CHAPTER V

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the experiments are presented and discussed in 3 sections at the end of which are given summaries of conclusion drawn from each discussion.

Water Quality Requirement for Automobile-wash Business

Turbidity was the only quality concerning in the research. In case of the washwater before use, turbidity enables water quality criterion to be specified. The extent of reclamation can be forecast accordingly. The purpose of turbidity measurement of the washwater after use is to help make selecting the suitable method of its reclamation easier. It will also enables one to decide the feasibility of the filtration process making use of burnt rice husk as filter medium, with or without prefiltration of similar natures to those conventional rapid gravity filtration system using relatively coarse media. The results of the findings for all the 160 samples are shown in Table 5 and Fig. 14, and are discussed separately as follows.

Washwater Before Use

Turbidity measurement at the same service station conducted at 4 various times did not show much variation. The turbidity of 80 samples collected from the selected 20 service stations ranged between 4.7 and 16.5 JTU, as shown in Table 5. The averages of all the corresponding turbidity values were found to be : 9.7 , 10.1 , 10.3 and 10.8 JTU respectively, showing a very small difference between the minimum and maximum values (only 1.1 JTU). The increased averages are believed to result from the accumulation of suspended solids in the storage tank.

The overall average turbidity of all the 80 samples tested was found to be 10.275 JTU as shown in Fig.14. This is a bit higher than that of the public water system. It may be due to the fact that the washwater used by the service station is mostly drawn directly from deep wells without any sort of pretreatment.

From the results above, a definite conclusion can be arrived at accordingly. Any proposed filtration process for reclamation must be able to reduce the effluent turbidity to as low as 10 JTU.

Washwater After Use

Turbidity values of washwater after use at the same station measured at 4 various times flustuated considerably and did not show any relationship with the turbidity of the source. They were unpredictable either. The turbidity of 80 samples of washwater after use collected from the same twenty stations as above ranged between 62.4 and 97.5 JTU, as also shown in Table 5. The averages of all the corresponding turbidity values were found to be : 78.1 , 75.9 , 79.2 and 77.1 JTU respectively, also showing a very small difference between the minimum and maximum values (only 3.3 JTU, or about 4%). The overall average turbidity of all the 80 samples tested was equal to 77.5 JTU, and is also shown in Fig.14.

The results of investigation described above show that the turbidity of the washwater after use lies within the "low range" of turbidity. At such a low "turbidity loading",filtration process exploiting burnt rice husk as the filter medium can be effective enough without any need for pretreatment whatsoever.

Summary of Conclusion

Washwater after use can be reclaimed for reuse in the automobile-wash business. The range of its turbidity lies between 60 and 100 JTU. Hence, any treatment process proposed must be able

Table 5 Characteristic of Automobile Washed Water at Various Service Stations

Group	No.	Name of Service Stations	Brand	Location (Amphur)	Turbidity before using, JTU				Turbidity after using, JTU			
					13/1/75	16/1/75	21/1/75	24/1/75	13/1/75	16/1/75	21/1/75	24/1/75
Group 1	1	Preeda Borikarn	Caltex	Bangrak	10.0	10.6	9.0	9.4	64.3	71.0	67.7	81.7
	2	P.Sapan Lueng	Esso	Pathumwan	6.5	7.0	7.2	7.7	73.0	67.2	90.4	62.4
	3	Piyawong (22 July)	Shell	Pomprab	11.0	11.8	12.6	13.8	76.4	68.6	82.0	83.6
	4	Sirasudhi	Shell	Pomprab	10.9	9.2	9.5	10.0	92.3	77.8	68.8	70.7
	5	Borvornsak Service	Esso	Pomprab	4.7	5.0	5.6	6.1	85.0	71.5	97.2	76.1
	6	Mahachai Service	Shell	Pranakorn	12.2	12.6	13.5	14.0	63.1	78.3	71.8	91.5
	7	Bamrungmitr Service	Shell	Pranakorn	11.0	12.3	12.5	13.1	85.7	74.3	79.7	93.7
	8	Prannok Service	Caltex	Bangkoknoi	15.3	15.8	16.1	16.5	62.7	84.9	70.3	87.2
	9	Visutkasat Center	Esso	Pranakorn	5.8	6.1	7.0	4.9	67.6	97.5	82.5	74.5
	10	Sapan Kao Borikarn	Esso	Pomparb	11.0	11.9	12.4	13.5	85.4	88.1	67.0	79.3
Group 2	11	Klueynamthai Borikarn	Summit	Prakanong	13.3	13.9	14.2	14.7	76.9	91.8	83.2	78.7
	12	Varavudth (Asoke)	Summit	Prakanong	12.5	13.1	13.9	14.5	78.4	62.9	84.5	73.5
	13	Makkason Borikarn	Summit	Payathai	8.3	9.0	10.0	10.8	88.0	64.9	82.3	71.4
	14	Ruam Charoen Borikarn	Caltex	Payathai	4.9	5.2	5.3	5.7	82.7	67.1	78.8	78.0
	15	Dao Suthisarn	Caltex	Payathai	15.7	14.0	14.7	15.2	78.5	94.1	82.8	73.2
	16	Sukontha (Klongprapa)	Caltex	Payathai	10.8	11.7	11.9	12.3	67.3	82.1	73.9	69.3
	17	Dao Rachawat	Caltex	Dusit	8.3	8.9	9.2	9.4	89.6	63.8	79.0	73.9
	18	Roj Rung Rueng	Shell	Dusit	7.3	7.7	5.0	5.2	80.2	74.7	88.3	67.4
	19	Banthadthong Center	Esso	Payathai	9.5	10.0	10.6	11.1	85.3	67.9	77.6	74.0
	20	Sor Saladaeng II	Shell	Pathumwan	6.1	7.2	7.6	8.1	79.9	69.5	76.3	81.9
Average					9.7	10.1	10.3	10.8	78.1	75.9	79.2	77.1

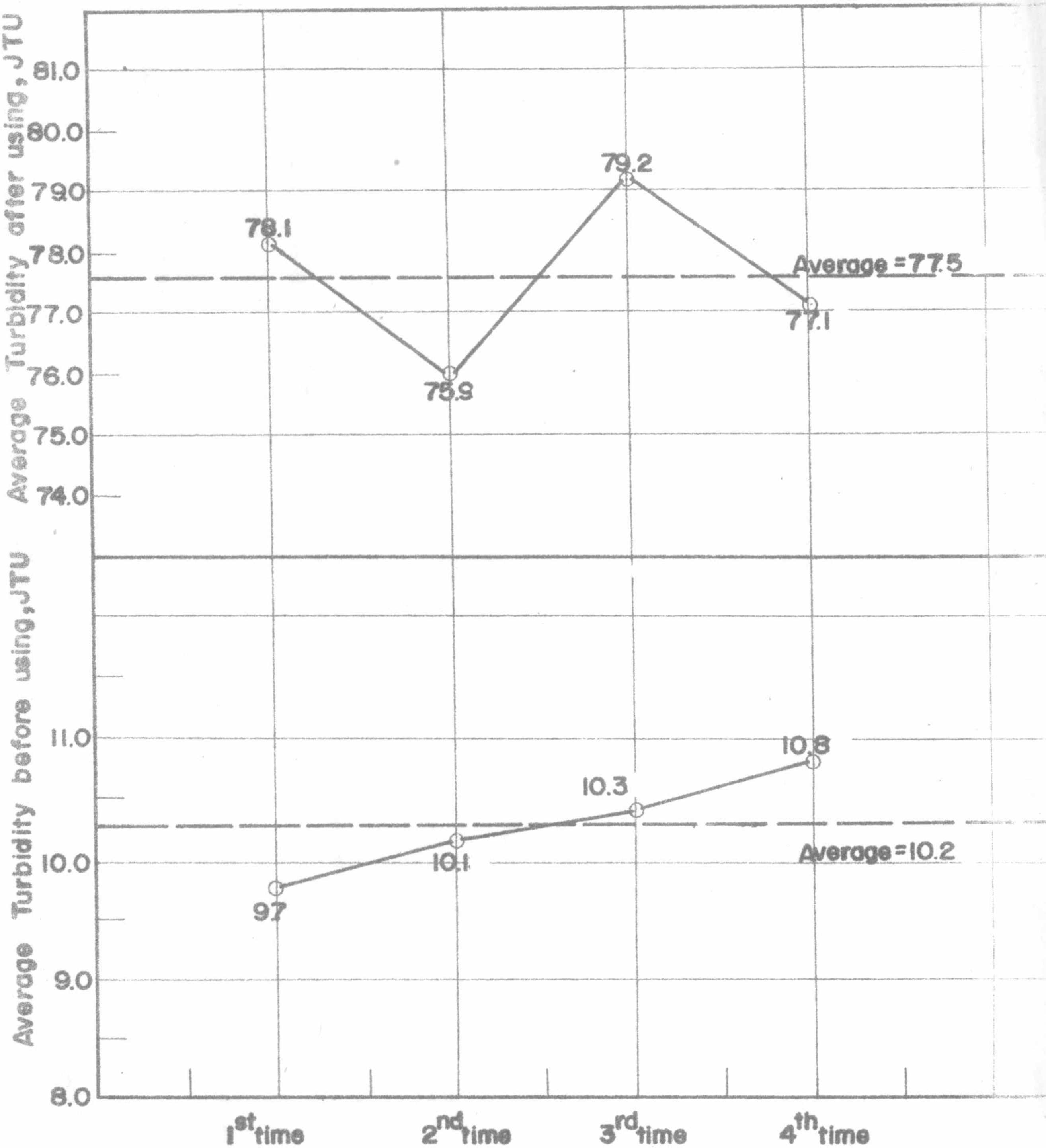

Fig. 14 Average Turbidity of Washwater from 20 Service Stations at Different Times.

to achieve an effluent turbidity of as low as 10 JTU at this range of turbidity loading. The filtration process making use of burnt rice husk as the filter medium can be effective enough for the task without any need for pretreatment of one kind or another.

Washwater Consumption for Automobile

The washwater consumption was investigated in order to determine the filter loading values to be used in designing a filter. In this respect, 4 service stations were investigated. In case of the first 3 stations, taking into account their similarity in the patterns of service rendered to their customers, servicing was available 24 hours daily. During daytime, that is, from 8.00 a.m. to 6.00 p.m., servicing with both washing-up and lubrication was rendered; whereas only automobile washing-up was performed during nighttime, that is, from 6.00 p.m. to 8.00 a.m. next morning. More water is consumed by lubrication rather than the ordinary wash-up. The consumption of the latter shew its peaks twice daily : once during the period from 3.00 a.m. to 6.00 a.m. and again during the period from 3.00 p.m. to 6.00 p.m. During these 2 periods of time, the stations were congested with taxis and samlors coming for a wash-up in order to get ready for shift transfer. Water demand for automobile washing-up decreased once during the period from 6.00 a.m. to 3.00 p.m. and again from 6.00 p.m. to 9.00 p.m.; water was needed only for the wash-up of private saloon cars as well as those parking in the hired parking-shed. The water demand would decrease further still until 3.00 a.m. next morning, since water was needed only for washing-up the remainder which parking in the hired parking-shed latterly plus some occasional wash-up.

In case of the fourth station, automobile washing-up and lubrication service was available only 12 hours daily, that is from 7.00 a.m. to 7.00 p.m. In this station, the major part of the service was given to lubrication.

The washwater consumption was measured with the meter installed at the outlet of the storage tank. Naturally, an error was inevitable, due to two facts. First, some small amount of water from the storage tank was also used by the employees in the station for bathing and some stuff washing-up. Last, water was also used for yard cleansing-up which was done twice monthly. However, these two amounts accounted for only a tiny part of the whole consumption and hence their effects can be regarded as negligible.

The results of the consumption measurements are shown in Tables A.1, A.2, A.3 and A.4 in the Appendix A. The summarized results are shown again in Table 6. The details are discussed station by station as follows.

Service Station 1

A 24 - hour - daily service was available at this station. Eight meter-readings were recorded daily at an interval of 3 hours, and are shown in Table A.1 in the Appendix A. It is obvious that water was consumed in every interval. However, it is not posible to obtain a definite pattern of water usage at each interval in order that predictions can be made. Nevertheless, it can be stated that the consumption figures were small during nighttime, that is, from 9.00 p.m. to 3.00 a.m. next morning, and became greater during daytime, that is, between 3.00 a.m. and 9.00 p.m. These recorded figures are compatible to the pattern of service rendered by the station as described earlier. Unfortunately, daily washwater consumption figures on the particular days of the week vary from week to week so much so that a definite pattern cannot be derived. However, it can be concluded that washwater consumption at each 3-hour interval lies between 1.89 and 6.21 m^3 whereas its daily consumption ranges from 31.60 to 44.22 m^3, resulting in an average of 38.24 m^3/day as shown in Table 6.

Table 6 Summary of Washwater Consumption for Automobile at Various Service Stations

Name of Service Station	Service Period (hr)	Recording Data		Water Used					Remarks
		Interval (hrs)	Period (days)	Minimum		Maximum		Average	
DAO RACHAWAT (ดาวราชวัตร)	24	3	59	1.89 m^3/3 hr	31.60 m^3/day	6.21 m^3/3 hr	44.22 m^3/day	38.24 m^3/day	1-Ø1½" Meter
P. SAPAN LUENG (พ.สะพานเหลือง)	24	6	60	11.45 m^3/6 hr	65.83 m^3/day	22.09 m^3/6 hr	83.11 m^3/day	75.549 m^3/day	2-Ø1½" Meter
RUAM CHAROEN BORIKARN (รวมเจริญบริการ)	24	12	59	7.90 m^3/12hr	28.90 m^3/day	29.70 m^3/12hr	46.00 m^3/day	39.407 m^3/day	1-Ø1½" Meter
MAHACHAI SERVICE (มหาชัยเซอร์วิส)	12	24	60		21.13 m^3/day		31.86 m^3/day	26.487 m^3/day	1-Ø1½" Meter

Service Station 2

A 24 - hour service was also available at this station. Four meter - readings were recorded daily at a 6 - hour interval and the results are shown in Table A.2 in the Appendix A. The figures show a definite pattern of water consumption through the days at each corresponding 6 - hour interval. During the interval of time between 9.00 p.m. and 3.00 a.m. next morning, the consumption was minimal. A slow increase appeared during 3.00 a.m. and 9.00 a.m. The consumption became greatest during 9.00 a.m. and 3.00 p.m. before it decreased slightly during 3.00 p.m. and 9.00 p.m. This consumption pattern conforms to the pattern of service rendered at the station as described earlier.

Again, it is not possible to derive the definite pattern of weekly consumption of this service station due to the same fact as that encountered at Service Station 1.

The results of measurement tabulated in Table 6 show that the washwater consumption of Service Station 2 ranges from 11.45 to 22.09 $m^3/6$ hours at all 6 - hour intervals and its daily consumption lies between 65.83 and 83.11 m^3, resulting in an average of 75.549 m^3/day.

Service Station 3

Service was also available 24 hours daily at this station. Twice meter - readings were recorded daily at a 12 - hour interval and the results are tabulated in Table A.3 in the Appendix A. The figures also show a definite pattern of consumption through the days at each corresponding 12 - hour interval. During daytime, from 6.00 a.m. to 6.00 p.m., when both lubrication and automobile washing-up were performed. The consumption was greater. The consumption decreased gradually as night came.

Again, the definite pattern of weekly consumption of this station was not achieved.

The results tabulated in Table 6 show the consumption of this station to range from 7.90 to 29.70 m^3/12 hour and from 28.90 to 46.00 m^3/day with an average of 39.407 m^3/day.

Service Station 4

Lubrication and washing-up service was available only 12 hour daily at this station and hence meter-readings were taken once a day and are listed in Table A.4 in the Appendix A. The consumption of this station is shown in Table 6 to vary between 21.13 and 31.86 m^3/day with an average of 26.487 m^3/day.

Summary of Conclusion

The average values of washwater consumption of the service stations investigated can serve as a guide-line in classifying service stations. In this connexion, they are divided into 3 classes with respect to the greatness of washwater demand, namely, 80, 60 and 40 m^3/day respectively, in case of 24 - hour - service stations. A smaller class demanding only about 20 m^3 of washwater daily is also suggested for those stations rendering 12 - hour - a day service. These values of washwater consumption are to be used in designing sizes of the filters for the reclamation of used washwater for reuse.

Experimental Filtration Tests

The purposes of the experimental tests are to determine the design parameters of a filter using burnt rice husk as filtering media to obtain an effluent turbidity of 10 JTU or lower at a turbidity loading range between 60 - 100 JTU. The design parameters include optimum filtration rate, the duration of filtration without excessive loss of head, the efficiency of burnt rice husk and the design depth of media etc. The experiments were conducted for two separated series to determine the value of turbidity of influent and effluent; pH for both mentioned and head loss too. From visual observation, there are very less oil and grease in the sample because they were caught by the grease trap. Thus, oil and grease were considered negligible. The first experimental series, three test runs, was the study of the performance of burnt rice husk at various filtration rates of constant depth of media to find the optimum filtration rate. The influent infiltrated through a 80 cm - depth of media with 3 rates of filtration - 2.5, 1.25 and 0.25 $m^3/m^2/hr$. The second experimental series was the study to find the optimum depth of media at constant optimum filtration rate obtained from the first run series. Three depth of media were considered for this run series - 80, 60 and 40 cm.

The results of the three test runs in the first experimental series are shown in Tables 7 - 9 and illustrated in Figs.15 - 17. The comparison of the tests is apparent in Figs.18 - 22. Table 10 shows the summary of results in run series I. Table 11-13 and Figs.23-24 show the results the two test runs included with one test run from the formal run series. The comparison of the test runs in run series II is illustrated in Figs. 25 - 29 and summary of the results is apparent in Table 14. The details of each run series are discussed as follows.

Run Series I : Experimental Study of the Performance of the Burnt Rice Husk, as a Filter Media, at Various Filtration Rates

Three test runs were conducted on this run series at filtration rate 2.5, 1.25 and 0.25 $m^3/m^2/hr$ respectively only with 80 cm depth of media. With the filtration rate of 2.5 $m^3/m^2/hr$, the duration of run due to a head loss of 1.2 m was 28 hours and the head loss value in each period is tabulated in Table 7. Table 8 shows the influent and effluent turbidity included the turbidity removal efficiency. The filter performance of burnt rice husk at 2.5 $m^3/m^2/hr$ rate is illustrated in Fig. 15.

The filter performance of this run shows that the increase in the head loss did not result with corresponding increase in effluent turbidity. Effluent turbidity was in the range of 0.43 - 1.7 JTU with the average value of 1.0 JTU. This average value is lower than the expected value (10 JTU) and still less than the WHO standard value for drinking water of 5 JTU. So we can use this water to be the washwater reasonably. The effluent turbidity value was higher than the average value only in the beginning period of the filter run, after the 13th hour of filter run the effluent turbidity value became lower than average value. The performance also shows that the effluent turbidity was not affected by the influent turbidity which fluctuated up and down the average influent turbidity all the time. The influent turbidity was fluctuated in the range of 67.6 to 90.3 JTU. This value is in the same range of the washwater after using turbidity which is in the range of 62.4 to 97.5 JTU. The average influent turbidity in this run was at 80.2 JTU which closed to the average of the washwater at 77.5 JTU as mentioned in previous section.

The turbidity removal efficiency of this run was in the range of 97.95 - 99.45% with the average value of 98.74%.Table 9 shows the influent and effluent pH which were fluctuated value and influent pH was almost higher than effluent pH at the same period of time. The average influent and effluent pH were 7.72 and 7.30 respectively. These values are in the range of drinking water standard so it can be used as the washwater exactly. From visual observation, it showed that the filtered water contained slightly oil which can be negligible and no harm to be used for washwater. During the long period of filter run it showed that the particles could penetrate through the depth of about 3 - 5 cm from the top layer of the filter bed.

The filtration rate of the second run was as half of the filtration rate in the first run, 1.25 $m^3/m^2/hr$. The duration of run at the same value of head loss 1.2 m was 152 hours, which was 5.4 times of the first run. Table 7 shows the head loss value at the various periods and is illustrated in Fig. 16 which is also included the turbidity values. The influent and effluent turbidity included the turbidity removal efficiency is apparent in Table 8.

The performance of the second run also shows that the increase of the head loss was not affected the effluent turbidity and the effluent turbidity was not depended on the influent turbidity which fluctuated up and down the average influent turbidity values all the time. In the beginning period of run, the effluent turbidity was higher than the average effluent turbidity value; but after the 98th hour of filter run up to the end of the run, the effluent turbidity was lower than the average value. The results of the second run indicated that the effluent turbidity was in the range of 0.21 - 1.6 JTU with the average value of 0.78 JTU, which was less than the drinking water standard. The influent turbidity was fluctuated in the range of 66.9 - 92.9 JTU and the average value of 81.6 JTU

The turbidity removal efficiency was in the range of 98.22 - 99.77% with the average value of 99.04%, this value is higher than the average value of the first run. The pH value of both influent and effluent in this test run is the same as the first run. The average pH value of the influent and effluent were 7.75 and 7.28 respectively, which are still in the range of drinking water standard. The oil of the filtered water and the bed penetration of the particles have the same results as the first run.

The last test run of this run series was conducted with the filtration rate at 0.1 time of the first run, 0.25 m^3/m^2/day. The length of filter run at the head loss of 1.2 m was 197 hours, which longer than the second run only 45 hours. The filter performance based on the head loss, influent and effluent turbidity is illustrated in Fig. 17 and the value of head loss at various periodsof time is also tabulated in Table 7. The influent and effluent turbidity included also the turbidity removal efficiency are shown in Table 8.

This test run; the results show that the filter performance for example the relation between, the head loss and the effluent turbidity, the influent and effluent turbidity, oil of the filtered water included the bed penetration of the particles had the same performance as the two former test run. The detailed results are as follows: The effluent turbidity value was in the range of 0.15 - 1.7 JTU and the average value was 0.66 JTU which is still better than the drinking water standard. The effluent turbidity value was higher than the average value only in the beginning period of the filter run; but after the 84th hour of filter run until the end of the run, the effluent turbidity value became lower than the average value. The influent turbidity is in the range of 64.9 - 94.1 JTU with the average value of 80.3 JTU.

The turbidity removal efficiency was in the range of 97.62 - 99.81%, with the average value of 99.13%. This average is slightly higher than the average of the second run. The average influent pH value was 7.88 and the average effluent pH value was 7.35, which is still in safety range to be used as washwater.

Figs. 18 - 19 illustrate the comparison of the head loss, influent and effluent turbidity at the filtration rate of 2.5, 1.25 and 0.25 $m^3/m^2/hr$. Results from the comparison shows that :

1) the influent turbidity value of all the test runs is always fluctuated,

2) the effluent turbidity value of all the test runs is lower than the average value at the end period of the filter run,

3) the effluent turbidity value of all the test runs is less than 1.7 JTU which is obviously better than the drinking water standard, and

4) for both rates of 1.25 and 2.5 $m^3/m^2/hr$, the effluent turbidity value after the 48th hour of filter run is lower than 1.0 JTU and lower than 0.5 JTU when filter runs after the 115th hour.

The comparison of the total turbidity removed at various filtration rates is illustrated in Fig.20. Total turbidity removed at filtration rates of 2.5, 1.25 and 0.25 $m^3/m^2/hr$ were 5.408, 14.863 and 3.883 $kg/m^2/run$ respectively. It shows that the maximum value occured at a filtration rate of 1.25 $m^3/m^2/hr$. The comparison of the amount of water filtered versus different filtration rates is illustrated in Fig.21. It shows that the amount of water filtered at filtration rates of 2.5, 1.25 and 0.25 $m^3/m^2/hr$ were 70, 190 and 49.25 m^3/m^2 of bed respectively and the maximum value also occured at a filtration rate of 1.25 $m^3/m^2/hr$ again.

Comparison of the duration of runs at different filtration rates as illustrated in Fig.22 shows that the duration of run at rate 2.5 $m^3/m^2/hr$ was only 28 hours while the duration at rate 1.25 $m^3/m^2/hr$, 152 hours, was 5.43 times that of the higher rate; and the duration of run at last rate 0.25 $m^3/m^2/hr$, 197 hours, was only 45 hours longer than at rate 1.25 $m^3/m^2/hr$. It is shown that the most efficient and reasonable filtration rate is at 1.25 $m^3/m^2/hr$.

Summary Conclusion. of Run Series I

The summary of the results in run series I are presented in Table 10 and the results will be concluded as follows :

1) Using burnt rice husk as the filtering media will provide good effluent quality that can be, again, used as the washwater as well. Because the result of all the three test runs for example, effluent trubidity value is in the range of 0.15 - 1.7 JTU, the average effluent turbidity value is in the range of 0.66 - 1.0 JTU, the average effluent pH value is in the range of 7.28 - 7.35 and the average turbidity removal efficiency value is at the range of 98.74 - 99.13%.

2) From the visual observation, it shows that after being used as a filter media, the burnt rice husk should be discarded rather than being attemp to be reused.

3) The optimum filtration rate for burnt rice husk media at the turbidity loading of washed water range of 60 - 100 JTU and 80 cm depth of media is a rate of 1.25 $m^3/m^2/hr$. This fact is considered from the total turbidity removed and the amount of filtered water which is maximum at this rate, when compared with any other rates. The quality of the effluent and the turbidity removal efficiency is very slightly different.

4) The optimum length of filter run at the rate of 1.25 $m^3/m^2/hr$ is 152 hours.

Table 7 Head Loss of Filter at Filtration Rate 2.5, 1.25 and 0.25 $m^3/m^2/hr$, Depth of Media 80 cm

Cumulative Hours of Operation	Head Loss, cm			Remark
	Run No. 1 @ 2.5 $m^3/m^2/hr$	Run No. 2 @ 1.25 $m^3/m^2/hr$	Run No. 3 @ 0.25 $m^3/m^2/hr$	
0	0.4	0.3	0.4	Depth of Media =80 cm.
1	7.0	-	-	
2	12.1	2.6	-	
3	17.8	-	-	
4	20.9	4.4	2.8	
6	23.7	-	-	
8	29.1	5.0	3.0	
10	39.7	-	-	
12	50.2	6.2	3.9	
15	62.3	-	-	
18	-	7.9	4.5	
19	77.1	-	-	
23	92.3	-	-	
24	-	12.4	6.0	
26	107.8	-	-	
28	121.0	-	-	
30		13.8	9.9	
36		19.6	16.0	
42		24.5	21.2	
48		26.1	24.3	
54		31.3	29.0	
60		37.0	33.4	
66		44.6	35.1	
72		46.9	38.6	

Table 7 (Continue)

Cumulative Hours of Operation	Head Loss, cm Run No. 1 @ 2.5 $m^3/m^2/hr$	Head Loss, cm Run No. 2 @ 1.25 $m^3/m^2/hr$	Head Loss, cm Run No. 3 @ 0.25 $m^3/m^2/hr$	Remark
78		54.7	43.9	
84		63.2	46.8	
90		68.5	47.7	
96		71.8	52.3	
102		73.9	55.4	
108		79.0	57.2	
114		83.1	58.1	
120		90.0	61.4	
126		92.2	63.3	
132		98.8	70.0	
138		106.4	71.4	
144		110.5	73.6	
148		117.6	-	
150		-	80.2	
152		120.6	-	
156			82.5	
162			88.7	
168			89.5	
174			96.9	
180			100.6	
186			105.2	
192			115.4	
197			120.8	

Table 8 Turbidity of Influent and Effluent Water at Filtration Rate 2.5, 1.25 and 0.25 $m^3/m^2/hr$, Depth of Media 80 cm

Cumulative Hours of Operation	Turbidity, JTU								
	Run No. 1 @ 2.5 $m^3/m^2/hr$			Run No. 2 @ 1.25 $m^3/m^2/hr$			Run No. 3 @ 0.25 $m^3/m^2/hr$		
	Inf.	Eff.	% Rem.	Inf.	Eff.	% Rem.	Inf.	Eff.	% Rem.
1	82.8	*1.7	#97.95	-	-	-	-	-	-
2	77.9	1.2	98.46	-	-	-	-	-	-
4	89.7	1.5	98.33	86.3	1.3	98.49	#64.9	1.4	97.84
8	76.4	0.88	98.85	-	-	-	-	-	-
12	82.1	1.1	98.66	90.1	*1.6	#98.22	81.0	1.4	98.27
15	80.2	0.82	98.98	-	-	-	-	-	-
19	#67.6	0.71	98.95	-	-	-	-	-	-
23	78.0	#0.43	*99.45	-	-	-	-	-	-
24	-	-	-	71.2	1.2	98.31	70.8	0.92	98.70
26	*90.3	0.97	98.93	-	-	-	-	-	-
28	77.6	0.92	98.81	-	-	-	-	-	-
36				92.0	1.5	98.37	71.5	*1.7	#97.62
48				72.5	0.87	98.80	67.3	1.0	98.51
60				69.4	0.61	99.12	80.1	0.78	99.03
72				#66.9	0.53	99.21	85.0	0.84	99.01
84				87.7	0.93	98.94	90.7	0.69	99.24
96				81.6	0.82	99.00	76.4	0.50	99.35
108				88.7	0.64	99.28	69.5	0.31	99.55
120				76.9	0.36	99.53	86.2	0.18	99.79
132				71.8	0.49	99.32	*94.1	0.33	99.65
144				89.0	0.30	99.66	90.0	0.46	99.49

Table 8 (Continued)

Cumulative Hours of Operation	Turbidity, JTU								
	Run No. 1 @ 2.5 $m^3/m^2/hr$			Run No. 2 @ 1.25 $m^3/m^2/hr$			Run No.3 @ 0.25 $m^3/m^2/hr$		
	Inf.	Eff.	% Rem.	Inf.	Eff.	% Rem.	Inf.	Eff.	% Rem.
148				88.2	0.38	99.57	-	-	-
152				*92.9	#0.21	*99.77	-	-	-
156							86.6	0.30	99.65
168							83.9	0.28	99.67
180							79.8	#0.15	*99.81
192							76.1	0.41	99.46
197							92.8	0.25	99.73
Average	80.2	1.0	98.74	81.6	0.78	99.04	80.3	0.66	99.13

Note: # = Mininum * = Maximun

Table 9 pH of Influent and Effluent Water at Filtration Rate 2.5, 1.25 and 0.25 $m^3/m^2/hr$, Depth of Media 80 cm

Cumulative Hours of Operation	pH					
	Run No. 1 @ 2.5 $m^3/m^2/hr$		Run No. 2 @ 1.25 $m^3/m^2/hr$		Run No. 3 @ 0.25 $m^3/m^2/hr$	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
1	7.60	7.11	-	-	-	-
2	7.32	6.95	-	-	-	-
4	7.76	7.29	7.96	7.44	7.71	7.23
8	7.94	7.62	-	-	-	-
12	8.31	7.68	7.62	7.14	8.05	7.49
15	7.40	7.02	-	-	-	-
19	7.51	7.16	-	-	-	-
23	7.85	7.36	-	-	-	-
24	-	-	7.86	7.36	7.67	7.14
26	8.02	7.69	-	-	-	-
28	7.58	7.17	-	-	-	-
36			7.79	7.31	7.82	7.25
48			7.90	7.40	7.88	7.30
60			8.18	7.60	7.57	6.99
72			7.93	7.42	8.16	7.53
84			7.68	7.23	7.73	7.20
96			7.55	7.11	8.00	7.47
108			7.60	7.19	7.97	7.55
120			7.38	6.97	7.88	7.28
132			7.69	7.25	8.06	7.57
144			8.07	7.50	7.64	7.19

Table 9 (Continued)

Cumulative Hours of Operation	pH					
	Run No. 1 @ 2.5 $m^3/m^2/hr$		Run No. 2 @ 1.25 $m^3/m^2/hr$		Run No. 3 @ 0.25 $m^3/m^2/hr$	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
148			7.40	7.02	-	-
152			7.74	7.28	-	-
156					8.24	7.68
168					7.77	7.24
180					7.89	7.38
192					7.66	7.17
197					8.24	7.64
Average	7.72	7.30	7.75	7.28	7.88	7.35

Table 10 Summary of Results in Run Series I

Run No.	Media	Depth of Media (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent		Effluent		Avg. Tur. Rem. Eff. (%)	Avg. pH of Effluent	Amount of water Filtered (m^3/m^2 of bed)	Duration of Run for Head Loss 1.2m (hour)	Rate of Head Loss (cm/hr)
				Turbidity Range (JTU)	Avg. (JTU)	Turbidity Range (JTU)	Avg. (JTU)					
1	BRH*	80	2.50	67.6-90.3	80.2	1.7-0.43	1.0	98.74	7.30	70.00	28	4.28
2	BRH	80	1.25	66.9-92.9	81.6	1.6-0.21	0.78	99.04	7.28	190.00	152	0.79
3	BRH	80	0.25	64.9-94.1	80.3	1.7-0.15	0.66	99.13	7.35	49.25	197	0.61

Note: BRH* = Burnt Rice Husk

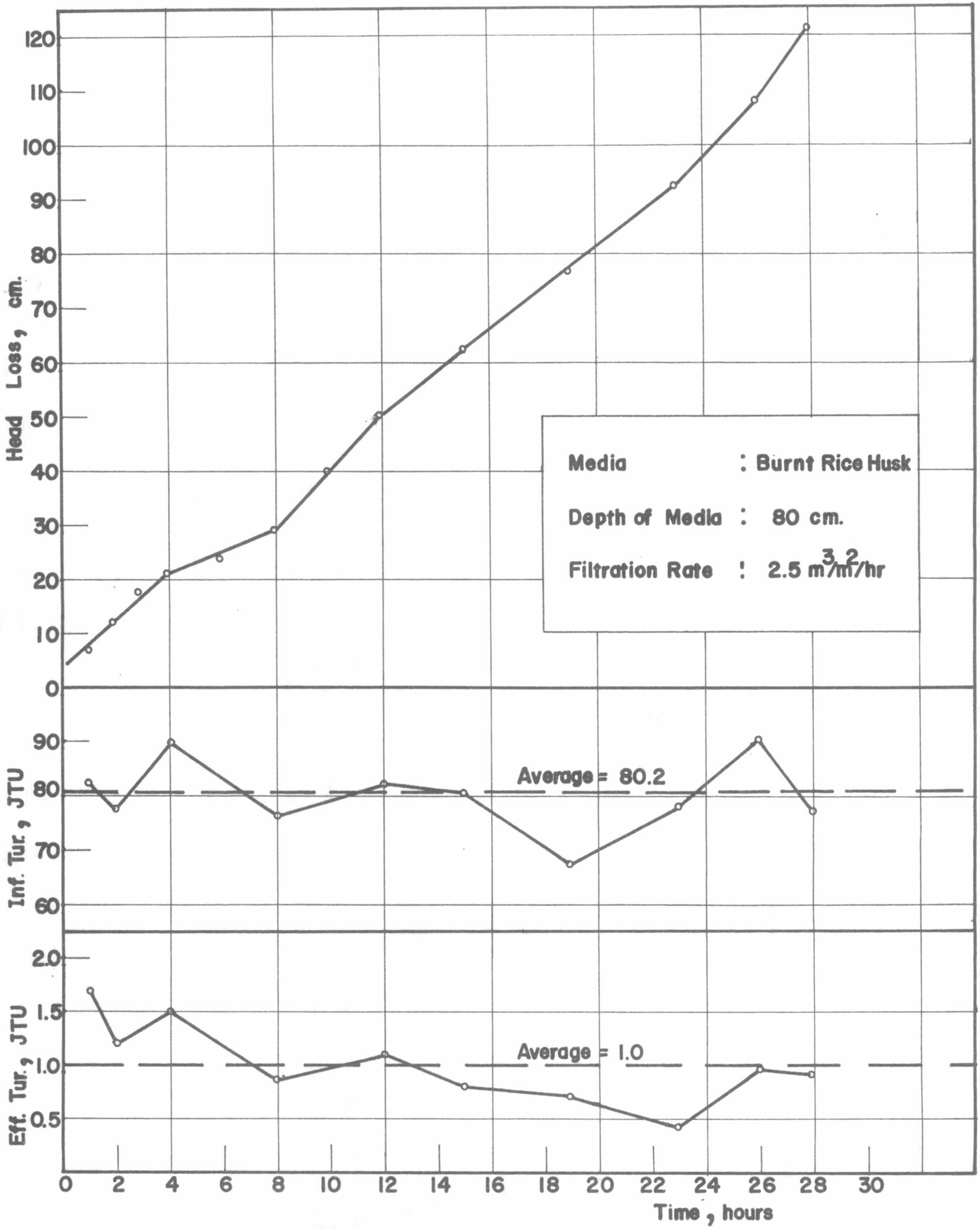

Fig. 15 Filter Performance at Filtration Rate 2.5 $m^3/m^2/hr$, Depth of Media 80 cm.

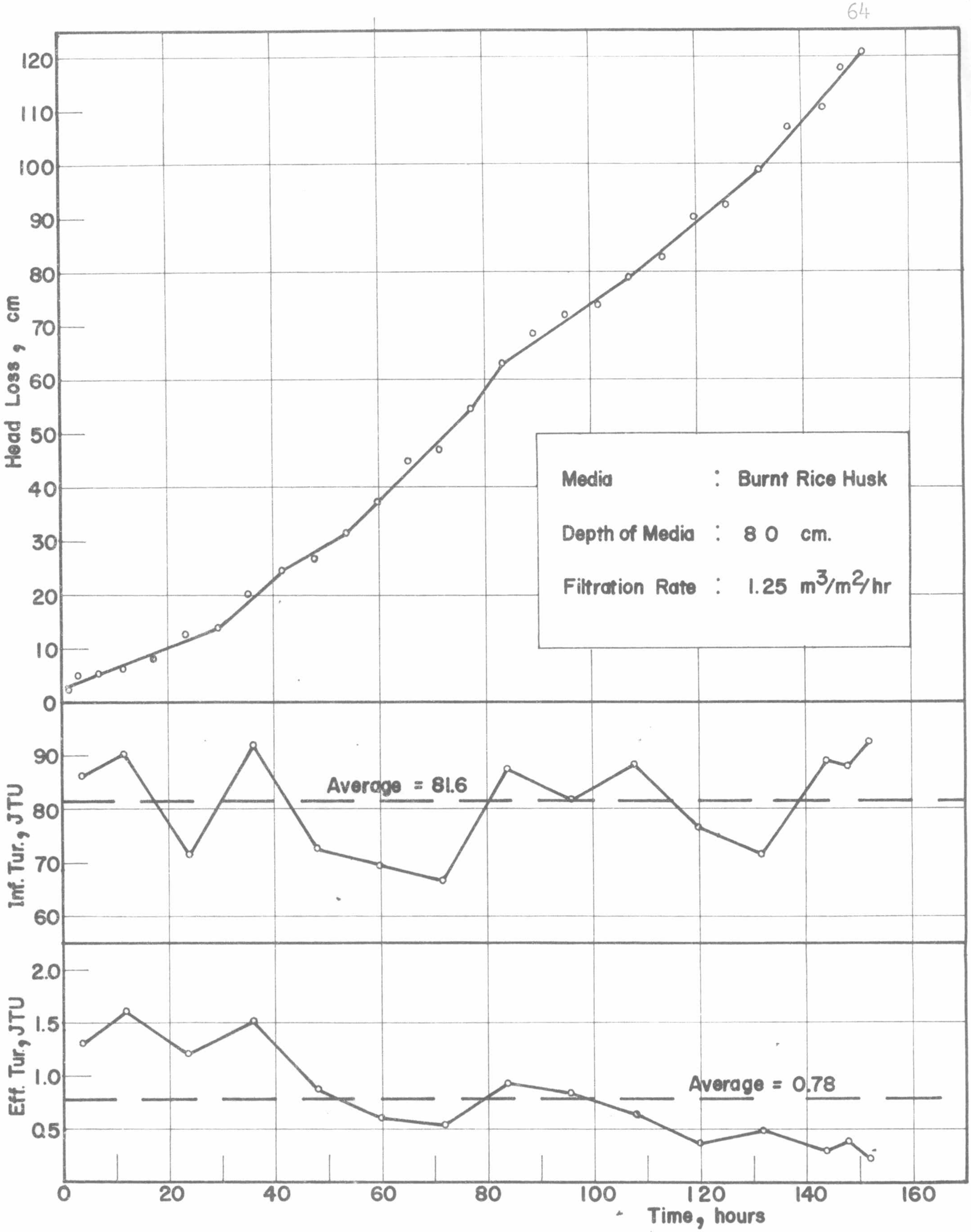

Fig. 16 Filter Performance at Filtration Rate 1.25 $m^3/m^2/hr$, Depth of Media 80 cm.

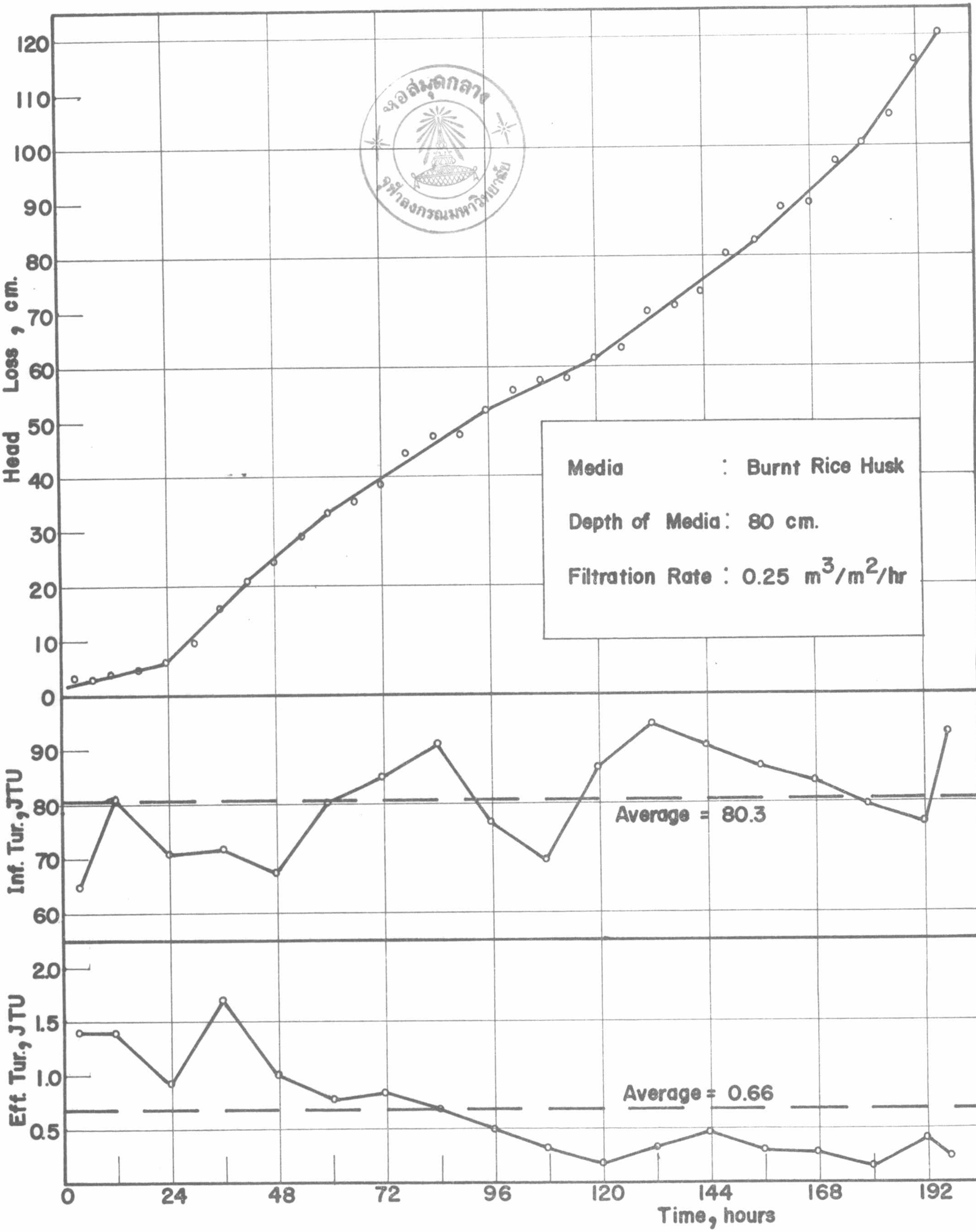

Fig. 17 Filter Performance at Filtration Rate $0.25\ m^3/m^2/hr$, Depth of Media 80 cm

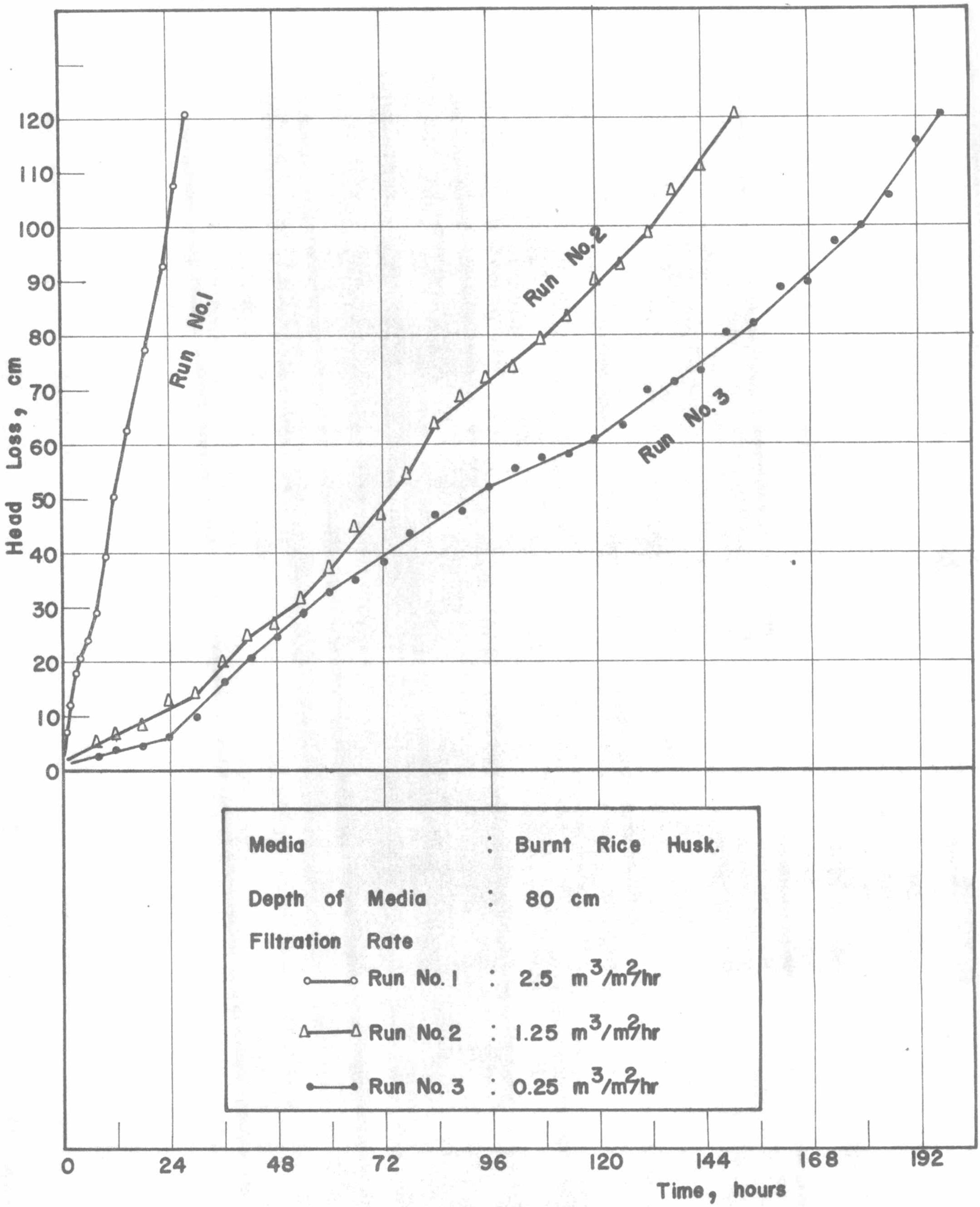

Fig. 18 Comparison of Head Loss at Filtration Rate 2.5, 1.25 and 0.25 $m^3/m^2/hr$

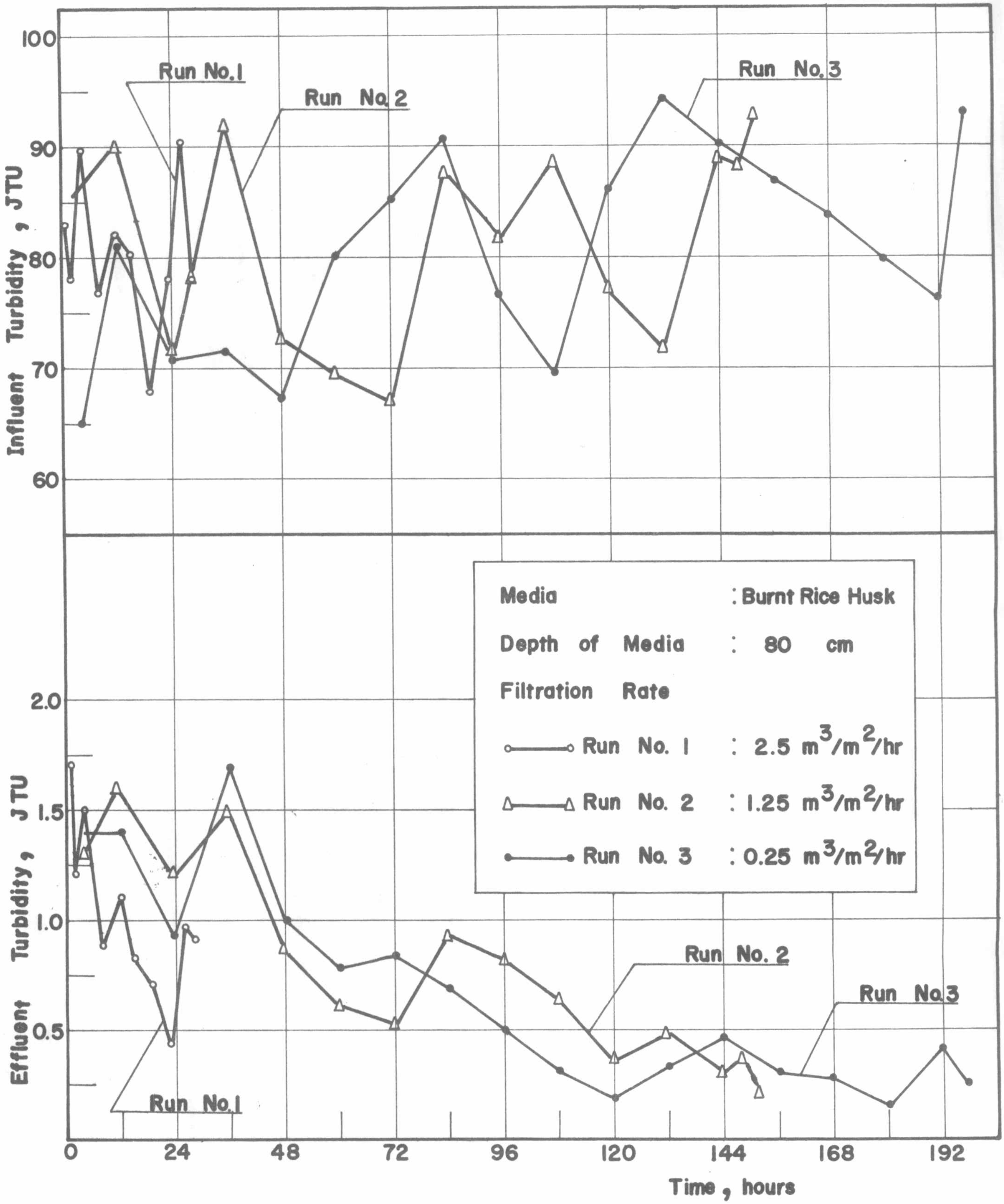

Fig. 19 Comparison of Influent and Effluent at Filtration Rate 2.5, 1.25 and 0.25 $m^3/m^2/hr$

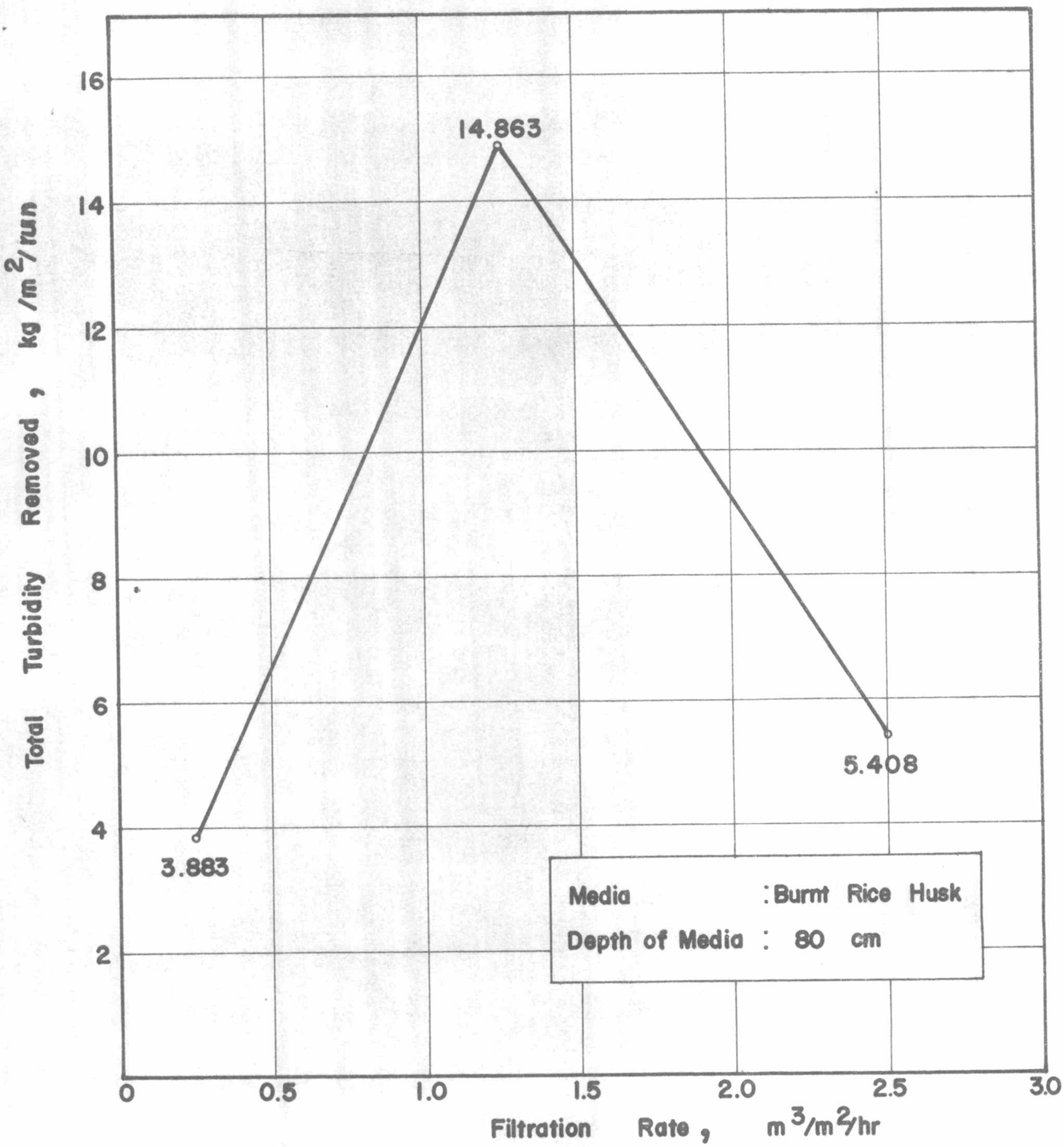

Fig. 20 Comparison of Total Turbidity Removed at Various Filtration Rates

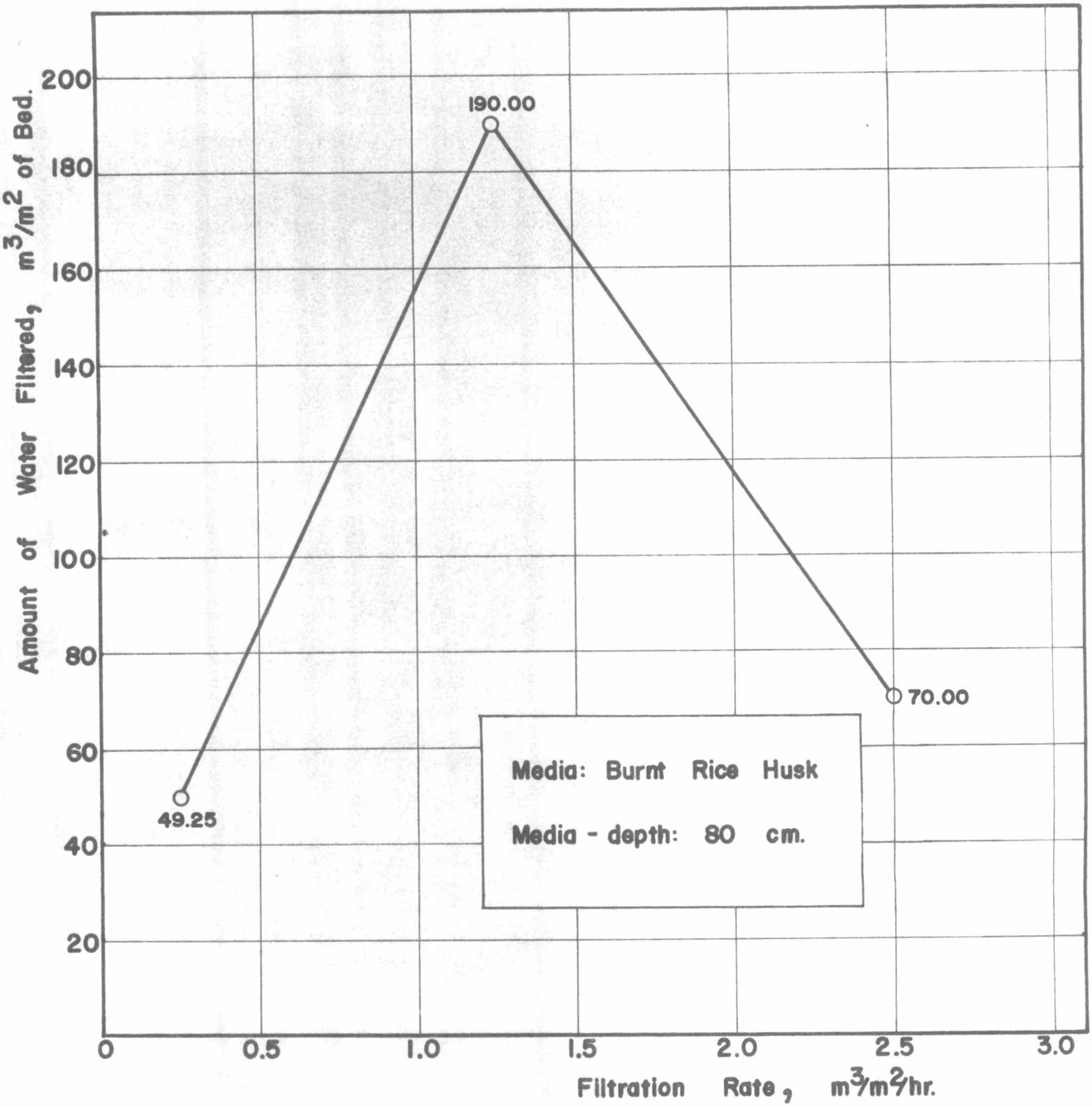

Fig. 21 Relation of Amount of Water Filtered Versus Filtration Rates of Burnt Rice Husk.

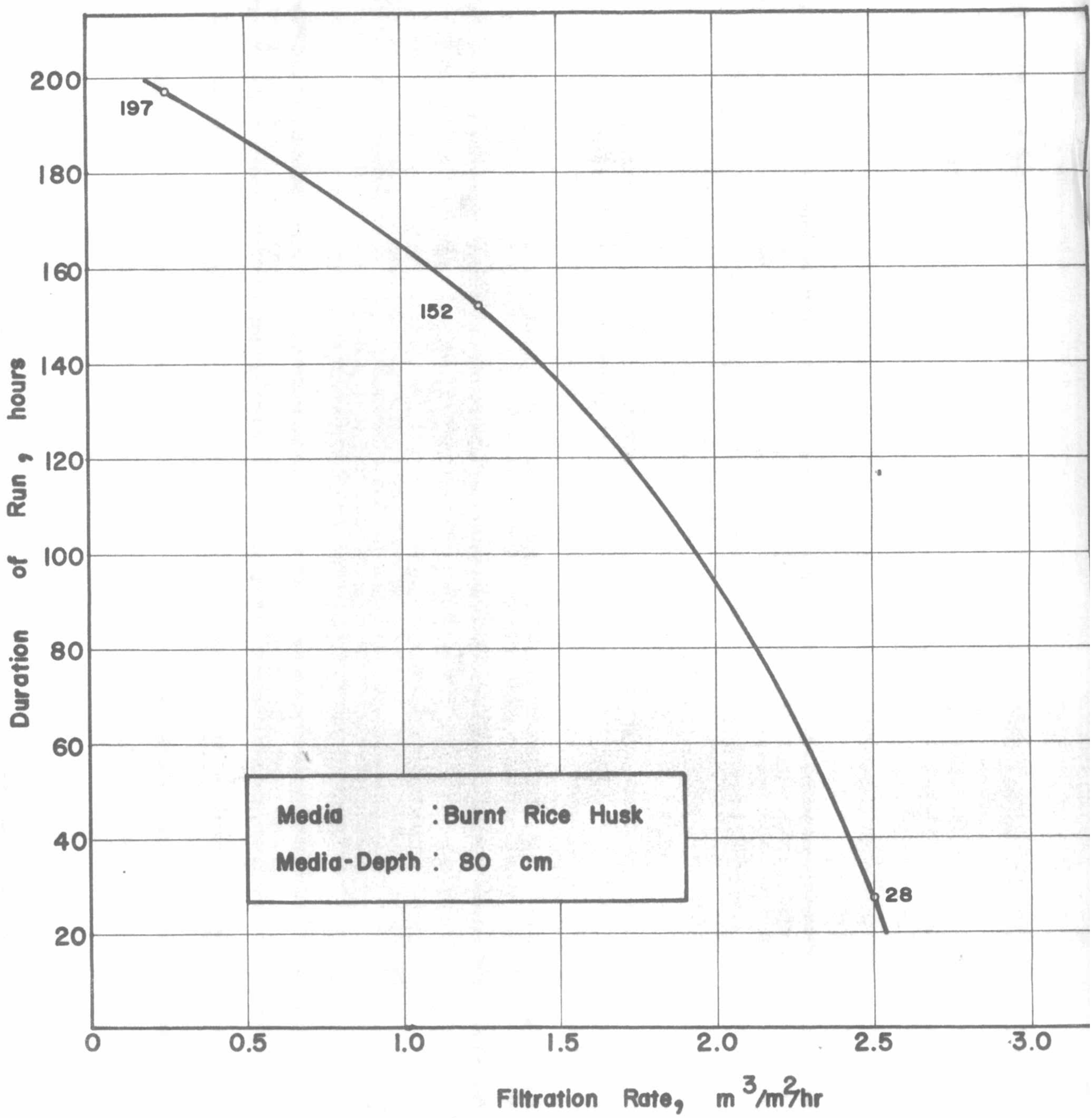

Fig. 22 Comparison of Duration of Run at Different Filtration Rates.

Run Series II : Experimental Study of the Performance of the Burnt Rice Husk, as a Filter Media, at Different Depths

Result from run series I, the optimum filtration rate is 1.25 $m^3/m^2/hr$ at 80 cm depth of media. To compare with the run series I, these tests were performed at 2 depths of the media, 60 and 40 cm, with the same filtration rate 1.25 $m^3/m^2/hr$. With the filtration rate of 1.25 $m^3/m^2/hr$, and media depth of 60 cm the filter was run up to 135 hours after this period the head loss of the filter was measured to be 1.2 m, illustrated in Fig.23 and the value is tabulated in Table 11. The turbidity of the influent and the effluent are illustrated in Fig.23 and Table 12 also with the turbidity romoval efficiency as well.

There are many results obtained from this run series such as the relation between the head loss and the effluent turbidity, the relation between the influent turbidity and the effluent turbidity, oil of the filtered water, the bed penetration of the particles, the performance of the media on the pH of water. All the results of the above mentions were as the same as the results obtained in the first run series tested, for example, the influent turbidity was fluctuated in the range of 66.5 - 89.3 JTU (with the average of 76.6 JTU), the effluent turbidity was in the range of 0.22 - 1.5 JTU (with the average of 0.75 JTU). It is obviously shown that there mentioned results are still better than that of the drinking water standard. The effluent turbidity value was higher than the average value in the beginning period of the filter run and it became lower after the 84th hour of the filter run up to the end of the test.

The turbidity removal efficiency was in the range of 98.08 - 99.74% with the average of 99.01%. It is a little bit lower than the value obtained from the run series I, 99.04%.

The average pH of the influent was 7.74 as shown in Table 13 and the average pH of the effluent was 7.26 which is in the able range to wash the automobile as well.

The last test was also run at the rate of 1.25 $m^3/m^2/hr$ but it had been conducted at the depth of 40 cm . The measured head loss at 1.2 m had been achieved at 126th hour of filter run, Fig.24 and Table 11. The influent and the effluent turbidity is illustrated in Fig.24 and Table 12 with also the turbidity removal efficiency.

The same as the previous performance, the detailed results are as follows : the influent turbidity was fluctuated in the range of 65.8 - 97.2 JTU (with the average of 80.3 JTU). The effluent turbidity was in the range of 0.20 - 1.6 JTU, with the average of 0.78 JTU, which is still similar to the values obtained from the test on 80 cm depth. The effluent turbidity value was higher than the average value from the beginning but would be lower than the average value after 60th hour of filter run up to the end of the filter run. The turbidity removal efficiency was in the range of 97.76 - 99.76% with the average of 98.98%, which is slightly less than the average value obtained from the test on 80 cm depth. The average pH of the influent was 7.67 and the average pH of the effluent was 7.21 which is, again, still in the washing range.

The comparison of head loss, influent and effluent turbidity at the depth of 80, 60 and 40 cm filter media are illustrated in Fig. 25 and Fig. 26. From the Figure, it is shown that the influent turbidity value is always fluctuated but the effluent turbidity of the 3 runs are very slightly near the end of the filter run, after the 48th hour of the filter run all the effluent turbidity is below 1.0 JTU. Besides the effluent turbidity values of the 3 tests is less than 1.6 JTU which is still better than that of the standard drinking water.

The comparison of the total turbidity removed and the amount of the water filtered at various depths of media are illustrated in Figs.27 and 28. Both two figures show that the maximum turbidity value occured at the depth of 80 cm. The maximum duration of filter run at various depths of the media, Fig.29, was also occured in the 80 cm media depth as well.

Summary Conclusion of Run Series II

Summary of results in Run Series II are shown in Table 14. It would be concluded as follows :

1) The results from this run series, it is to confirm that the burnt rice husk alone as the filter media can give the effluent quality sufficient to recycle back for the reuse purpose. From the three results of this run series, the effluent turbidity value is in the range of 0.2 - 1.6 JTU and the average effluent turbidity value is in the range of 0.75 - 0.78 JTU, the average pH of the effluent of the 3 tests is in the range of 7.21 - 7.28 and the average turbidity removal efficiency is in the range of 98.98 - 99.04%

2) The optimum depth of media, the burnt rice husk, with the filtration rate of 1.25 $m^3/m^2/hr$ is 80 cm for the turbidity loading of the range of 60 - 100 JTU. This value of depth obtained from the studies of the total turbidity removed, the amount of water filtered and the duration of filter run. This depth is the optimum depth when compared with the other depths since the obtained quality of the effluent is very slightly different.

Beside, below the 80 cm depth, the greater the depth the higher the total turbidity removed. But if the depth is more than 80 cm the construction cost of the filter tank is inevitably uneconomic.

Table 11 Head Loss of Filter at Depth of Media 80, 60 and 40 cm;Filtration Rate 1.25 $m^3/m^2/hr$

Cumulative Hours of Operation	Head Loss , cm			Remark
	Run No. 1 @ 80 cm depth	Run No. 2 @ 60 cm depth	Run No. 3 @ 40 cm depth	
0	0.3	0.4	0.2	Filtration Rate =1.25 $m^3/m^2/hr$
2	2.6	-	-	
4	4.4	4.1	4.0	
8	5.0	5.8	5.1	
12	6.2	9.2	6.2	
18	7.9	12.0	11.3	
24	12.4	15.7	13.5	
30	13.8	25.9	19.8	
36	19.6	34.1	22.4	
42	24.5	39.8	29.1	
48	26.1	43.0	36.3	
54	31.3	45.5	40.0	
60	37.0	50.3	45.9	
66	44.6	56.4	51.2	
72	46.9	61.2	55.0	
78	54.7	63.0	58.8	
84	63.2	69.7	67.4	
90	68.5	75.5	70.7	
96	71.8	79.0	77.5	
102	73.9	82.8	86.1	
108	79.0	88.1	92.6	
114	83.1	95.9	99.0	
118	-	-	96.2	

Table 11 (Continued)

Cumulative Hours of Operation	Head Loss, cm			Remark
	Run No. 1 @ 80 cm depth	Run No. 2 @ 60 cm depth	Run No. 3 @ 40 cm depth	
120	90.0	99.8	-	
122	-	-	115.0	
126	92.2	106.2	120.1	
130	-	116.0		
132	98.8	-		
135	-	120.3		
138	106.4			
144	110.5			
148	117.6			
152	120.6			

Table 12 Turbidity of Influent and Effluent Water at Depth of Media 80, 60 and 40 cm, Filtration Rate 1.25 $m^3/m^2/hr$

Cumulative Hours of Operation	Turbidity, JTU								
	Run No. 1 @ 80 cm depth			Run No. 2 @ 60 cm depth			Run No. 3 @ 40 cm depth		
	Inf.	Eff.	% Rem.	Inf.	Eff.	% Rem.	Inf.	Eff.	% Rem.
4	86.3	1.3	98.49	79.6	1.4	98.24	68.0	1.5	97.79
12	90.1	*1.6	#98.22	78.1	*1.5	#98.08	79.3	1.2	98.49
24	71.2	1.2	98.31	*89.3	1.0	98.88	70.1	1.0	98.57
36	92.0	1.5	98.37	75.0	1.2	98.40	71.4	*1.6	#97.76
48	72.5	0.87	98.80	72.4	0.71	99.02	81.7	0.98	98.80
60	69.4	0.61	99.12	81.7	0.49	99.40	90.5	0.81	99.10
72	#66.9	0.53	99.21	70.0	1.10	98.43	#65.8	0.62	99.06
84	87.7	0.93	98.94	74.5	0.76	98.98	93.6	0.35	99.63
96	81.6	0.82	99.00	80.0	0.27	99.66	*97.2	0.90	99.07
108	88.7	0.64	99.28	83.8	#0.22	*99.74	86.0	0.27	99.69
118	-	-	-	-	-	-	82.9	#0.20	*99.76
120	76.9	0.36	99.53	73.2	0.38	99.48	-	-	-
122	-	-	-	-	-	-	76.1	0.43	99.43
126	-	-	-	-	-	-	82.0	0.31	99.62
130	-	-	-	71.9	0.54	99.25			
132	71.8	0.49	99.32	-	-	-			
135	-	-	-	#66.5	0.30	99.55			
144	89.0	0.30	99.66						
148	88.2	0.38	99.57						
152	*92.9	#0.21	*99.77						
Average	81.6	0.78	99.04	76.6	0.75	99.01	80.3	0.78	98.98

Note: # = Minimum * = Maximum

Table 13 pH of Influent and Effluent Water at Depth of Media 80, 60 and 40 cm, Filtration Rate 1.25 $m^3/m^2/hr$

Cumulative Hours of Operation	pH					
	Run No. 1 @ 80 cm depth		Run No. 2 @ 60 cm depth		Run No. 3 @ 40 cm depth	
	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.
4	7.96	7.44	7.85	7.40	7.36	7.02
12	7.62	7.14	7.68	7.24	7.77	7.14
24	7.86	7.36	7.50	7.03	7.81	7.30
36	7.79	7.31	8.15	7.66	7.56	7.12
48	7.90	7.40	7.74	7.27	7.49	7.03
60	8.18	7.60	7.66	7.20	7.90	7.31
72	7.93	7.42	7.71	7.25	7.79	7.23
84	7.68	7.23	7.89	7.49	7.33	7.00
96	7.55	7.11	8.02	7.53	7.64	7.14
108	7.60	7.19	7.40	6.97	8.12	7.73
118	-	-	-	-	7.77	7.20
120	7.38	6.97	7.65	7.08	-	-
122	-	-	-	-	7.35	7.06
126	-	-	-	-	7.93	7.55
130	-	-	7.82	7.25		
132	7.69	7.25	-	-		
135	-	-	7.60	7.05		
144	8.07	7.50				
148	7.40	7.02				
152	7.74	7.28				
Average	7.75	7.28	7.74	7.26	7.67	7.21

Table 14 Summary of Results in Run Series II

Run No.	Media	Depth of Media (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Influent Avg. (JTU)	Effluent Turbidity Range (JTU)	Effluent Avg. (JTU)	Avg. Tur. Rem. Eff. (%)	Avg. pH. of Effluent	Amount of Water Filtered (m^3/m^2 of bed)	Duration of Run for Head Loss 1.2m (hour)	Rate of Head Loss (cm/hr)
1*	BRH	80	1.25	66.9-92.9	81.6	1.6-0.21	0.78	99.04	7.28	190.00	152	0.79
2	BRH	60	1.25	66.5-89.3	76.6	1.5-0.22	0.75	99.01	7.26	168.75	135	0.89
3	BRH	40	1.25	65.8-97.2	80.3	1.6-0.20	0.78	98.98	7.21	157.50	126	0.95

Note: 1* = Result from Run No. 2 in Run Series I

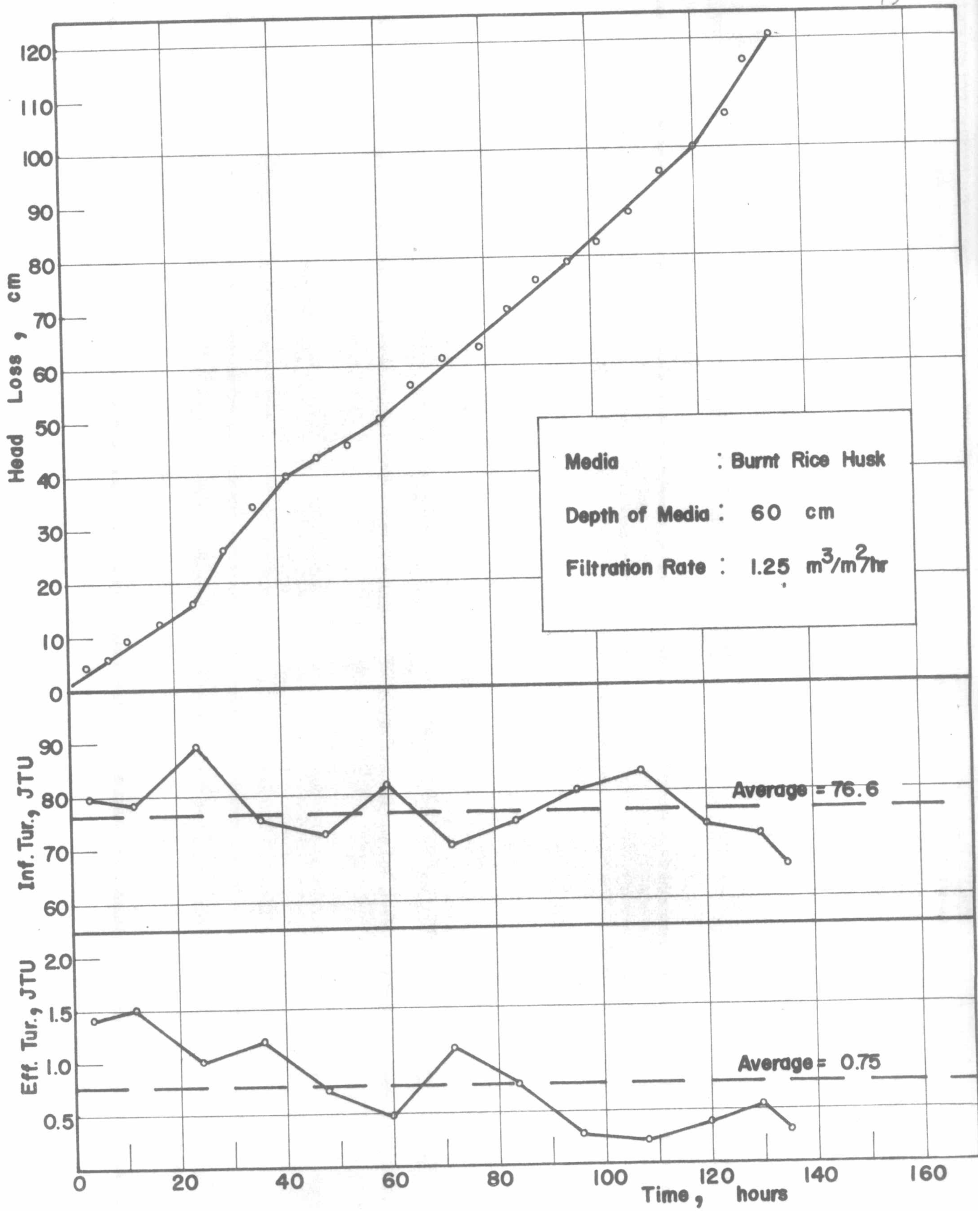

Fig. 23 Filter Performance at Filtration Rate $1.25\ m^3/m^2/hr$, Depth of Media 60 cm

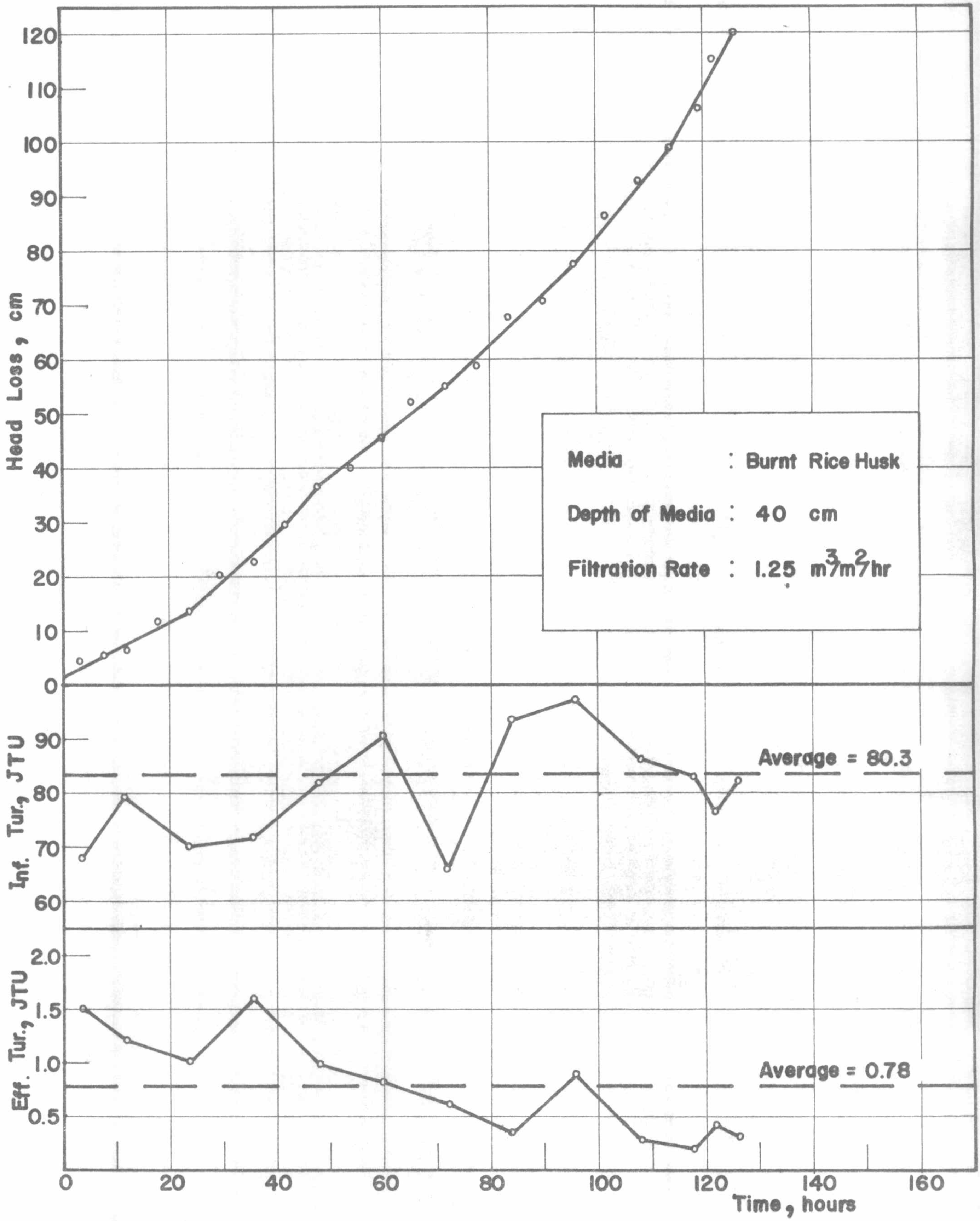

Fig. 24 Filter Performance at Filtration Rate 1.25 $m^3/m^2/hr$ Depth of Media 40 cm.

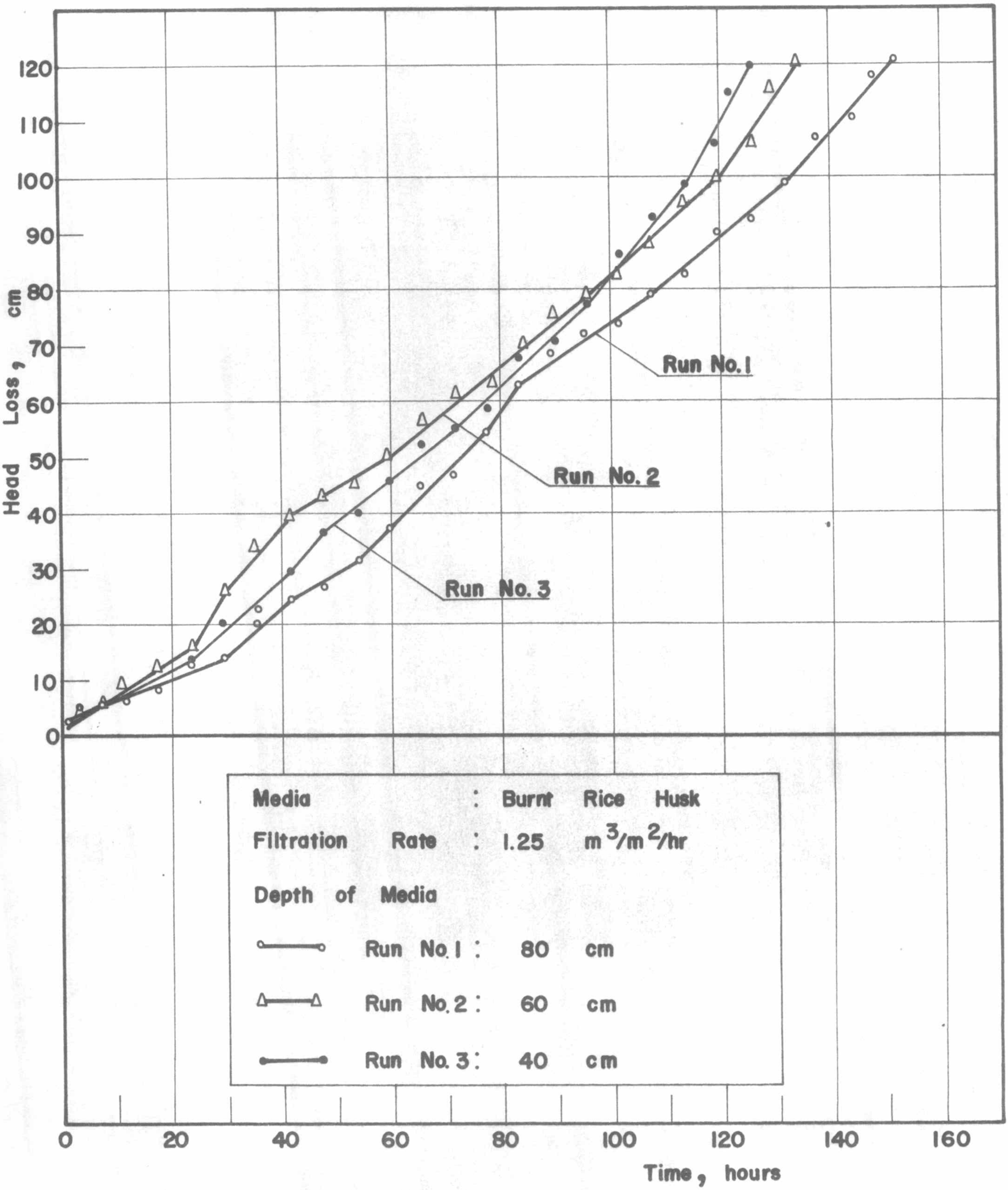

Fig. 25 Comparison of Head Loss at Depth of Media 80, 60 and 40 cm

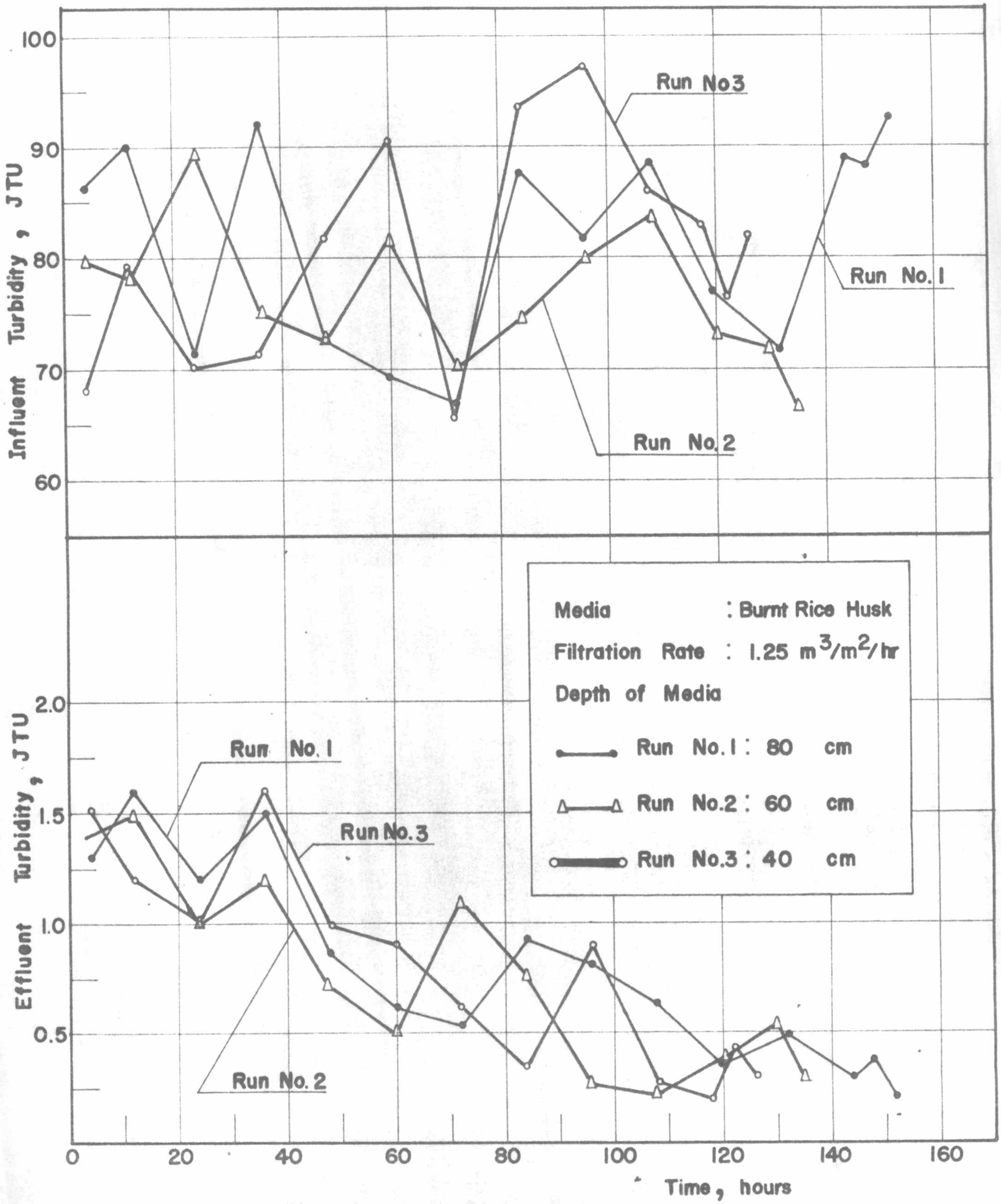

Fig. 26 Comparison of Influent and Effluent at Depth of Media 80, 60 and 40 cm

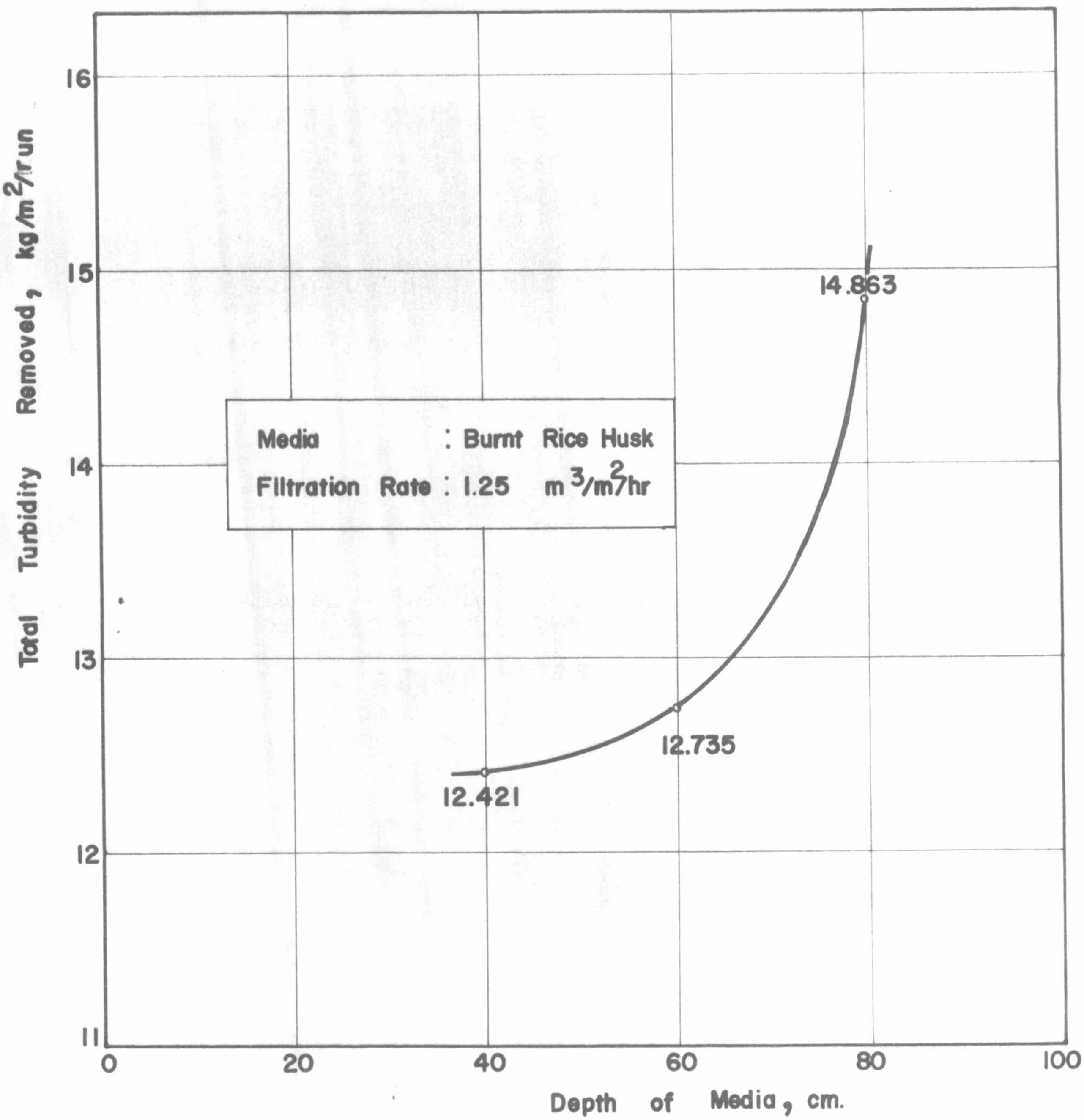

Fig. 27 Comparison of Total Turbidity Removed at Various Depths of Media

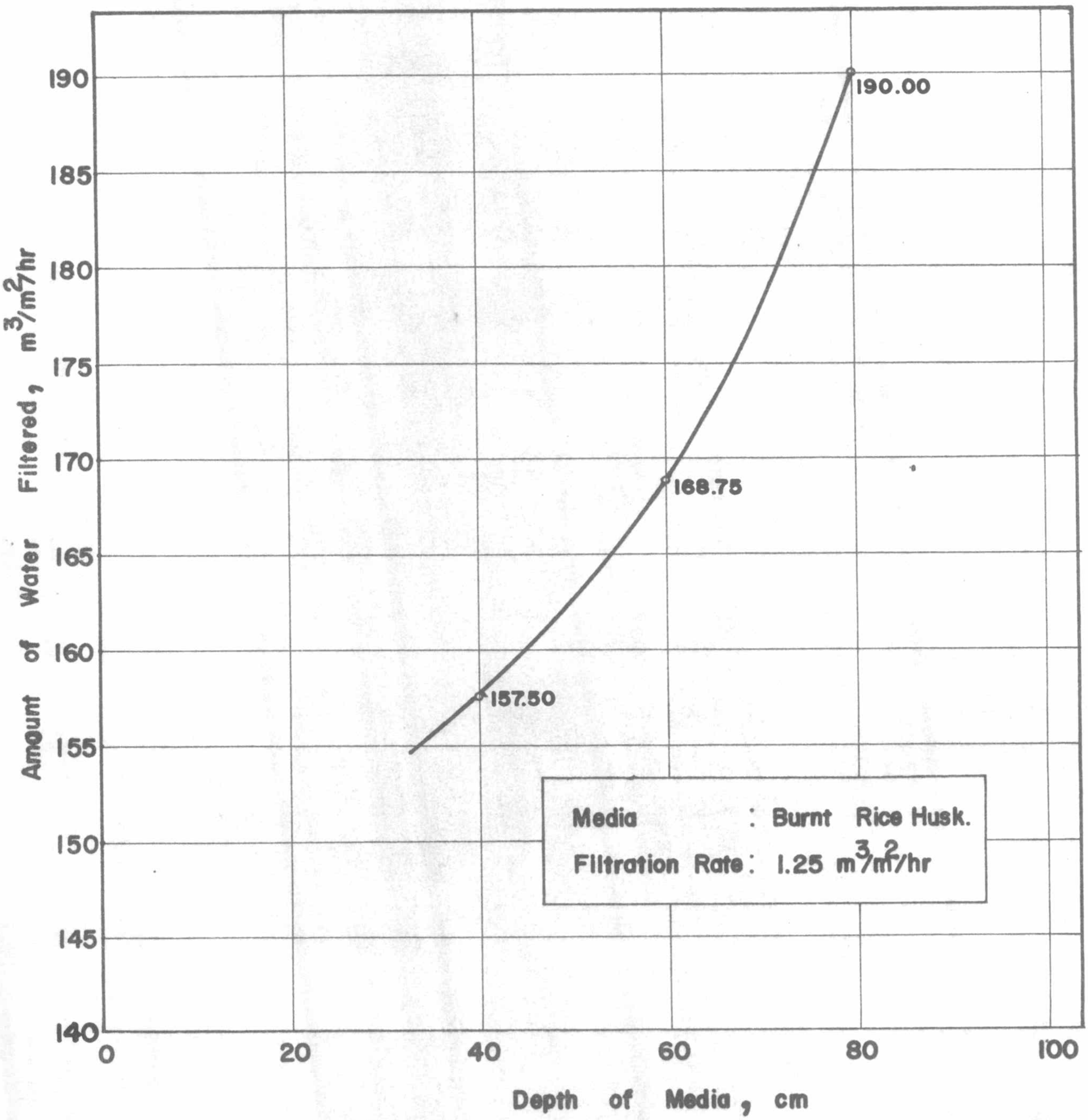

Fig. 28 Comparison of Amount of Water Filtered at Various Depths of Media.

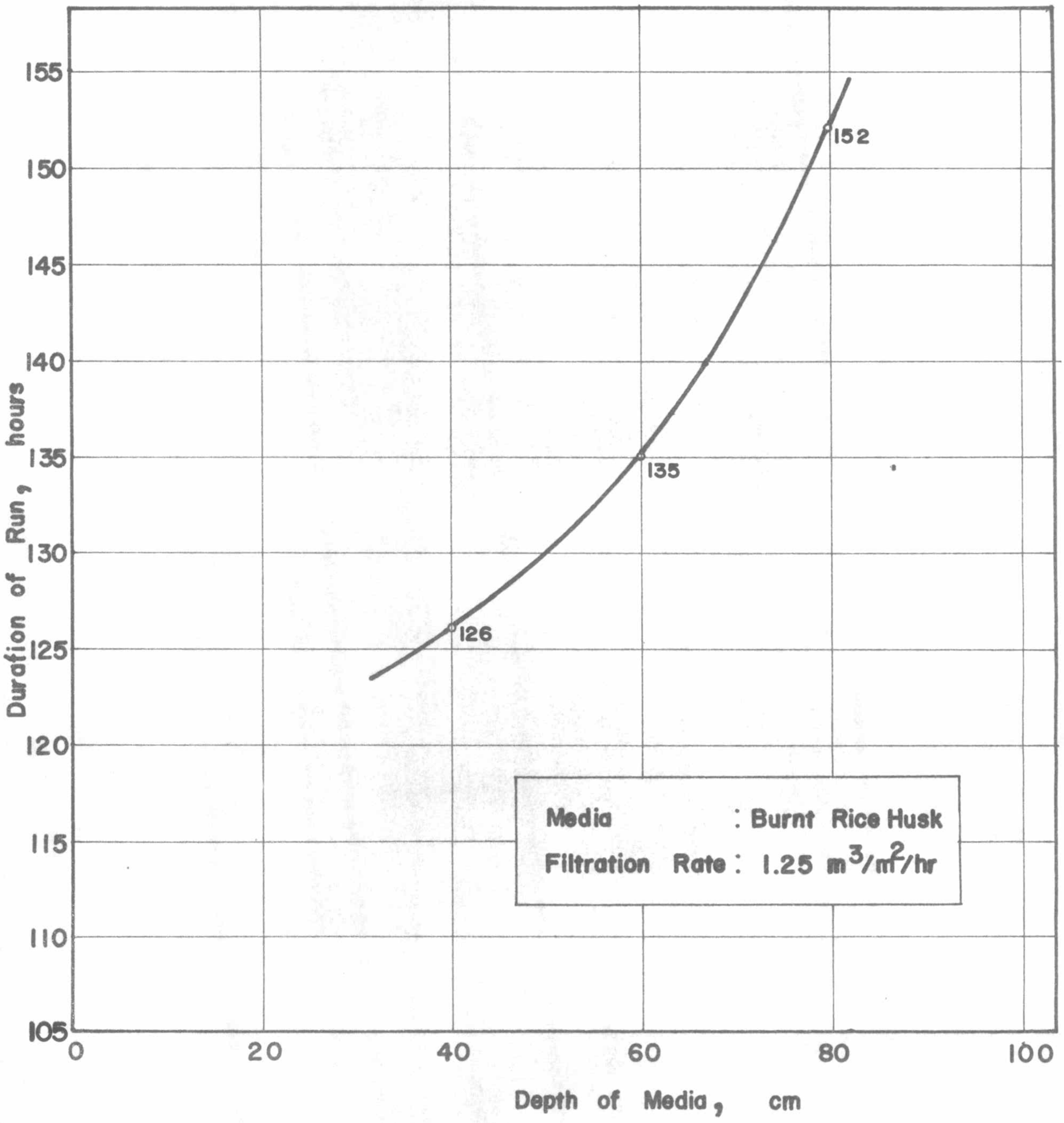

Fig. 29 Comparison of Duration of Run at Various Depths of Media.