JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(4), 117–139
https://doi.org/10.12911/22998993/159399
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Received: 2022.12.27
Accepted: 2023.02.07
Published: 2023.02.20

Performance of Intermittent Slow Sand Filter Processing Units in Treating Food Court Wastewater

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ABSTRACT

This study aimed to determine the performance of modified slow sand filter (SSF) media with blood clam shells (*Anadara granosa*) and activated carbon to remove turbidity, TSS, TDS, and FOG on the food court wastewater. The concentration of water pollutant parameters processed by SSF was determined based on Indonesia water quality standards, as well as knowing the optimum operational parameters of intermittent slow sand filter with Response Surface Methodology (RSM). The research data was processed using the Optimal type (custom) design which consisted of independent factors including the type of filter media, the addition of bacteria to the grease trap pre-treatment unit, and running time, as well as the research response in the form of the effectiveness of removing turbidity, TSS, TDS, and FOG. The reactor was operated intermittently (48 hours) for a maximum of 22 days and the concentration of pollutant parameters was calculated using the Standard Methods. The results of the Analysis of Variance (ANOVA, $p<0.05$) in the 2FI model of the study showed that there was a significant effect of all independent factors on the effectiveness of removing all water pollutant parameters. The most optimal operational parameters were achieved with the type of activated carbon media, the addition of Bacillus sp. in the grease trap pre-treatment unit in the amount of as much as 1%, and the detention time of 4 days, with the effectiveness of removing turbidity reaching 39.53%; TSS 45.25%; TDS 19.30%; FOG 61.35%.

Keywords: *Anadara granosa*, environmental pollution, FOG, intermittent slow sand filter, response surface methodology, TDS, TSS, turbidity.

INTRODUCTION

Minister of Environment Regulation No. 68/2016 explains that domestic wastewater is the wastewater originating from businesses and or residential activities, restaurants, offices, commerce, apartments, and dormitories. Restaurant wastewater, which includes domestic wastewater, generally comes from washing food utensils, wastewater and food waste, such as fat, rice, vegetables, and others (Zahra and Purwanti, 2015). Restaurant wastewater can be a source of river pollution, because of the community's habit of throwing water used for washing directly into water bodies (Pratiwi, 2015). The raw materials for clean water used by water treatment plants are generally sourced from river water, but 60% of river water pollution in Surabaya comes from domestic wastewater (Imron et al., 2023; Fatnasari and Hermana, 2010). Restaurant wastewater should not be discharged directly into water bodies, because it can cause a decrease in the quality of water bodies. The wastewater can be reused for sanitation hygiene purposes by going through several processing processes.

Physically, water quality is determined by the content of total suspended solids (TSS) and turbidity where it is expected that the water is clear, colourless, and odourless (Asmadi, 2012 in Fitri et al., 2013). Restaurant wastewater has a fat content of up to 10% of the organic compounds present, suspended solids content of around 100–1,000 mg/L, dissolved solids of more than 1,000 mg/L, and turbidity of more than 50 NTU (Widyaningsih, 2011). The condition of the restaurant wastewater indicates the need for efficient, inexpensive, and easy-to-maintain wastewater treatment technology. The treatment technology that can improve water quality is the Slow Sand Filter (SSF) unit with preliminary treatment in the form of a Grease Trap (GT) unit (Fitriani et al., 2020).

Restaurant kitchen activities produce the wastewater containing oil and fat. Oils and fats are triglycerides consisting of fatty acid chains, as are esters in glycerol. The absence of prior processing of oils and fats will cause clumping and blockage of the wastewater treatment unit (Matsui et al., 2005). This can be overcome by using a grease trap treatment unit to reduce oil and fat levels in wastewater, so that there is no clogging in the slow sand filter processing unit. In their research, Wongthanate et al. (2014) stated that the efficiency of a grease trap to remove oil and grease in wastewater can reach 90%. Grease traps have the advantages of relatively long service life, low operating and maintenance costs; they produce less sludge and can be configured with biological treatment (Imron et al., 2021; Purwanti et al., 2017; Maharani, 2017).

Slow sand filter technology has the advantage that it does not require chemicals (coagulants) in the pollutant removal process (Maryani, 2014). The technology used is the intermittent slow sand filter (ISSF). The advantage of the intermittent slow sand filter is that the quality of the treated water is better because the contact time between the biofilm layer and wastewater lasts longer (Ni'matuzaroh et al., 2022; Ranjan and Prem, 2018). The physical process that occurs in the SSF is the filtration process which includes the transport and attachment of pollutant particles to the filtering media. Sedimentation and adsorption processes also affect the effectiveness of the removal (Dampang et al., 2022; Kurniawan et al., 2022). SSF is very suitable for water treatment in developing countries, due to its uncomplicated design, passive mechanism, operation, and relatively easy maintenance (Byrne, 2010). SSF was able to reduce turbidity by 89%, TSS by 96%, TDS by 5% (Jami'ah and Hadi, 2014; Mirza, 2019).

The research conducted by Andriani et al. (2015) previously used a residence time of 48 hours. The results of this study indicate that ISSF has good efficiency in reducing colour parameters, reaching 93% and also has efficiency in reducing total coli up to 98%. However, a large efficiency value does not necessarily guarantee that the ISSF effluent meets the quality standards of other parameters. Hence, it is necessary to conduct further research on the efficiency of ISSF. ISSF filter media is not limited by one particular media type; the use of other media can be combined or varied (Fitriani et al., 2023).

The variety of media added to the slow sand filter is activated carbon. Activated carbon is often used as an adsorbent in water filtration to remove pollutants caused by the content of organic matter in water (Sari, 2011). Activated carbon is processed carbon with high porosity and wide pores on its surface, so that it is useful for the adsorption process. Activated carbon can effectively reduce certain organic and inorganic compounds, such as micropollutants, lead, chlorine, fluorine, dissolved radon, colour, taste, and odour-causing compounds, which may not be removed in a slow sand filter (Bryant et al., 2015).

Another variation of media used is skin waste blood rang (*Anadara granosa*). Blood clam shells contain chitin, which is a natural polysaccharide that is used as an adsorbent. In addition to chitin, blood clams also contain calcium carbonate ($CaCO_3$) in their shells, causing the blood clam shells to have pores that have the ability to absorb pollutants into the surface pores. Seashells have negatively charged chemical functional groups (amine, hydroxyl, and carbonyl), which function to attract pollutant ions in positively charged water (Khan, 2016). The use of blood clamshell waste as a filter media can also help reduce the amount of shellfish waste in coastal areas.

The research will use a series of reactor units consisting of a grease trap, a horizontal roughing filter, and a laboratory-scale slow sand filter. Specifically, this research will focus on the analysis of the modified intermittent slow sand filter processing unit in processing liquid waste from culinary centre activities with a residence time of 48 hours. The parameters that become the main focus are suspended solids (TSS), dissolved solids (TDS), turbidity, oils and fats. The independent variable in this study was the variation of the

ISSF filter media, namely a combination of sand with activated carbon and a combination of sand with blood clam shells. Variations in treatment were carried out to obtain the effect of variables on the removal of turbidity parameters, TSS, TDS, oil and fat.

The results of the parameter test will be analysed using the response surface methodology (RSM) to obtain optimum results from the data collected. The slow sand filter is still as effective today and is increasingly solving many water quality problems, but there is a need to further increase the effectiveness of SSF in treating water, so its use with new modifications must be carried out (Brandt et al., 2016).

MATERIAL AND METHODS

Place and time of research

The research was conducted from January 2021 to June 2021. This research includes the acclimatization process, reactor simulation, and data analysis. The wastewater used is from the Deles Culinary Centre, Surabaya. The research was carried out at the Faculty of Science and Technology, Airlangga University, to be precise in three laboratories, namely the Drinking Water Treatment Technology Laboratory, the Microbiology Laboratory, and the Ecology and Environment Laboratory. The intermittent SSF reactor was placed in the Drinking Water Treatment Technology Laboratory so that the samples from the SSF processing are carried out at that location. The analysis of turbidity, TSS, TDS, and FOG was carried out at the Microbiology Laboratory and Ecology and Environment Laboratory, Faculty of Science and Technology, Airlangga University.

Tools and materials

The tools used include 1 unit of HDPE 1100 L profile tank, 2 units of grease trap reactor, 2 units of horizontal roughing filter, 4 units of slow sand filter reactor, and 1 unit of Yamano brand submersible water pump with a capacity of 4,000 L/hour. The equipment used when sampling wastewater included 2 Yamano brand submersible water pumps with a capacity of 3,000 L/hour; 2 hoses ⅝" diameter 20 m long; 2 roll cables 15 m long; raffia roll rope; 20 jerry cans of 25 L; and 5 jerry cans of 30 L. The jerry cans were used to collect wastewater before being put into a 1,100 L HDPE tank profile at the reactor placement site.

The equipment used in the turbidity analysis is the Thermo Scientific Eutech TN-100 turbidimeter. The equipment used in the TDS analysis is the TDS meter TDS-3. The equipment used for TSS analysis is a desiccator containing a desiccant, an oven with a temperature range of 103 °C to 105 °C, an analytical balance with a readability of 0.1 mg; 25 ml volumetric pipette or 50 ml measuring cup; petri dish; Gooch cup 100 ml; tweezers; and vacuum system. The equipment used for FOG analysis is a 250 ml separatory funnel; 100 ml beaker, 50 ml cylinder measuring cup, funnel, a set of distillation apparatus with 125 ml distillation flask, water bath, desiccator, analytical balance, Whatman number 40 filter paper.

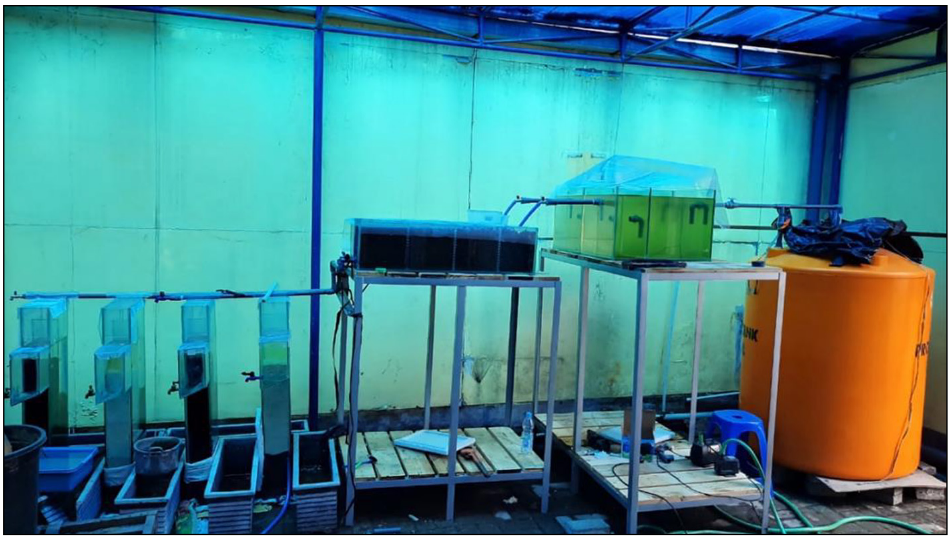

Figure 1. Slow sand filter reactor, roughing filter, grease trap, and profile tank

The materials used in the reactor simulation include wastewater from food court, blood clam shells (*Anadara granosa*), fine sand with a diameter of 0.15–0.35 mm; gravel diameter 10, 20, and 30 mm, activated carbon mesh size No. 60, distilled water, 2 long ½” and ¾” PVC pipes 4 m long, PVC pipe accessories ½” and ¾”, and mosquito netting.

The materials used in the analysis of turbidity are turbidimeter, distilled water, and calibration solution. The materials used in the TDS analysis are TDS meter, distilled water, and calibration solution. The materials needed for TSS analysis are distilled water and Whatman 934AH filter paper. The materials needed in the analysis of fatty oils are distilled water, n-hexane, Na_2SO_4, and H_2SO_4.

Statistical analysis of response

Experimental responses were analysed by the Analysis of Variance (ANOVA) test. The recommended ANOVA model is the 2FI model which has significance in the ANOVA and non-significance to the lack of fit test. A final equation in terms of actual factors is released as a mathematical function of the research model that can be applied in the field to predict and calculate response values. The interaction between single or multiple independent factors on the response is visualized in contour graphs and 3D surface graphs.

RESULT AND DISCUSSION

This study used four slow sand filter (SSF) reactors with variations that can be seen in Table 1. The modified treatment of SSF filter media was divided into two, namely using a combination of sand with activated carbon and a combination of sand with shells.

Effectiveness of SSF on test parameter allowance

SSF1 uses sand filter media, activated carbon, and control liquid waste (liquid waste without the addition of bacterial augmentation); SSF2 uses sand filter media, clam shells (*Anadara granosa)*, and control liquid waste; SSF3 uses sand filter media, activated carbon, and liquid waste with the addition of 1% augmentation of *Bacillus sp*. (addition of bacterial augmentation is carried out in the grease trap pre-treatment unit); SSF4 uses sand filter media, shells, and liquid waste with the addition of bacterial augmentation.

The addition of 1% bacterial consortium *Bacillus* sp. is done by removing ±843 ml of the liquid waste in the grease trap, then putting it into the grease trap ±843 ml of the bacterial consortium that had previously been diluted in physiological water. The SSF circuit that has been arranged was then given protective iron gauze to avoid mosquito contamination which can produce mosquito larvae in the supernatant in the SSF reactor.

Effectiveness of SSF on turbidity parameter removal

The graph of the average percentage effectiveness of turbidity removal can be seen in Figure 2.

On the basis of Figure 2, SSF1 has the highest removal effectiveness value of 74.88 ± 7.06% and the lowest removal effectiveness value of 45.68 ± 1.68%. SSF3 was able to achieve the highest effectiveness value of 91.73 ± 0.73% while the lowest effectiveness value was 32.81 ± 0.52%. SSF2 obtained the highest effectiveness value of 82.43 ± 2.82% and the lowest effectiveness value of 48.50 ± 6.93%. SSF4 achieved the highest effectiveness value of 91.01 ± 0.38% and the lowest of 47.71 ± 4.39%. Compared to the results of research conducted by Thomas and Kani (2016), the percentage of turbidity removal by a slow sand filter can reach 70%, this shows the results that are not much different from the results of this study.

Table 1. Variation of slow sand filter (SSF)

Reactor	Control wastewater	Wastewater + *Bacillus sp.*	Sand & act. carbon	Sand & clam shells
SSF1	√		√	
SSF2	√			√
SSF3		√	√	
SSF4		√		√

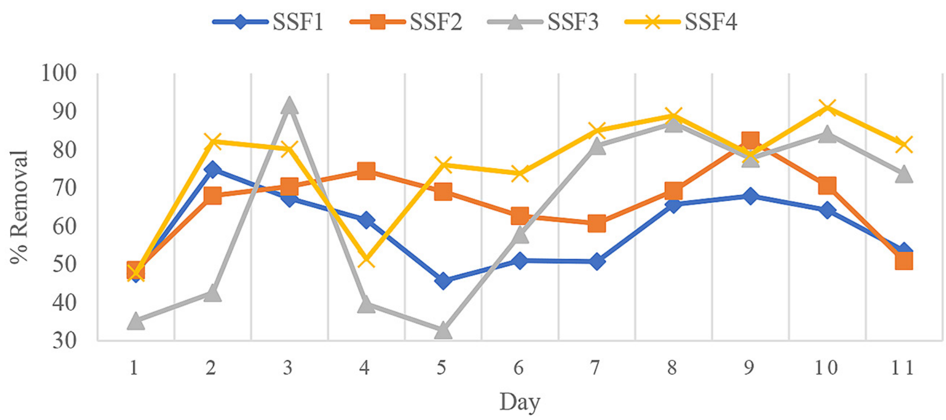

Figure 2. Graph of average percentage of effectiveness of turbidity removal by SSF1, SSF2, SSF3, and SSF4 per day

Table 2. ANOVA Model 2FI turbidity

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	5,204.09	6	867.35	13.93	< 0.0001	significant
A	2426.07	1	2426.07	38.98	< 0.0001	
B	680.81	1	680.81	10.94	0.0029	
C	382.26	1	382.26	6.14	0.0203	
AB	1,524.82	1	1,524.82	24.50	< 0.0001	
AC	25.42	1	25.42	0.41	0.5286	
BC	164.71	1	164.71	2.65	0.1163	
Residual	1556.09	25	62.24			not significant
Lack of fit	403.16	5	80.63	1.40	0.2671	
Pure error	1,152.93	20	57.65			
Total cast	6,760.18	31				
Information						
A = Detention time (days) B = Wastewater (% bacteria) C = Filter media (SSF)			A, B, C = main effects AB, AC, BC = interaction effects			

Table 3. Fit statistics ANOVA turbidity

Standard deviation	7.89	R^2	0.77
Mean	56.45	Adjusted R^2	0.71
Coefficient of variation, %	13.98	Predicted R^2	0.65
		Adeq precision	12.87

ANOVA model 2FI turbidity above, the experimental results show that the *F-value* of 13.93 with a *P-value of* less than 0.05 proves that the three factors namely detention time, wastewater, and the type of filter media used in the study affect the effectiveness of turbidity removal in liquid waste from culinary centre activities. Lack of Fit F - value 1.4 indicates that Lack of Fit is relatively insignificant to pure error. An insignificant lack of fit is a good result because a model should ideally be fit, that is, the model can be used to predict response values with different factor values (Anderson, 2016). Table 3 shows that the coefficient of determination (Adjusted R^2) of 0.71 and a coefficient prediction (Predicted R^2) of 0.77 has a difference of less than 0.2 which indicates no deviation model or data so it can be accepted, as well as a strong correlation between independent factors on the response to the research model.

All data on the actual response value of the effectiveness of the removal of turbidity that have been entered into the software design expert -11

Table 4. Comparison of actual and predicted values of the effectiveness of turbidity removal

Run	Independent factor			Response	
	A (Day)	B (% bacteria)	C (SSF)	Actual (%)	Prediction (%)
1	11	1	P+KR	79.40	83.78
2	6	1	P+AC	51.50	55.34
3	11	0	P+KR	50.90	54.08
4	1	0	P+AC	47.60	47.54
5	6	0	P+AC	39.00	50.65
6	6	1	P+AC	64.20	55.34
7	11	0	P+AC	49.60	53.76
8	1	0	P+KR	48,50	51.97
9	6	0	P+KR	62.00	53.03
10	1	1	P+AC	35,30	36.28
11	11	1	P+KR	81.40	83.78
12	11	0	P+AC	53.50	53.76
13	11	0	P+KR	49.60	54.08
14	1	1	P+AC	34,20	36.28
15	11	0	P+AC	57,40	53.76
16	1	0	P+AC	36,70	47.54
17	1	0	P+KR	41.60	51.97
18	1	1	P+KR	47.70	49.79
19	11	0	P+KR	52,20	54.08
20	11	1	P+KR	83.40	83.78
21	1	1	P+KR	43.30	49.79
22	1	0	P+KR	55,40	51.97
23	1	1	P+AC	36,40	36.28
24	1	0	P+AC	58,40	47.54
25	6	1	P+KR	64.00	66.79
26	6	0	P+AC	63.00	50.65
27	11	1	P+AC	64.00	74.39
28	6	1	P+KR	83.00	66.79
29	6	0	P+KR	64.00	53.03
30	1	1	P+KR	52.10	49.79
31	11	1	P+AC	83.40	74.39
32	11	1	P+AC	73.70	74.39

Note
P+AC = Sand & activated carbon
P+KR = Sand & seashells

also released a comparison of the actual response value with the predicted response value, as well as a normal probability plot test. This statistical analysis is useful for measuring the accuracy of the data against software predictions and knowing whether the residual value data follows a normal distribution. Data is declared normally distributed if the scatter plot follows a diagonal line. The comparison of the actual value and the predicted value of the software can be seen in Table 4 while the normal probability plot graph can be seen in Figure 3.

On the basis of Table 4 and Figure 3, the data obtained were normally distributed and there was no significant difference between the predicted data and the actual observed data. The results of the interaction between independent factors on the 2FI model are illustrated in the form of a three-dimensional surface graph to make it easier to observe differences in removal effectiveness. Three-dimensional graphs of the removal effectiveness of each medium on the turbidity parameters are presented in Figures 4 and 5.

On the basis of the results of the illustrations in Figures 4 and 5, it is found that all SSFs have

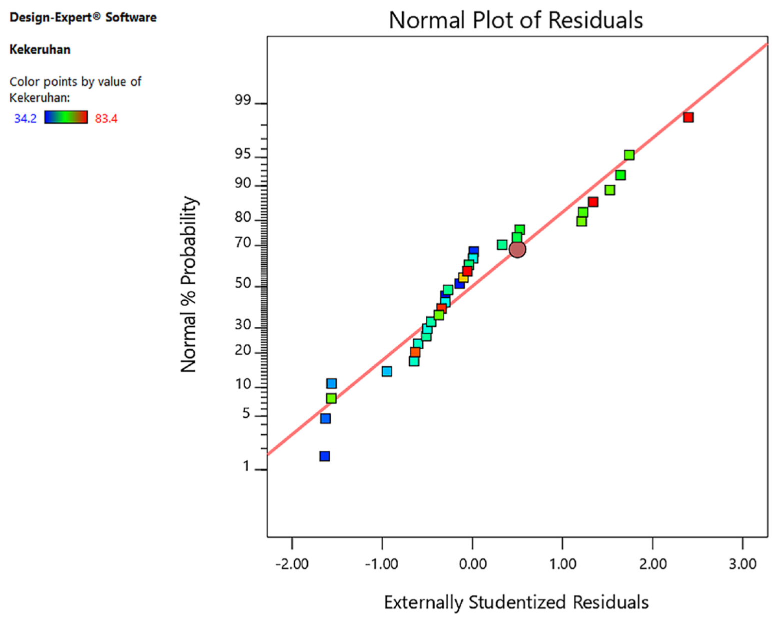

Figure 3. Normal probability graph of turbidity plot

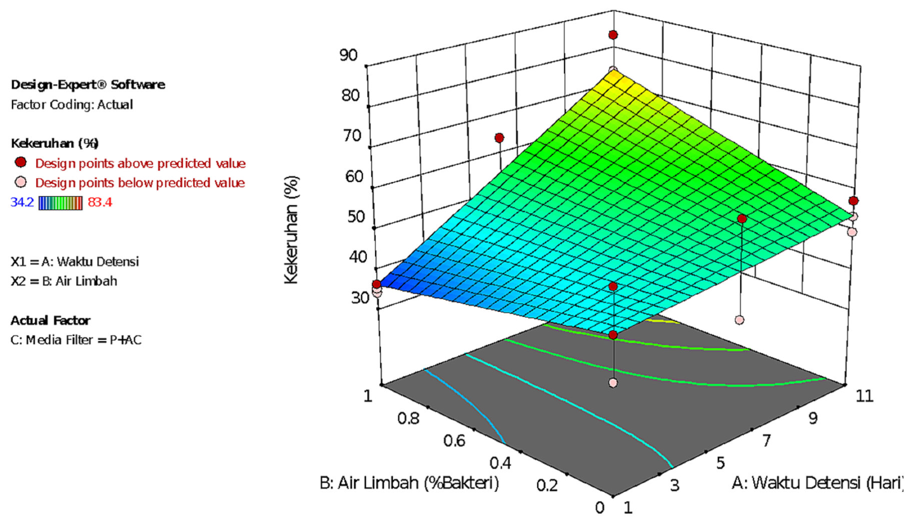

Figure 4. 3D graph of effectiveness turbidity removal by activated carbon filter media

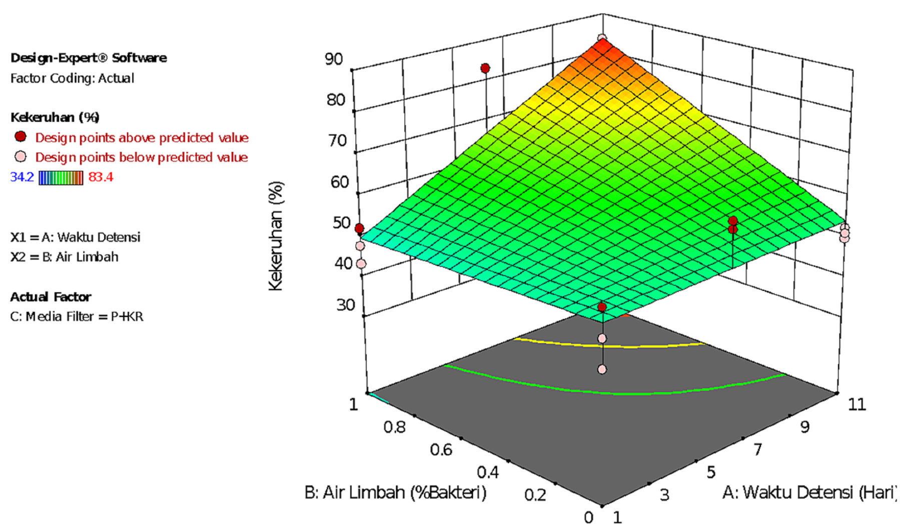

Figure 5. 3D graph of effectiveness turbidity removal by clam shell filter media

a trend of turbidity removal effectiveness which will increase frequently with increasing simulation time. The SSF with a combination of sand and shell filter media has higher removal effectiveness than SSF with a combination of sand and activated carbon filter media. The most optimal turbidity removal process is found in SSF4 with the effectiveness of turbidity removal reaching 50–80%. This result is also supported by research conducted by Theresia (2020), where the combination of sand and shell filter media has the best percentage in turbidity removal. This is also because the diameter of the shell grains is smaller than the diameter of the activated carbon grains so that the spaces or gaps between the shell grains are tighter. The diameter of the shells used was 4 x 10^{-4} m and the diameter of the activated carbon used was 5 × 10^{-3} m. The tighter gaps between the shell grains can hold suspended particles better.

Effectiveness of SSF on TSS parameter removal

The data and graphs of the average percentage effectiveness of TSS removal by SSF1, SSF2, SSF3, and SSF4 can be seen in Figure 6.

Figure 6 shows that SSF1 has the highest effectiveness value at 80.77 ± 7.69% while the lowest effectiveness is 5.26 ± 2.63%. SSF3 achieved the highest effectiveness of 80 ± 10% and the lowest was only 0.47 ± 2.36%. The greatest effectiveness of SSF2 was 68.75 ± 18.75% and the lowest was only 0.92 ± 0.92%. SSF4 showed the highest effectiveness of 60.71 ± 25% while the lowest was only 3.13 ± 1.04%. The effectiveness obtained is close to the results of a study conducted by Sarasdewi (2015), which is the TSS removal value reaching 72%.

On the basis of Table 5 ANOVA of the 2FI TSS model above, the experimental results show

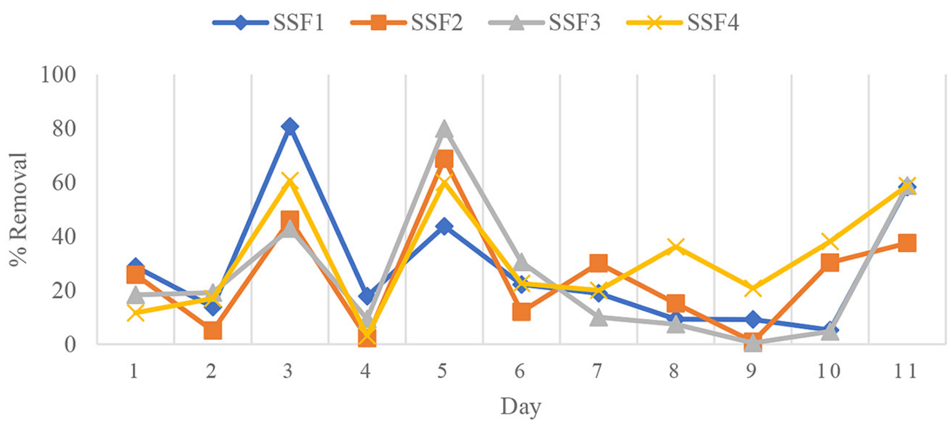

Figure 6. Graph of average percentage effectiveness of TSS removal by SSF1, SSF2, SSF3, and SSF4 per day

Table 5. ANOVA Model 2FI TSS

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	7,707.73	6	1284.62	7.40	0.0001	significant
A	6,144.00	1	6144.00	35.37	< 0.0001	
B	32.00	1	32.00	0.18	0.6714	
C	528,12	1	528.12	3.04	0.0935	
AB	835.44	1	835.44	4.81	0.0378	
AC	53.40	1	53.40	0.31	0.5842	
BC	114.76	1	114.76	0.66	0.4240	
Residual	4,342.34	25	173.69			
Lack of fit	1,748.22	5	349.64	2.70	0.0509	not significant
Pure error	2,594.12	20	129.71			
Total cast	12,050.07	31				
Note						
A = Detention time (days) B = Wastewater (% bacteria) C = Filter media (SSF)			A, B, C = main effects AB, AC, BC = interaction effects			

Table 6. Fit Statistics ANOVA TSS

Standard deviation	13.18	R^2	0.64
Mean	33.37	Adjusted R^2	0.55
Coefficient of variation, %	39,50	Predicted R^2	0.41
		Adeq precision	7.81

that the *F*-value of 7.4 with a *P*-value *of* less than 0.05 proves that the factors namely detention time, wastewater, and the type of filter media used in the study affect the effectiveness of the removal. The most influential factors are detention time, as well as the interaction between types of wastewaters and detention time. Lack of Fit F - value 2.7 indicates that Lack of Fit is relatively insignificant to pure error. Lack of Fit that is not significant is a good result, because an ideal model must be fit, that is, the model can be used to predict response values with different factor

Table 7. Comparison of actual and predicted values of TSS removal effectiveness

Run	Independent ffactor			Response	
	A (Day)	B (% bacteria)	C (SSF)	Actual (%)	Prediction (%)
1	11	1	P+KR	41.20	52.61
2	6	1	P+AC	28.00	36.54
3	11	0	P+KR	33.30	35.02
4	1	0	P+AC	28,80	26.73
5	6	0	P+AC	23.90	38.33
6	6	1	P+AC	32.90	36.54
7	11	0	P+AC	33.00	49.92
8	1	0	P+KR	25,80	17.80
9	6	0	P+KR	10,10	26.41
10	1	1	P+AC	18.30	13.15
11	11	1	P+KR	58,80	52.61
12	11	0	P+AC	58,30	49.92
13	11	0	P+KR	26,70	35.02
14	1	1	P+AC	10.00	13.15
15	11	0	P+AC	83.30	49.92
16	1	0	P+AC	27,00	26.73
17	1	0	P+KR	18,20	17.80
18	1	1	P+KR	11.70	11.79
19	11	0	P+KR	50.00	35.02
20	11	1	P+KR	76.50	52.61
21	1	1	P+KR	6.70	11.79
22	1	0	P+KR	33.30	17.80
23	1	1	P+AC	26,70	13.15
24	1	0	P+AC	30,30	26.73
25	6	1	P+KR	20.00	32,20
26	6	0	P+AC	22.00	38.33
27	11	1	P+AC	52.90	59.93
28	6	1	P+KR	26.00	32,20
29	6	0	P+KR	13.90	26.41
30	1	1	P+KR	16.70	11.79
31	11	1	P+AC	64.70	59.93
32	11	1	P+AC	58,80	59.93
Note P+AC = Sand & activated carbon P+KR = Sand & seashells					

values. Table 6 shows that the coefficient of determination (Adjusted R^2) of 0.55 and a coefficient prediction (Predicted R^2) of 0.41 has a difference of less than 0.2 which indicates no deviation model or data so it can be accepted, as well as a strong correlation between independent factors on the response to the research model.

All data on the actual response value of the effectiveness of the removal of turbidity that have been entered into the software also released a comparison of the actual response value with the predicted response value, as well as a normal probability plot test. This statistical analysis is useful for measuring the accuracy of the data against software predictions and knowing whether the residual value data follows a normal distribution. The comparison of the actual value and the predicted value of the software can be seen in Table 7 while the normal probability plot graph can be seen in Figure 7.

Figure 7 has shown that the data is normally distributed because the *scatterplot* has followed the diagonal line on the *normal probability* graph. The results of the 3D graphics, i.e. Figures 8 and 9 show that the longer the detention time, the trend of the effectiveness of TSS removal in the four SSFs will also increase, but

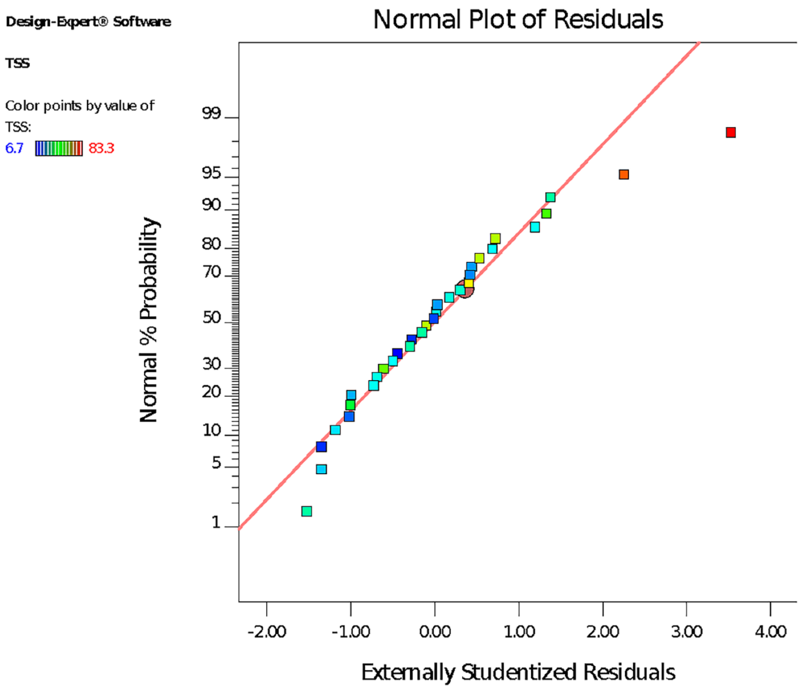

Figure 7. Normal probability plot TSS graph

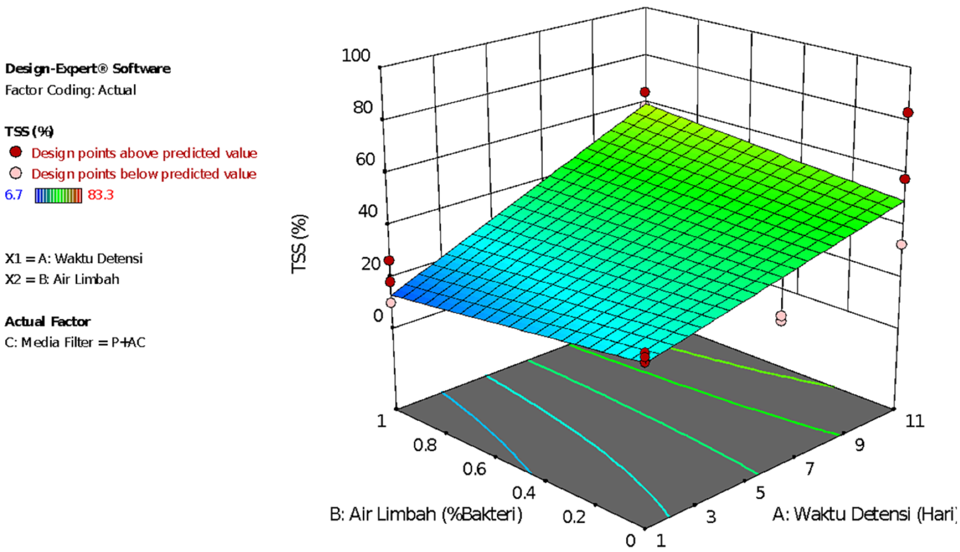

Figure 8. 3D graph of TSS removal effectiveness by activated carbon filter media

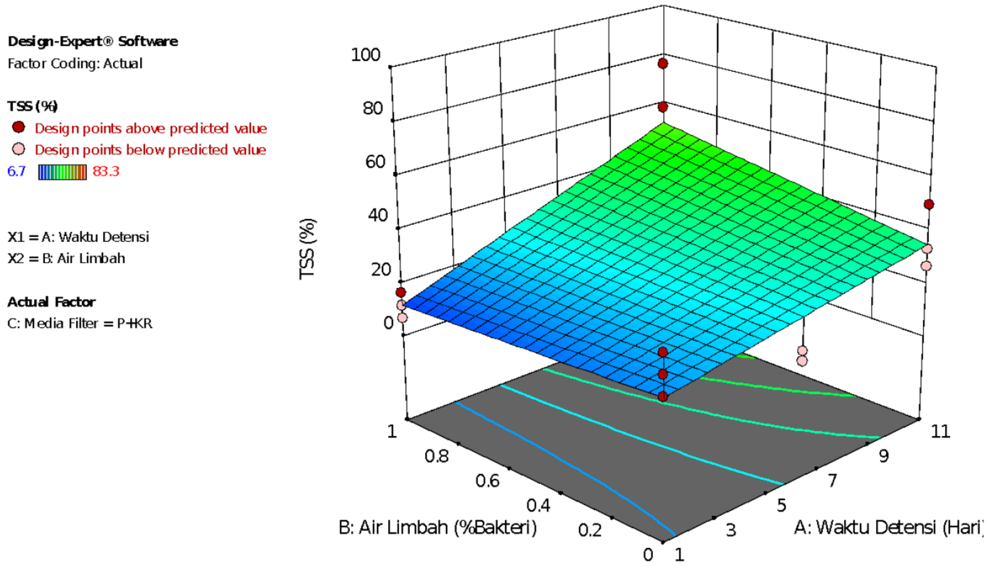

Figure 9. 3D graph of TSS removal effectiveness by clam shell filter media

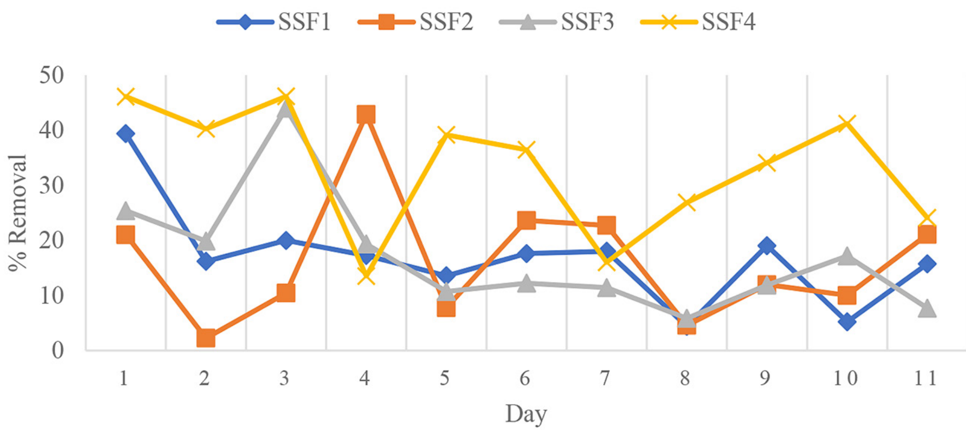

Figure 10. Graph of the average percentage effectiveness of TDS removal by SSF1, SSF2, SSF3, and SSF4 per day

Table 8. ANOVA Model 2FI TDS

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	3,261.37	6	543.56	10.90	< 0.0001	*significant*
A	1,447.71	1	1447.71	29.04	< 0.0001	
B	25.38	1	25.38	0.51	0.4821	
C	508.01	1	508.01	10,19	0.0038	
AB	83.63	1	83.63	1.68	0.2071	
AC	158.11	1	158.11	3.17	0.0871	
BC	1,038.54	1	1038.54	20.83	0.0001	
Residual	1,246.29	25	49.85			*not significant*
Lack of fit	465,16	5	93.03	2.38	0.0753	
Pure error	781.13	20	39.06			
Total cast	4,507.66	31				
Note						
A = Detention time (days) B = Wastewater (% bacteria) C = Filter media (SSF)			A, B, C = *main effects* AB, AC, BC = *interaction effects*			

of the four SSFs, the one that is superior in removing TSS is SSF with activated carbon filter media. The most optimal TSS removal process occurs in SSF3 with an effectiveness reaching 20–55%. This is supported by the research previously conducted by Astuti (2012), where SSF using a combination of activated carbon filter media can achieve a TSS removal of around 80–90%.

Effectiveness of SSF on TDS parameter removal

The graph of the average percentage effectiveness of removal of turbidity by SSF1, SSF2, SSF3, and SSF4 can be seen in Figure 10.

The figure above shows the effectiveness of TDS removal. SSF1 has the highest effectiveness

Table 9. Fit Statistics ANOVA TDS

Standard deviation	7.06	R^2	0.72
Mean	24.25	Adjusted R^2	0.66
Coefficient of variation, %	29.11	Predicted R^2	0.54
		Adeq precision	11.69

Table 10. Comparison of actual and predicted values of TDS removal effectiveness

Run	Independent factor			Response	
	A (Day)	B (% bacteria)	C (SSF)	Actual (%)	Prediction (%)
1	11	1	P+KR	23.60	27.76
2	6	1	P+AC	6.30	15.46
3	11	0	P+KR	18.30	18.32
4	1	0	P+AC	23.60	33.54
5	6	0	P+AC	12.90	25.08
6	6	1	P+AC	18,20	15.46
7	11	0	P+AC	13.70	16.61
8	1	0	P+KR	16.70	24.98
9	6	0	P+KR	17,00	21.65
10	1	1	P+AC	23.80	27.66
11	11	1	P+KR	23.80	27.76
12	11	0	P+AC	15,70	16.61
13	11	0	P+KR	21.10	18.32
14	1	1	P+AC	25,40	27.66
15	11	0	P+AC	17.80	16.61
16	1	0	P+AC	39,40	33.54
17	1	0	P+KR	21.00	24.98
18	1	1	P+KR	43.30	41.89
19	11	0	P+KR	23.80	18.32
20	11	1	P+KR	24.10	27.76
21	1	1	P+KR	44.70	41.89
22	1	0	P+KR	25,30	24.98
23	1	1	P+AC	26.90	27.66
24	1	0	P+AC	55,20	33.54
25	6	1	P+KR	36.00	34.83
26	6	0	P+AC	22.30	25.08
27	11	1	P+AC	5.20	3.26
28	6	1	P+KR	37,00	34.83
29	6	0	P+KR	30.00	21.65
30	1	1	P+KR	46,10	41.89
31	11	1	P+AC	7.70	3.26
32	11	1	P+AC	10,20	3.26

Note
P+AC = Sand & activated carbon
P+KR = Sand & seashells

value at 39.38 ± 15.78% and the lowest is 4.40 ± 0.45%. SSF3 has the highest effectiveness value of 43.99 ± 0.72%, while the lowest effectiveness is 5.84 ± 5.16%. SSF2 the highest effectiveness value is 42.87 ± 0.06% and the lowest effectiveness is only 2.24 ± 0.36%. The highest effectiveness of SSF4 was 46.01 ± 0.13% and the lowest was 14.77 ± 1.25%. The results of this study tend to have a lower removal effectiveness compared to the research conducted by Sarasdewi (2015) which can reach 73%.

On the basis of Table 8, the results from ANOVA model 2FI TDS show that the F-value of 10.9 with a P-value of less than 0.05 proves that the three factors namely detention time, wastewater, and the type of filter media used in the study affect the effectiveness of TDS removal. In the liquid waste of culinary center activities, the most influential factors are detention time, type of filter media, and the interaction between the type of wastewater and the type of filter media. Lack of Fit F-value 2.38 indicates that *Lack* of Fit is relatively insignificant to pure error. Lack of Fit that is not significant is a good result, because an ideal model must be fit, that is, the model can be used to predict response values with different

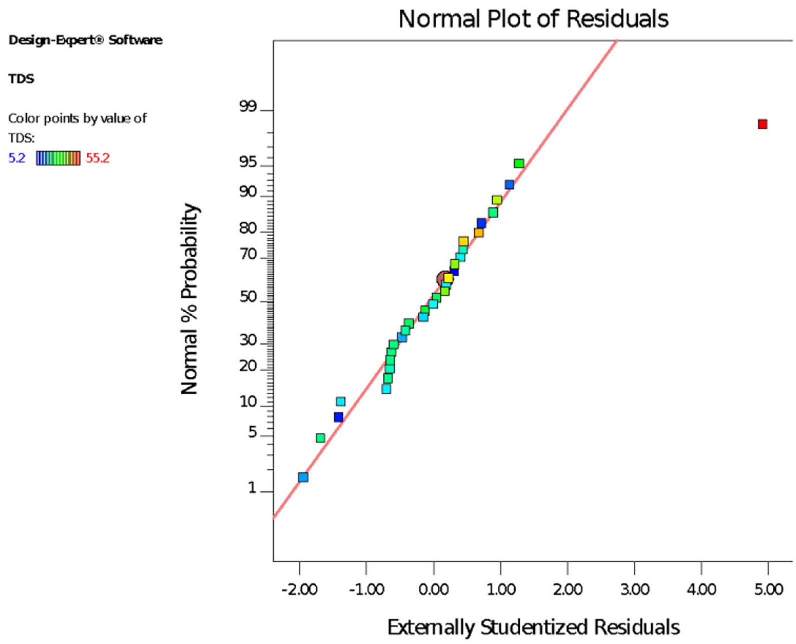

Figure 11. Graph of normal probability plot TDS

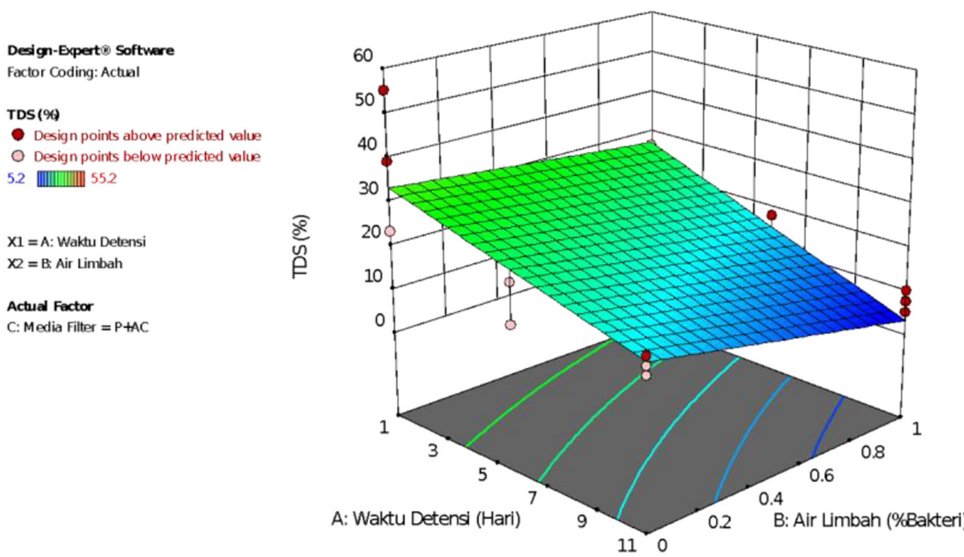

Figure 12. 3D graph of TDS removal effectiveness by activated carbon filter media

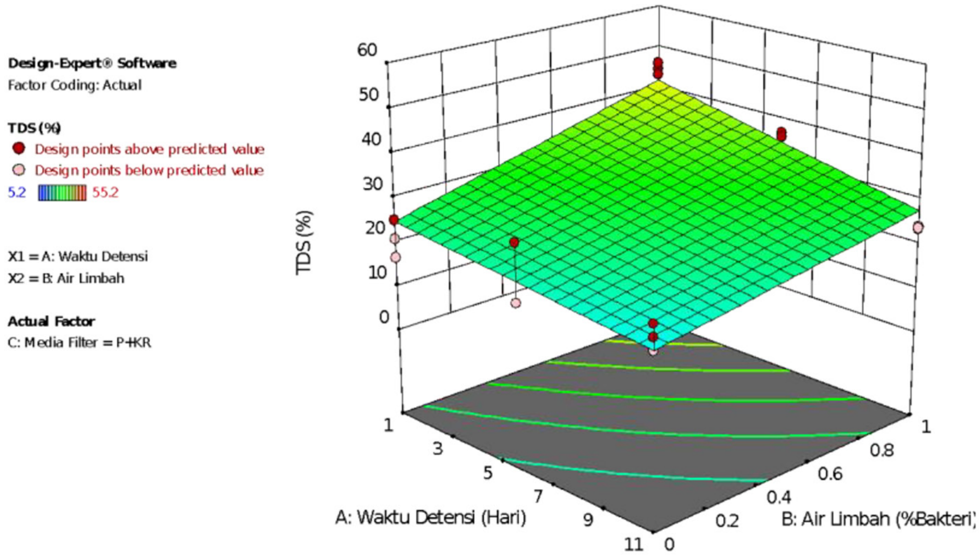

Figure 13. 3D graph of TDS removal effectiveness of seashell filter media

factor values. Table 9 shows that the coefficient of determination (Adjusted R^2) of 0.66 and a coefficient prediction (Predicted R^2) of 0.54 has a difference of less than 0.2 which indicates no deviation model or data so it can be accepted, as well as a strong correlation between independent factors on the response to the research model.

All data on the actual response value of the effectiveness of the removal of turbidity that have been entered into the software also released a comparison of the actual response value with the predicted response value, as well as a normal probability plot test. This statistical analysis is useful for measuring the accuracy of the data against software predictions and knowing whether the residual value data follows a normal distribution. The comparison of the actual value and the predicted value of the software can be seen in Table 10, while the normal probability plot graph can be seen in Figure 11.

On the basis of Figure 11, the data is shown to be normally distributed. Figures 12 and 13 show that the four SSFs have high removal effectiveness at the beginning and the trend will decrease with increasing detention time. SSF with variations in the media of sand and shells showed better removal effectiveness results. SSF4 has the most optimal TDS removal process, which is around 30%-40%. This is supported by the research of O'marga (2020) which found that *Anadara granosa* shells have a high pollutant adsorption capacity.

Effectiveness of SSF on fat, oil, and grease (FOG) parameters removal

The graph of the average percentage effectiveness of FOG removal by SSF1, SSF2, SSF3, and SSF4 can be seen in Figure 14.

The figures and tables above show the effectiveness of FOG removal. SSF1 has the highest

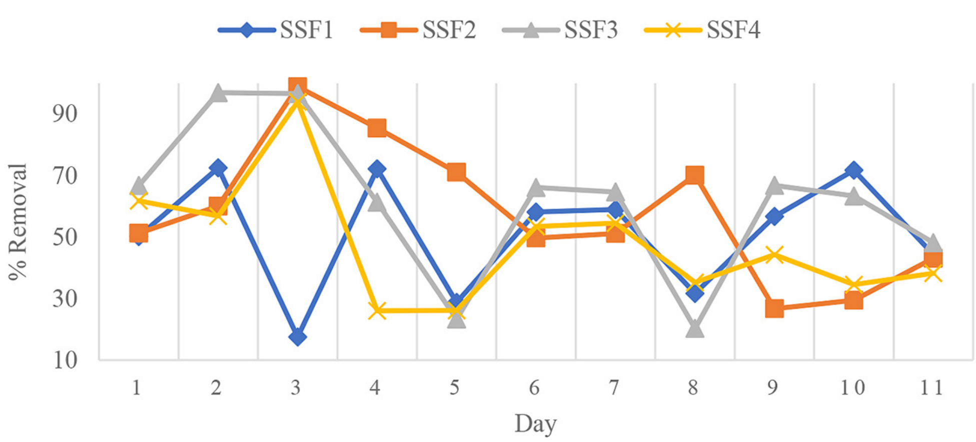

Figure 14. Graph of average percentage effectiveness of FOG removal by SSF1, SSF2, SSF3, and SSF4 per day

Table 11. ANOVA Model 2FI FOG

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	2132.52	6	355.42	9.40	< 0.0001	significant
A	1180,20	1	1180,20	31.23	< 0.0001	
B	310.63	1	310.63	8.22	0.0083	
C	241.45	1	241.45	6.39	0.0182	
AB	298.92	1	298.92	7.91	0.0094	
AC	20.35	1	20.35	0.54	0.4699	
BC	80.96	1	80.96	2.14	0.1558	
Residual	944.91	25	37.80			not significant
Lack of fit	321.50	5	64.30	2.06	0.1130	
Pure error	623.42	20	31.17			
Total cast	3077.43	31				
Note						
A = Detention time (days) B = Wastewater (% bacteria) C = Filter media (SSF)			A, B, C = main effects AB, AC, BC = interaction effects			

Table 12. *Fit Statistics* ANOVA FOG

Standard deviation	6.15	R^2	0.69
Mean	52.11	Adjusted R^2	0.62
Coefficient of variation, %	11.80	Predicted R^2	0.54
		Adeq precision	10.35

effectiveness value of 72.53 ± 25.13% and the lowest is 17.52 ± 7.54%. SSF3 has the highest effectiveness value of 96.99 ± 2.74%, while the lowest effectiveness is 20.29 ± 4.35%. SSF2 the highest effectiveness value is 98.91 ± 0.12% and the lowest effectiveness is only 26.72 ± 15.41%. The highest effectiveness of SSF4 was 94.00 ± 4.67% and the lowest was 26.03 ± 1.29%. Suryadi (2014) found that SSF can remove FOG up to 86%.

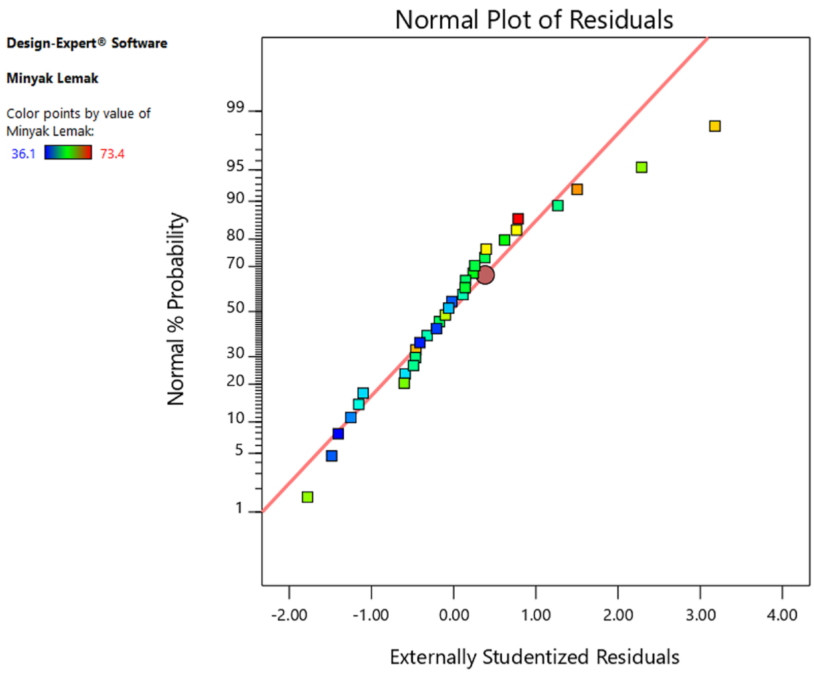

Figure 15. Normal probability plot graph of FOG

On the basis of Table 11 ANOVA model 2FI FOG, the results show that the F-value of 9.4 with a P-value of less than 0.05 proves that the three factors namely detention time, wastewater, and the type of filter media used in the study affect the effectiveness removal of FOG in the liquid waste of culinary center activities, while the most influential factors are detention time and the type of filter media. Lack of Fit F-value 2.06 indicates that Lack of Fit is relatively insignificant to pure error. Lack of Fit that is not significant is a good result because a model should ideally fit, so this model can be used to predict response values with different factor values. Table 12 shows that the coefficient of determination (Adjusted R^2) of 0.62 and a coefficient prediction (Predicted R^2) of 0.54 has a difference of less than 0.2 which indicates no deviation model or the current data so that it can be accepted, as well as their strong correlation between independent factors and responses in the research model.

All data on the actual response value of the effectiveness of the removal of turbidity that have been entered into the software also released a comparison of the actual response value with the predicted response value, as well as a normal

Table 13. Comparison of actual and predicted values of FOG removal effectiveness

Run	Independent factor			Response	
	A (Day)	B (% bacteria)	C (SSF)	Actual (%)	Prediction (%)
1	11	1	P+KR	37.20	39.42
2	6	1	P+AC	64.00	59.56
3	11	0	P+KR	43.10	43.43
4	1	0	P+AC	50.20	52.71
5	6	0	P+AC	51.00	50.15
6	6	1	P+AC	68.00	59.56
7	11	0	P+AC	48.20	47.59
8	1	0	P+KR	49.60	52.24
9	6	0	P+KR	39.50	47.84
10	1	1	P+AC	73.40	69.18
11	11	1	P+KR	38.30	39.42
12	11	0	P+AC	41.00	47.59
13	11	0	P+KR	36.10	43.43
14	1	1	P+AC	60.10	69.18
15	11	0	P+AC	44.40	47.59
16	1	0	P+AC	46.60	52.71
17	1	0	P+KR	53.00	52.24
18	1	1	P+KR	64.50	62.35
19	11	0	P+KR	50.10	43.43
20	11	1	P+KR	39.30	39.42
21	1	1	P+KR	59.10	62.35
22	1	0	P+KR	51.30	52.24
23	1	1	P+AC	66.70	69.18
24	1	0	P+AC	54.00	52.71
25	6	1	P+KR	52.40	50.89
26	6	0	P+AC	65.80	50.15
27	11	1	P+AC	48.20	49.94
28	6	1	P+KR	54.50	50.89
29	6	0	P+KR	60.00	47.84
30	1	1	P+KR	61.80	62.35
31	11	1	P+AC	44.10	49.94
32	11	1	P+AC	52.00	49.94
Note P+AC = Sand & activated carbon P+KR = Sand & seashells					

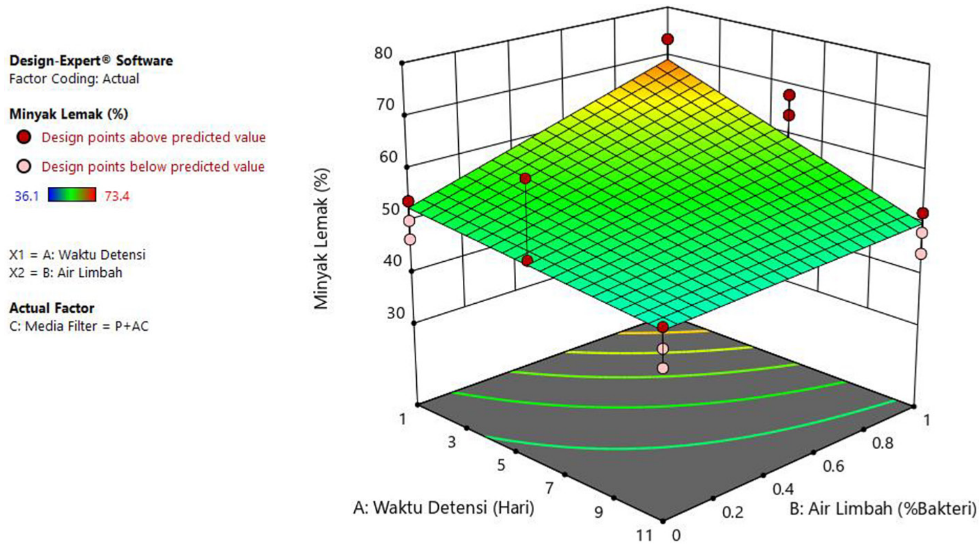

Figure 16. 3D graph of FOG removal effectiveness by activated carbon filter media

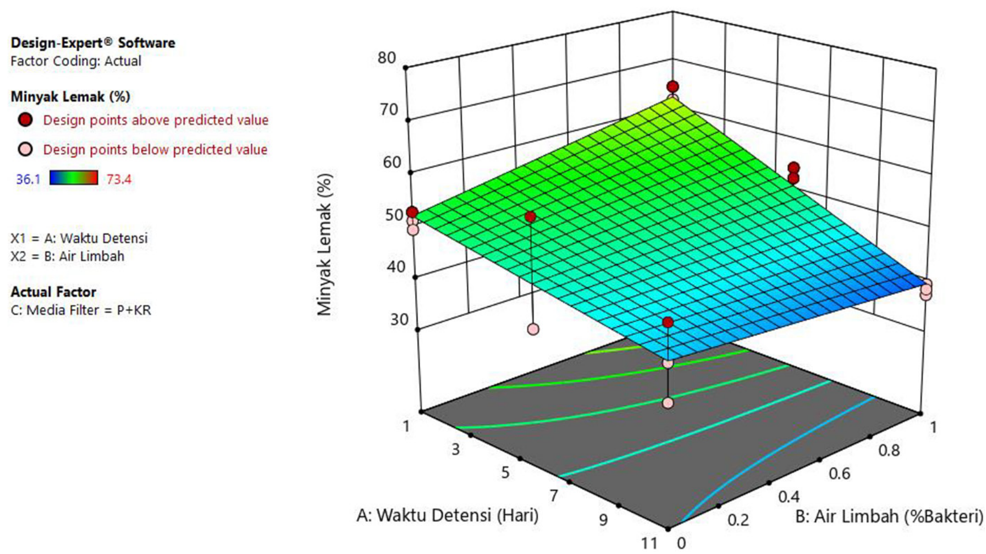

Figure 17. 3D graph of FOG removal effectiveness by clam shell filter media

probability plot test. This statistical analysis is useful for measuring the accuracy of the data against software predictions and knowing whether the residual value data follows a normal distribution. The comparison of the actual value and the predicted value of the software can be seen in Table 13 while the normal probability plot graph can be seen in Figure 15.

Figure 15 shows that the existing data is normally distributed, while Figures 16 and 17 show a downward trend in the effectiveness of FOG removal. A variation of filter media that is superior in oil and grease removal is SSF which uses sand and activated carbon as filter media. The most optimal SSF removal process for FOG removal is SSF3 at 50-65%. The research conducted by Yuliana (2018) also shows that SSF filter media that uses a combination of sand and activated carbon is better at removing FOG in domestic liquid waste.

Comparison with Indonesian water quality standard

The results of the wastewater treatment effluent need to be compared with the quality standard according to its designation. This research has the aim that the processed liquid waste can be used for sanitation needs, so that the quality standard used is based on the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017. The parameters that are not

Table 14. Results of SSF effluent against turbidity quality standards, TSS, TDS, and FOG

Run	SSF1	SSF2	SSF3	SSF4	Quality standards
Turbidity (NTU)					
1	1.40	1.37	1.77	1.43	25 NTU (Permenkes)
2	0.76	0.97	1.53	0.48	
3	0.73	0.66	0.34	0.82	
4	1.24	0.83	0.64	0.52	
5	1.29	0.73	0.64	0.23	
6	0.86	0.65	0.96	0.60	
7	0.81	0.65	0.95	0.76	
8	0.81	0.72	0.65	0.55	
9	0.74	0.40	0.42	0.40	
10	0.95	0.78	0.62	0.36	
11	0.89	0.94	0.65	0.46	
TSS (mg/L)					
1	23.5	24.5	24.5	26.5	100 mg/L (PP RI)
2	94.0	103.5	93.0	95.5	
3	5.0	14.0	8.0	5.5	
4	37.0	44.0	43.5	46.5	
5	5.0	2.5	2.0	4.0	
6	62.0	69.5	57.0	63.5	
7	36.5	31.5	40.5	36.0	
8	39.0	36.5	50.0	34.5	
9	99.0	108.0	105.5	84.0	
10	36.0	26.5	40.0	26.0	
11	5.0	7.5	7.0	7.0	
TDS (mg/L)					
1	388.0	505.5	479.0	355.0	1,000 mg/L (Permenkes)
2	580.0	676.5	532.5	399.0	
3	606.5	679.0	428.5	413.0	
4	693.0	478.5	680.0	718.5	
5	710.5	758.0	750.0	510.5	
6	748.5	694.0	754.0	543.0	
7	732.5	690.5	760.5	725.5	
8	859.0	857.5	830.5	736.0	
9	714.5	777.0	794.0	629.5	
10	847.5	804.5	731.0	566.0	
11	774.0	725.0	840.5	693.5	
FOG (mg/L)					
1	228.5	252.8	95.0	103.0	1 mg/L (PP RI)
2	246.0	357.5	11.0	157.5	
3	339.0	4.5	5.0	9.0	
4	143.5	75.0	143.5	75.0	
5	478.0	194.0	149.5	144.0	
6	74.5	94.5	69.5	88.0	
7	228.5	272.0	103.0	133.0	
8	187.5	382.0	82.5	67.0	
9	264.0	447.0	79.5	134.0	
10	70.5	176.0	70.5	126.0	
11	331.0	365.5	296.5	326.0	

listed in the Minister of Health of the Republic of Indonesia will use Indonesian Government Regulation No. 22 of 2021, which refers to the third class of river water quality standards and the like. The results of the effluent of all SSFs compared with the quality standard can be seen in Table 14.

On the basis of the table above, the turbidity effluent in all SSF values is far below the quality standard, so that when viewed from the turbidity parameter alone, the results of the water treated by SSF can be used according to the designation of the quality standard. TSS effluent in SSF2 and SSF3 within a few days produces TSS effluent that exceeds the quality standard, so it is not recommended for sanitation needs, but it is still safe to flow into class 3 rivers or lakes.

The TDS effluent of all SSF has met the quality standard. The treated water of the entire SSF does not mean that it can be used according to the quality standard, because all the parameters in the quality standard need to be evaluated in order to obtain definite results whether the treated water is indeed suitable for use for sanitation needs.

The results of FOG effluent in all SSF starting from day 1 to day 11 did not meet the quality standard. Treated water, when viewed from the parameters of FOG, is not recommended to be used as a clean water requirement and is not recommended to be discharged into rivers or lakes. The water still has to be processed again so that the FOG content meets the quality standards. On the basis of the results of research by Almojjly et al. (2018), the use of SSF can be used to treat the FOG content in water if the FOG content is ≤ 50 mg/L in raw water. FOG content ≥ 50 mg/L in raw water is recommended to use a treatment that involves a coagulation process. The results of the software prediction effluent are also converted to the units contained in the quality standard. The results of the software prediction effluent are presented in Table 15.

The prediction data of the software design expert also shows that the turbidity is below the quality standard value and has an insignificant difference in value with the actual data, this shows that the turbidity prediction data can still be used to compare with the quality standard, the result is that the predictive data also meets the quality standard. The data used is only three data because the software design expert simplifies the data requirements needed, the data needed is the most representative data prediction to describe the situation that is close to the actual observation results (Anderson, 2016). This can be seen from the trend in the average percentage effectiveness graph of the removal and the 3D graphic image of the software prediction results which are not significantly different. The results of the prediction of the effectiveness of the TSS and TDS removal show that they have met the quality standard, the predicted value and the actual observation data are also not much different. The predicted FOG results are not different from the actual results, as both do not meet the quality standards.

Table 15. Results of SSF predicted effluent against quality standards for turbidity, TSS, TDS, and FOG

Run	SSF1	SSF2	SSF3	SSF4	Quality standards
Turbidity (NTU)					
1	1.40	1.28	1.74	1.37	25 NTU
6	0.87	0.82	1.02	0.76	
11	0.89	0.88	0.63	0.40	
TSS (mg/L)					
1	24.18	27.13	26.06	26.46	100 mg/L
6	48.72	58.14	52.04	55,60	
11	6.01	7.80	6.81	8.06	
TDS (mg/L)					
1	425.3	480.1	464.4	373.1	1,000 mg/L
6	680.6	711.8	726.2	559.8	
11	765.9	750.2	880.8	657.7	
FOG (mg/L)					
1	224.2	226.4	62.6	76.4	1 mg/L
6	94.7	99.1	117.9	143.2	
11	274.1	295.9	252.6	305.6	

Determining the most optimal SSF variation

The most optimal variation of SSF in processing all test parameters is SSF3, namely SSF with sand and activated carbon filter media, simulation time of 4 days (detention time between the first and second days for 48 hours), and the addition of 1% *Bacillus sp.* bacteria in the *grease trap* unit. The probability of accuracy of the observed value against the predicted value which is denoted by the desirability value is 0.613. The results of other point optimization techniques can be observed visually with 3D desirability graphs and overlay plots that are used to find opportunities for the accuracy of the validation experimental results to the predicted value, as well as mapping the surface area of independent factors that are able to produce the highest average value of removal effectiveness for all test parameters. The results of the 3D desirability graph and the overlay plot of the optimal solution model can be seen in Figures 18 and 19, respectively.

On the basis of Figures 18 and 19 above, a validation experiment was carried out to confirm

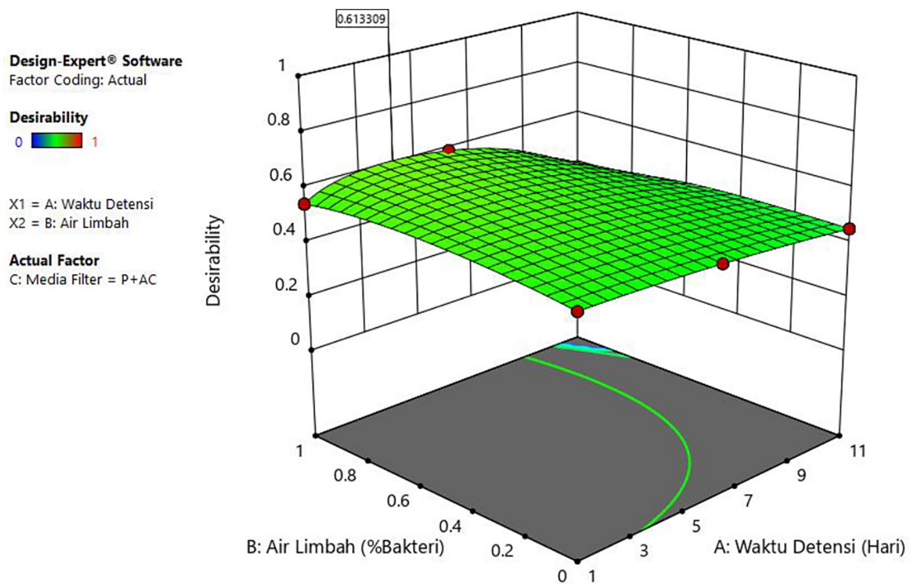

Figure 18. 3D desirability graph of optimum model solution

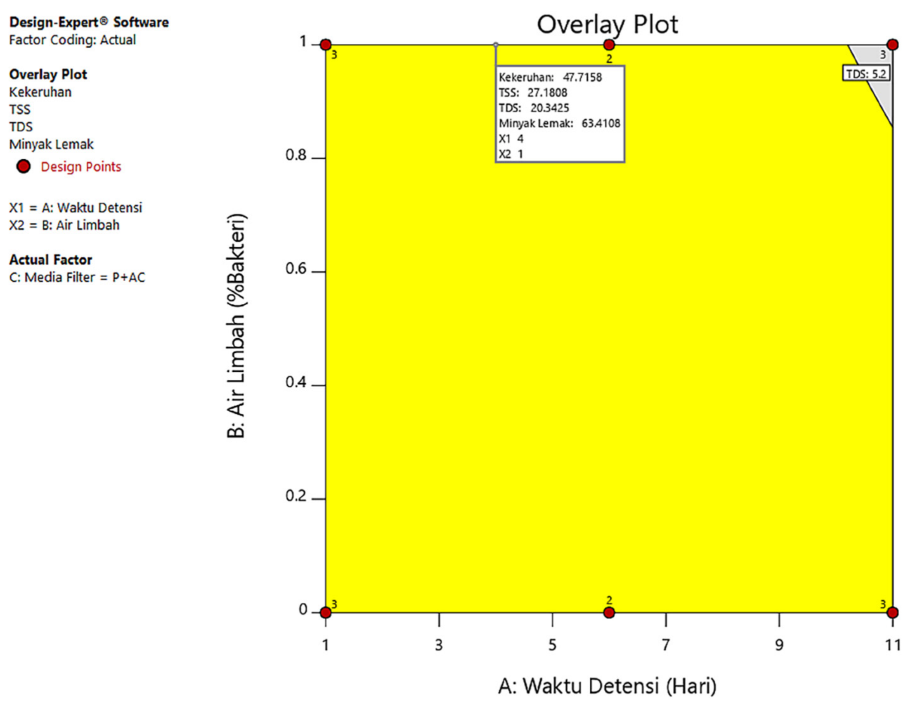

Figure 19. Graph overlay plot optimum solution model

Table 16. Most optimal SSF variations

Solution 4 of 13 response	Predicted (%)	Observed (%)	Std dev.	A (day)	B (% bacteria)	C (SSF)
Turbidity	47.72	39.53	7.89	10.1	1	P+KR
TSS	27.18	45.25	13.18			
TDS	20.34	19.30	7.06			
FOG	63.41	61.35	6.15			

whether the predicted value calculated by the software was in accordance with the actual results in the field (observed value) and to produce a response to the effectiveness of the maximum test parameter allowance. The experimental results of the selected optimum parameter validation can be seen in Table 16.

The *observed* results (% Allowance) when converted to units that match the quality standards (NTU and mg/L) will produce a turbidity of 0.64 NTU; TSS 26.28 mg/L; TDS 682.58 mg/L; and FOG 74.98 mg/L. The results of the observations obtained varied; the results of the observation of the effectiveness of the TSS were higher than the predicted results. The results of the observation of the effectiveness of Turbidity, TDS, as well as FOG were lower than the predicted results. The lower result is still within the standard deviation range so that it remains in optimal data conditions. The results of the confirmation test compared with the data that had been obtained were not significantly different, the data obtained previously was 0.65 NTU turbidity; TSS 40 mg/L; TDS 680 mg/L; and 75 mg/L FOG.

CONCLUSIONS

On the basis of the obtained results, it can be concluded that the optimal variation of filter media in the slow sand filter unit in reducing turbidity and TDS parameters contained in the food court wastewater is SSF4 (sand and clam shells filter media). The percentage of turbidity removal and TDS obtained in the range of 50–80% and 30–40%, respectively. The optimal variation of filter media in the slow sand filter unit in reducing TSS and FOG parameters contained in the food court wastewater is SSF3 (sand and activated carbon filter media). The percentages of removal of TSS and FOG were obtained in the range of 20–55% and 50–65%, respectively. The results of Design Expert 11 with the optimal custom design method show that the most optimal variation of the slow sand filter in removing turbidity, TSS, TDS, and FOG in the food court wastewater is to use a combination of sand and activated carbon media, detention time on day 4, and with the addition of 1% Bacillus sp. bacteria in the grease trap unit (SSF3). The results of the validation experiment showed that the observed values for turbidity, TSS, TDS, and FOG were respectively 39.53%; 45.25%; 19.30%; and 61.35% close to the predicted value of 47.72%; 27.18%; 20.34%; and 63.41%.

REFERENCES

1. Almojjly, A., Johnson, D., Oatley-Radcliffe, D.L., Hilal, N. 2018. Removal of oil from oil-water emulsion by hybrid coagulation/sand filter as pre-treatment. Journal of Water Process Engineering, 26(July), 17–27.
2. Anderson, Mark J. 2016. RSM Simplified: Optimizing Processes Using Response Surface Methodology for Design of Experiments. United States. CRC Press.
3. Andriani, G., Andari, G.S.B., Gusniani, I. 2015. Effectiveness of Intermittent Slow Sand Filter in Surface Water Treatment related to pH, Color, Nitrate, Nitrite, and Total Coliform Parameters (Case Study: Infiltration Reservoir and Mahogany Lake UI). Faculty of Engineering, University of Indonesia. Depok, Indonesia.
4. Astuti, D.R.P. 2012. Effect of Activated Carbon Diameter on Biosand Filter on Decrease in BOD Concentration. Essay. Faculty of science and technology. Airlangga University. Surabaya.
5. Brandt, M.J., Johnson, K.M., Elphinston A.J., Ratnayaka D.D. 2016. Twort's Water Supply 7th Edition. London: Elsevier
6. Bryant, Isaac M. 2015. Using Slow Sand Filtration System with Activated Charcoal Layer to Treat Salon Wastewater in a Selected Community in Cape Coast, Ghana. Journal Advanced Chemical Engineering, 5, 135.
7. Byrne, T.M. 2010. Analysis of the Removal Capabilities of Intermittently and Continuously Run Slow Sand Filters, Thesis, The Pennsylvania State University, USA.

8. Dampang, S., Purwanti, E., Destyorini, F., Kurniawan, S.B., Abdullah, S.R.S., Imron, M.F. 2021. Analysis of Optimum Temperature and Calcination Time in the Production of CaO Using Seashells Waste as CaCO3 Source. J. Ecol. Eng., 22, 221–228.
9. Fatnasari, H., Hermana, J. 2010. Strategies for Wastewater Management in Settlements on the banks of Kali Surabaya. Proceedings of the National Seminar on Technology Management XI MMT-ITS Study Program, 52–58.
10. Fitri, I.T., Samudro, G., Sumiyati, S. 2013. A Study of Decreasing TSS and Turbidity Parameters in Artificial Domestic Wastewater Using a Vertical Roughing Combination. Journal of Environmental Engineering, Faculty of Engineering, Diponegoro University, Semarang, 2(2), 1–7.
11. Fitriani, N., Wahyudianto, F., Salsabila, N.F., Radin Mohamed, R., Kurniawan, S. 2023. Performance of Modified Slow Sand Filter to Reduce Turbidity, Total Suspended Solids, and Iron in River Water as Water Treatment in Disaster Areas. J. Ecol. Eng., 24, 1–18.
12. Fitriani, N., Kusuma, M.N., Wirjodirdjo, B., Hadi, W., Hermana, J., Ni'matuzahroh, Kurniawan, S.B., Abdullah, S.R.S., Mohamed, R.M.S.R. 2020. Performance of geotextile-based slow sand filter media in removing total coli for drinking water treatment using system dynamics modelling. Heliyon, 6.
13. Imron, M.F., Firdaus, A.A.F., Flowerainsyah, Z.O., Rosyidah, D., Fitriani, N., Kurniawan, S.B., Abdullah, S.R.S., Hasan, H.A., Wibowo, Y.G. 2023. Phytotechnology for domestic wastewater treatment: Performance of Pistia stratiotes in eradicating pollutants and future prospects. J. Water Process Eng., 51.
14. Imron, M.F., Kurniawan, S.B., Abdullah, S.R.S. 2021. Resistance of bacteria isolated from leachate to heavy metals and the removal of Hg by Pseudomonas aeruginosa strain FZ-2 at different salinity levels in a batch biosorption system. Sustain. Environ. Res., 31, 14.
15. Indonesian Government. 2016. Regulation of the Minister of Environment of the Republic of Indonesia Number: P.68/Menlhk-Setjen/2016 concerning Domestic Wastewater Quality Standards. Ministry of Environment and Forestry RI, Jakarta.
16. Indonesian Government. 2017. Regulation of the Minister of Health of the Republic of Indonesia Number 32 concerning Environmental Health Quality Standards and Water Health Requirements for Sanitary Hygiene, Swimming Pools, Solus Per Aqua, and Public Baths. Indonesian Ministry of Health, Jakarta.
17. Indonesian Government. 2021. Government Regulation of the Republic of Indonesia Number 21 concerning Implementation of Environmental Protection and Management. Central Government, Jakarta.
18. Jami'ah, Hadi, W. 2014. The Use of Slow Sand Filter Units, Ozone Generators and Rapid Sand Filters to Improve Shallow Well Water Quality into Drinking Water with Turbidity, Fe, and Mn Parameters. Journal of Engineering POMITS, 3(2).
19. Khan, Aszahra A. 2016. Efektivitas Pemanfaatan Limbah Cangkang Kerang Dara (*Anadara Granosa*) Sebagai Media Adsorben Logam Cu (II) Dalam Air. Universitas Islam Indonesia, Yogyakarta.
20. Kurniawan, S.B., Pambudi, D.S.A., Ahmad, M.M., Alfanda, B.D., Imron, M.F., Abdullah, S.R.S. 2022. Ecological impacts of ballast water loading and discharge: insight into the toxicity and accumulation of disinfection by-products. Heliyon, 8, e09107.
21. Maharani, V.S. 2017. Studi Literatur: Pengolahan Minyak dan Lemak Limbah Industri, Tugas Akhir, Institut Teknologi Sepuluh Nopember, Surabaya.
22. Maryani, D., Masduqi, A., Moesriati, A. 2014. Effect of Media Thickness and Filtration Rate on Sand Filters in Reducing Turbidity and Total Coliform. Journal of ITS Engineering, 3(2), D76–D81.
23. Matsui, T., Miura, A., Iiyama, T., Shinzato, N., Matsuda, H., Furuhashi, K. 2005. Effect of fatty oil dispersion on oil-containing wastewater treatment. Journal of Hazardous Materials, 118(1–3), 255–258.
24. Mirza, D.H. 2019. Effect of Roughing Filter and Slow Sand Filter in Treating Amprong River Water, Malang into Ready-to-Drink Water on Turbidity, Color, TSS, and TDS Parameters, Thesis, Airlangga University, Surabaya.
25. Ni'matuzahroh, N., Fitriani, N., Nuswantara, E.N., Affandi, M., Prasongsuk, S., Kurniawan, S. 2022. Isolation and Characterization of Schmutzdecke in Slow Sand Filter for Treating Domestic Wastewater. J. Ecol. Eng., 23, 76–88.
26. Ni'matuzahroh, Fitriani, N., Ardiyanti, P.E., Kuncoro, E.P., Budiyanto, W.D., Isnadina, D.R.M., Wahyudianto, F.E., Radin Mohamed, R.M.S. 2020. Behavior of schmutzdecke with varied filtration rates of slow sand filter to remove total coliforms. Heliyon, 6(4), e03736.
27. O'Marga, T. 2020. Effect of Modification of Slow Sand Filter Media with Blood Shells (Anadara Granosa) and Acclimatization Time on Total Coliform Removal in Treating Domestic Wastewater. Essay. Faculty of Science and Technology, Airlangga University, Surabaya.
28. Pachoka, M. 2010. Intermittent Slow Sand Filters: Improving Their Design for Developing World Applications.
29. Pratiwi, Hospital 2015. Planning for Domestic Wastewater Management in Keputih Surabaya. Final Project, Sepuluh Nopember Institute of Technology, Surabaya.

30. Purwanti, I.F., Putri, T.P., Kurniawan, S.B. 2017. Treatment of chromium contaminated soil using bioremediation, in: AIP Conference Proceedings, 040008.
31. Ranjan, P., Prem, M. 2018. Schmutzdecke-A Filtration Layer of Slow Sand Filter. International Journal of Current Microbiology and Applied Sciences, 7(7).
32. Sarasdewi, A., Semadi Antara, N., Suryawan Wiranatha, A. 2015. Effect of Flow Rate on Reduction of Pollution in Domestic Wastewater Treatment Plants with Biofilter Systems. Journal of Agroindustrial Engineering and Management, 3(2), 17–29.
33. Sari, N.M. 2010. Study on the Performance of Biosand Filter for Drinking Water Treatment for Reducing Turbidity and Iron. Jurusan Teknik Lingkungan, FTSP, Institut Teknologi Sepuluh Nopember.
34. Suryadi, Asep. 2014. Design of Filter Technology for House-Scale Wastewater in the IPB Campus Circumference Area, Darmaga. Essay. Department of Civil and Environmental Engineering, Faculty of Agricultural Technology, Bogor Agricultural University.
35. Theresa, Ledy. 2020. The Effect of Media Variations and Acclimatization Time on Modified Intermittent Slow Sand Filter Units in Reducing pH, Turbidity, Ammonia, and Phosphate. Essay. Faculty of Science and Technology, Airlangga University, Surabaya.
36. Thomas, T.A., Kani, K.M. 2016. Efficiency of Slow Sand Filter in Wastewater Treatment. International Journal of Scientific & Engineering Research, 7(4).
37. Widyaningsih, V. 2011. Liquid Waste Treatment of the Yongma Fisip UI Canteen, Thesis, University of Indonesia, Jakarta.
38. Wongthanate, J., Mapracha, N., Prapagdee, B. 2014. Efficiency of Modified Grease Trap for Domestic Wastewater Treatment. The Journal of Industrial Technology, 10(2), 2557.
39. Yuliana. 2018. Effect of Biosand Filter Media Variations in Removal of Oil and Fat from Laboratory Wastewater. Faculty of Engineering, Andalas University.
40. Zahra, L.Z., Purwanti, I.F. 2015. Restaurant Waste Treatment with Aerobic Biofilter Process. Journal of ITS Engineering, 4(1).