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Removal of Suspended Solids Using Pumice Stone in Integrated Fixed Film Activated Sludge Process

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Abstract:

Wastewater treatment plants operators prefer to make adjustments because they are more cost effective, to use the existing tank instead of building new ones. In this case an imported materials would be used as bio-loads to increase biomass and thus maintain efficiency as the next organic loading increases.In the present study, a local substance "pumice stone" was used as a biological carrier in the aeration tank, and the experiments were carried out in five stages: without biological carriers, filling ratio of 4%,10%,20%, and25% with pumice stone, the maximum organic loading at each stage (1.1884, 1.2144, 1.9432, 2.7768, 3.3141)g BOD /l.d respectively.Other experiments were carried out to determine the best filling ratio, the SS removal ratio was (67.57%, 69.5%,79.44%,89.61%,and 99.2%) when the filling ratio with pumice stone was (0, 4, 10, 20, and 25)% respectively, at organic loading 2 ± 0.0528 g BOD /l.d, so the best filling ratio of pumice stone was 25% .

Key words: Activated sludge, Biological Carriers, Pumice Stone, Suspended Solid.

Introduction:

Sewage treatment plants are designed for a period of (25-30) years, and at the end of it, engineering procedures must be taken to preserve the plant's output due to the increased organic loading coming to the plant.

These procedures are:

Either the horizontal expansion of the treatment plant units (i.e. building new treatment units) and this procedure requires a high cost, or technical procedure to increase the biomass without adding new units.

At the present time, it is preferable for the sewage treatment plants to make modifications because they are more cost-effective, as they use the existing tank instead of building new tanks.

The combined modification of the conventional activated sludge process uses suspended or fixed media of a suitable material, which acts as carriers for the growth of active biomass on its surface, and this is called the IFAS system(1).

An integrated fixed-film activated sludge (IFAS) system is one of the most popular modified activated sludge processes which increases the microbial population and accelerates the biodegradation of organic compounds by adding a fixed media to a suspended growth basin (1).

This process is actually an integration process which includes the suspended and attached growth and provides the advantages of both attached and suspended growth systems (2).

The IFAS process has many advantages in comparison with conventional processes of the activated sludge. This system provides more resistance against organic and hydraulic shock load; besides, it has more flexibility and higher efficacy than other activated sludge processes (3,4)

The IFAS system is a good option to upgrade the Activated Sludge System especially in case of facing scarcity of land and provides higher removal efficiency of COD and nutrients relative to conventional activated sludge. It also possesses a lower retention time, higher hydraulic load, and less tank volume (5,6).

In the present study, a local substance "pumice stone" with a surface specificity of 224 m^2/m^3 was used as a fixed biological carrier in the aeration tank over 253 days, with different filling ratio of 0%, 4%, 10%, 20%, and 25% when the organic loading changed from 0.92±0.0384 to 3.4 ±0.0706 gBOD / l.d .

While in a previous study, moving plastic holders of type PVC with a surface specificity of 350 m2/ m3 was used with a filling ratio of 25% with increasing the organic loading inside the experimental plant over 105 days, the best removal ratio of SS was 85.24 ± 3.21% when the organic loading was 0.44 gCOD / l.d ..(7)

In another study ,Moving Bed Biofilm Reactors (MBBR) was used to rehabilitate a sewage plant in Kiththal city, India, samples at inlet and outlet during the period from January 2014 to April 2014 were collected, the SS removal ratio was 83.11% .. (8)

Six full-scale IFAS were surveyed to quantify Trace organic contaminants and estrogenic activity removal, the type of media varies for each IFAS, it is shown in Table 1, all of them performed well in terms of the removal of TSS (91- 99%).(9).

Table1. Characteristics of surveyed wastewater treatment plants (WWTPs). (9).

WWTP ID	Sample Date (in 2015)	IFAS Install Date	Design Capacity (MGD)	Median Flow [a](MGD)	SRT[b] (d)	Aerobic SRT[c] (d)	Temp[d] (^oC)	IFAS Media Type	Carrier Media Filling Ratio
A	24-Sep	2013	0.15	0.05	12.4	6.7	21.6	AnoxKaldnes K5	0.35
B	30-Oct	2010	7.5	2.5	9	6	19.7	Active Cell 450	0.35
C	14-Oct	2013	10.7	6.4	17.5	8.8	23	Active Cell 450	0.50
D	27-Oct	2011	15	9.3	6.7	4.3	17.5	BiofilmChip™ p	0.38
E	16-Oct	2013	23.2	11.5	9.9	5.1	21.5	AnoxKaldnes K1/K3	0.50/0.67
F	8-Oct	2013	50	32.2	9.1	4.4	20.8	AnoxKaldnes K3	0.52

Materials and Methods:

The experiments were conducted at the sewage plant in Homs, Syria, over 253 days.

The operation was started on July 1, 2018 using aerated sludge from wastewater treatment plant in Dweir, Homs, Syria which is a plant that works with conventional activated sludge technology, to accelerate the formation and growth of biomass. The wastewater used to accomplish this research was brought from the outlet of the first sedimentation tank.

The characteristics of the wastewater and sludge which were taken from Homs wastewater treatment plant, are shown in Table(2):

Table 2. Characteristics of wastewater and sludge of Homs wastewater treatment plant.

Biological Oxygen Demand	BOD_5	191.7 mg/l
Suspended Solids	SS	202 mg/l
Mixed Liquid Suspended Solids in Aeration Tank	$MLSS_{AT}$	2988 mg/l
Sludge Retention Time	SRT	4 -5 days

The pumice stone is considered chemically inert due to its high content of Silicon dioxide, SiO_2 =75%.

The black basalt pumice stone with a specific weight = 1.2 gr /cm^3, was used in this study.

The pumice stone was prepared in a cylindrical shape with dimensions D = 2.5 cm, H = 1 cm, and the specific surface measurement was 224 m^2/m^3.

The pumice stone was fixed on a metal holder.

The percentage of filling of fixed biological carriers is calculated by dividing the size of the outer frame of the holder of the biological carriers are fixed on it, by the effective tank size ... (10)

Effective aeration tank volume = 10 liters

Single holder size = 122.7185 cm^3 = 0.123 liters

The OLR (Organic Loading Rate) of the experimental plant was changed by mixing the water from the sedimentation with a percentage of the water entering the Homs wastewater treatment plant.

-Pilot plant components:

The experimental tank was manufactured according to studies conducted by many researchers…(11,12)

Fig (1) shows the components of the experimental plant used in the experiments, which consist of the following:

1- 50liters wastewater collection tank, from which the water was transferred to the aeration tank with a flow of 2 liters / hour " Q_{AT} = 2 l/h".

2- Aeration tank, cylindrical in shape D = 20 cm, H = 33 cm, where the effective tank volume is 10 liters "V_{AT} = 10 L", it means the Hydraulic Retention Time (HRT) in aeration tank was 5 hours: "HRT= V_{AT} / Q_{AT} ".

The tank was equipped with a compressed air system located at the bottom of the tank, with dissolved oxygen value more than 2 mg/l. Water enters the tank by flowing from the collecting tank to the secondary sedimentation tank

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3- Secondary sedimentation tank, cylindrical with dimensions D = 20 cm, H = 30 cm, which has in it a sludge collection funnel with height H=15cm.
The treated wastewater collected on the surface is transferred to the treated water tank
4- The sludge return pump: to transfer returned activated sludge "RAS" from the bottom of the secondary sedimentation tank to the aeration tank, tank with a flow of 2 liters / hour " Q_{RAS} = 2 l/h", which means the recycle ratio was 100%.
5- Treated water tank: The treated water is collected in this tank.

Figure 1. The experimental plant used for experiments

Fig(2) shows the schematic diagram of the experimental plant used in the experiments

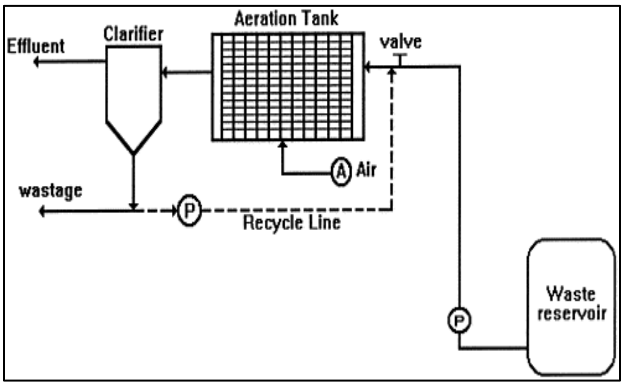

Figure 2. The schematic diagram of the experimental plant used in the experiments

The concentration of the biomass MLSS in aeration tank and the SS concentration of the treated wastewater from the secondary sedimentation tank were measured in the lab of Homs wastewater treatment plant in Dweir, Homs, Syria

Results and Discussion:

First: The experiments were carried out in stages: without biological carriers, and by adding pumice stone with different filling ratios, all stages are shown in Table (3),the pumice stone filling ratio increased when the SS removal decreased to less than 83%.

Table 3. SS removal ratio and MLSS concentration when changing the organic loading with different pumice stone filling ratio.

pumice stone filling ratio	operation time	OLR	Removal of SS	MLSS	F/M
%	day	g BOD /l.d	%	g/l	g BOD /g Total $MLSS_{AT}$ .d
0	15-22	0.92±0.0384	90.71	2.988	0.308
	23-29	0.99±0.0288	89.23	3.176	0.312
	30-36	1.05 ±0.024	86.07	3.308	0.317
	37-43	1.15±0.0384	**82.86**	3.392	0.339
4	58-64	1.15±0.0384	84.69	3.6085	0.319
	65-71	1.15±0.0384	84.78	3.6225	0.317
	72-78	1.15±0.0384	84.96	3.6958	0.311
	79-85	1.2 ±0.0144	82.93	3.7598	0.319
	86-92	1.25 ±0.024	**80.36**	3.7898	0.330
10	93-99	1.25±0.024	87.66	4.529	0.276
	100-106	1.25±0.024	90.38	4.544	0.275
	107-113	1.25±0.024	91.59	4.570	0.274
	114-120	1.4±0.0528	93.82	5.220	0.268
	121-127	1.5 ± 0.144	95.27	6.613	0.227
	128-134	1.6 ± 0.048	96.15	7.428	0.215
	135-141	1.8±0.0432	88.56	6.667	0.270
	142-148	2±0.0528	**79.44**	6.086	0.329
20	149-155	2 ±0.0528	88.26	6.474	0.309
	156-162	2±0.0528	89.34	6.498	0.308
	163-169	2 ±0.0528	91.23	6.580	0.304
	170-176	2.1 ±0.0408	92.82	6.961	0.302
	177-183	2.25±0.048	96.85	7.493	0.300
	184-190	2.4 ±0.072	94.17	7.808	0.307
	191-197	2.55±0.0624	92.55	8.160	0.312
	198-204	2.7 ±0.0768	90.13	8.556	0.316
	205-211	2.85±0.0624	**80.45**	8.825	0.323
25	212-218	2.85±0.0624	89.17	9.3677	0.304
	219-225	2.85±0.0624	90.45	9.6066	0.297
	226-232	2.85±0.0624	92.28	9.7535	0.292
	233-239	3 ±0.0744	90.62	10.1712	0.295
	240-246	3.2 ±0.1141	88.9	10.2159	0.313
	247-253	3.4 ±0.0706	**80.12**	10.3275	0.329

The organic loading increased over periods starting from the beginning of the experimental plant.

SS was measured for five samples per week for the wastewater coming from the secondary sedimentation in the experimental plant and the removal percentage was calculated.

MLSS was also measured in the experimental aeration tank.

The number 15 means 15 days from the start of operation, and the period (15-22) indicates that the organic loading in this period was almost constant and the yield also. As for the subsequent periods, the loading increased and the yield decreased and became lower than 83%.

Fig (3), (4), (5), (6), and(7) show the effect of the change in the organic loading rate on removal SS when using pumice stone with a filling ratio 0, 4, 10, 20, 25%, respectively.

The maximum organic loading rate was (1.1884, 1.2144, 1.9432, 2.7768, 3.3141)g BOD /l.d, at each stage.

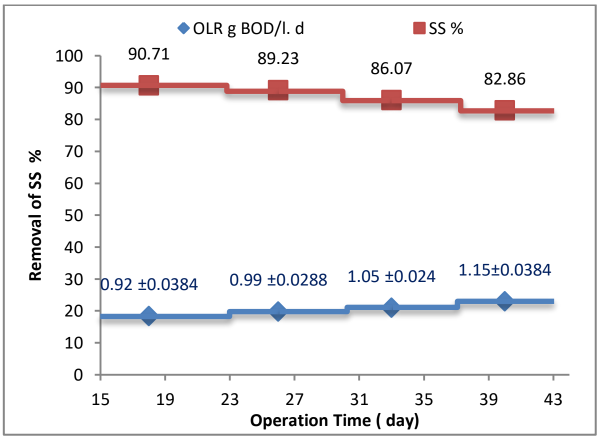

Figure 3. Effect of OLR change on SS removal

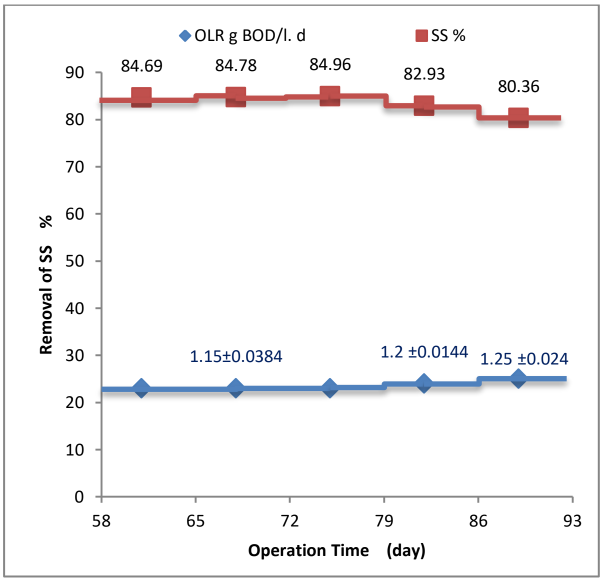

Figure 4. Effect of OLR change on SS removal when using pumice stone at 4% filling ratio.

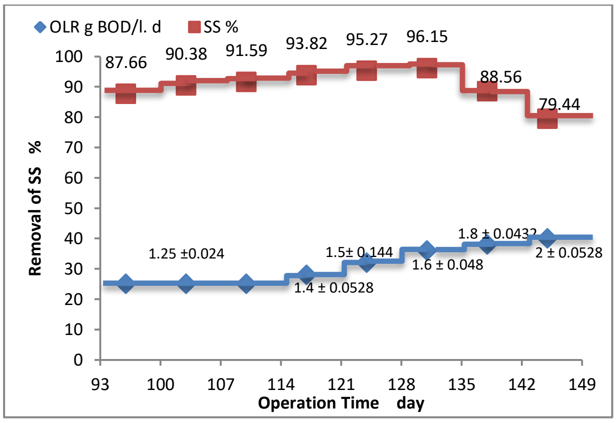

Figure 5. Effect of OLR change on SS removal when using pumice stone with 10% filling ratio.

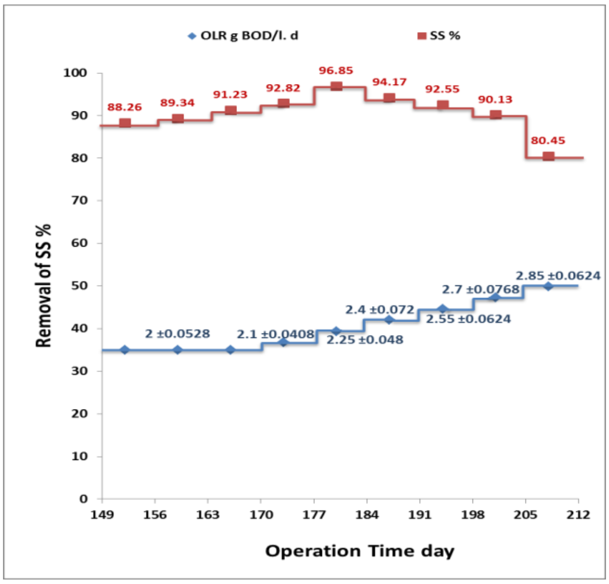

Figure 6. Effect of OLR change on SS removal when using pumice stone with 20% filling ratio.

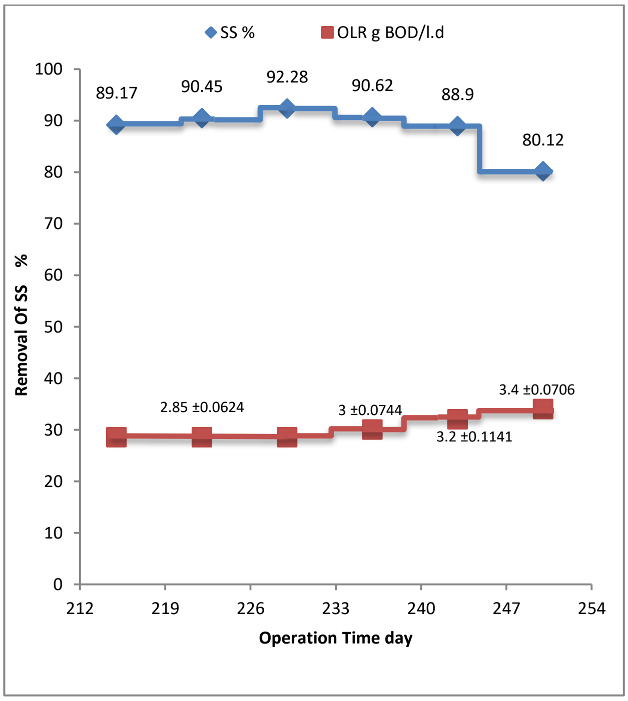

Figure 7. Effect of OLR change on SS removal when using pumice stone with 25% filling ratio.

The yield decreases due to the increase of organic loading rate with slightly increase of biomass.(6)

Second: Experiments were carried out to determine the best pumice stone filling ratio at the same OLR. The SS removal ratio was (67.57%, 69.5%,79.44%,89.61%,and 99.2%) when the filling ratio with pumice stone was (0, 4, 10, 20, and 25)% respectively, at organic loading 2 ± 0.0528 g BOD /l.d**.**

Figure(8) shows the removal of SS with different pumice stone filling ratio, when OLR was 2 ±0.0528 g BOD /l.d.

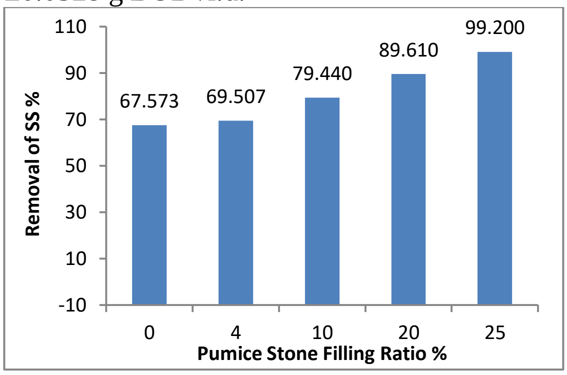

Fig 8. Removal of SS with different pumice stone filling ratio

In a previous study, the best removal ratio of SS was 85.24 ± 3.21% when the organic loading was 0.44 gCOD/ l.d.(8)

In another study the removal of TSS was (91- 99%).(9).Comparing the results of different studies with those of the present study revealed that the IFAS system has had high efficiency in TSS removal which might be due to the fixed media of the biological reactor.

Indeed, hybrid systems like IFAS create the conditions of attached and suspended biological growth, and thereby the sludge sedimentation capability improves, so suspended solids along with the sludge are deposited faster with better conditions.(1)

Conclusion:

In this study, the following conclusions are obtained:

1- The maximum organic loading rate is (1.1884, 1.2144, 1.9432, 2.7768, 3.3141)g BOD /l.d, when the filling ratio with pumice stone is (0, 4, 10, 20, and 25)% respectively, to obtain the yield equal and more than 83%.

2- The SS removal ratio is (67.57%, 69.5%,79.44%,89.61%,and 99.2%) when the filling ratio with pumice stone is (0, 4, 10, 20, and 25)% respectively, at organic loading 2 ± 0.0528 g BOD /l.d, so the best filling ratio of pumice stone is 25% .

Table of terms:

MBBR	Moving Bed Biofilm Reactors
BOD	Biological Oxygen Demand
SS	Suspended Solids
MLSS	Mixed Liquid Suspended Solids
IFAS	Integrated Fixed-Film Activated Sludge Process
F/M	Food/ Mass

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in Damascus University.

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إزالة المواد المعلقة SS باستخدام حجر الخفان في نظام الحمأة المنشطة المشترك

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الخلاصة:

عند انتهاء العمر التصميمي لمحطات المعالجة لابد من إجراء تعديلات للمحافظة على المردود، في الوقت الحاضر يفضل في محطات معالجة مياه الصرف الصحي القيام بالتعديلات وذلك لأنها أكثر فعالية من حيث التكلفة، وتستخدم الحوض الموجود بدلا من بناء أحواض جديدة، يتم عادة استخدام مواد مستوردة كحوامل بيولوجية لزيادة الكتلة الحيوية وبالتالي المحافظة على المردود مع زيادة الحمل العضوي القادم.في هذه الدراسة تم استخدام مادة محلية "حجر الخفان" كحامل بيولوجي في حوض التهوية، وإجراء التجارب على خمس مراحل: دون حوامل بيولوجية، وبنسبة ملء بحجر الخفان 4%، 10%،20% 25%، وكان التحميل العضوي الاعظم في كل مرحلة (1.1884، 1.2144، 1.9432، 2.7768، 3.3141) g BOD /l.d على التوالي للحفاظ على مردود المحطة 82% في إزالة SS. أجريت تجارب اخرى لمعرفة أفضل نسبة ملء، كانت نسبة إزالة SS (67.57، 69.5 ، 79.44، 89.61، و99.2)% عند استخدام حجر الخفان بنسبة ملء(0، 4، 10، 20، و25) % على التوالي، وذلك عند التحميل العضوي 0.0528 ± 2 g BOD /l.d .أي أن أفضل نسبة ملء بحجر الخفان هي 25 %.

الكلمات المفتاحية: حمأة منشطة، حوامل بيولوجية، حجر الخفان، مواد معلقة.