrigation Purposes

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Abstract: Egypt is one of the countries that is expected to face future water scarcity. So, searching for alternative water resources for reuse for irrigation purposes became an essential aim. So, the treatment of wastewater produced from the industrial sector, especially soft drinks is considered to be the golden solution to provide massive amounts of water instead of direct disposal into the drains which affects negatively the surrounding environment. In this paper, a fixed biofilm reactor (FBR) was used as a biological wastewater treatment with some modifications. New bio carriers were used instead of the conventional, high-cost plastic media such as construction wastes (Concrete) and aquatic wastes (marine sponges) with a filling ratio of 30 %. Four treatment units were performed to get high-quality wastewater. The flocculation tank was the first unit where alum was added as a coagulant with a dose of 3 mg/l and HRT of 0.5 hr. then wastewater influent to a micro sand filter. The main treatment unit was the FBR tank where biodegradation of bacteria was operated for HRT of 12 hr. and 24 hr. The effluent from the FBR unit was allowed to settle in the final settling tank for 2 hr. The effluent quality from FBR packed with Concrete wastes was much better than effluent from FBR packed with marine sponges in removing COD and BOD. The removal efficiency reached up to 90.7 % and 91.47%. respectively. On the other hand, FBR packed with marine sponges was more efficient in removing TN and TP with a removal efficiency of 82.9 %, and 68 % respectively.

Keywords: Concrete wastes, sea sponges, Fixed biofilm reactor, irrigation, bio carrier.

1. Introduction

The industrial effluent from food processing, soft drinks, pulp and paper, pharmaceuticals, textile, and tannery industries contains high concentrations of organic matter while the industrial effluent from steel, petroleum, textiles, tanneries, and chemical industries contains high concentrations of heavy metals. Furthermore, the wastewater produced by these industries usually contains high concentrations of BOD, COD, suspended solids, and nitrogen. The following are loads of various pollutants found in industrial wastewater produced from previously mentioned industries: 235, 423, 168, 296, and 1.65 tons/day, respectively, for BOD, COD, oil and grease, TDS, and heavy metals. The chemical sector accounts for around 60% of heavy metals discharge, whereas food processing accounts for roughly 50% of BOD loading from comparative analyses within the industrial wastewater treatment literature (Mohamed Mostafa and Robert W. Peters, 2012)

Nowadays, soft drinks are a widely distributed industry that is consumed in large quantities by people. As a result, it is necessary to determine the levels of pollutants in the water used to manufacture soft drinks and to treat generated wastewater as a result of this to reduce toxic element levels in them such as heavy metals, Chlorinated compounds, and Phthalates [2]. Wastewater from the soft drinks industry contains a range of pollutants stemming from ingredients like sugars and additives, contributing to organic compounds, suspended solids, and nutrients. Acids and alkaline substances used in flavoring and pH adjustment, as well as cleaning agents and sanitizers, add to the wastewater's chemical composition. Additionally, trace amounts of heavy metals may be present in ingredients or manufacturing processes. Overall, the composition of soft drink wastewater varies based on ingredients, processes, and wastewater management practices.

Every year, the soft drink industry utilizes more than 4500 cubic meters of water in its manufacturing process. As a result, the wastewater treatment methods used in the production process cannot achieve proper removal efficiency to achieve suitable wastewater disposal [3]. So, treating wastewater from Pepsi production is crucial for supplying water for irrigation or reuse in various industries. Identifying the elements in soft drink production helps determine the appropriate treatment technology needed for effective wastewater treatment.

Due to the massive range of consumer tastes and preferences, soft drink components might vary significantly. Water is the most abundant component, followed by carbon dioxide, caffeine, sweeteners, acids, aromatic compounds, and a slew of other chemicals in much lesser quantities. Diet soft drinks contain up to 99 percent water, whereas regular soft drinks include 90 %. Carbon dioxide is the gas found in soft drinks [4]. It's a colorless gas with a little sour odor. When carbon dioxide dissolves in water, it adds an acidic, biting flavor that refreshes the drink by stimulating the mucous membranes in the mouth. Soft drink manufacturers receive carbon dioxide in liquid form, which is kept in high-pressure metal cylinders. Caffeine is a natural fragrant chemical found in cacao beans, tea leaves, coffee beans, and kola nuts, among other plants. Caffeine has a harsh taste that complements other flavors when taken in tiny amounts. Glucose and fructose are used as sweeteners [5]. Sweeteners make up around 7–14 % of regular (non-diet) soft drinks. The most common acids found in soft drinks are citric acid, phosphoric acid, and malic acid. Acidity is added to soft drinks to balance out the sweetness while also serving as a preservative [6].

Soft drink wastewater is often treated biologically due to its high organic content; aerobic treatment is rarely used. Aerobic treatment can still be performed if the waste stream has a low organic content due to its simplicity of operation. BOD and COD can be removed using a variety of aerobic suspended or attached (fixed film) growth treatment methods. For optimum treatment outcomes, there must be enough contact time between the wastewater and the microorganisms, as well as appropriate quantities of dissolved oxygen and nutrients. Many wastewater treatment technologies can be employed to reduce the pollutant concentrations in Pepsi wastewater. Activated sludge process (ASP) [7], Fixed biofilm reactor (FBRs) [8], sequence batch reactors (SBRs) [9], and moving bed biofilm reactor (MBBR) [10] are the most common industrial wastewater methods that achieved remarkable COD, BOD, TN, TP, and heavy metals removal efficiency.

Fixed biofilm reactors (FBRs) seem to be the most effective wastewater treatment among the previous technologies [8]. It combines the advantages of both suspended and attached growth systems which enables a massive increase in mixed liquor suspended solids (MLSS) which reflects positively on the microbial population inside the reactor [11]. Several types of bio-carriers are employed in FBR to enable more bacteria (heterotrophic & autotrophic) to attach to the inner and outer layers of the media. The type and the material of the bio-carrier affect the performance of pollutant removal due to its material properties [12], surface area, and surface charge as some of these media could be natural such as Luffa sponges [12], marine sponges, banana stem, and zeolite [13] and some are artificial ones such as plastic media [14] and Ringlace.

In this experimental study, reusing construction wastes such as concrete parts remaining from construction works and aquatic wastes such as marine (sea) sponges are considered the main purpose as these media were modified to be used as FBR media to provide proper treatment for Pepsi wastewater to reuse it again for irrigation

2. Materials and Methods

2.1 Collection of Pepsi wastewater samples

Pepsi Factory in Nasr City, Egypt provided samples of Pepsi industrial effluent. Four plastic containers, each having a capacity of 25 liters, were used to collect raw wastewater samples. Before filling the plastic containers with wastewater samples, the containers were sterilized by washing them with distilled water to prevent any changes in raw water properties. The samples were acidified to retain COD and BOD levels before being transferred to the experiment location, where the small model was erected. Typically, samples for COD and BOD analysis are acidified to a pH below 4 using sulfuric acid to preserve the integrity of the organic matter and prevent biological activity that could alter the results. However, the specific pH at which the samples were acidified would depend on the analytical method and laboratory protocols being followed.

2.2 Preparation of Construction wastes (Concrete Wastes)

The concrete waste was obtained from a nearby construction site. The concrete was cleaned, split into 2 × 2 ×2 cm parts, and dried for two days at 105°C. For two days, the concrete carriers were loaded to the FBR with a constant air supply.

Table 1: Characteristics of Concrete Blocks

Parameters	value
Packing media volume	0.015 m^3
Dimensions	2 × 2 ×2 cm
Total bio-carrier surface area	150 m^2/m^3
Total media depth	10 cm

2.3 Preparation of marine sponges biocarrier

Sea sponges were sliced to the desired size (2 × 2 ×2 cm) and cleansed with distilled water at least twice. The sample was oven-dried for 24 hours at 45 degrees Celsius before being kept in a desiccator until future use. The characteristics of sea sponges after preparation are illustrated in Table 2.

Table 2: Characteristics of Sea sponges after preparation

Parameters	value
Filling fraction (%)	30 %
Dimensions	2 × 2 ×2 cm
Shape	Cube
Density	0.24 gm/cm^3
Specific surface area	800 m^2/m^3

Figure 1 The concrete wastes

Figure 2: Sea sponges

2.4 Determination of Alum dose

The gar test was used to assess the dosage of aluminum sulfate additions. The test was carried out at Egypt's National Research Center in Cairo. The Gar test was carried out as follows: Six jars were filled with 12-hour aeration cycle treated wastewater samples (500 or 1000 mL), then varying concentrations of the selected additives (aluminum sulfate) were applied to each jar (1; 2; 3; 4mg/L). A mixer was spun at 100 to 150 rpm for a minute to disseminate the additives throughout each container. To generate flocs, the mixing speed was lowered to 25 to 30 rpm for 15 to 20 minutes to increase flocs formation, which resulted in bigger flocs. The mixers were switched off for 50 minutes to enable the flocs to settle, after which the final residual turbidity in each jar was measured to calculate the appropriate dose.

2.5 Description of the FBR batch reactor

This experimental study is based on establishing an effective system for Pepsi wastewater treatment. The pilot scalepilot scale consists of four treatment units each one responsible for eliminating the specific type of pollutants found in wastewater. A flocculation tank, Micro-sand filter, Fixed bio-reactor, and a final settling tank are the main units of the used pilot scale. In the flocculation tank, aluminum sulfate was used as a coagulant with a dose of 3 mg/l. The flocculation tank was equipped with a mixer operated at 50 rpm and lowered to 30 rpm to prevent the reaction between alum and wastewater. Also, the micro-sand consists of two media (sand and gravel) which are placed with a portion of 1:1 to reduce suspended solids concentration besides the soluble organic substances. The FBR tank was equipped with an air blower to provide the sufficient amount of dissolved oxygen required for microorganism growth. The FBR tank was packed with concrete blocks in the first experimental trial and (sea marine) in the second trial. Each bio-carrier allowed the microorganism to attach to its fibers which increased the MLSS. Finally, the final settling tank was able to settle the inorganic substances produced from the FBR tank. All characteristics of the Pilot are described in Table 3.

2.6 The Experimental Program

As shown in Figure 3, Raw Pepsi wastewater was fed into the flocculation tank where the coagulation process was performed. At the beginning of the process, aluminum sulfate was added with a dose of 3 mg/l then the mixer was operated with a speed of 50 r.p.m. AfterAfter a hydraulic retention time (HRT) of 0.5 hours of mixing, the mixer was turned off then Pepsi wastewater was passed under gravity to the Micro sand filter to remove any flocs formed in the flocculation tank. The effluent from the Micro sand filter was fed into the FBR tank where the concrete wastes were packed with a depth of 10 cm in the first experimental trial and the marine sponges with a thickness of 10 cm in the second trial. Pepsi wastewater samples were taken after HRT of 12 hours and 24 hours. The effluent from the FBR tank was passed under gravity to the final settling tank where the inorganic matter produced from the biodegradation of organic matter settled under gravity after an HRT of 2 hours.

2.7 Physiochemical analysis

- The factors evaluated were chemical oxygen demand (COD), biological oxygen demand (BOD), pH, total suspended solids (TSS), Total Kjeldahl Nitrogen (TKN), and total phosphorus (TP). The tests followed the APHA2010 standard technique for water and wastewater analysis.
- The surface area of concrete blocks and sea sponges was measured using the Brunauer-Emmett-Teller (BET) technique on a Gemini VII 2390 V1.02T analyzer (Micromeritics Instrument Corp., Norcross, GA, USA).
- The temperature was measured daily before taking wastewater samples from the treatment stages.

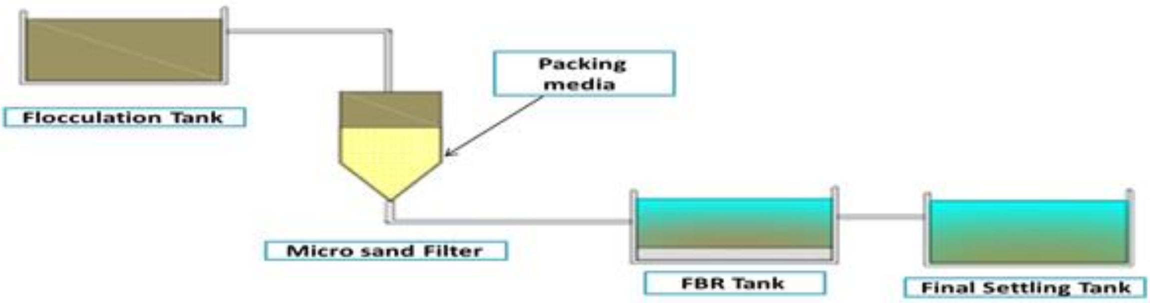

Figure 3: describes the scheme of the laboratory pilot

Table 3 : Dimensions of the Pilot-Scale Model

Treatment unit	Parameters	Values
Flocculation Tank	Length × width × depth	60 × 30 × 30 cm
	Volume of water	45 liters
	Hydraulic retention time	0.5 hr.
	Type of coagulant	Aluminum sulfate
	Dose of coagulant	3 mg/l
Micro sand filter	Type of media	Sand & gravel
	Mixing Percentage	1:1
	Media thickness	10 cm for each media
	The grain size of Micro sand	0.02 mm
FBR Tank	Length × width × depth	60 × 30 × 30 cm
	Volume of water	45 liters
	Hydraulic retention time	12 hr & 24 hr (extended aerated systems)
	Media thickness	10 cm
	Filling ratio %	30 %
Final settling tank	Length × width × depth	60 × 30 × 30 cm
	Volume of water	45 liters
	Hydraulic retention time	2 h
Air blower	Rate of flow	420 L/h

Figure 4: shows the treatment stages used in this experimental study

3. Results and discussion

3.1 Characteristics of Raw Pepsi WastewaterWastewater

Table 4 illustrates the physiochemical characteristics of Pepsi wastewater. As shown in Table 4, it was clear that the pH of the raw sample tended to alkalinity due to the compounds entered in manufacturing Pepsi such as carbon dioxide and sweeteners. Other studies reported that the pH of Pepsi wastewater was in the range of 6.6 to 9.1 [15] which was similar to the pH value of the Pepsi wastewater sample. The organic compound concentrations represented in COD and BOD are 850, and 561 mg/l, respectively. From this value, it was noticed that Pepsi wastewater has a moderate organic loading. By comparing the organic loading concentrations with the previous studies, the COD, and BOD concentrations are lower than the previous ones and are limited to (1200 to 8000) mg/l for COD, and (600 to 4500) mg/l for BOD [4].

3.2 Results of The First Experimental Trial (FBR packed with concrete wastes)

Table 5 shows the performance of each treatment stage by illustrating the concentrations of TSS, COD, BOD, TKN, and TP concentrations after each treatment stage.

Table 4 describes the characteristics of Raw Pepsi wastewater

Parameters	Unit	Value
pH	-	8.8
Total Suspended Solids, TSS	mg/l	410
Biological oxygen demand, BOD	mg/l	561
Chemical Oxygen Demand, COD	mg/l	850
Total Kjeldahl Nitrogen, TKN	mg/l	28
Total Phosphorous, TP	mg/l	0.74

Table 5 describes the concentrations of pollutants after each treatment stage (First Trial)

Parameters	Unit	Raw	Flocculation	Sand Filter	FBR	FBR	Final Settling
					12 hr	24 hr	
pH	-	8.8	8.9	8.4	8.5	8.5	8.3
Total Suspended Solids, TSS	mg/l	410	51	12	15.6	18	11
Biological Oxygen Demand, BOD	mg/l	561	234.6	114.9	13.9	9.8	7.3
Chemical Oxygen Demand, COD	mg/l	850	295.5	156.8	20.4	14.6	9.7
Total Kjeldhal Nitrogen, TKN	mg/l	28	5.1	3.2	1.2	0.89	0.81
Total Phosphorous, TP	mg/l	0.74	0.33	0.27	0.13	0.11	0.1

The initial COD and BOD concentrations were 850, and 561 mg/l, and reduced to 295.6, and 234.6 mg/l, respectively after the flocculation stage with a removal efficiency of 65.24%, and 58.18%. after passing through a micro sand filter, the COD and BOD concentrations were reached to 156.8, and 234.6 mg/l with a removal efficiency of 46.9%, and 51%. The FBR was effective in reducing the organic matter concentrations to 20.4 mg/l for COD and 13.9 mg/l for BOD at a hydraulic retention time (HRT) of 12 hours. By increasing HRT from 12 hr to 24 hr, COD and BOD concentrations were 14.6, and 9.8 mg/l, respectively with a removal efficiency of 90.7%, and 91.47%. After the final settling tank, the effluent COD and BOD concentrations were 9.7 and 7.3 mg/l.

From the previous data, it was noticed that the effect of alum on COD and BOD concentrations was very observed as it was successful in removing organic compounds with a removal efficiency of up to 55%. Other studies reported that alum was capable of removingof removing dissolved organic compounds with removal efficiency ranging from 20% to 40% [16]. By observing the performance of FBR technology on the quality of Pepsi wastewater, it was clear that using a bio-carrier like concrete was very effective as it decreased the COD and BOD concentrations by 72.2%, and 90.7% at HRT of 24 hours. This performance was lower than those reported by other studies as concrete blocks were able to remove organic compounds up to 90% [17]. This difference in performance may be due to the difference in aeration times or the insufficient dissolved oxygen (DO) provided within the FBR tank that may result from the insufficient air blower used in the treatment process besides the imbalance in oxygen distribution within the reactor.

Despite the absence of an anoxic tank to perform the denitrification process, concrete wastes as a mediummedium were able to form anoxic zones within the inner area of its porous voids to perform the denitrificationdenitrification process. other researchers reported the efficiency of using concrete as FBR media as it decreased total nitrogen removal (up to 95%) [17]. Also, the decrease in total nitrogen removal was due to the insufficient carbon source in the reactor as concrete blocks are nonbiodegradable materials so an external carbon source was needed for the denitrification process.

3.3 Results of The SecondSecond Experimental Trial (FBR packed with sea sponges)

By replacing the concrete blocks with marine sponges in the FBR tank to work as bio-carriers. It was observed as shown in Table 6 that it was also effective in reducing pollutant concentrations.

Table 6 illustrates the concentrations of pollutants after each treatment stage (Second Trial)

Parameters	Unit	Raw	Flocculation	Sand Filter	FBR 12 hr	FBR 24 hr	Final settling
pH	-	8.8	8.7	8.4	8.6	8.7	8.4
Total suspended solids, TSS	mg/l	410	65	17.6	19.2	21.7	9.4
Biological oxygen demand, BOD	mg/l	561	220.5	127.6	45.8	34.8	16.3
Chemical oxygen demand, COD	mg/l	850	275.6	136.1	51.7	32.7	13.1
Total nitrogen, TKN	mg/l	28	6.7	3.7	0.74	0.63	0.44
Total phosphorous, TP	mg/l	0.74	0.36	0.25	0.12	0.08	0.06

The initial COD and BOD concentrations were 850, and 561 mg/l, and reduced to 275.6, and 220.5 mg/l, respectively after the flocculation stage with a removal efficiency of 67.58%, and 60.7 %. after passing through a micro sand filter, the COD and BOD concentrations reached 136.1, and 127.6 mg/l with a removal efficiency of 50.62%, and 42.13%. The FBR was effective in reducing the organic matter concentrations to 51.7 mg/l for COD and 45.8 mg/l for BOD at a hydraulic retention time (HRT) of 12 hours. By increasing HRT from 12 hr to 24 hr, COD and BOD concentrations were 32.7, and 34.8 mg/l, respectively with a removal efficiency of 75.97 %, and 72.73 %. After the final settling tank, the effluent COD and BOD concentrations were 13.4 and 16.3 mg/l.

3.4 Comparison between the performance of marine sponges and concrete blocks

Using marine sponges in this experimental study is novel as employing such a bio-carrier was a great chance to examine their effect on organic matter and nutrient removal. it was observed that sea sponges actact less efficiently than concrete blocks as observed in TablesTables 5 and 6. The control parameter was surface area. TheThe surface area of marine sponges is up to 800 m^2/m^3 if compared with the surface area of concrete blocks which is limited to 155 m^2/m^3. The low density of marine sponges was a parameter that obstacles the full mixing with wastewater so a portion of marine sponges' surface area wasn't coated with biomass which affects the microbial population [18].

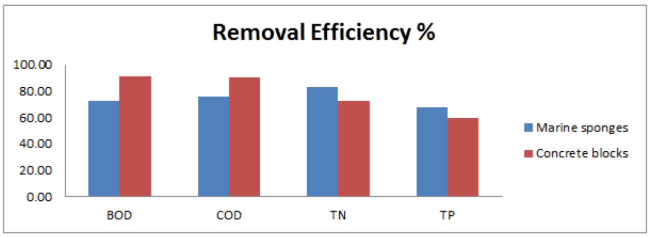

Figure 4 illustrates the performance of marine sponges and concrete wastes

It was clear from Figure 4, that concrete wastes were better than marine sponges in reducing COD and BOD concentrations. On the other hand, marine sponges achieved higher TN and TP removal efficiencies than concrete blocks which may be due to the high surface area (800 m^2/m^3) which enables nitrifying bacteria to grow with the outer layers of sponges also, large zones of anoxic zones were formed within the inner layers where bacteria convert NO_3 into nitrogen gas [19].

3.5 Availability of reusing Pepsi wastewater for irrigation purposes

By comparing the final effluents of each experimental trial by the allowable limitations of Law 92 for 2013 which is stated the allowable limits suitable to irrigation as shown in Table 7.

So, the effluent from both trials was suitable to be used in irrigation especially unrestricted irrigation such as wood trees.

Table 7 shows the allowable limitations of LawLaw 92 for 2013

Concentrations	PH	TSS	COD	BOD	TN	TP
FBR Packed with Concrete Wastes	8.3	11	7.3	9.7	0.81	0.1
FBR Packed with Marine Sponges	8.4	9.4	16.3	13.1	0.44	0.06
Law 92 for 2013	8 - 9	50	80	60	40	10

4. Conclusion

The utilization of a fixed biofilm reactor (FBR) in the treatment of wastewater from the soft drink industry, exemplified by Pepsi, has proven to be a highly effective approach in mitigating the potential water scarcity challenges faced by Egypt. Through a meticulously designed experimental study, incorporating modifications such as the adoption of construction waste (Concrete blocks) and aquatic waste (marine sponges) as bio-carriers within the FBR system, significant reductions in critical pollutant concentrations, including COD, BOD, TSS, TN, and TP, were achieved. Notably, the effluent quality from both trials met the stringent standards outlined in Law 92 for 2013, rendering it suitable for unrestricted irrigation, particularly in arid regions. This underscores the viability of employing innovative wastewater treatment strategies to address water resource sustainability concerns while simultaneously repurposing waste materials, thereby aligning with principles of environmental stewardship and resource conservation.are

References

[1] Mohamed Mostafa and Robert W. peters, "Characterization and Assessment of Industrial Wastewaters in Egypt." Accessed: Apr. 07, 2022. [Online]. Available: https://www.researchgate.net/publication/267309153_278364_Characterization_and_Assessment_of_Industrial_Wastewaters_in_Egypt

[2] S.-S. Seng, Y.-T. Hung, and J. Paul Chen, "Soft Drink Waste Treatment," Waste Treat. Food Process. Ind., pp. 255–269, 2005, doi: 10.1201/9781420037128.ch7.

[3] M. Wołowiec, M. Komorowska-Kaufman, A. Pruss, G. Rzepa, and T. Bajda, "Removal of Heavy Metals and Metalloids from Water Using Drinking Water Treatment Residuals as Adsorbents: A Review," Miner. 2019, Vol. 9, Page 487, vol. 9, no. 8, p. 487, Aug. 2019, doi: 10.3390/MIN9080487.

[4] L. Tebai and I. Hadjivassilis, "Soft drinks industry wastewater treatment," Water Sci. Technol., vol. 25, no. 1, pp. 45–51, 1992, doi: 10.2166/WST.1992.0008.

[5] A. J. Mitchell, Formulation and production of carbonated soft drinks. London ;;Glasgow ;;Weinheim: Blackie academic and professional, 1995.

[6] S. V. Kalyuzhnyi, J. Valadez Saucedo, and J. Rodriguez Martinez, "The Anaerobic Treatment of Soft Drink Wastewater in UASB and Hybrid Reactors," Appl. Biochem. Biotechnol. - Part A Enzym. Eng. Biotechnol., vol. 66, no. 3, pp. 291–301, 1997, doi: 10.1007/BF02785595.

[7] A. M. A. Elmagd and M. S. Mahmoud, "Tannery Wastewater Treatment Using Activated Sludge Process System (Lab Scale Modeling)," Int. J. Eng. Tech. Res., vol. 2, no. 5, pp. 21–28, 2014.

[8] M. N. Ali, H. A. Fouad, M. M. Meky, and R. M. Elhefny, "Pilot-scale study based on integrated fixed-film activated sludge process for cement industrial wastewater treatment," J. Degrad. Min. Lands Manag., vol. 9, no. 1, pp. 3073–3081, Oct. 2021, doi: 10.15243/JDMLM.2021.091.3073.

[9] S. Q. Aziz, H. A. Aziz, A. Mojiri, M. J. K. Bashir, and S. S. A. Amr, "Landfill leachate treatment using sequencing batch reactor (SBR) process: limitation of operational parameters and performance," Int. J. Sci. Res. Knowl., vol. 1, no. 3, pp. 34–43, 2013.

[10] Wuxi Tont-BC, "MBBR & IFAS Solution & Technology." Accessed: Aug. 30, 2021. [Online]. Available: https://cdn.komachine.com/media/product-catalog/gng_108606_mvtrwx.pdf

[11] Metcalf and Eddy, "Metcalf & Eddy, Inc. Wastewater Engineering Teatment and Reuse," Journal of Wastewater Engineering. p. 4th edition, 2003.

[12] A. Saeed and M. Iqbal, "Loofa (Luffa cylindrica) sponge: Review of development of the biomatrix as a tool for biotechnological applications," Biotechnol. Prog., vol. 29, no. 3, pp. 573–600, May 2013, doi: 10.1002/btpr.1702.

[13] A. E. N. Mohamed N. Ali, Hanan A. Fouad, Ashraf M. Heniegal, "Yeast Waste Water Treatment Using Fixed Biofilm Reactor Packed With Hybrid Bio- Carrier." Accessed: Feb. 20, 2022. [Online]. Available: https://www.researchgate.net/publication/354691751_Yeast_Waste_Water_Treatment_Using_Fixed_Biofilm_Reactor_Packed_With_Hybrid_Bio-_Carrier

[14] G. Mannina, M. Capodici, A. Cosenza, D. Di Trapani, Z. Zhu, and Y. Li, "Integrated Fixed Film Activated Sludge (IFAS) membrane BioReactor: The influence of the operational parameters," Bioresour. Technol., vol. 301, no. January, p. 122752, 2020, doi: 10.1016/j.biortech.2020.122752.

[15] B. El-Adily, "Study of some charcters of Pepsi-Akad soft drinks factory wastewater." 2019.

[16] E. N. Hidayah, Y.-C. Chou, and H.-H. Yeh, "Characterization and removal of natural organic matter from slow sand filter effluent followed by alum coagulation," Appl. Water Sci. 2018 81, vol. 8, no. 1, pp. 1–7, Jan. 2018, doi: 10.1007/S13201-018-0671-4.

[17] H. T. Le, N. Jantarat, W. Khanitchaidecha, K. Ratananikom, and A. Nakaruk, "Utilization of Waste Materials for Microbial Carrier in Wastewater Treatment," Biomed Res. Int., vol. 2016, 2016, doi: 10.1155/2016/6957358.

[18] Z. Song et al., "Zeolite powder based polyurethane sponges as biocarriers in moving bed biofilm reactor for improving nitrogen removal of municipal wastewater," Sci. Total Environ., vol. 651, pp. 1078–1086, 2019.

[19] T. T. Nguyen, H. H. Ngo, W. Guo, A. Johnston, and A. Listowski, "Effects of sponge size and type on the performance of an up-flow sponge bioreactor in primary treated sewage effluent treatment," Bioresour. Technol., vol. 101, no. 5, pp. 1416–1420, 2010, doi: 10.1016/j.biortech.2009.07.081.