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Yeast Waste Water Treatment Using Fixed Biofilm Reactor Packed With Hybrid Bio-Carrier

Mohamed N. Ali[a,*], Hanan A. Fouad[b], Ashraf M. Hennigal[c], Ahmed E. Naguib[d]

a Associate Professor in Environmental and Sanitary Engineering Department, Faculty of Engineering- Beni-Suef University, Egypt.
b Professor in Environmental and Sanitary Engineering Department, Faculty of Engineering inShoubra, Benha University, Egypt.
c Professor, Civil Engineering Department, Faculty of Engineering- Suez University, Egypt.
d Demonstrator inEnvironmental and sanitaryengineering department, Faculty of Engineering Suez University, Egypt.
E-mail: dr.mohamednabil8080@gmail.com.

Abstract:

Yeast industryis one of the most important industries that used as substrate in some food processing industries. This industry produces large quantities of wastewater that characterized with high organic impurities due to the use ofmolasses.Several treatment methods such as activated sludge, moving bed biofilm reactor (MBBR), electrocoagulation, and chemical treatment could be used for yeast wastewater treatment.In this study the treatment was done on four samples of yeastwastewater using a scale-pilot consists of 3 tanks followed with sand filter. The 3 tanks were installed on different levels to feed each tank under gravity. 4 trails were performed as following:theactivated sludge as a control attempt,integrated fixed biofilm reactor FBR using different media, gravel only in the second trial, zeolite only in the third trial, and combined between zeolite and gravel in the fourth trial.Results show that the most efficient trail was FBR with combined media gravel and zeolite with a HRT 24 h where the removal efficiency of COD,BOD, TSS, TKN, and TP was 94.5%, 96.3%, 97%, 85%, and 83.5%, respectively and the effluents met the acceptable limitation of law 48 year 1982 for reuse for irrigation purposes.

Key Words:*Yeast industry wastewater,fixed biofilm reactor FBR,zeolite,Gravel.*

I. INTRODUCTION

Due to the increase in water consumption that caused the depletion of water in addition to the huge amounts of water consumed in irrigation purposes. SO, new sources of water should be found, one of the promising resources is the treatment of domestic or industrial wastewater in order to

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reuse it for unrestricted irrigation.Due to the unfriendly effects to the surrounding environment, polluted wastewater must be treated before the discharge to the water surface. One of these industrialwastewater is yeast industry that produces huge amounts of wastewater that reachedup to 1000 m3/day[1], so treatment of yeast wastewater industry provides treated water that can be used for irrigation purposes. Treated wastewater should be met the limitations of law 48 year 1982 to be able to use it forirrigation purposes.

Yeast industry processes are molasses preparation, fermentation, and separation and drying of the yeast[2]. The main raw material used for yeast industry is molasses which is a sugar manufacturing by-product. Molasses contains 45–50% residual sugars, 15-20% non-sugar organic substances, 10-15% ash (minerals), and about 20% water[3]-[4], sowastewater from this industry ischaracterized with high chemical oxygen demand(COD), dark brown color, and high concentrations of total nitrogen (N_{tot}) and non-biodegradable organicpollutants[5]. Hence advanced techniques are required to improve the quality of wastewater effluent.

Nowadays, technologies aim to focus on spatial priorities than the past. The old methods of biological or mechanical treatment were give high efficiency in removing mainly organic carbon and the suspended solids.Recently old methods are the topic of modification to achieve improvement in the removal efficiency of biogenic compounds like nitrogen and phosphorus[6].Biological treatment can be divided in two categories.The first categoryissuspended growth processes such as activated sludge process (ASP), sequencing batch reactors (SBRs), membrane bioreactors (MBRs), and aerated lagoons. The second categoryisattached growth processes such as trickling filters (TFs), fluidized bed bioreactor (FBR), and rotating biological contactor (RBC)[7].One of the oldest technologies of biological treatment is activated sludge process (ASP) that used for treatment of municipal and industrial wastewater. (ASP) characterized by high efficiency, flexibility of operations and the ability to remove nutrients. On the other hand, there are some defects such as the high cost of construction and operations, if the volume of sewage or characteristics of sewage are suddenly changedthat affects the working of the process, is sensitive to certain types of industrial wastewater and the wet sludge requires a suitable method for its disposal[8]-[9].

The trickling filter is one of the first methods used for wastewater treatment. Trickling filter is a fixed-biofilm reactor. Within, wastewater is distributed over the media and treatment mechanism occurs when wastewater pass through the media. In the trickling filter, the media is not submerged. Despite the high performance and effectiveness of the trickling filter, many defects are associated with using it such as high cost of construction, large area is required and breeding place for flies and it is an environmental problem[10]-[11].

The biofilm attached growth reactor is characterized by low energy, low cost of equipment maintenance, simple operation, no bulking of sludge and very well thickening of sludge, high surface area so it works as a compact unit,co-existence of aerobic and anoxic microorganisms within the same system and lower sensitivity[12]. All previous advantages make the cost of construction less than previous system. It is a compact unit so no need large area as there is any need for anoxic tank. It decreases the environmental problems of breeding flies.Based on the previous discussion, using the fixed biofilm reactor (FBR) is the key solution for all the disadvantage of other treatment

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methods. FBR is one of the economic and effective technologies so it will be used with a different submerged media as (gravel and zeolite) and air blowers to provide dissolved oxygen required for bacteria to be able to grow. FBR was used to produce treated water met the allowable limitations of law 48 year 1982 for reusing for unrestrictedirrigation in addition to besafe for disposal.The remarkable properties of zeolite as ion-exchange properties, adsorption capabilities, mechanical, chemical, and thermal resistance, and low price that make it absorb nitrogen in wastewater and improve the efficiency of de-nitrification. This media could be regenerated and reused after it became exhausted. The NH_4^-exchanged zeolite can be exchanged or regenerated using NaCl or KCl solutions[13],so zeolite was asuitable media to be used in the FBR to get the safe and desired characteristics of treated wastewater.That makes the effluent safe to be discharged or reused for irrigation.

II. MATERIALSAND METHODS

1-Yeast industry wastewater

The yeast industry wastewater used for practical experiments was obtained from yeastfactory in Beni-Suef, Egypt.Four samples were collected in 5 containers with a capacity of 20 liters for each container and they were acidified to fix BOD and COD valuesand transferred to the lab where thepilot was installed to carry out the experiments.

2-Pilot Description

The laboratory pilot consists of similar tanks with dimensions 50*30*30 cm as following: primary sedimentation tank followed by an aeration tank equipped with air blower with capacity 3.5 l/min followed by a final sedimentation tankthen followed by well graded sand filter to improve the quality of the effluent. The tanks were installed on different levels to ensure that the wastewater would pass under gravity. Figure no (1) illustrates the schematic diagram of the pilot.

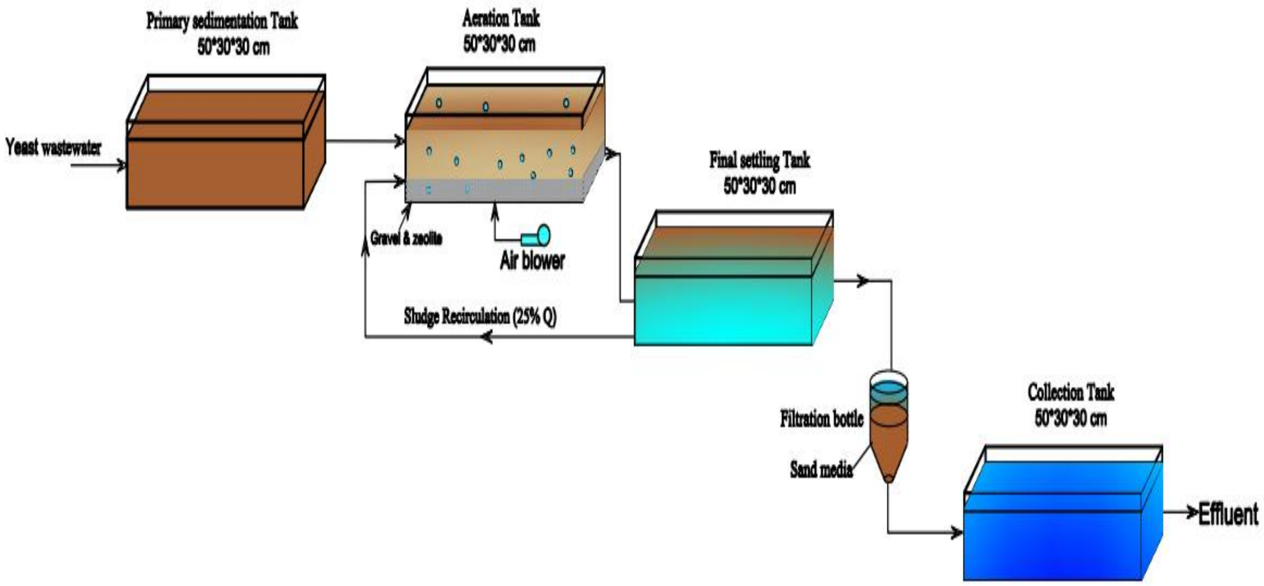

Fig 1:Schematic diagram of the pilot

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3- Naturalzeolites

Clinoptilolite Natural zeoliteson the Earth surface are sedimentary origin, and zeolites in such deposits occur in clusters of crystals often having inter crystalline pore sizes of 10 to 1000 nm in diameter [13]. Natural zeolites can be applied for domestic and industrial wastewater treatment due to their unique ion-exchange properties, adsorption capabilities, mechanical, chemical,thermal resistance,and low price[14]. Physiochemical properties of zeolite are shown in table (1).

Table (1) shows physiochemical properties of natural zeolite.

PARAMATERS	CHARACTERISTICS
APPEARANCE	Russet and grey colors
MINERAL FORM	Clinoptilolite
ABSORBATION CAPACITY FOR AMMONIUM ION	0.75 – 1.25
DENSITY (g/cm3)	2.25
BET SURFACE AREA	17 m^2/g
TOTAL PORE VOLUME	0.2216 cm^3/g

4- Experimental work

The procedures of practical experiments were done in 4 trails.In each trail, the first stage was using of a primary sedimentation tank where the tank was filled with wastewater then let suspended solids settle for 2, 2.5, 3 hours then samples were taken for analysis after 2, 2.5, 3 hours.

The second stage was usage of aeration tank with air blower capacity 3.5 l/min. The effluent from primary sedimentation tank was passed to the aeration tank where the four attempts in the aeration tank were:

-Usage of activated sludge process where the wastewater was aerated using air blower with capacity 3.5 l/min in the aeration tank for 24 hours and samples for analysis were taken after 12 and 24 hours and activated sludge were returned from final sedimentation tank according to the equation belowand the return sludge ratio was in range 25%[15].

$R = \frac{QR}{Q} = \frac{X}{XR - X}$Where:

R: Return activated sludge ratio

Q_R: return sludge flow rate, m^3/s.

Q: secondary influent flow rate, m^3/s.

X: mixed liquor suspended solids, mg/l.

X_R; return activated sludge suspended solids, mg/l. taken with range (4000-12000 mg/l [15])

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-Usage of fixed biofilm reactor FBR where the aeration tank was prepared with gravel as a media for bacteria to grow on it. Then media was used in the tank with percent 30% that was equal about 10 cmand aerated with air blower for 24 hours and samples were taken after 12 hours and 24 hours[16].

- Usage of FBR with the zeolite media. The aeration tank was prepared with zeolite as a media, and it was used with thickness 10 cm nearly 30% of volume. Then aerated for 24 hours and samples for analysis were taken after 12 and 24 hours.

- Usage of FBR with combined gravel and zeolite after preparation of aeration tank with media with percent 30%, then aerated for 24 hours and samples for analysis were taken after 12 and 24 hours.

The third stage was usage of final sedimentation tank, where the effluent from aeration tank was passed to final sedimentation tank for 2 hours and samples for analysis were taken after 2 hours.

Finally, the fourth stage was usage of sand filter.The final sedimentation tank was followed by well graded sand filter.The treated wastewater was passed through the filter then sample for analysis was taken after the filter.

5-Physical and chemical analysis

-All characteristics and parametersof raw yeast industry wastewater and treated wastewater were measured in national research center.

-The parameters werechemical oxygen demand(COD), biological oxygen demand (BOD), PH, total suspended solids (TSS), Total Kjeldahl Nitrogen (TKN) and total phosphorus(TP). The measurements were carried out according to standard methods of examination of water and wastewater APHA2010.

- The surface area of gravel and zeolite was analyzed by the Brunauer-Emmett-Teller (BET) method using a Gemini VII 2390 V1.02T analyzer (Micromeritics Instrument Corp., Norcross, GA, USA).

- Temperature was measured daily before taking wastewater samples from treatment stages.

III.DATAANALYSIS AND INTERPRETATION

1- Raw Samples

Four raw samples were taken from yeast industry wastewater. The samples were tested in national research center according to standards[17] and results as shown in table (2).

Table (2). Characteristics of raw wastewater:

PARAMETERS	UNIT	SAMPLES				MIN.	MAX.	AVERAGE
		1st	2nd	3rd	4th			
COD	mg/l	1800	1680	1764	1810	1680	1810	1763.5
BOD	mg/l	630	615	590	680	590	680	628.8
PH	-	10.4	9.8	10.7	10.9	9.8	10.9	10.5
TSS	mg/l	550	580	610	650	550	650	597.5
TKN	mg/l	95	105	93	98	93	105	97.8
TP	mg/l	17	16	14	18	14	18	16.3

Table (2) shows the physiochemical properties of four raw samples were used in the practical experiments and there is no significant difference between each other. The values of physical and chemical parameters match with other studies [1]-[4]-[18].

Wastewater PH was in range of 10.5 that mean this water was strongly basic as they were related with washing processes using caustic and nitric acid[4]. PH must be lowered and that occurred by using HCL acid to decrease alkalinity to provide suitable PH ranges from 4 to 9.5 for bacteria to grow.

2- Results of treatment

Table (3), physiochemical properties of treated wastewater after each stage:

PARAMETERS		COD (mg/l)	BOD (mg/l)	PH	TSS (mg/l)	TN (mg/l)	TP (mg/l)
FIRSTTRAIL	Raw sample 1	1800	630	10.4	550	95	17
	After primary sedimentation (3hr)	1080	386	6.7	214.5	69	13.5
	After aeration tank (12 hr.)	468	260	7.1	278.9	57	11
	After aeration tank (24 hr.)	320	197	7.3	321.8	53	8.6
	After final sedimentation tank (2 hr.)	260	120	6.8	151	47	7.9
	After sand filter	180	75	6.8	100	45	7.5
	% Of Removal	90	88.1	…….	81.8	53	55.9
SECOND TRAIL	Raw sample 2	1680	615	9.8	580	105	16
	After primary sedimentation (3hr)	1008	376.2	7.1	226.2	76.9	12.7
	After aeration tank	403.2	143	7.6	294.1	58	9.3

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	(12 hr.)						
	After aeration tank (24 hr.)	273.3	105	7.8	339.3	53.3	8.2
	After final sedimentation tank (2 hr.)	190	75	7.3	89	48	6.05
	After sand filter	130	48	7.3	55	46	6
	% Of Removal	92.5	92	……	90.5	57	62.5
THIRD TRAIL	Raw sample 2	1764	590	10.7	610	93	14
	After primary sedimentation (3hr)	1058.4	361.2	6.5	237.9	68.1	11.1
	After aeration tank (12 hr.)	388.1	140	7.1	309.3	34.7	5.3
	After aeration tank (24 hr.)	190	87	7.2	356.9	25	4.3
	After final sedimentation tank (2 hr.)	146	61	6.9	78	17.9	2.9
	After sand filter	125	51.5	6.9	40	17	2.7
	% Of Removal	92	91	……	93.5	82	81
FOURTH TRAIL	Raw sample 2	1810	680	10.9	650	98	18
	After primary sedimentation (3hr)	1086	416.2	6.4	253.5	71.7	14.3
	After aeration tank (12 hr.)	380.1	115.6	7.2	329.6	31	6.8
	After aeration tank (24 hr.)	162.9	47.6	7.6	380.3	23	5.2
	After final sedimentation tank (2 hr.)	130.3	39.7	7	31.5	15	3.1
	After sand filter	99	25	6.9	19.7	15	3
	% Of Removal	94.5	96.3	…….	97	85	83.5
Law 48 year 1982		100-120	50	6-9	60	40	5

Generally, raw wastewater wasn’t match with the permissible limits according to Egyptian standards.After the first, second and third trail the physiochemicalparameters of the treated water wasn’t lower than allowable values according to Egyptian standards. After the fourth trail the treated wastewater was match with allowable according to the law 48year 1982.

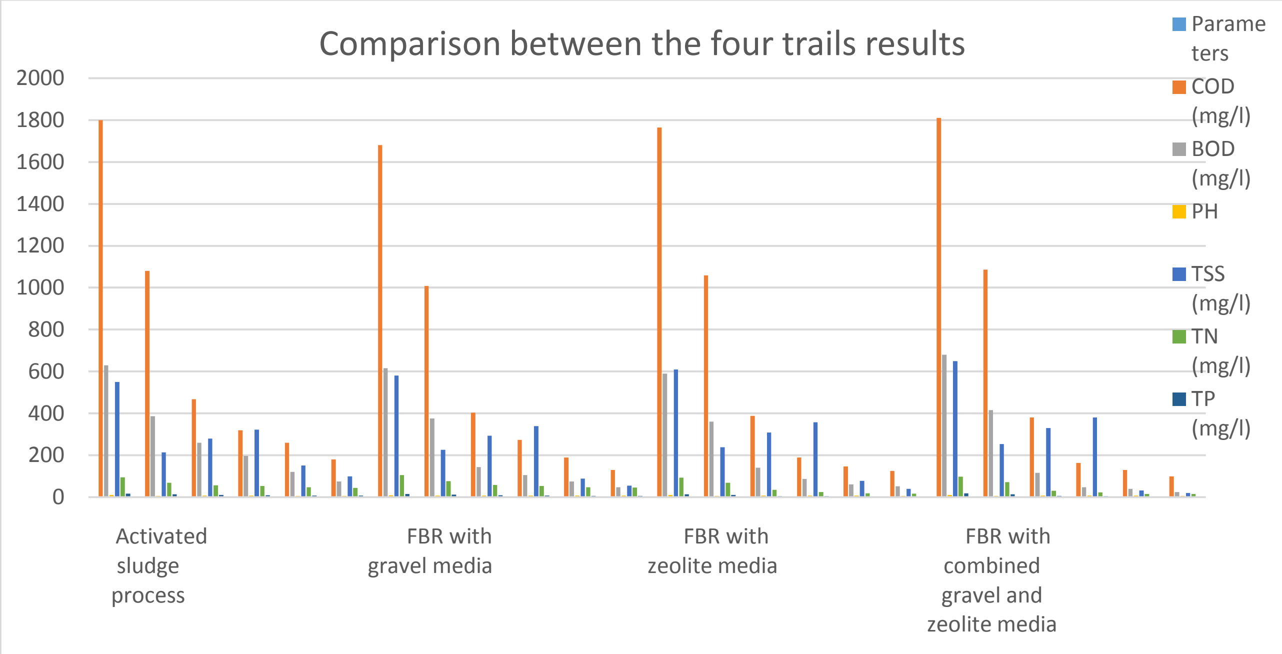

Fig (2): Comparison between the stages of yeast industry wastewater treatment.

2.1. Chemical oxygen demand(COD)

The COD removal occurs due to the activity of aerobic bacteria during aeration phase. The bacteria convert the organic substances in to settleable substances that can settle in the final sedimentation tank. The experimental results indicate the removal efficiency of COD after the primary sedimentation tank was in the range of(40%) after all trails and that match with otherstudies[15]-[19]. In the first trail the influent COD of the aeration tank and effluent from sand filter respectively was 1080 and 180 mg/l,in the second trail was 1008 and 130 mg/l, in the third trail was 1058.4 and 125 mg/l, finally in the fourth trail was 1086 and 99 mg/l respectively.That means the removal efficiency in the first, second, third, and fourth trail was in range (83.3%), (87.1%), (88.2%), and (91%) respectively.

The efficiency of removal in the second trail was higher than in the firstbecause of the effect of gravel media and the bacteria favor the growth in the surface than in suspension[20]-[21]. The third trail efficiency was (88.2%) that because of the high surface area of zeolite and the adsorption capacity of natural zeolite for organic substances. The fourth trail efficiency was (91%) that because of the zeolite and gravel working as a compact unit aerobically and anaerobically[22]. In all trails the efficiency was higher with the longer hydraulic retention time HRT, where the efficiency was higher with HRT 24hrs than 12hrs, such as in the fourth trail the efficiency of removal in the aeration tank after 12hrs was (65%) and after 24hrs was (85%).The efficiency was calculated according to the equation:

$$*R.E\ (\%) = \frac{CODin - CODout}{CODin} x100.$$

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2.2. Biological oxygen demand (BOD)

Influent wastewater was contained organic and inorganic substances. Organic substances are carbon-based and contain fecal matter. This organic matter is readily bio-degradable organic matter by bacteria (*heterotrophicbacteria*) in thetreatment process. This mechanism involves using of dissolved oxygen in wastewater to convert organic matters into settleable matter, carbon dioxide and water[23]. The amount of oxygen required for completion of this process is known as the biological oxygen demand BOD. The experimental results indicate that removal efficiency of BOD in all trails after primary sedimentation tank was in range of (38.8%) and that match with other studies [19]. In the first trail the influent BOD of the aeration tank and effluent from sand filter respectively was 386 and 75 mg/l, in the second trail was 376.2 and 48 mg/l, in the third trail was 361.2 and 51.5 mg/l, finally in the fourth trail was 416.2 and 25 mg/l respectively. That means the removal efficiency in the first, second, third, and fourth trail was in range (80.5%), (87.2%), (88.2%), and (94%) respectively. The variance is due to the same previous reasons illustrated in the COD removal.

The efficiency of removal increases with the increase of HRTWhere the efficiency in the first trail increased from (58.7%) to (68.7%), in the second trail increased from (76.7%) to (82.9%), in the third trail increased from (76.3%) to (85.3%), finally in the fourth trail increased from (83%) to (94%). That was due to the rapid and slow growing bacteria after 24hrs was taken the sufficient time to grow.

2.3. Total suspended solid (TSS)

TSS are the suspended matters that settles in the primary sedimentation tank in which the removal efficiency was nearly the same(60%) in the different trails and the highest removal efficiency of TSS with HRT 3hrs and there was no significant change with higher HRT [19].TSS also issettleable biomass that produced from the feeding of bacteria on the organic matters and settles in the final sedimentation tank.High value of TSS reflects high concentration and activity of bacteria and nutrients. Where in the first trail the influent and effluent TSS of the aeration tank and sand filter respectively was 214.5 and 100 mg/l, in the second trail was 226.2 and 55 mg/l, in the third trail was 237.9 and 40 mg/l, finally in the fourth trail was 253.5 and 19.7 mg/l respectively. That means the removal efficiencyin the first, second, third, and fourth trail was in range (53.4%), (75.7%), (83.2%), and (92.2%) respectively. The higher removal efficiency was in the fourth trail (92.2%) and that because it was the most effective trail and the higher activity of bacteria so more biomass production and more TSS removed, also theAmmonium ions that adhere to crystal surfaces within macro pores of zeolite rock, it may serve as a nutrient source for microorganisms and that increase the activity of bacteria and production of biomass[13].

2.4. Total Nitrogen (TN)

Removal of ammonia occurs due to biochemical oxidation of ammonia nitrogen (NH_3 and NH_4^+) to nitrite (NO_2) and finally to nitrate nitrogen (NO_3). The previous transformation called nitrification and that accomplished in two steps by *Nitrosomonas* and *Nitrobacter* bacteria[24].The influent and effluent TN in the first trail was 95 and 45 mg/l, in the second trail was 105 and 48 mg/l, in the third trail was 93 and 17 mg/l and the fourth trail was 98 and 15 mg/l respectively. The organisms are slow in growing and prefer the growth on the surface rather than suspended growth

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and that's why fixed bed gives more efficient in the removal of ammonia nitrogen, so the efficiency of removal in the first trail (52.6%) less than that in the second trail (54.3%).

The efficiency in the third trail (82%) was more than that in the second trail (54.3%) because of the effect of natural zeolites that have ion-exchange properties and adsorption of the ammonia (NH_4^+) from wastewater, also natural zeolite is a favorable environment for nitrifying bacteria so number of bacteria that grow in this media more than in the first or second trail. In the fourth trail the efficiency was (85%) and slightly more than that in the third trail and that because of the effect of ion-exchange properties of zeolites, in addition to thepores between zeolites and gravel that work as anoxic. In the pores the dissolved oxygen is very poor, so the bacteria (*Heterotrophic bacteria*)obtain the needed oxygen from (NO_3) and nitrogen escalates and that is called de-nitrification [16]. At other studies almost the same removal efficiency for TN by using natural zeolites [20].Nitrification and de-nitrification wereoccurred according to the following equations [13].

$$Z^{-}NH_4^{+} + 2O_2 \rightarrow Z^{-}H^{+} + HNO_3 + H_2O \text{ (nitrification)}$$

$$2HNO_3 + 5H_2 \rightarrow N_2 + 6\,H_2O \quad \text{(de-nitrification)}$$

* Where Z^{-} is the zeolite substrate.

2.5 Total phosphorus (TP)

Theremoval of phosphor occurred through incorporating it to the cell biomass that is removed lastly with sludge. The bacteria that are responsible for this process are called phosphorus accumulating organisms (PAOs).Conditions of aerobic and anaerobic should be applied to achieve the removal of phosphor[16].Total phosphorus removal efficiency in the primary sedimentation tank in all trails was in range of (20%) and that because of the presence of insoluble phosphor that precipitate in the tank. The efficiency of removal in the fourth trail was (83.5%) and in the third trail was (81%), but in the first and second trail was (55.9%), (62.5%) respectively. Efficiency in the third and fourth trail was higher than in first and second. That is due to the presence of zeolite that characterized by high percentage of pores in which bacteria works anaerobically and produces polyphosphate to get energy. And in the aerobic zone bacteria accumulate phosphor and incorporate it to the cell biomass which removed lastly with sludge. There wasn't asignificant change in the phosphor removal with HRT12 h than 24 h in all trails as the time 12 h was sufficient to the growing of most bacteria.

IV. CONCLUSION

FBR technology was used for the treatment of yeast industry wastewater. The experiments were implemented under laboratory conditions to study the effect of using different media and hydraulic retention time HRT in the efficiency of treatment and removing of organic matter, TP, and TN.

*Results proved that the most efficient trail wasintegrated FBR with gravel and zeolite in the removal of pollutants.

*The usage of natural zeolite as a media was the best in the removal of TN that because of the ion exchange properties of zeolite that made it able to adsorb the cautions of NH_4^+, also

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natural zeolite is a favorable environment for nitrifying bacteria so number of bacteria that grow in this media is more than others used media.

* Usage of zeolite and gravel as a media in the aeration tank combines the good properties of zeolite and gravel as wide surface, ion-exchange, and durability.

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