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DEVELOPMENT OF A SERIES FILTRATION WATER TREATMENT METHOD FOR SMALL COMMUNITIES OF ASIA

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DEVELOPMENT OF A SERIES FILTRATION WATER TREATMENT METHOD FOR SMALL COMMUNITIES OF ASIA

by

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ABSTRACT

A series filtration water treatment system using local materials was developed for treating surface water in small communities of Asia. Design criteria were developed using coconut husk fiber as roughing filter medium and burnt rice husk as polishing filter medium. The optimum filtration rate was 1.25 $m^3/m^2/hr$ for both filters. The optimum depth of media using series filtration units was at 100 cm for coconut husk fiber and 80 cm for burnt rice husk.

A dual media filter, comprising coconut husk fiber of 80 cm depth followed by burnt rice husk of 20 cm depth, fed at a filtration rate of 1.25 $m^3/m^2/hr$, had efficiencies for turbidity and coliform removal greater than 99% when treating surface waters. Duration of the filter run, using the dual media, would approximate one month's operating time based on current village water use habits in Thailand. The dual media filter appears promising as a tertiary waste treatment process also.

For raw water sources with turbidity less than 40 JTU, a single media filter of burnt rice husk, fed at filtration rate of 0.25 $m^3/m^2/hr$, proved to be satisfactory to provide a high efficiency of turbidity and coliform removal.

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I INTRODUCTION

Rural Community Water Supply in Asia

Water supply is a critical factor in public health protection and economic development in most parts of the world, particularly in the developing countries. Water is also a key element in the growth of any community, rural or urban. The explosive growth of population in Southeast Asia makes the goal of distributing water from a central source to each village a difficult objective to strive for when so often sufficient funds for treatment and distribution of water are not available.

Slow sand filters using local materials as filter media are considered to be an attractive alternative for producing potable water in rural communities in Asia. These areas rarely have qualified technicians to operate a conventional coagulation rapid sand filter effectively. The availability of land, labour, local materials, no chemicals required and climatological conditions in Asia favour the use of slow sand filters which would be an inexpensive method of treating surface water.

The exploratory research of SEVILLA (1971) indicated that a series filtration system using local materials could produce a sparkling clear water from a highly turbid surface water source without the prior need for coagulation and sedimentation. An attractive pallatable water supply could be produced using a series of roughing filter followed by a polishing filter. Roughing filter media of pea gravel and coconut husk fiber (shredded husk) proved to be effective in removing suspended solids and in reducing colloidal turbidities. Of the two media, coconut husk fiber approved more attractive because removal efficiencies were higher and clogging of the medium was accompanied by a reasonable head loss which could be used as an operational parameter for knowing when to change the filter medium. A breakthrough of poorer quality effluent did not occur when the medium became clogged. Clogging was accompanied by a rapid build up in head loss. Flow rates in the range of 2.5 m^3/m^2 /hr appeared optimal.

A polishing filter medium of either sand or burnt rice husks proved successful in meeting WHO drinking water standards for turbidity. Efficiency in terms of microorganism removal was not tested. Both media removed turbidity at the surface but penetrating was superficial. Flow rates of 0.25 m^3/m^2/hr appeared best as effluent quality was excellent and filter runs were longest.

SEVILLA (1971) recommended further studies to determine optimal rates and filter depths for the various filter media as well as to develop a practical configuration for the series filter system. Because the preliminary findings appeared attractive enough to warrent further study, this research was carried out to fulfil SEVILLA's recommendations.

Purpose of Research

The series filtration system of treating surface waters and wastewater using local materials for filter media was studied for the purposes of determining:

1. the optimum range of filter rates for the various media under a wide range of raw water quality conditions;

2. the design depths of the filter media for both roughing and polishing filters;

3. the duration of filter runs as a function of depth and filtration rates;

4. the efficiencies of the single media and dual media to remove microorganisms, colour and turbidity.

Scope of Research

Tests were carried out on four water sources;

1. municipal tap water with added Kaolin clay to produce a water with a low level of turbidity (15-40 JTU)[1];

2. municipal tap water with added Kaolin clay to produce a water of high turbidity levels (180-350 JTU);

3. Chao Phya River water;

4. high rate oxidation pond effluent from the flotation unit following algae separation[2];

Laboratory tests to determine the removal efficiencies of the media to remove turbidity, coliform organisms, COD, NH_3-nitrogen, organic-nitrogen, colour, odor and taste were conducted in various test series. Each series of runs was carried out at various filtration rates, various depths of media and different contaminants loadings in order to determine optimum design parameters for the media. A series of tests were also run using the two media in one dual media filter unit.

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[1] JTU stands for Jackson Candle Turbidity Unit

1 JTU = 1 ppm or mg/l of SiO_2

[2] See TUNTOOLAVEST, M. (1971), Reclamation of Potable Water From High Rate Oxidation Pond Effluent, Master's Thesis, Asian Institute of Technology, Bangkok.

Water source (1) of a low turbidity level plus added coliform organisms (E. Coli Culture) was tested on burnt rice husk and sand media at filtration rates 0.25 and 0.10 $m^3/m^2/hr$. Three levels of burnt rice husk depth were selected for testing the effect of depth on turbidity removal and coliform removal efficiency: 80, 40 and 20 cm. Turbidity removal of sand and burnt rice husk at 2.5 and 1.25 $m^3/m^2/hr$ were conducted too. Results on turbidity and coliform removals were compared between the different depths of burnt rice husk media and the control medium sand using a filter depth of 80 cm. The optimum filtration rate and design parameter for this media were determined.

Run series II on coconut husk fiber using water source (2) at influent turbidity 180-350 JTU was performed at three depths of media - 120, 100 and 80 cm. Filtration rates for these tests were 2.5 and 1.25 $m^3/m^2/hr$. Duration of runs, total turbidity removed were compared through the various depths of media.

Run series III using a dual media filter of coconut husk fiber and burnt rice husks were conducted using Chao Phya River water. A dual media filter of pea gravel combined with burnt rice husks were run as an alternative filter combination. Physical, chemical and bacteriological tests were analyzed to determine efficiency and the optimum filtration rate for the dual media filters.

Run series IV on combined media in a single filter-coconut husk fiber with burnt rice husks were performed on high rate oxidation pond flotation unit effluent of two levels of filtration rates, 1.25, 0.25 $m^3/m^2/hr$. These results were compared with those from single media, coconut husk fiber at 1.25 $m^3/m^2/hr$ and burnt rice husks at 0.25 $m^3/m^2/hr$.

The filter performances of the various media at different depths and different kinds of water in series or in a dual filter was evaluated to give the design parameters for the system. Emphasis was placed on obtaining operational guidelines for using the media in usual in rural community water supply.

II LITERATURE REVIEW

Slow Sand Filtration - Its Advantages and Biological Processes

HUISMAN (1970) made a report including practical guidance on the construction and operation of slow sand filters, modern improvements in design and operating techniques and a considerable part on biological activity. Biological filtration, under suitable circumstances, may be not only the cheapest but also the most efficient method of water treatment, simple to construct and operate. The purification of water which takes place during its passage through a biological filter is an extremely complex process: straining, sedimentation, adsorption, oxidation and bacterial action. The physical, chemical and biological oxidation of the water are all improved by means of the single process.

Slow sand filters are able to cope with raw water turbidities of 100-200 mg/l for a few days, the turbidity should not rise above 50 mg/l for a longer period. The best results can be obtained when the average turbidity is less as 10 mg/l while excellent results can be obtained when the turbidity drops below 2 mg/l (measured as SiO_a). Pretreatment such as rapid filtration or roughing filters will be required for high influent turbidity. When working ideally, these filters have been shown to reduce total bacterial counts by 99.9 to 99.99% and E. Coli by 99 to 99.9%. Laboratory tests on slow sand filtration have also shown that viruses are removed more efficient in lower flow rate than higher flow rate.

Slow sand filtration rate varies from less than 0.1 to about 0.4 $m^3/m^2/hr$ and is so small that only after an extended period of service, a few weeks to a few months, cleaning is necessary. The filter bed composed of fine grains, effective diameter between 0.15 and 0.35 mm, suspended and colloidal material from the raw water are kept in the top of the filter bed. Cleaning of a slow sand filter is performed by scraping off the upper one to a few centimeters. Two important parameters appeared to be considered, the filtration rate and the length of filter run.

The advantages by slow sand filter especially in tropical countries are as follows:

Cost of Construction The actual cost of construction of slow sand filter is less than that of rapid filter because of hand labour required, an inexpensive land. In developing countries, where foreign exchange is of special importance, the use local available material favours slow sand filters.

Ease of Construction Because the dimensions of slow sand filter and grading the composition of sand for this filter are much less critical than other types. A greater use of local materials and the minimum skilled supervision are required and design is simpler with no special pipe work, equipment or instrument required.

Cost of Operation Cost of operation consists mainly in labour required to clean the filter beds where in rural areas labour is available and inexpensive. No imported chemicals, fuel, equipment, or materials are needed in the operation of slow sand filter.

Ease of Operation Less training and skilled and close supervision are required than those in charge of rapid-gravity filter.

Conservation of Water A small amount of wash water is required; thus in case where the quantity of water is limited, slow sand filtration has a further advantage over rapid gravity system which requires a large amount of wash water.

For rural water supplies in developing countries, slow sand filtration offers the enormous advantage of being safe and stable, simple and reliable. Slow sand filters require a minimum of operational and maintenance skill. They can be built of local materials, less requirements and they are suitable in the place that land and labour are in ample supply. The reliability can be maintained with simple means, with local skills and labour, while the complicated mechanical, electrical and electronical equipments of modern rapid filter ask for specialists, which in developing countries are commonly not available and otherwise must be paid very high wages.

Slow sand filters are efficient in retaining bacteria and suspended matter, they remove organic substances by the help of bacteria to oxidise these and they are also able to remove the last traces of impurities, reducing color, taste and odour producing compounds and delivering a water low in bio-degradable organic matter.

In the symposium on trends in the treatment of water for public supply, HOUGHTON (1970) reported the biological merits of slow sand filtration and primary treatment under use to remove some of the impurities before loading in the secondary slow sand filter. The decline in the popularity of slow sand filtration was due to costly structures and sizeable areas of land occupied. The biological process therefore affected by climatic conditions is unpredictable and with using eutrophic waters, sudden blockage of algae make the output of a given work difficult to forecast. Degree of experience and some local knowledge are required for the design of this filter. For highly turbid or coloured waters, coagulation methods are essential while, at the other extreme, simple micro-straining may be sufficient. For eutrophic waters, pre-filtration has long been regarded as desirable, conventional rapid filters are widely used for the purpose to get the water to the best condition for secondary filtration.

A great merit of slow sand filtration is when a number of beds are operated in parallel, they are often all at different stages of head-loss and should there be any abnormality in one filter the chances are that others will not be affected. By dilution, the blend remains acceptable, meanwhile the offending bed can be detected and isolated or slowed down. If primary filters are inuse, the secondary beds can be run up to 0.25 m^3/m^2/hr or higher velocities.

Sludge disposal problems are far less severe with slow sand methods than in the case of coagulation plants. The removal of faecal coli by the secondary filter in the Essex, England plant was about 90% in 1968 but that occasion appreciable counts of the organism, were present before the final chlorination. A limit to the bacterial load a bed is doubtless dependent on the head loss conditions and temperature. Small viruses might be accepted to be removed through low filtration velocities and slow sand schmutzdecke. The relative importance of adsorption and biochemical oxidation when a slow sand filter removes dissolved organic matter does not appear to have been firmly established. All the solid materials are removed in the top inch, clean sand being replaced or trenched back after several runs have elapsed. The open slow sand filter that is subjected to seasonal infestiation of algal growths is able to cause taste and odour difficulties and there is no doubt that such trouble do occur but it is equally true for capability of slow sand filter to remove some taste and odour from the incoming water. Slow sand beds constitute a particularly good physical barrier against algal penetration. Compared with plants using coagulation, the capital cost of double sand filtration works is greater but their operating costs are much lower: the magnitude of the overall financial margin is uncertain and more rigid cost-benefit analysis is required.

Alternative Media for Slow-Sand Filters

AWWA (1965) stated that the finer sand may be shallower than coarse sand but the former produces greater head loss and clog quickly than the latter. The depth of sand can cause flow resistance and additional cost. It is therefore recommended that the size of the sand and depth should not be finer and larger than that necessary to provide a good efficiency and low head loss.

BAILEY (1939) performed a study of using anthracite coal in a slow sand filter as a filter media at the Eastman Kodac Company's water purification plant. An experiment with "Anthrafilt" was performed by replacing the top four (4) inches of sand with washed Anthrafilt, an effective size 0.40-0.45 mm, and a uniformity co-efficient of 1.4. Each grain of Anthrafilt was approximately twice the size of each grain of sand of the same weight, in reality, that is a roughing filter on top of the regular sand filter. He has shown that Anthrafilt was strong enough to withstand the rough cleaning action without breaking down and it was found that there was considerable mixing of the sand and Anthrafilt to a maximum depth of eleven (11) inches. There was no loss of large particles of Anthrafilt in wash water except very fine particles drown of during the first few washings. An equivalent output was obtained for washing the Anthrafilt unit one-third as often as a regular unit and the rate of this unit had no effect upon the turbidity of the efficient.

The series of tests were performed on a sample of 10 ppm influent turbidity for comparision of effluent from the Anthrafilt unit and sand filters. The effectiveness on removal of turbidity and change of chemical content of the effluent was shown in Tables 1 & 2. The effluent of the Anthrafilt filter was softer than the effluent from the sand filter but the latter was more effective in case of removal of organic matter and also showed more effectiveness in reducing colour. However, both showed an increase in the degree of removal of organic matter as their time in service increased. The broader aspect the problem is one of increasing the capacity of a slow sand filter without building new filters making changes other than in the filter medium.

Factors Affecting Filtration Rates

HUDSON (1957) studied the various factors affecting filtration rates, factors to be considered were the quality of raw water, pretreatment facilities, sand size, bed depth, head conditions and hydraulic conditions in the filter piping. The design of filters has

Table 1 - Comparison between the Effluent of the Anthrafilt and the Sand Filter (figures represent ppm, unless otherwise noted)

	Raw Water	Sand Filter	Anthrafilt Filter
Color	12	3	5
Turbidity	10	trace	trace
Odor - cold	1 veg	1 veg	1 veg
- hot	1	1	1
Iron	0.5	0.1	0.1
Ammonia-nitrogen: Free	0.038	0.002	0.004
:Albuminoid	0.246	0.148	0.006
Nitrites	0.009	0.004	0.003
Nitrates	0.16	0.3	0.3
Oxygen consumed	2.9	2.4	2.2
Chlorides	13.8	14.0	13.4
Hardness (total)	124.0	126.0	114.0
Alkalinity	95	95	95
pH	7.9	7.8	7.9
Bacterial per ml 24 hrs at 37°C	600	2	2

Table 2 - Comparison between the Effluent of the Anthrafilt Filter and the Sand Filter, Results Obtained on the Day of Highest Turbidity

	Raw Water	Sand Filter	Anthrafilt Filter
Color	10	2	5
Turbidity	80	7	trace
Odor - cold	1 Aromatic	2 Aromatic	1 veg
- hot	1 Aromatic	2 Aromatic	1 veg
Iron	1.16	0.2	0.003
Ammonia-nitrogen - Free	0.030	0.002	0.004
- Albuminoid	0.140	0.042	0.044
Nitrites	0.006	0.001	0.001
Nitrates	0.04	0.3	0.3
Oxygen consumed	3.3	2.3	2.4
Chlorides	13.4	14.2	11.0
Hardness (total)	120.0	114.0	112.0
Alkalinity	93.0	87.0	83.0
pH	7.7	7.7	7.7

(All figures represent ppm, unless otherwise noted)

SEVILLA (1971) used rice husks burnt and unburnt, shredded coconut husk and pea gravel for slow sand media. Results of his findings are reviewed elsewhere and are sufficiently encouraging to warrent further investigation.

been almost exclusively based on practical experience, which has demonstrated that satisfactory filter runs can be obtained with usual design and pretreatment during those times of the year when filtration occur in cold weather conditions in high concentrations of very tiny particles bed but this difficulty in condition is not important in Asia. The ability of the sand filter to remove turbidity is a function of the size of the passage through the sand. Thus, sand of 0.5 mm diameter is twice as good in removing turbidity as sand of 0.7 mm size, and sand of 0.35 mm size is twice as good as 0.5 mm sand. The finer sand will produce a better quality of filtered water but it also produces short filter runs. If the effective size of the filter sand is halved, the filter run will be shortened to one quarter of their former length. The size of the opening through filter beds is also governed by the porosity of the sand which in the filter beds about 43% compared with the porosities of angular materials-crushed coal porosity 55% do a less adequate job of removing suspended matter than material of lower porosity. Use of relatively thin layer of 4 to 6 in. of coarse crushed coal on top of the sand bed of 0.5 mm works out extremely well. The coal serves as a roughing pre-filter, relieving the sand of much of the load, and filter runs are greatly lengthened. This gives the advantage of low clogging rate of coarse material together with the high filtering ability of the finer material below it.

Bed thickness is equally important in the behaviour of filters, since the thicker the bed is the more complete the removal of material will be. Practically, 2 ft-beds do a good job but 3 ft-beds do better but they are expensive to build. However, depths as 6 ft are sometimes used in European, coarser material should be possible used, as a result of long filter run. The thickness of the filter beds has practically no affect on the length of filter run. The author operated a series of four filters, having thickness of 6, 12, 24 and 36 in. respectively. They all had the same size of sand and were operated at the same rate of filtration, the length of runs were practically indistinguishable but there was a real difference in the water quality produced. The higher the filtration rate is, the shorter the filter run and the worst quality will be during critical periods.

The total head loss to which the filter is operated is one of the most critical factors in determining the quality of the filtered water. When a filter is operated at a constant rate, as the bed clogs up, more empty space in the sand is accepted by solids strained out of the water. The water is forced to go up faster through the remaining space to maintain the same total flow. Velocity increases as the loss of head increases, solid materials in the applied water continue to penetrate deeper and deeper into the bed. Another factor that severely upsets the operation of filter is unsteady flow. Filters that are directly connected to pump which may produce variance in flow through the bed cannot be expected to produce good filter.

In Asia, coal is not available to be used as coarse material on the top of the sand bed and also sand quality here is not within the standard. Pea gravel will be used as filter media for roughing filter instead of coal. Bed thickness varying from 2 to 3 ft will be recommended for filter media. Most severe and limited conditions must be based on, for the choice of plant design and plant operation.

Laboratory Experiments on Filtration

Most of the experiments, at Chicago Experimental Filtration Plant, were performed on 2-in. glass tube filters, results from glass tube units were comparable to those from large filters. Monthly average of filter runs and effluent turbidities from three experimental units having 10 $ft^2$of filter and from three glass tube filters about 2 in. in diameter were found the same. In comparing filter runs on settled water, it was found that those from glass tube filters were about 30 percent shorter than plant filter runs, but the results on unsettled water were almost identical. HUDSON (1938) thought that the differences between plant and glass tube filter run might be explained due to the plant filters were not kept in the best condition during the experiement while the glass tube filters were kept quite clean. In the plant filters there was observed some pulling away from the side walls which did not occur in the case of glass tube units. The results were collected during periods of reasonably good coagulation, indicated that the quality of filtered water from glass tube filters was comparable to that from larger filters. Glass tube filters appeared to produce slightly better water than the larger units, probably because case was taken to keep them in excellent condition.

SEVILLA (1971) studied water filtration using local materials, pea gravel, coconut husk fiber, burnt rice husk, raw rice husk and sand as filter media. In preliminary test runs two levels of filtration rate were studied: semi-rapid rates of 2.5 and 1.25 $m^3/m^2/hr$. Two levels of turbidity were investigated 300 JTU and lower and 1000 JTU and higher. Secondary filter runs were designed for the purpose of determination of the performance of media at low turbidity loading level used was 50 JTU average and filtration rate was held at 0.25 m^3/m^2/hr. All influent water used in these two test runs were synthetic water. River water taken from Chao Phya River was used as influent filter in another series of tests and filter performance was compared to that using synthetic water. This test run was carried out for both slow sand and semi-rapid rate.

Results of the preliminary test runs, the maximum filtration rates for different media to achieve an effluent turbidity of 5 JTU or lower at the highest turbidity loadings of about 1000 JTU were as follows:

Pea gravel : less than 2.5 m^3/m^2/hr
Coconut husk fiber : 1.25 m^3/m^2/hr
Burnt rice husk : 1.25 "
Raw rice husk : less than 1.25 m^3/m^2/hr

All the runs except burnt rice husk, breakthrough occurrence was highly dependent on the filtration rates, porosity of media more than the influent turbidity. Burnt rice husk removed turbidity so efficiently at any level with a defined head loss that a secondary filter might not be needed if it was found reliable in terms of chemical and biological effects. Because of the difficulty in cleaning filter media, burnt rice husk, raw rice husk, and coconut husk fiber, after using, it was more practical to discard them at the end of filter run.

In this study, it is apparent that all the media investigated have two limitations: (1) good effluent quality but relatively short filter runs; and (2) relatively long filter runs with lower efficient quality. The comparison of removal efficiency of the different media in order of preference with number 1 denoting first choice are shown in Table 3. Table 4 summarized the length of runs and the average effluent turbidity and Table 5 compared the performance of the media based on several selection criteria.

Burnt rice husk at filtration rate 1.25 $m^3/m^2/hr$ appeared to be more attractive than rate at 2.5 $m^3/m^2/hr$ for any level of influent turbidities in terms of head loss and length of run. Burnt rice husk was the most efficient compared with sand of 0.34 mm size and uniformity coefficient of 1.35. Longer filter run of burnt rice husk was obtained by almost 30% than the filter run of sand.

Although raw rice husk gave efficient with high efficiency turbidity removal, the difficulties occurred in cleaning, colour during the initial period of operation and no significant head loss for turbidity breakthrough which would be difficult to detect whether removal capacity has deteriorated or not. Filtration rate of about 1.25 $m^3/m^2/hr$ and influent turbidity level of about 100 JTU appeared to be the designed parameters of this type of media.

Coconut husk fiber gave the longest filter run with comparable effluent quality at any level of influent turbidity and at slow rate and low turbidity loading this media still performed efficient in turbidity removal after 18 days with no corresponding head loss. Pea gravel and coconut husk fiber can be substituted as media for slow

Table 3 - Comparison of Removal Efficiency

Media	1.25 $m^3/m^2/hr$ @ 1000 JTU	2.5 $m^3/m^2/hr$ @ 100 JTU	2.5 $m^3/m^2/hr$ @ 1000 JTU
Pea gravel	-	3	3
Burnt rice husk	1	1	-
Raw rice husk	3	2	2
Coconut husk fiber	2	-	1

Table 4 - Comparison of Effluent Turbidity (JTU) & Length of Runs (HRS)

Media	1.25 $m^3/m^2/hr$ @ 1000 JTU		2.5 $m^3/m^2/hr$ @ 100 JTU		2.5 $m^3/m^2/hr$ @ 1000 JTU	
	Time	Effluent	Time	Effluent	Time	Effluent
Pea gravel	-	-	70	54	14	540
Burnt rice husk	40	.06-0.4	16	.01	-	-
Coconut husk fiber	117	0.7-18.0	-	-	49	2.5-25
Raw rice husk	74	8.0-60.0	88	20-45	16	25-65

Effluent values were after break-in and before occurrence of breakthrough.

Table 5 - Comparison of Results based on Selective Criteria

Media	Effluent turbidity 10 JTU	Length of run	Breakthrough occurrence	Head loss of 1.2 m.
Pea gravel	No @ 2.5$m^3/m^2/hr$	3	Yes	No
Burnt rice husk	Yes	4	No	Yes
Coconut husk fiber	Yes @ 1.25	1	Yes	Yes
Raw rice husk	No @ 2.5	2	Yes	No

filters due to relative good effluent quality and long term operation with no appreciable head loss.

The most effective media to remove turbidity was burnt rice husk, followed by sand, coconut husk fiber and pea gravel. No media seemed to be superior than the other if they were considered not only removal efficiency but also length of run.

Although burnt rice husk shows the best efficiency in turbidity removal. colour and length of run, bacteriological and chemical effects need to be investigated.

Design of Experimental Filters

GHOSH (1958) investigated the effects of the physical characteristics of the media when applied to filtration of turbid water, with particularly reference to loss of head and removal of turbidity at different depths under different condition of flow, using media of different size and without the case of chemical coagulants. The experimental filter consists of a ¼ in. thick perspex tubing, 3½ in. internal diameter, 5 ft long. The under drainage system was circular ½ in. thick porous plate. The depth of filter media used was 30 in., and there was a constant head of 27 in. of water over top surface of the filter bed. A manometer was connected to measure head loss from a point of few inches above the top surface of the media and then from different depths of bed.

ROBECK and WOODWARD (1959) studied conventional municipal needs by using plant 16 gpm capacity consisting of 2 ft and 10 ft filter columns. CONLEY and PITMAN (1960) used small filters for evaluation at Hanford, these smallest filters were 3/4 in. in diameter and 2 ft long. They were used to obtain rough approximations of the effects of changing water treatment variables. A glass tube filter 2.5 in. in diameter and 6 ft long was used to treat water in the fall size filter plants. A small 5 gpm complete filter plant used 6 in. in diameter and gave every reliable data.

CLEASBY and BAUMANN (1962) used pilot sand filters of 6 in. internal diameter plexiglass tubes ½ in. thick and 53 in. long in selection of sand filtration rates at the IOWA State University Sanitary Engineering Laboratory. Piezometer and sampling connections were ¼ in. inside diameter plexiglass tube. The piezometer boards were 10 ft long and equipped with nine 4 mm inside diameter glass tubes. IVES and DIAPER (1965) in studying filtration through size-graded media used pilot plant filter of 5½ in. internal diameter, 6 ft high perspex columns for flow rate of 2 to 4 gpm per ft^2.

Summary of Literature Review

Slow sand filtration was used for water treatment in rural areas in developing countries. Size of sand and bed depth had the effect on quality of treated water. Work by SEVILLA (1971) shows that the series filtration using local materials, burnt rice husks, raw rice husks, coconut husk fiber and pea gravel, appears as an alternative water treatment method warranting further research.

III EXPERIMENTAL INVESTIGATION

Design of Continuous Operation Filters

All four series of test runs were performed at the Environmental Engineering Laboratory of the Asian Institute of Technology from October 1971 to April 1972. Tests were originally performed using equipment and laboratory filters developed by SEVILLA (1971). Later work required on additional four filters to be fabricated, bringing the total of laboratory size filters to eight. Four filters of the same area and dimensions were compacted and were made of 0.6350 cm (¼ in.) thick perspex sheets. The four filters were connected to each other but functioned as individual filters. The details and dimensions of the experimental filters are illustrated in Fig. 1. Fig. 2 shows the experimental filter set-up. Influent water in all filters were fed in a single overhead tank with 2 outlets going to each of second over head tank. Influent from the each of second over head tank was going to four compacted filters.

A 1 - cu.m. tank was used for mixing synthetic water and also for storage river water and high rate oxidation pond effluent from flotation unit. Influent water was pumped from the storage tank to the over head tank by pilot plant size centrifugal pump. A manometer board, about 3 meters high, 45 glass tubes attached, 0.635 cm (¼ in.) diameter to measure head losses as shown in the left side board of Fig. 2.

Design of Experiments

Experimental studies on synthetic water, Chao Phya River water and

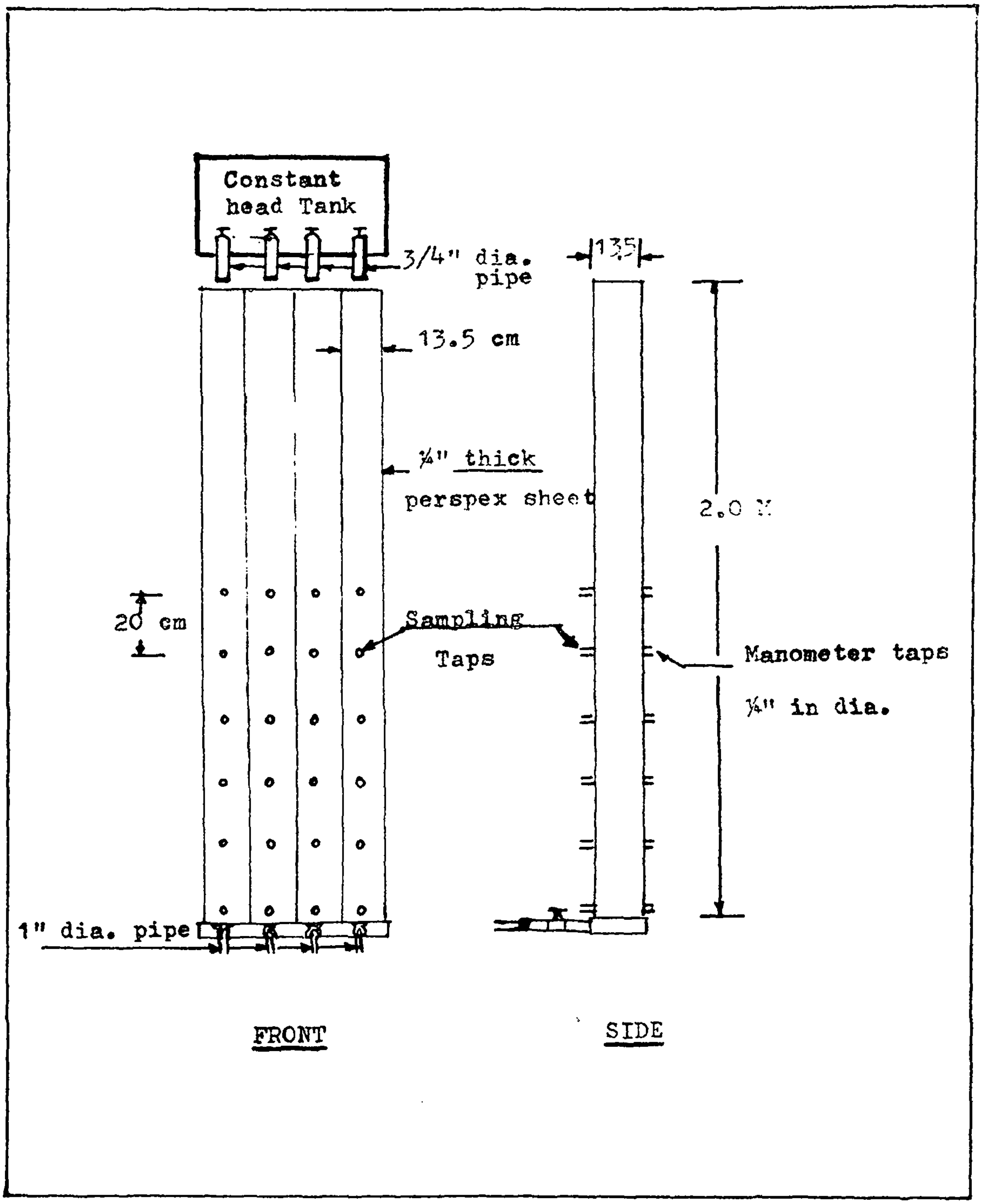


Fig.-1 Detail of Experimental Filter Unit

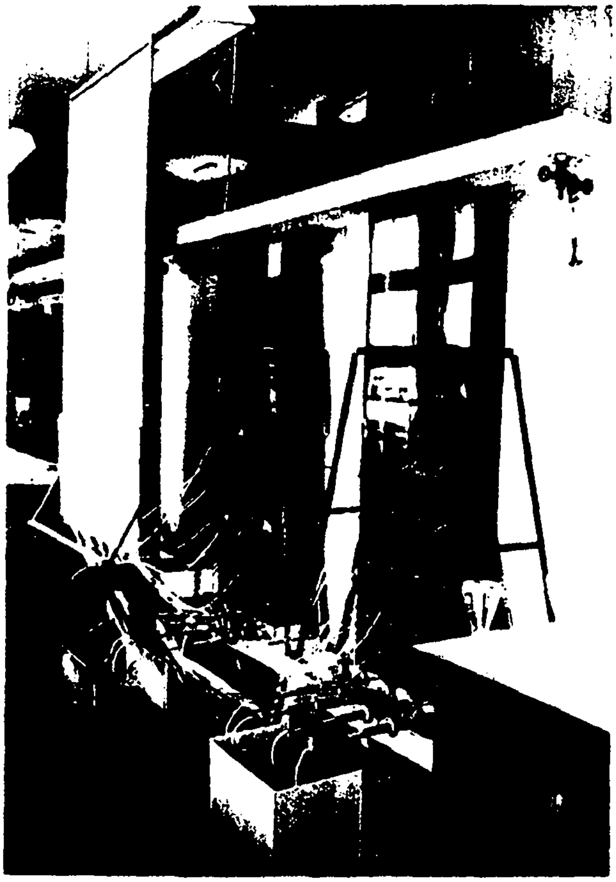


Fig.-2 Experimental Filter Set-up

waste water from high rate oxidation pond effluent from flotation unit were carried out. The first series of test runs were conducted to determine the effect of burnt rice husk depth compared with sand. Table 6 shows the sechedule of the test runs in run series I. Municipal tap water with added coliform organisms and kaolin clay was used as influent water. The second series of runs using high load turbidity water were performed at the depths of coconut husk fiber medium. Table 7 gives the list of 6 runs at filtration rate 2.5 and 1.25 $m^3/m^2/hr$ at three depths of media - 120, 100, and 80 cm. Run series III was conducted to use the dual media filter for determining physical, chemical and bacteriological removals compared with the use of single medium alone. The influent water was Chao Phya River water. The analysis of river water is given in Table 9 Lastly, dual media of coconut husk fiber and burnt rice husk were used to treat the high rate oxidation pond effluent from flotation unit and the removal efficiencies of turbidity, coliforms, COD, NH_3-nitrogen, organic-nitrogen and colour were compared with the results from conventional processes used by TUNTOOLAVEST, M. (1971). Details of test runs were scheduled in Table 10.

The independent variables in this study include:

1. loading or filtration rate;
2. type of media; and
3. influent turbidity and water source.

The dependent variables include:

1. head loss;
2. removal efficiencies of turbidity, coliform, COD, NH_3-nitrogen, organic-nitrogen, and colour; and

Table 6 - Schedule of Test Runs in Run Series I

Run No.	Media	Depth (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Remarks
1	Sand	80	0.25	15-40	Effective
2	Sand	80	0.10	15-40	size = 0.30 mm
3	BRH	80	0.25	15-40	Uniformity
4	BRH	80	0.10	15-40	Coefficient =2.66
5	BRH	40	0.25	15-40	Run No. 1-8:
6	BRH	40	0.10	15-40	Coliform organisms
7	BRH	20	0.25	15-40	added
8	BRH	20	0.10	15-40	
9	Sand	80	2.5	15-30	Effective
10	Sand	80	1.25	15-30	size = 0.30 mm
11	BRH	80	2.5	15-30	Uniformity
12	BRH	80	1.25	15-30	Coefficient =2.66
					BRH : Sizes not analyzed

Water source: Municipal tap water with kaolin clay

The following stands for the symbols presented:

BRH = Burnt Rice Husk

CHF = Coconut Husk Fiber

PG = Pea Gravel

Table 7 - Schedule of Test Runs in Run Series II

Run No.	Media	Depth (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Remarks
1	CHF	120	2.5	180-350	CHF: Only fibers
2	CHF	100	2.5	180-350	were used
3	CHF	80	2.5	180-350	BRH: Sizes not analyzed
4	CHF	120	1.25	180-350	Water Source:
5	CHF	100	1.25	180-350	Municipal tap water
6	CHF	80	1.25	180-350	with added Kaolin clay
7	CHF+ BRH	60+ 20	1.25	180-350	
8	CHF+ BRH	60+ 20	0.25	180-350	

Table 8 - Schedule of Test Runs in Run Series III

Run No.	Media	Depth (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Remarks
1	CHF+ BRH	80 20	2.5	180-400	
2	CHF+ BRH	80 20	1.25	180-400	
3	CHF+ BRH	80 20	0.25	180-400	
4	PG+ BRH	80 20	1.25	180-400	

Table 9 - Chao Phya River Water Analysis April 1st, 1972

Constituents	Value
pH @ 25^oC	8.3
Colour	40-60 Hazen Units
Turbidity	250 JTU Average
Organic-nitrogen	0.80 mg/1
COD	23.1 mg/1
Coliform organism	750,000-1,100,000 MPN/100 ml

Table 10 - Schedule of Test Runs in Run Series IV

Run No.	Media	Depth (cm)	Filtration Rate $(m^3/m^2/hr)$	Influent Turbidity Range (JTU)	Remarks
1	CHF	100	1.25	20-60	High rate oxidation
2	BRH	20	0.25	20-60	pond effluent
3	CHF$_+$	80	1.25	20-60	from algae
	BRH	20			flotation unit
4	CHF$_+$	80	0.25	20-60	
	BRH	20			

3. duration of runs before head loss build up to 1.2 meters.

Materials and Equipment Utilized

Four kinds of media used for this investigation were sand, pea gravel, coconut husk fiber and burnt rice husks. Burnt rice husk size was the same as taken from a local rice mill. The burnt rice husk was obtained free of charge except for transportation costs to and from the mill. Coconut husk fiber was obtained from a local mill where the coconut husk was shredded to fibrous material to be used on furniture stuffing. Coconut husk fiber was required to be soaked in water overnight before filling into the filter columns so that it was filled easily and its colour was removed. Costs at the mill for the husk were 0.50 Bahts per Kg. and for the shredded husk 3 Bahts per Kg. The size of pea gravel was selected by using sieve analysis to get effective size of ¼"-3/8". Sand used in these filter runs were prepared by selecting sand size corresponding to grain size distribution. Effective size of 0.30 mm and uniformity coefficient of 2.66 were calculated from the percentage of size distribution and sand was selected from available stock sand obtained from local construction supply stores.

Influent turbidity and effluent turbidity were measured by a Hach Turbidimeter. Head loss throughout the bed will be measured by air-manometer tubes to a manometer board. Filter column description was stated in the previous section. Oridinary valves were used to control water flow measured by a volumetric cylinder and a stop watch. A small plant size pump of maximum head loss 6 m. was used to pump water from the storage tank to a constant head tank. Kaolin clay was added to municipal tap water to get the desired level of turbidity.

Procedure and Analytical Methods

Turbidity of raw and effluent water at all levels was measured in Jackson Turbidity Units using the Hach Turbidimeter. Procedure for the analysis of COD, NH_3-nitrogen, organic-nitrogen were as described in Standard Methods for the Examination of Water and Wastewater. Color of influent and effluent was measured by B.D.H. Lovibond Colorimeter. Coliform organisms were determined by the presumptive test. Head loss was measured through the manometers attached at the filter columns. Turbidity, coliform organism and head loss were analyzed every 6 hours until head loss build up to 1-2 meters. COD, NH_3-nitrogen and organic-nitrogen and colour of effluent and influent water were analyzed once a day.

IV PRESENTATION AND DISCUSSION OF RESULTS

The results of the laboratory tests for the filter media are reported in reverse order of the recommended filter design, that is, coconut husk fiber as the roughing (primary) filter and burnt rice husks as the polishing (secondary) filter. This was done because the series of runs were started with the secondary filter in an effort to load the filter to its highest filtration and loading rates while still meeting the constraint of WHO drinking water standards. Once these tests were performed the results were used to determine the effluent constraints from the primary filters and to design the filtration rates for the primary filters.

Run Series I: Experimental Study of the Performance of Media at Low Load Turbidity.

Media for these run series I were sand and burnt rice husks. The influent water was municipal tap water of low turbidity with added coliform organisms in this influent for bacteriological studies. Influent turbidity was 15-40 JTU and influent coliform organisms (E. Coli Culture) were 430,000-640,000 MPN per 100 ml.

Sand

For sand, only depth of 80 cm was considered but four (4) levels of filtration rates - 2.5, 1.25 and 0.25 $m^3/m^2/hr$ were performed. Effective size of sand was 0.30 mm and uniformity coefficient was 2.66. Influent turbidity was 15-40 JTU and influent coliform organisms (E. Coli Culture) were 430,000-640,000 MPN/100ml. These coliform tests were performed for filtration rate 0.25 and 0.10 m^3/m^2/hr only. The filter performances of the media are shown in Fig. I-1 and I-5.

Fig. I-1 shows the filter performances at rates of 0.25 and o.10 m^3/m^2/hr. Turbidity removals for these two slow rates were nearly the same efficiency as well as for coliform removal. Average effluent turbidity at both rates was 0.90 JTU. Effluent turbidity was less than 2.0 JTU at the beginning of runs until the end of runs. The effluent turbidity was nearly uniform throughout the runs. Durations of runs for a head loss up to 1.2 m was nearly the same for both filter rates. At a rate of 0.10 m^3/m^2/hr the run was only 17 hours longer (less than a 10% increase for a filter rate two and one half times as slow). Removal efficiency of coliform organisms was low at the beginning because it took time to build up the biological layer, percent removal efficiency was up to 99% after the 100th hour of operation. After the biological layer had been built up, removal efficiency of coliform organisms was as high as 99.997-99.998% - only 10 MPN/100 ml was counted from the effluent at the end of runs. Coliform removal efficiency for sand is shown in Figs I-7, I-8, I-9 and I-10. Efficiency at 0.10 m^3/m^2/hr to remove coliform organisms looks better than that at 0.25 m^3/m^2/hr. The differences are very small however.

Fig. I-5 shows the filter performance of sand at 2.5 and 1.25 m^3/m^2/hr with influent turbidity between 15-30 JTU. Bacteriological tests were not conducted. The duration of run at 2.5 m^3/m^2/hr was only 33 hours and effluent turbidity was still less than the WHO Standard of 5 JTU - about 1.0 JTU. This filtration rate was not desirable even though the effluent turbidity was still low because of too rapid end of run.

For a rate of 1.25 m^3/m^2/hr, the duration of run was longer about three (3) times of the rate at 2.5 m^3/m^2/hr and effluent turbidity was less than 0.50 JTU after the 30 hours of operation.

Comparison of total turbidity removed versus different filtration rates of sand is shown in Fig. I-13. At a filtration rate of 1.25 m^3/m^2/hr total turbidity removed (Kg/m^2/run) was the maximum value. This was an unexpected finding as the accepted filter rate for slow-sand filters is about 0.1 m^3/m^2/hr. This rate was obviously chosen because of the much longer duration of run between required sand scrappings. The low rate does not appear best in terms of optimizing the ability of the filter to remove turbidity loads.

Burnt Rice Husk

The easy way to fill the burnt rice husk into the filter column was by filling the water first at depth higher than depth of media required and then pour burnt rice husk into the column and let it settle overnight, the fine screen was put on the top of this media. By this means, the media was well compacted. The biological layer developed on the burnt rice husk surface as shown by the white layer in Fig. 3.

Four filtration rates were considered for these tests - 2.5, 1.25, 0.25, 0.10 m^3/m^2/hr. At rate 2.5 and 1.25 m^3/m^2/hr, only 80 cm depth of media was used and only turbidity removal was determined. For both slow rates, 0.25 and 0.10 m^3/m^2/hr, the effects on depth of media and coliform removal efficiency were also conducted. Figs. I-2 to I-4

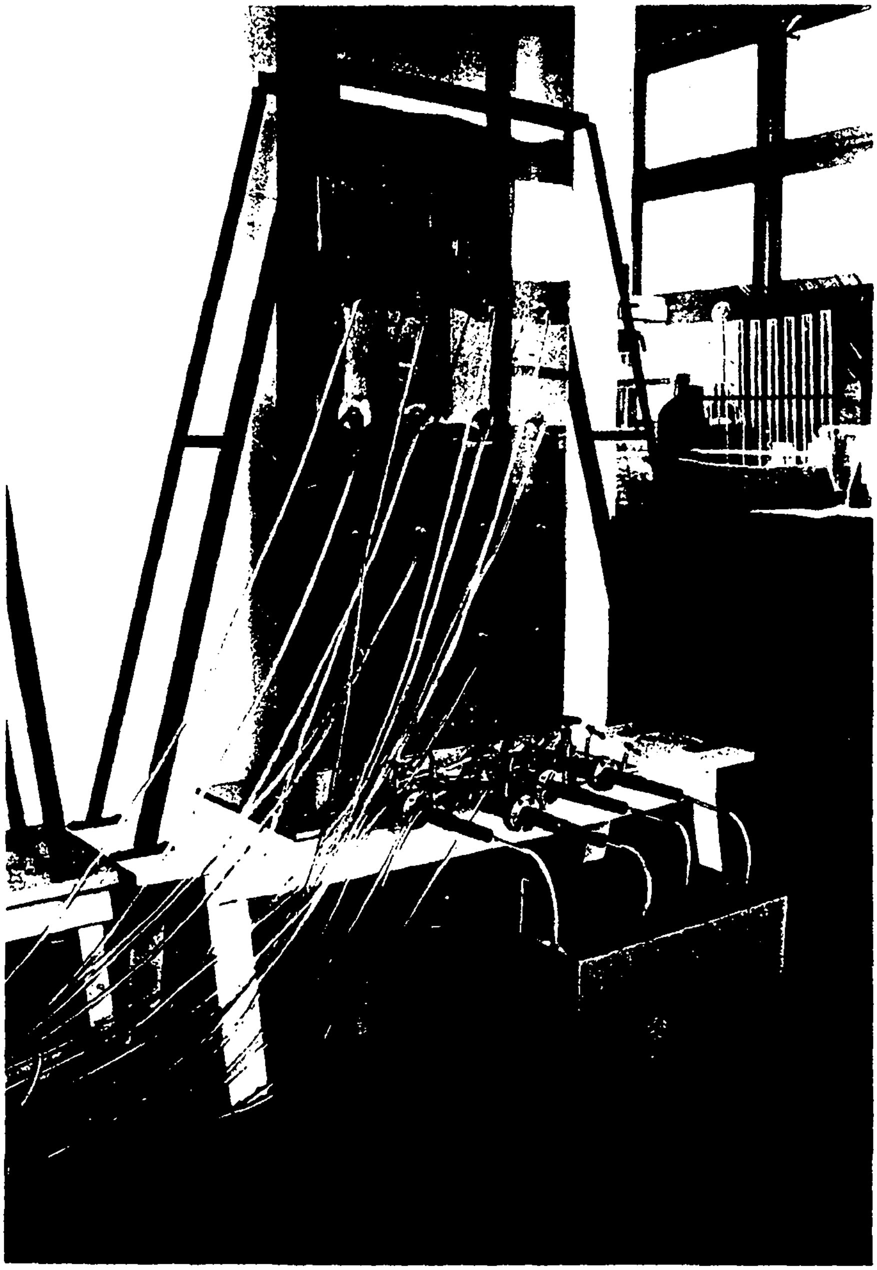


Fig.-3 Biological Layer on surface of Burnt Rice Husk and I-6 show the filter performance on turbidity removal and head loss at various depths. Effluent turbidity of run No. 3 (rate of 0.25 $m^3/m^2/hr$ and depth of 80 cm.) after 40 hours of operation showed a reasonably low range of 0.01-0.08 JTU until the end of run. At a rate of 0.10 $m^3/m^2/hr$ (Run No. 4), longer duration than 0.25 $m^3/m^2/hr$ was obtained but the average effluent turbidity was slightly higher averaging 0.09 JTU. The effluent turbidity was compared to influent water in Fig. 4.

Comparison of the effluent turbidity at 0.25 $m^3/m^2/hr$ at various depth 80, 40 and 20 cm is shown in Fig. I-11. Turbidity removal was different only at the beginning of runs but after 100th hour, all runs performed to the same effluent turbidity - turbidity less than 0.10 JTU. Effluent turbidity at rate 0.10 $m^3/m^2/hr$ as shown in Fig. I-12, was higher than that at 0.25 $m^3/m^2/hr$ but the duration of run was longer. However, the effluent turbidity was still less than 0.50 JTU.

Comparison of coliform removal at 0.10 $m^3/m^2/hr$ with rate at 0.25 $m^3/m^2/hr$ at corresponding different depths of media is shown in Figs I-8 and I-10. Coliform removal efficiency at 0.25 $m^3/m^2/hr$ was better than at 0.10 $m^3/m^2/hr$. At a depth of media of one-fourth (¼) of the original depth, there was little difference in coliform removal efficiency towards the later part of the runs. All depths reached above 99% removal. However, the smaller the depth the longer the period of time required to reach the high removal efficiency. At 80 cm depth 99% removal efficiency was reached in 24 hours of operation. At 40 cm depth the same removal was obtained in 78 hours, and at 20 cm depth in 146 hours.

Fig. I-6 shows the filter performance of burnt rice husks at 2.5

Fig.-4 Comparison of Effluent and Influent Water and 1.25 m^3/m^2/hr with influent turbidity 15-30 JTU. Bacteriological tests were not conducted. The duration of run at 2.5 m^3/m^2/hr was only 39 hours while the duration at 1.25 m^3/m^2/hr was nearly 4 times that of the higher rate. However, the average effluent turbidity of both rates was 0.20 JTU.

Comparison of total turbidity removed and amount of water filtered versus different filtration rate of burnt rice husk is shown in Fig. I-13. Maximum total turbidity removed and amount of water filtered occurred at a filtration rate of 1.25 m^3/m^2/hr.

Summary of results of sand and burnt rice husks at different filtration rates and media are presented in Table 11.

Summary on the Filter Performance of Sand and Burnt Rice Husks

Sand and burnt rice husk of 80 cm depth were compared from the point of view of total turbidity removed, Kg/m^2/run, and amount of water filtered, m^3/m^2/ of bed, versus filtration rate, m^3/m^2/hr, as shown in Fig. I-13. Burnt rice husk can remove turbidity more than sand and both media showed the maximum turbidity removed and amount of water filtered at filtration rate of 1.25 m^3/m^2/hr.

Comparison of duration of runs versus filtration rates, as shown in Fig. I-14, indicates that burnt rice husk will have a longer duration than sand at any of the filtration rates. For coliform removal efficiency, burnt rice husk could not remove coliform organisms up to 99.997% as sand did. but the removal efficiency reached above 99% in 24 hours of operation while sand reached only 89% in the same period of time.

Table 11 - Summary of Results in Run Series I

Run No.	Media	Depth of Media (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Average Influent Turbidity (JTU)	Effluent Turbidity Range (JTU)	Average Effluent Turbidity (JTU)	Turbidity Removal Efficiency Range (%)	Coliform Removal Efficiency Range (%)	Amount of water Filtered (m^3/m^2 of bed)	Duration of run for Head Loss1.2m (hour)	Rate of Head Loss (cm/hr)
1	Sand	80	0.25	15-40	25	1.5-0.34	0.90	90.0-98.1	89.3-99.998	43.7	175	0.68
3	BRH	80				0.85-0.01	0.05	99.4-99.98	99.65-99.98	52.4	210	0.57
5	BRH	40				0.88-0.01	0.10	98.7-99.98	93.02-99.96	48.7	195	0.61
7	BRH	20				0.95-0.01	0.22	94.7-99.98	65.21-99.79	47.5	190	0.63
2	Sand	80	0.10	15-40	25	1.5-0.20	0.94	92.66-99.88	89.30-99.997	19.2	192	0.63
4	BRH	80				0.85-0.02	0.09	98.95-99.95	98.50-99.95	25.0	250	0.48
6	BRH	40				0.95-0.01	0.33	96.65-99.96	90.70-99.53	21.1	211	0.57
8	BRH	20				0.95-0.03	0.33	94.72-99.09	74.40-99.09	20.8	208	0.58
9	Sand	80	2.5	15-30	20	1.8-0.50	1.0	Average(%) 95.0	-	82.5	33	3.64
10	Sand	80	1.25			1.6-0.30	0.75	96.25	-	120	96	1.25
11	BRH	80	2.5			1.4-0.02	0.15	99.25	-	97.5	39	3.08
12	BRH	80	1.25			1.1-0.01	0.08	99.60	-	181	145	0.83

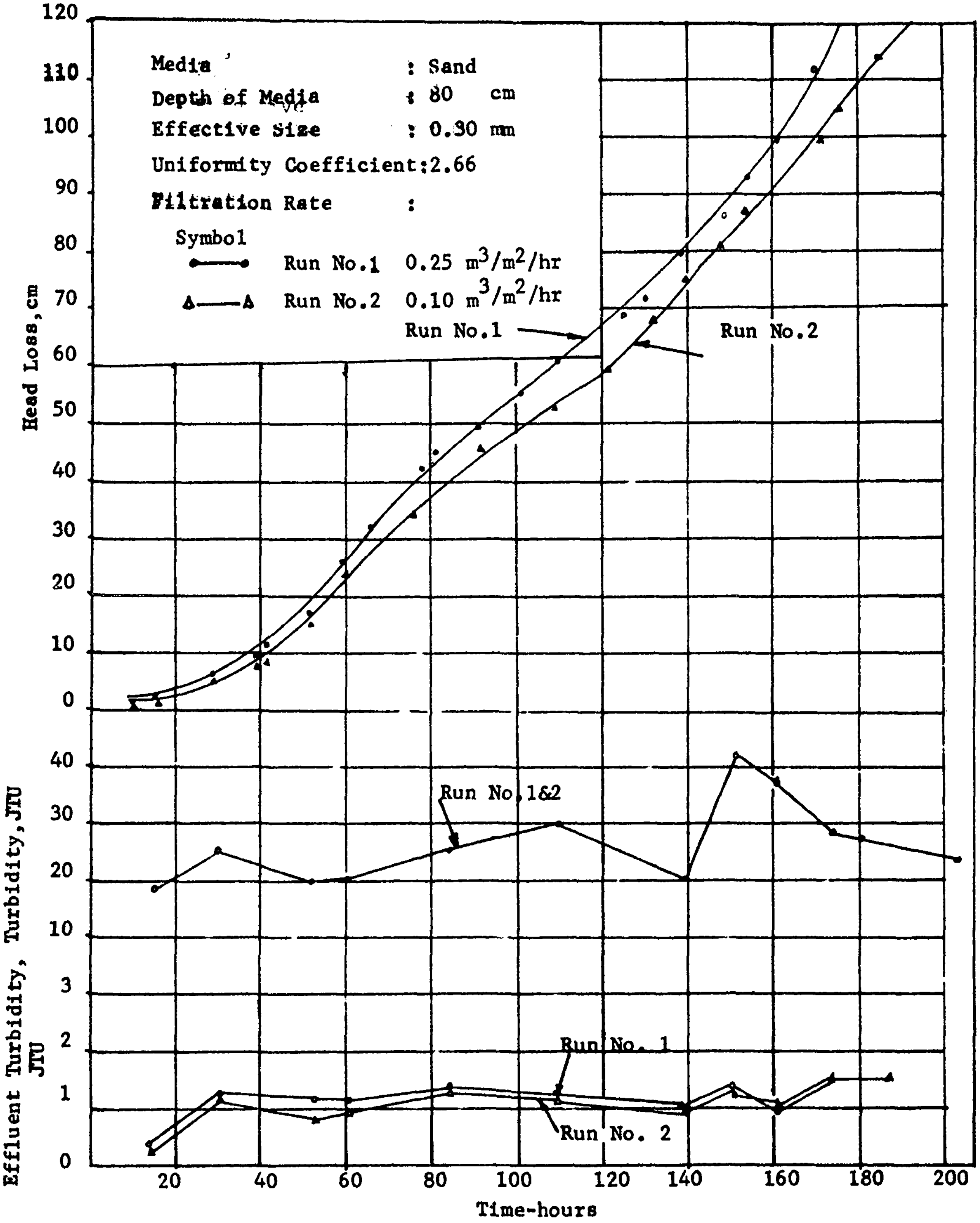


Fig.I-1- Comparison of Control Media (Sand) at Filtration Rate 0.25 and 0.10 $m^3/m^2/hr$

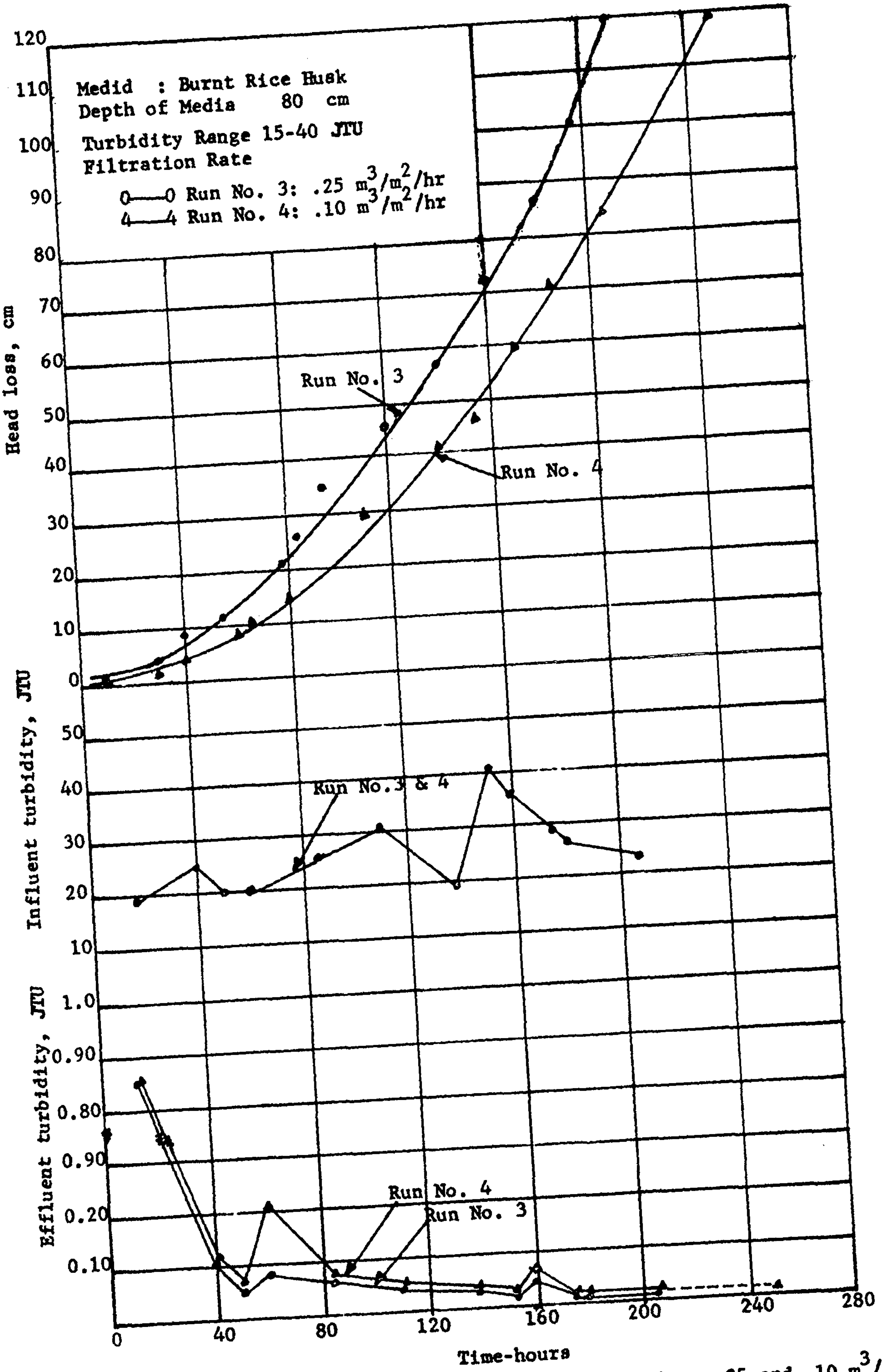


Fig.-I-2. Comparison of Burnt Rice Husk (BRH) at .25 and .10 $m^3/m^2/hr$

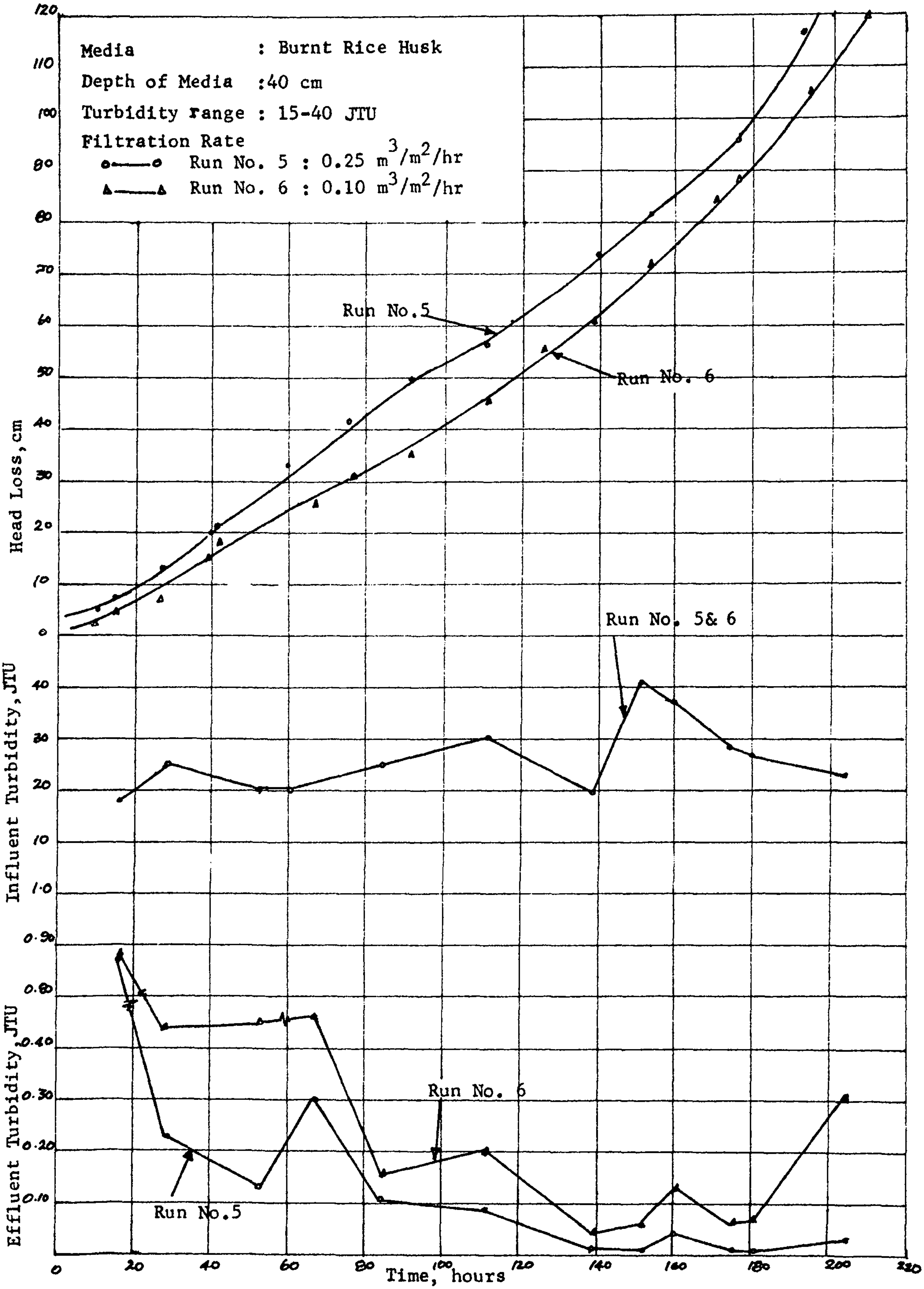


Fig. I-3-Comparison of Burnt rice Husk at 0.25 and 0.10 $m^3/m^2/hr$, depth of medium 40 cm

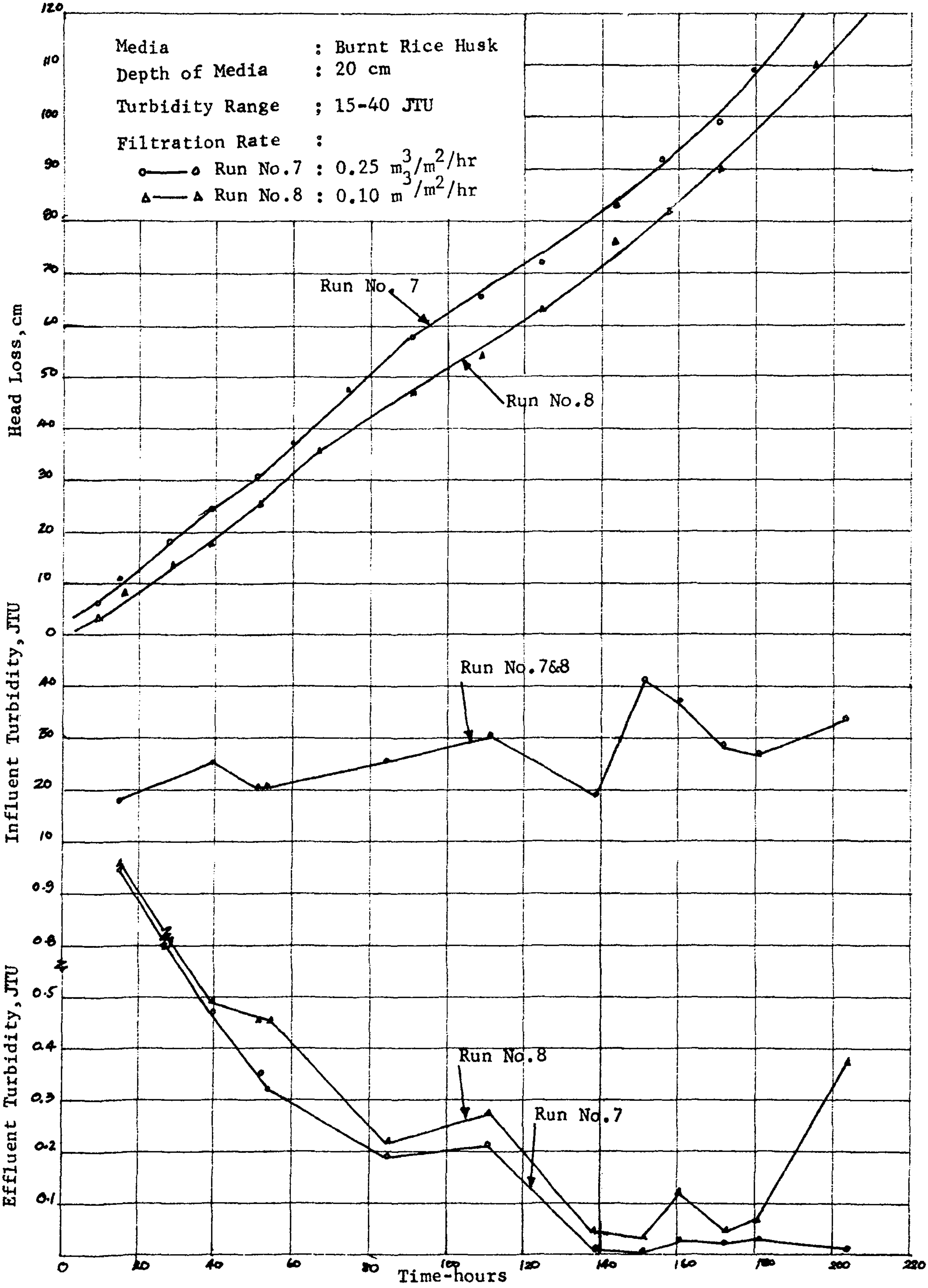


Fig.I-4- Comparison of Burnt Rice Husk at Filtration Rate 0.25 and 0.10 $m^3/m^2/hr$, depth of medium 20 cm

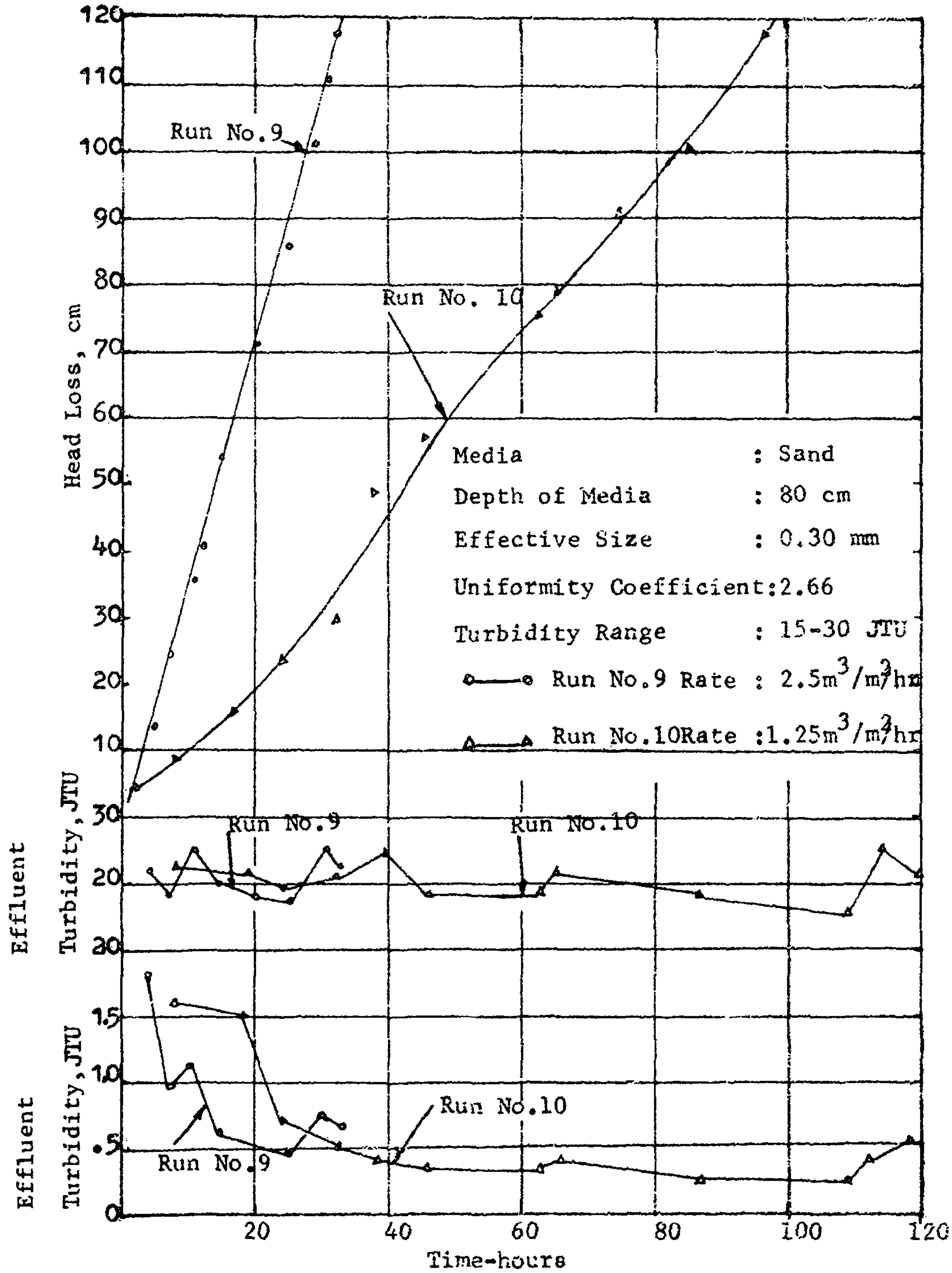


Fig.I-5- Filter Performance of Control Media(Sand) at 2.5 and 1.25 $m^3/m^2/hr$

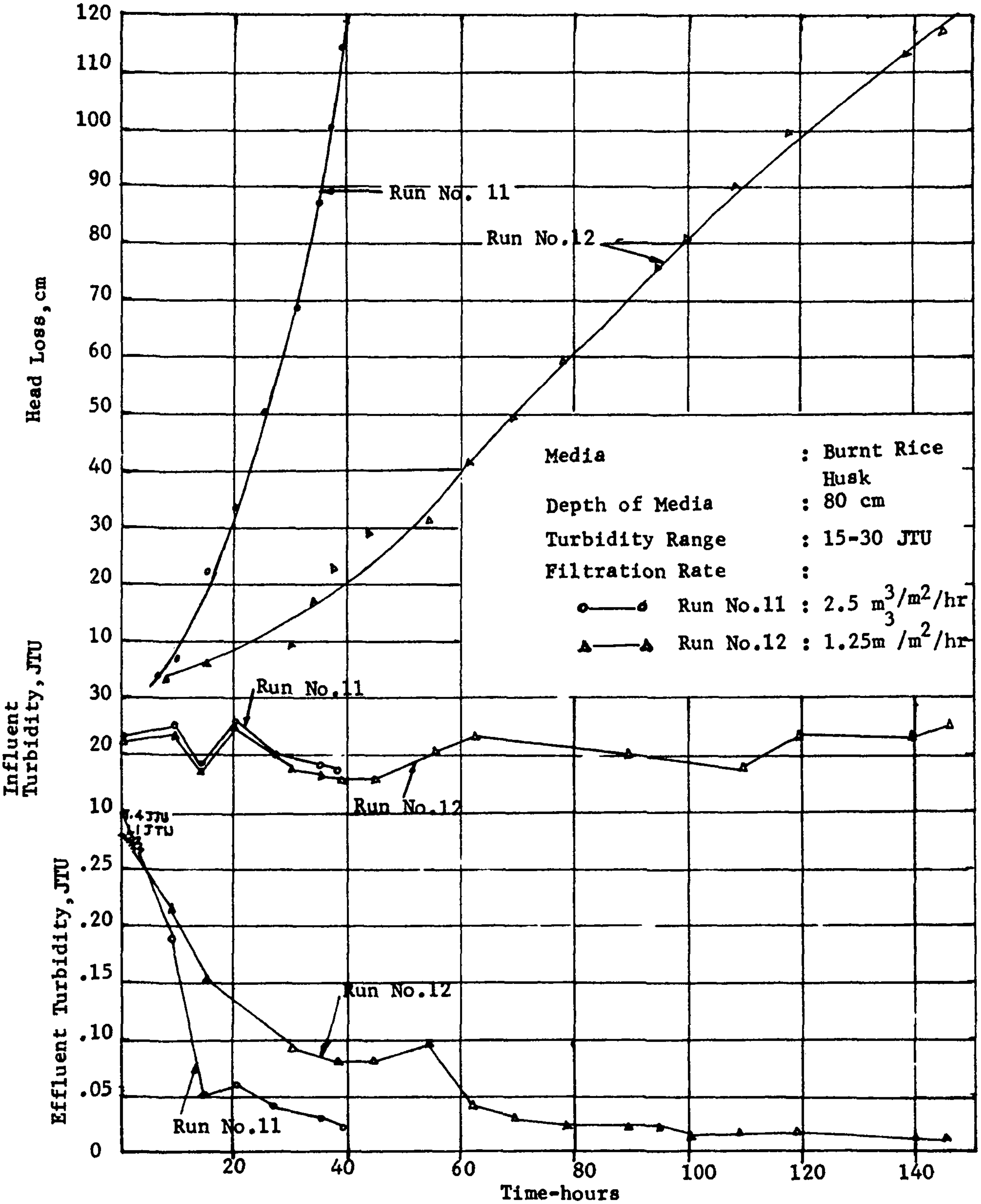


Fig.I-6- Filter Performance of Burnt Rice Husk at Filtration Rate 2.5 and 1.25 $m^3/m^2/hr$

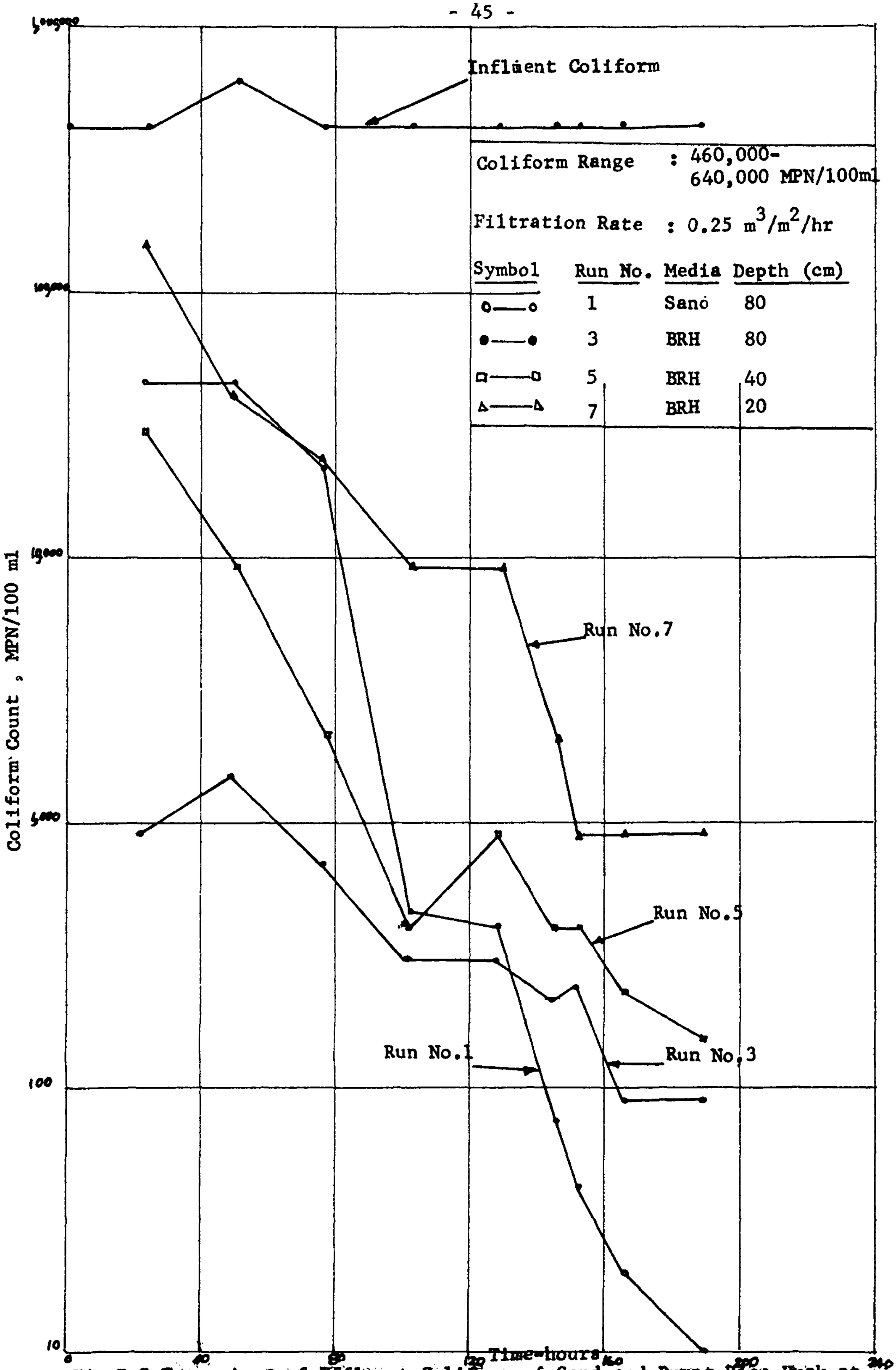


Fig. I-7-Comparison of Effluent Coliform of Sand and Burnt Rice Husk at different depths at 0.25 $m^3/m^2/hr$

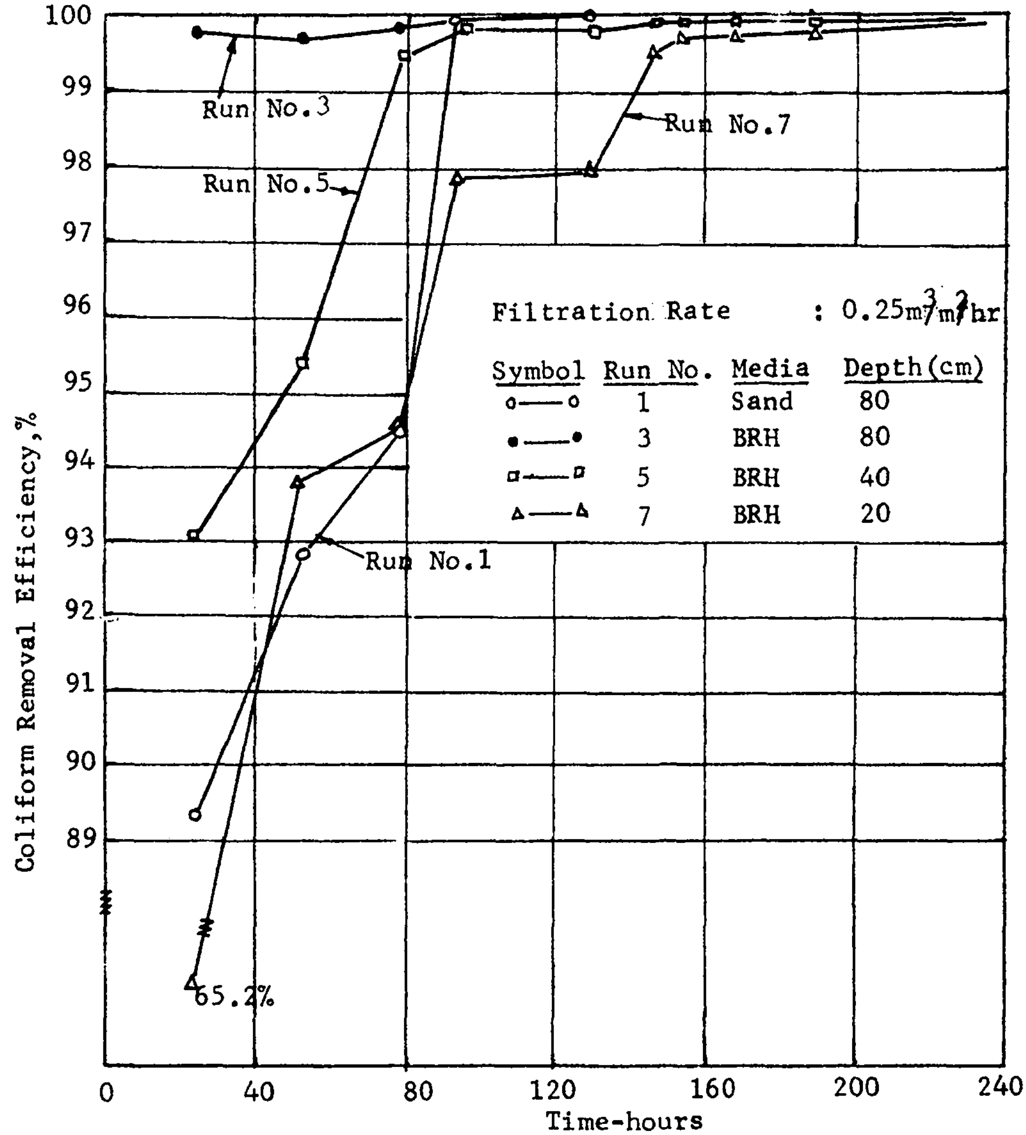


Fig.I-8- Coliform Removal Efficiency of Sand and Burnt Rice Husk at different depths of media at $0.25 m^3/m^2/hr$

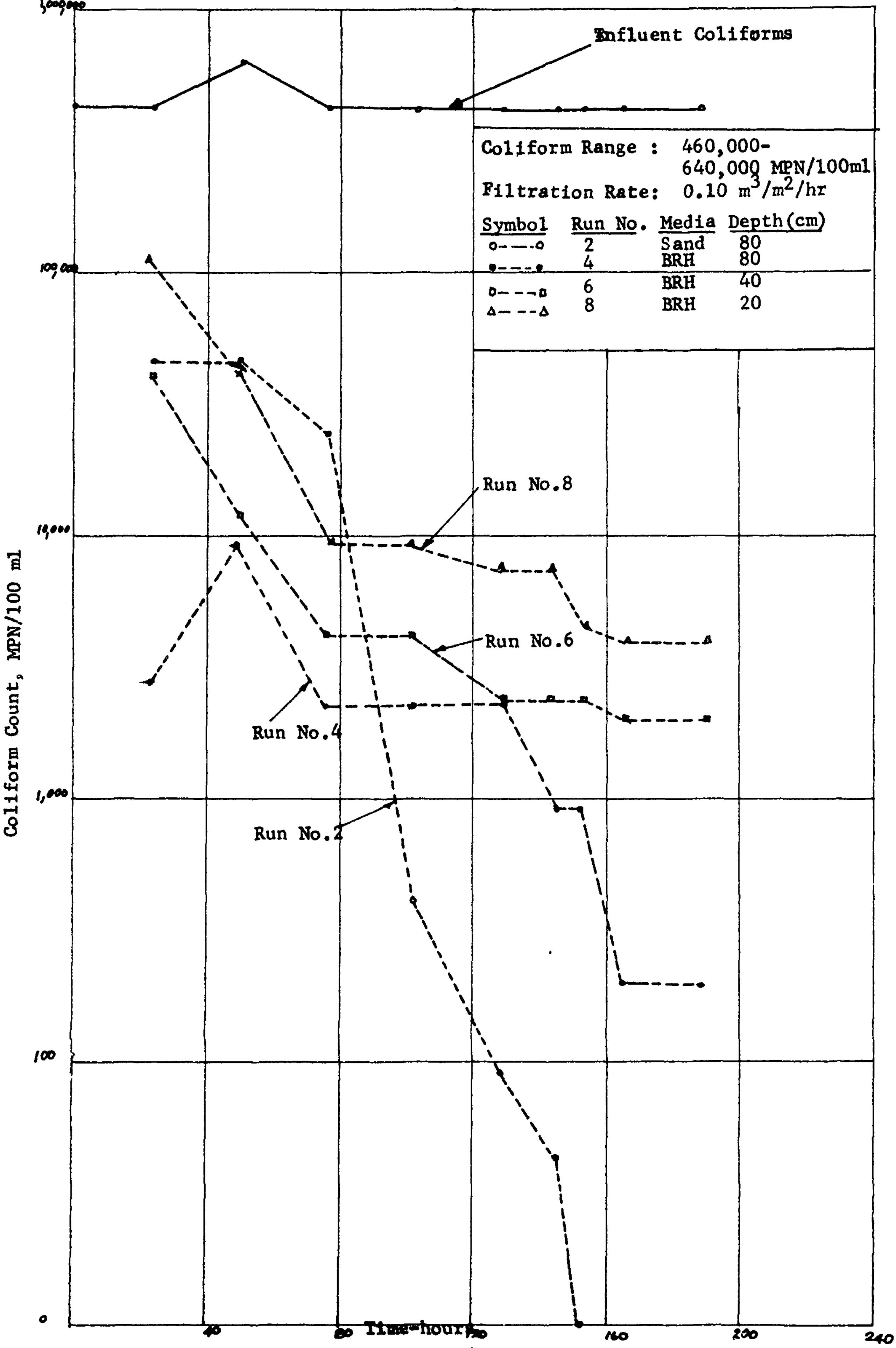


Fig. I-9 Comparison of Effluent Coliform of Sand and Burnt Rice Husk at different depths of media at 0.10 $m^3/m^2/hr$

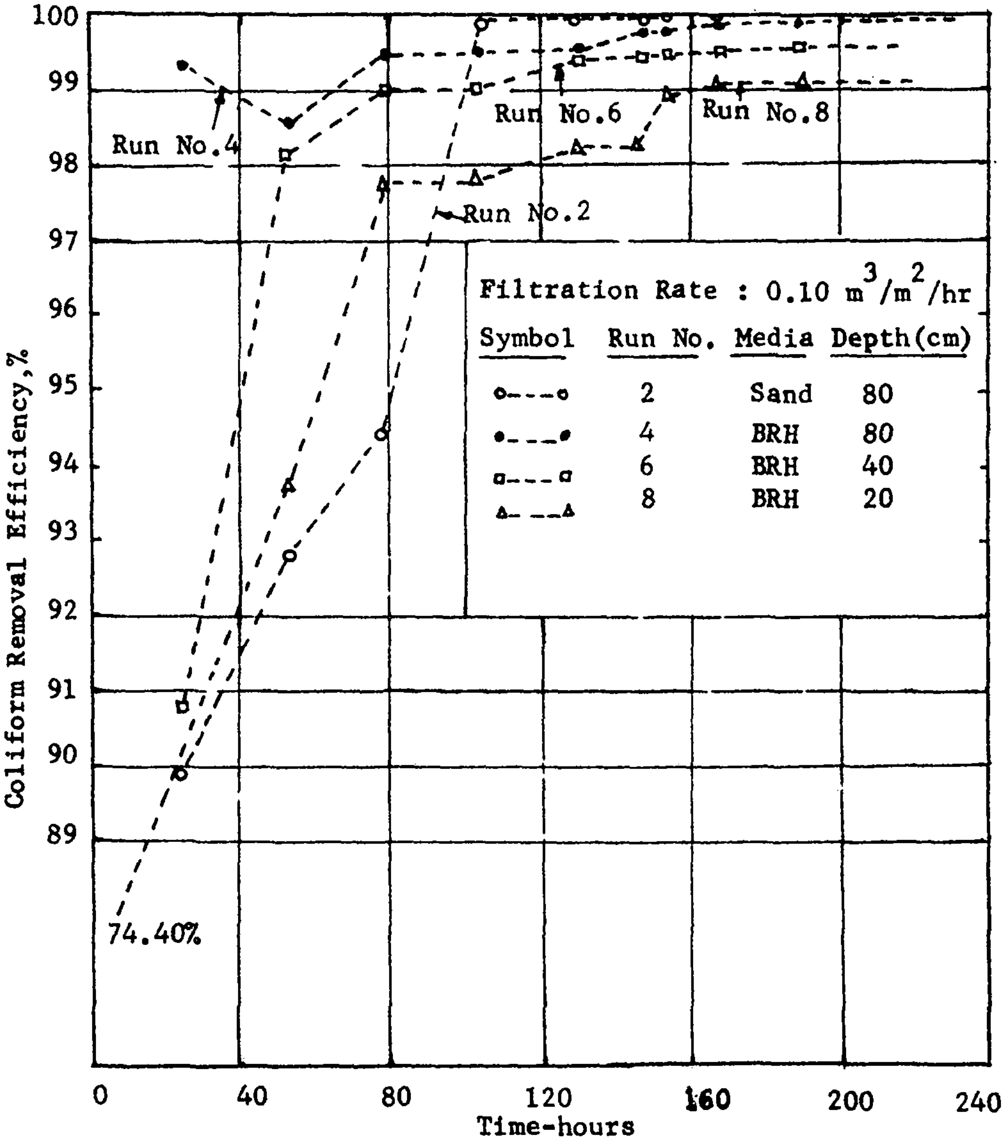


Fig.I-10- Coliform Removal Efficiency of Sand and Burnt Rice Husk at different depths at 0.10 $m^3/m^2/hr$

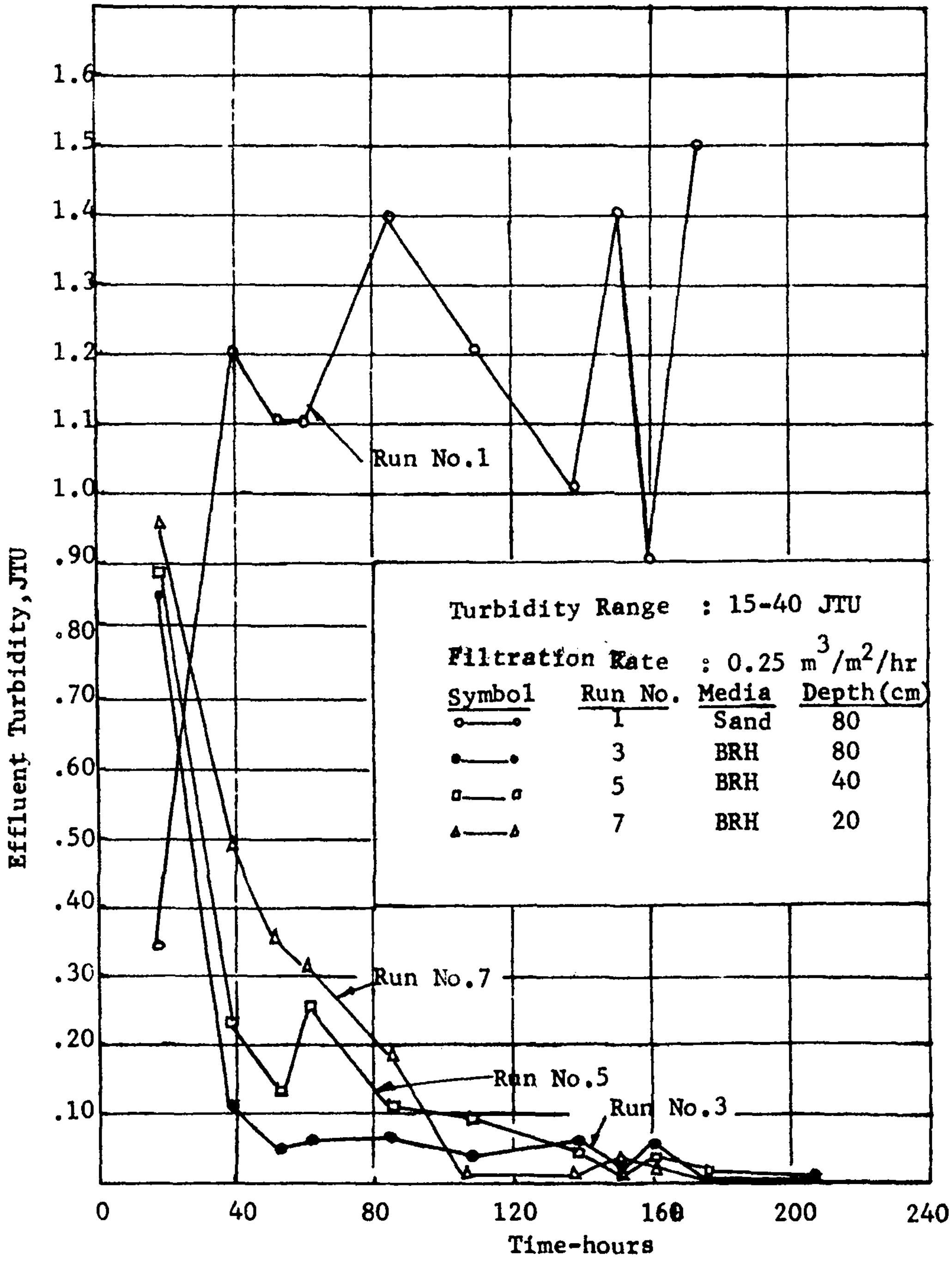


Fig.I-11- Comparison of Effluent turbidity Between Sand and Burnt Rice Husk at 0.25 $m^3/m^2/hr$

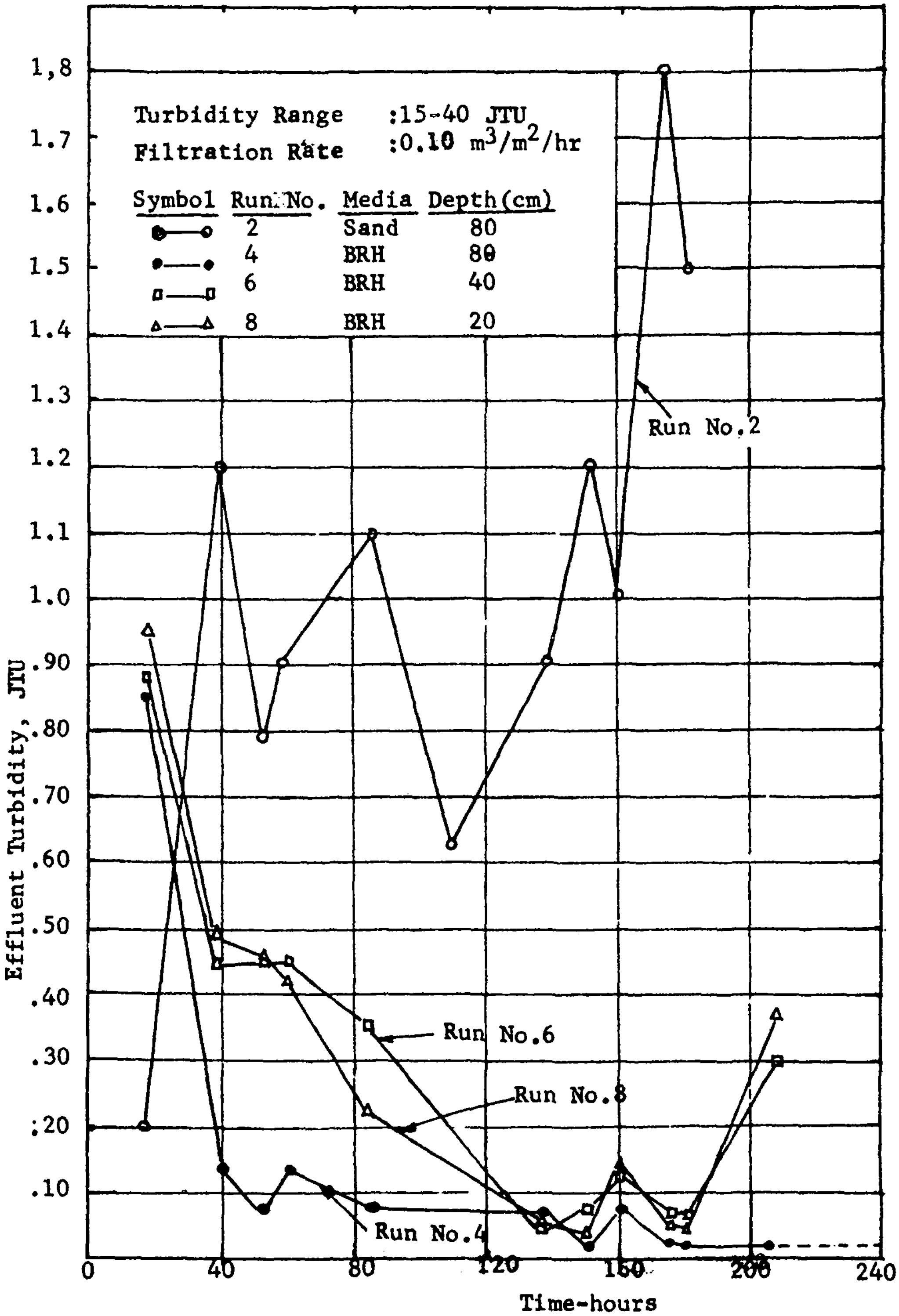


Fig.I-12- Comparison of Effluent Turbidity Between Sand and Burnt Rice Husk at 0.10 $m^3/m^2/hr$

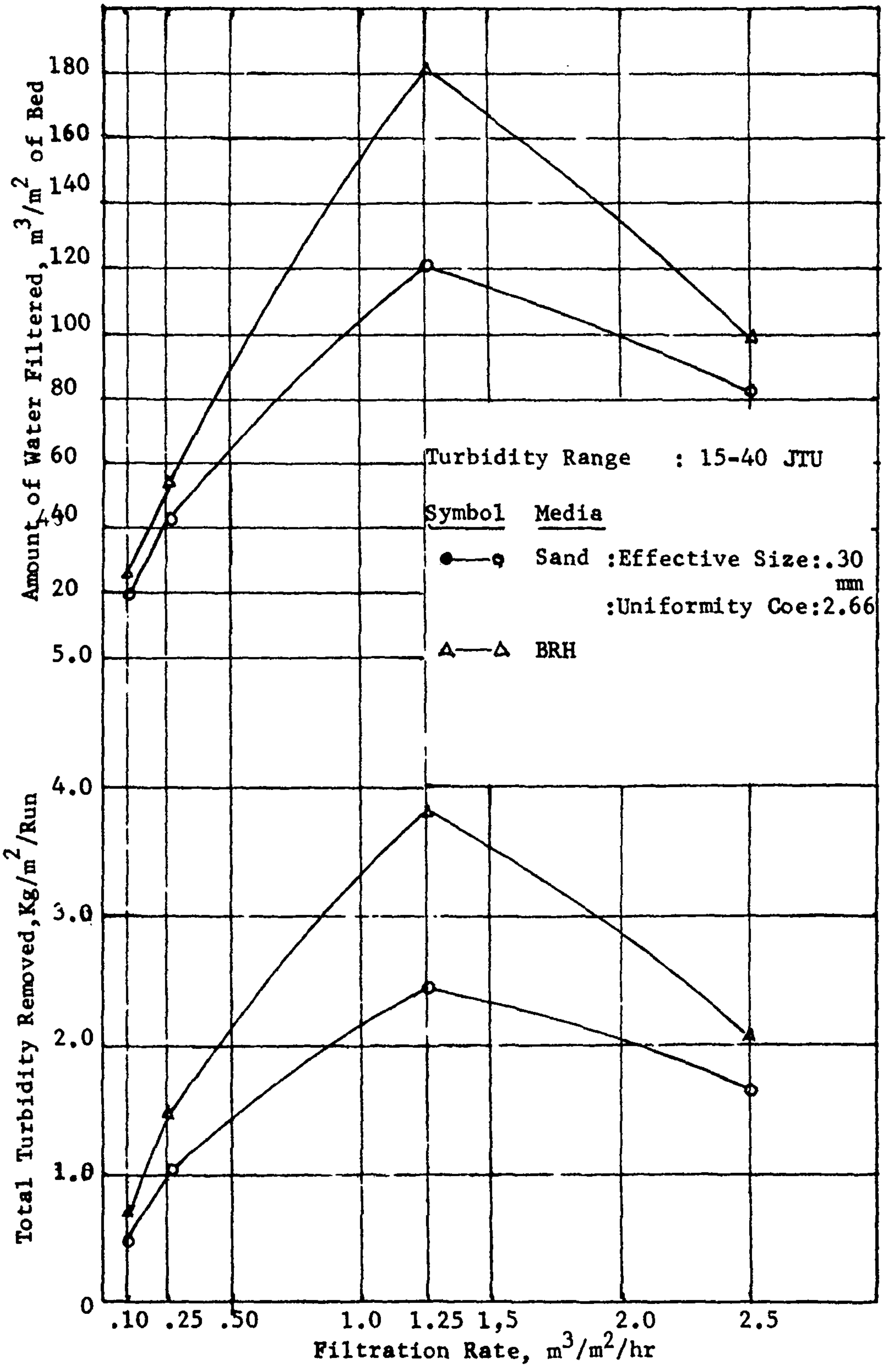


Fig.I-13- Relation of Total Turbidity Removed and Amount of Water Filtered versus Filtration Rates of Sand and Burnt Rice Husk

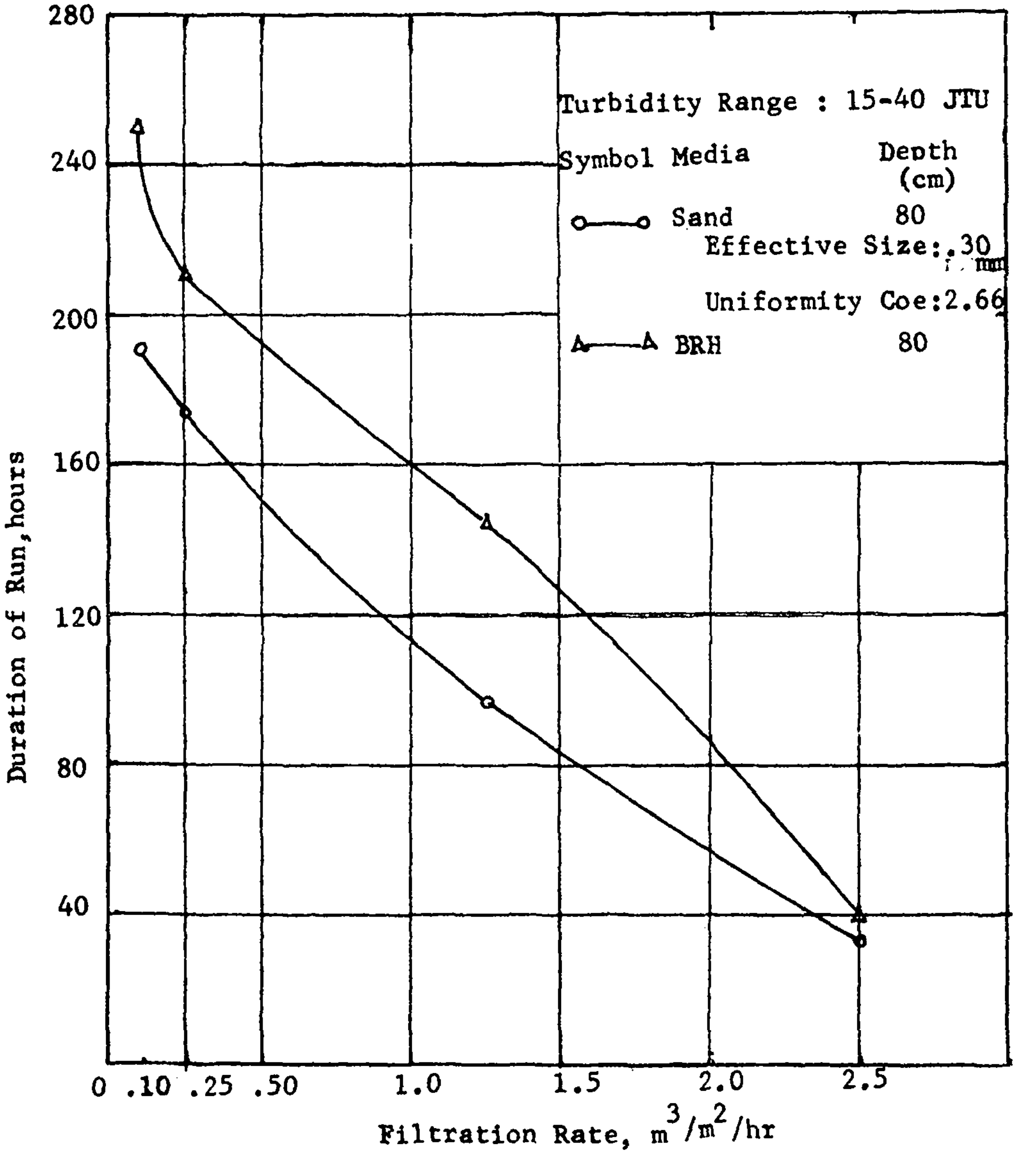


Fig.I-14- Comparison of Duration of Run Between Sand and Burnt Rice Husk at Different Filtration Rates

Run Series II : Experimental Study on the Performance of Coconut Husk Fiber at Different Depths of Media at High Load Turbidity

Tests were conducted with municipal tap water added kaolin clay to produce a turbidity range of 180-350 JTU, and at depths of coconut husk fiber media of 120, 100 and 80 cm for both filtration rates of 2.5 and 1.25 $m^3/m^2/hr$. A dual media filter, using coconut husk fiber at 60 cm depth plus burnt rice husk at 20 cm depth was performed at 1.25 and 0.25 $m^3/m^2/hr$. These tests were run to determine the effect of turbidity removal only due to depth and not bacteriological removal efficiency.

Coconut Husk Fiber

The filter performance of runs at filtration rate of 2.5 $m^3/m^2/hr$ and depth of medium 120, 100 and 80 cm are shown in Fig. II-1. It was shown that duration of run were increased according to the depth of medium. Turbidity removal was also affected by the depth of medium. Average effluent turbidity of three different depths at filtration rate 2.5 $m^3/m^2/hr$ was between 50-65 JTU. Turbidity removal efficiency of coconut husk fiber 100, 80 cm was nearly the same but for 120 cm depth the efficiency was 7% higher than that of 100, 80 cm.

Runs at filtration rate of 1.25 $m^3/m^2/hr$ and three (3) different depths are shown in Fig. II-2.

Average effluent turbidity at three different depths of medium was between 33-36 JTU. Removal efficiency of turbidity at 120 cm depth of medium was 8-9% higher than that at 100, 80 cm while efficiency of turbidity removal at 100, 80 cm was nearly the same. The effluent turbidity at the latter part of the run was as low as 15-20 JTU but it was still higher than WHO Standard for drinking water.

Coconut husk fiber can be only the roughing (primary) filter and effluent from this filter needs to be further treated in polishing (secondary) filter to meet the WHO Standard. The depth of medium had the effect on duration of run and turbidity of effluent, too. The greater the depth the longer the filter run and the greater the removal.

Results from comparison of duration of runs at 2.5 and 1.25 m^3/m^2/hr are shown in Figs. II-5 and II-9. For the same duration of run at a flowrate of 2.5 m^3/m^2/hr, the depth of medium needs to be increased to twice the depth of media for filtration rate 1.25 m^3/m^2/hr, as indicated by the dashed lines in Fig. II-9. At constant flow rate, the increasing in duration of runs was directly proportional to increasing the depth of medium.

Rate of turbidity load removed (Kg/m^2/hr) is shown in Fig. II-7 and II-8 for filtration rate 2.5 and 1.25 m^3/m^2/hr respectively, indicates that for greater depths, higher rate of turbidity will be removed. The effective depth of coconut husk fiber is the highest depth of media. Total turbidity load removed versus filtration rate, as shown in Fig. II-6, shows that at 1.25 m^3/m^2/hr the total turbidity load removed was higher than at 2.5 m^3/m^2/hr

SEVILLA (1971) made the experiment on coconut husk fiber 80 cm depth, influent turbidity 24-130 JTU and at a filtration rate 0.25 m^3/m^2/hr. He found that after 18 days of operation the filter was still performing efficiently with a low head loss the effluent turbidity was below 0.5 JTU. Investigation of coconut husk fiber at flow rate less than 1.25 m^3/m^2/hr on physical and bacteriological qualities and duration of run is recommended for future studies.

Dual Media: Coconut Husk Fiber + Burnt Rice Husk

Two filtration rates 1.25, 0.25 m^3/m^2/hr of coconut husk fiber 60 cm with burnt rice husk 20 cm were run at influent turbidity range 180-350 JTU, only turbidity removal was considered. The average effluent turbidity for high rate was 4.0 JTU and for low rate 1.4 JTU. Duration of run for low rate 0.25 m^3/m^2/hr was only 24% longer than the rate 1.25 m^3/m^2/hr. Filter performance is shown in Fig. II-3 and Fig. II-4 for turbidity effluent. After 10 hours of operation, effluent turbidity decreased below 5 JTU.

Comparison of Turbidity Removal Efficiency of Coconut Husk Fiber at Different Depths of Media

Turbidity in the effluent from the end of coconut husk fiber at 60 cm at 1.25 m^3/m^2/hr can be compared to turbidity removal at 80, 100 and 120 cm at the same rate shown in Fig II-2. Turbidity removal efficiency at four (4) different depths of coconut husk fiber is shown in Fig. II-10. It can be concluded that of the same filtration rate, depth of medium is important up to a depth of about 80 cm; that is, below 80 cm the greater the depth the higher the turbidity removal efficiency. After a depth of 80 cm, there appears to be no increase in efficiency of turbidity removal but only in the duration of filter runs.

Table 12 - Summary of Results of Test Runs in Run Series II

Run No.	Media	Depth of Media (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Effluent Turbidity Range (JTU)	Average Effluent Turbidity (JTU)	Removal Efficiency Range (%)	Amount of Filtered Water (m^3/m^2 of bed)	Duration of run for head 1.2 m. (hour)	Rate of Head Loss (cm/hr)
1	CHF	120	2.5	180-350	95-24	49	69.5-90.5	260	104	1.15
2	CHF	100	2.5	180-350	115-42	63	66.8-83.2	205	84	1.43
3	CHF	80	2.5	180-350	120-48	66	67.1-82.5	158	63	1.90
4	CHF	120	1.25	180-350	60-13	33.6	76.3-94.9	254	203	0.57
5	CHF	100	1.25	180-350	82-13	34.2	67.2-94.9	220	176	0.68
6	CHF	80	1.25	180-350	80-12	36.0	68.0-95.1	189	151	0.79
7	CHF + BRH	60 20	1.25	180-350	15-2.1	4.0	94.0-99.3	181	145	0.83
8	CHF + BRH	60 20	0.25	180-350 Average 250 JTU	8.0-.12	1.4	96.9-99.8	45	180	0.68

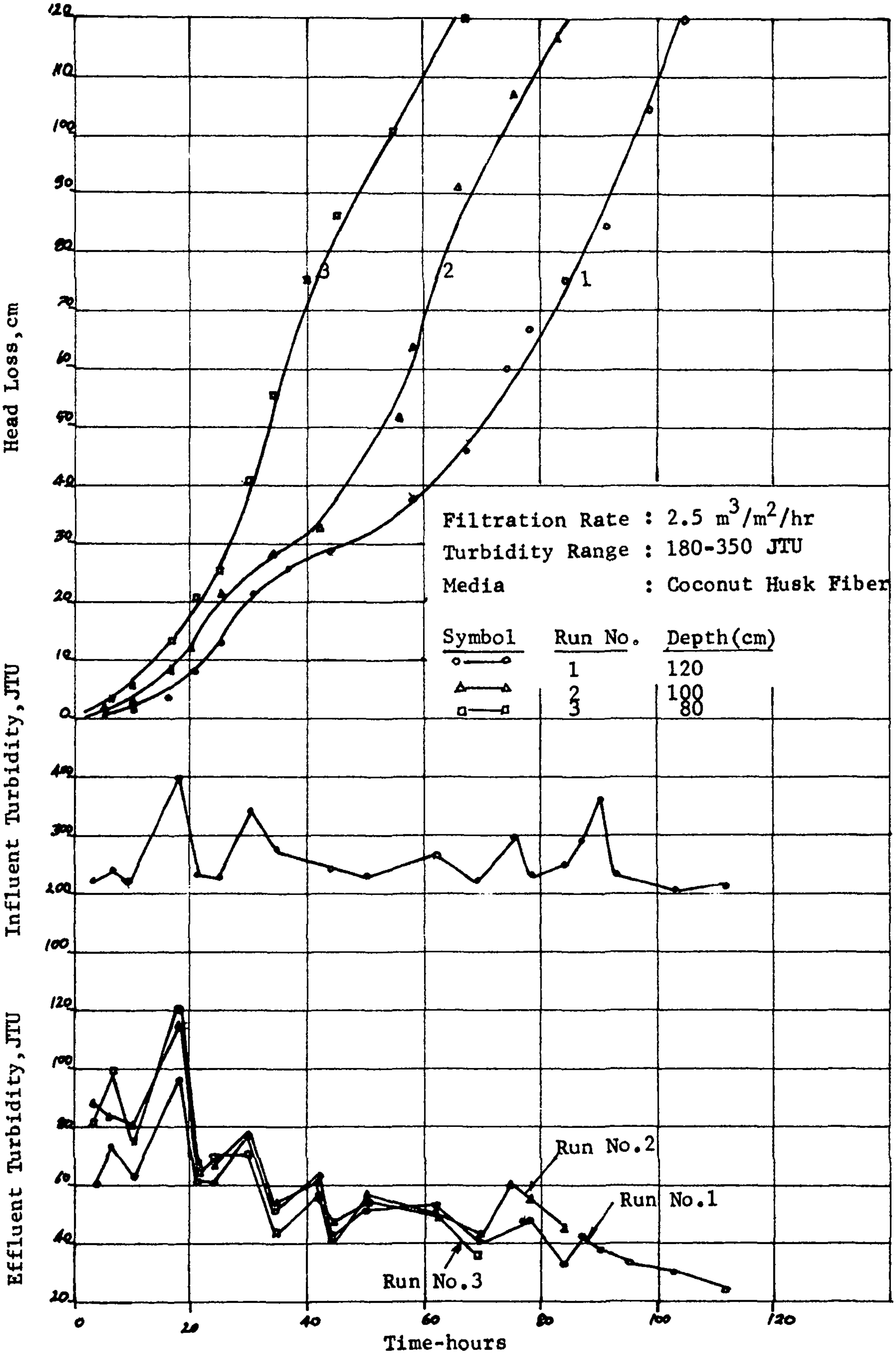


Fig.II-1- Filter Performance of Coconut Husk Fiber at Different Depths of Media at 2.5 $m^3/m^2/hr$

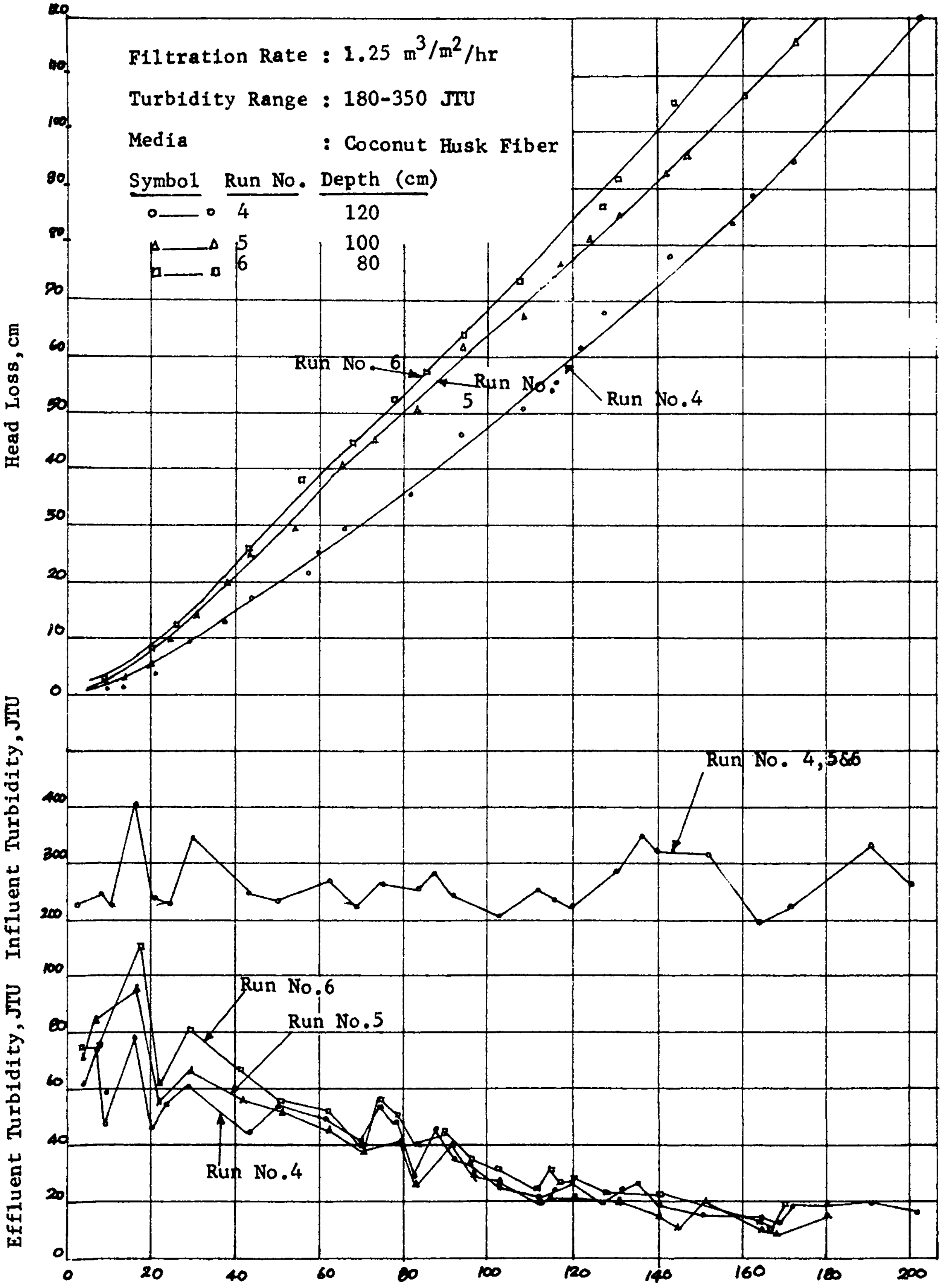


Fig.II-2- Filter Performance of Coconut Husk Fiber at Different Depths of Media at 1.25 $m^3/m^2/hr$

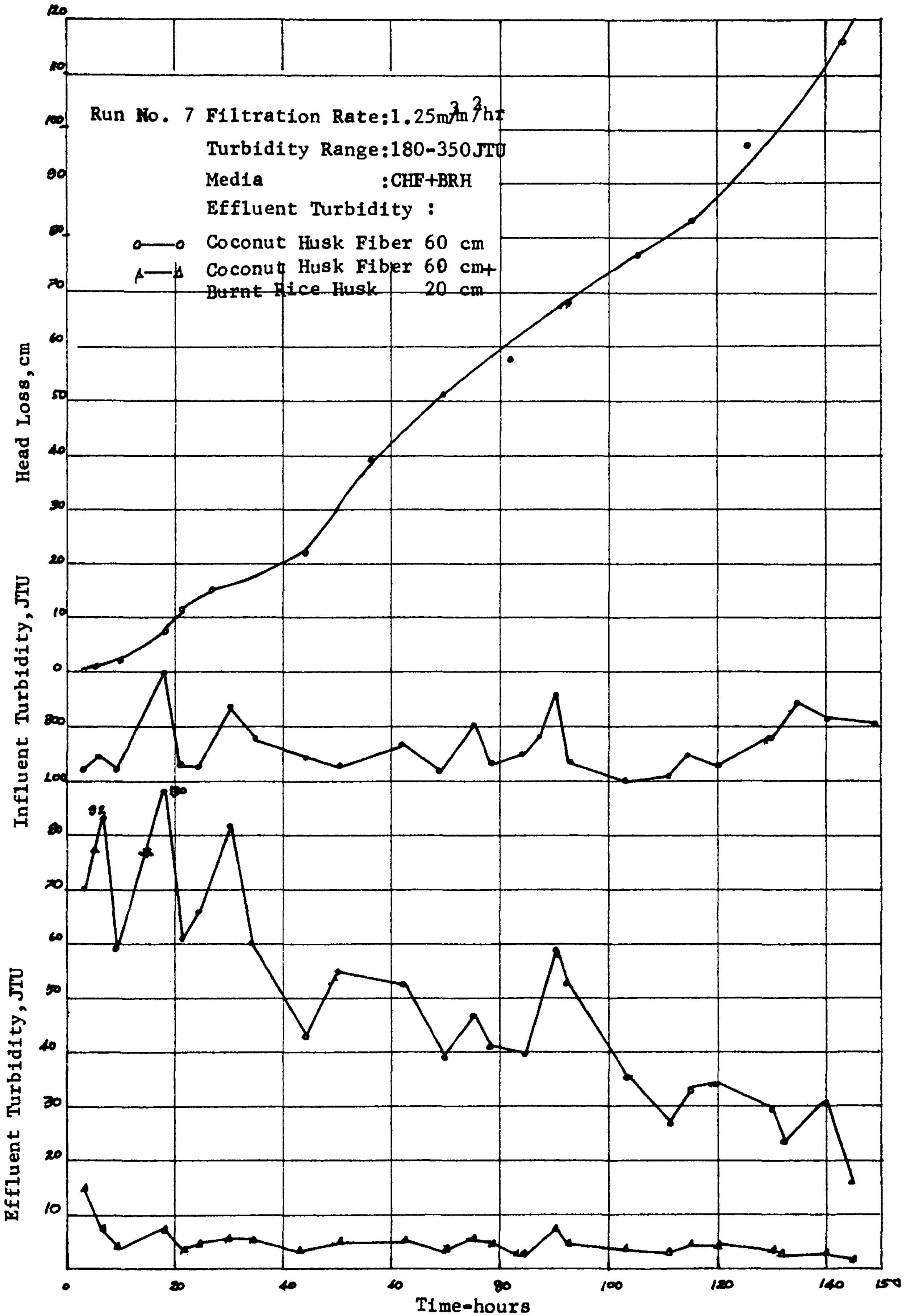


Fig.II-3- Filter Performance of Combined Media-CHF+BRH at 1.25 $m^3/m^2/hr$

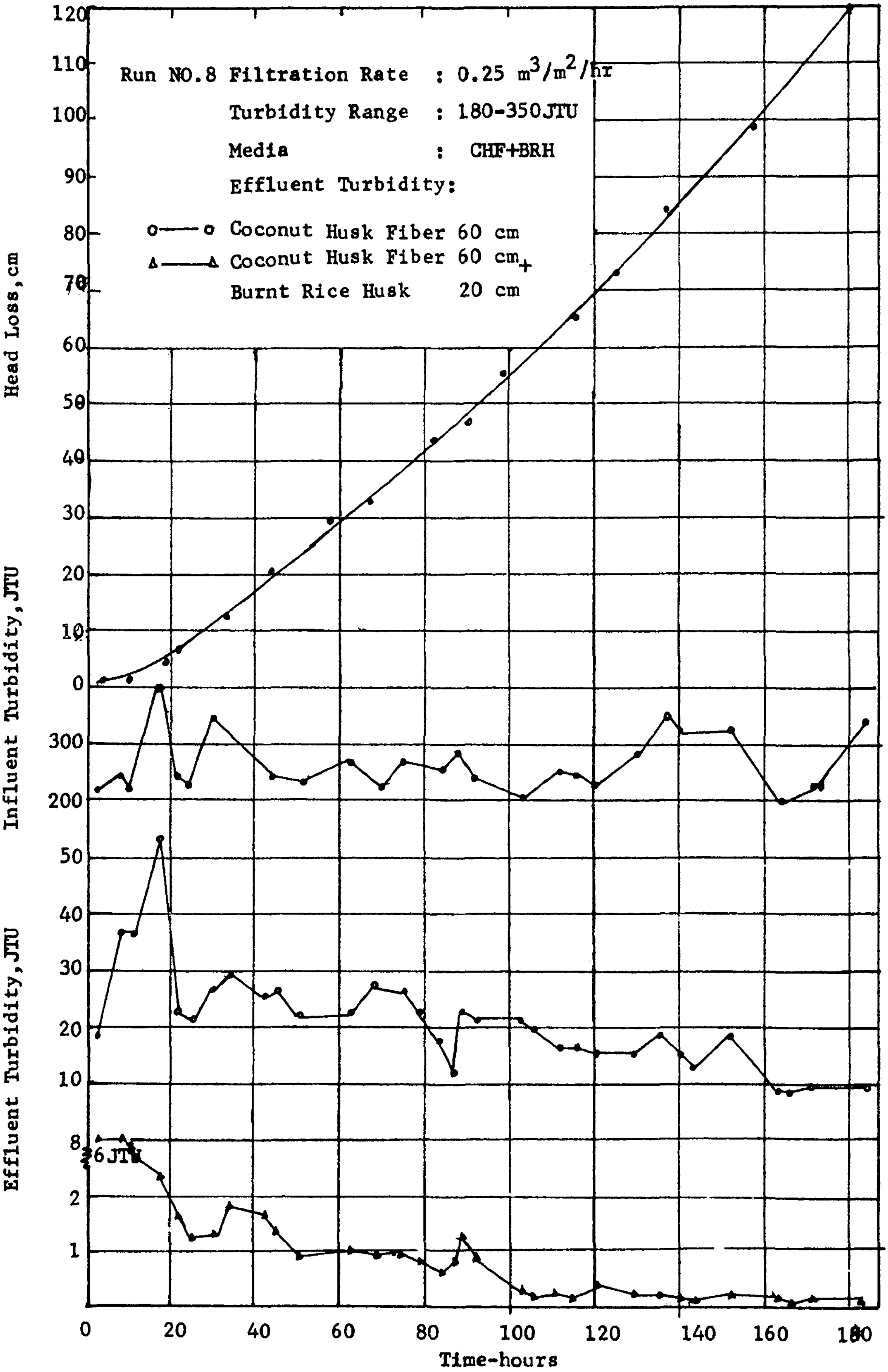


Fig.II-4- Filter Performance of Combined Media-CHF+BRH at 0.25 $m^3/m^2/hr$

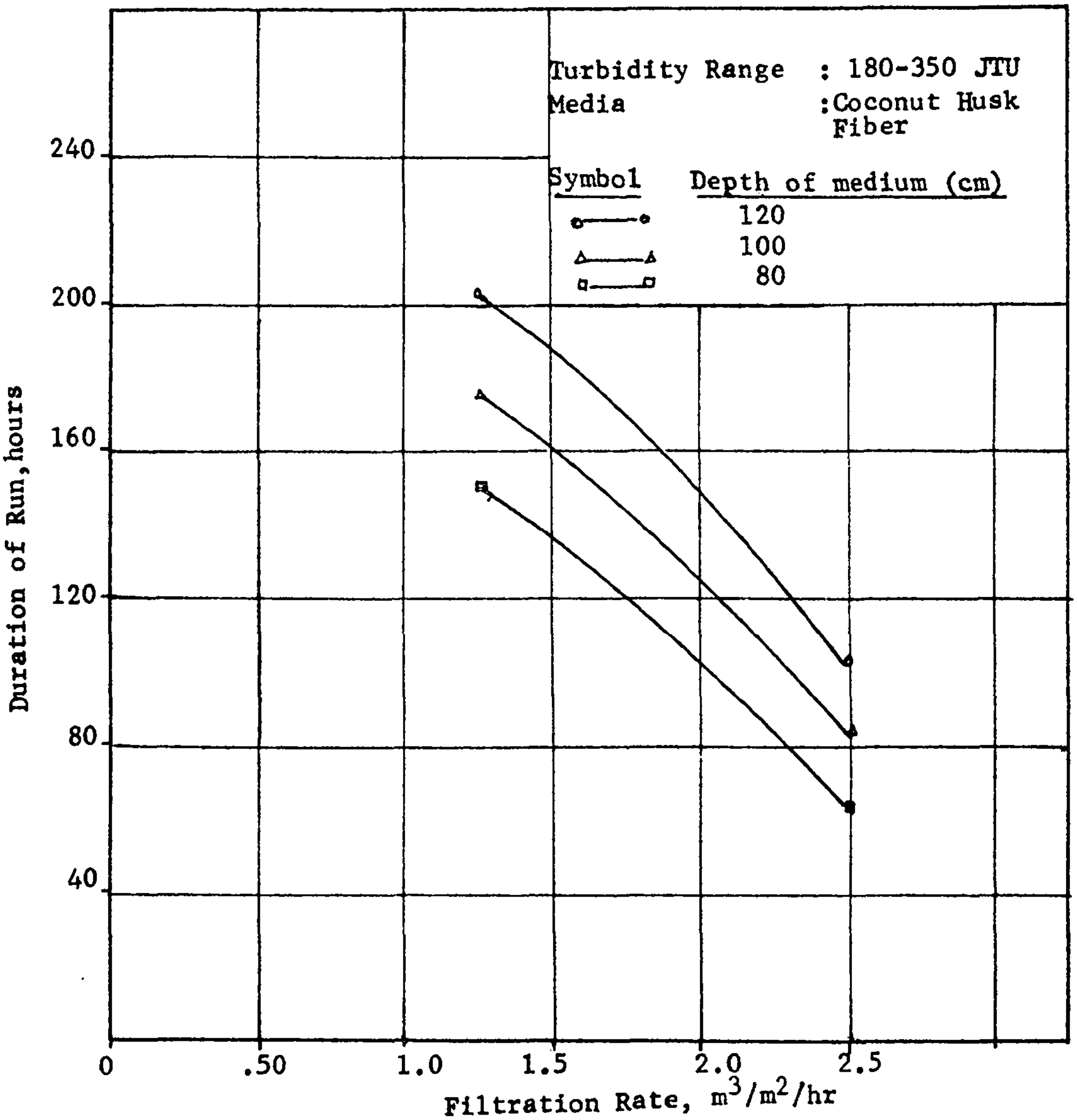


Fig.II-5- Comparison of Duration of Run of Coconut Husk Fiber of Different Depths at Various Filtration Rates

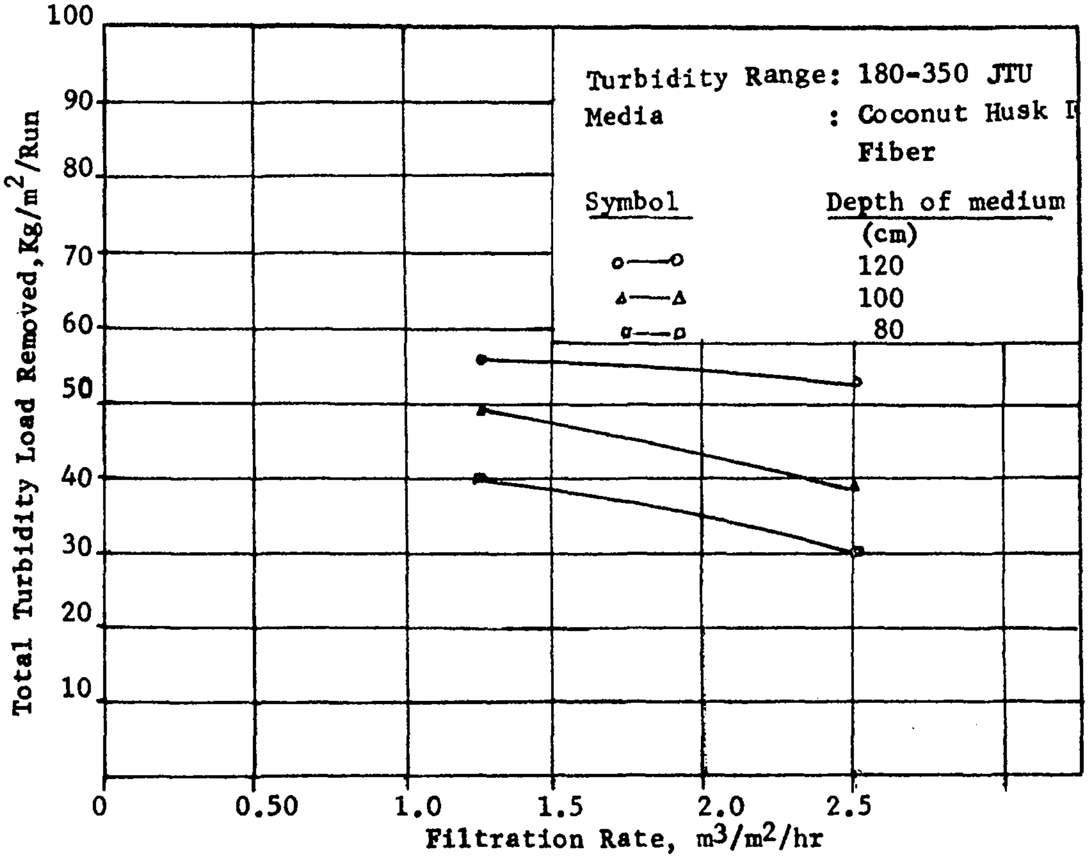


Fig.II-6- Relation of Total Turbidity Removed versus Filtration Rates of Coconut Husk Fiber at differen depths

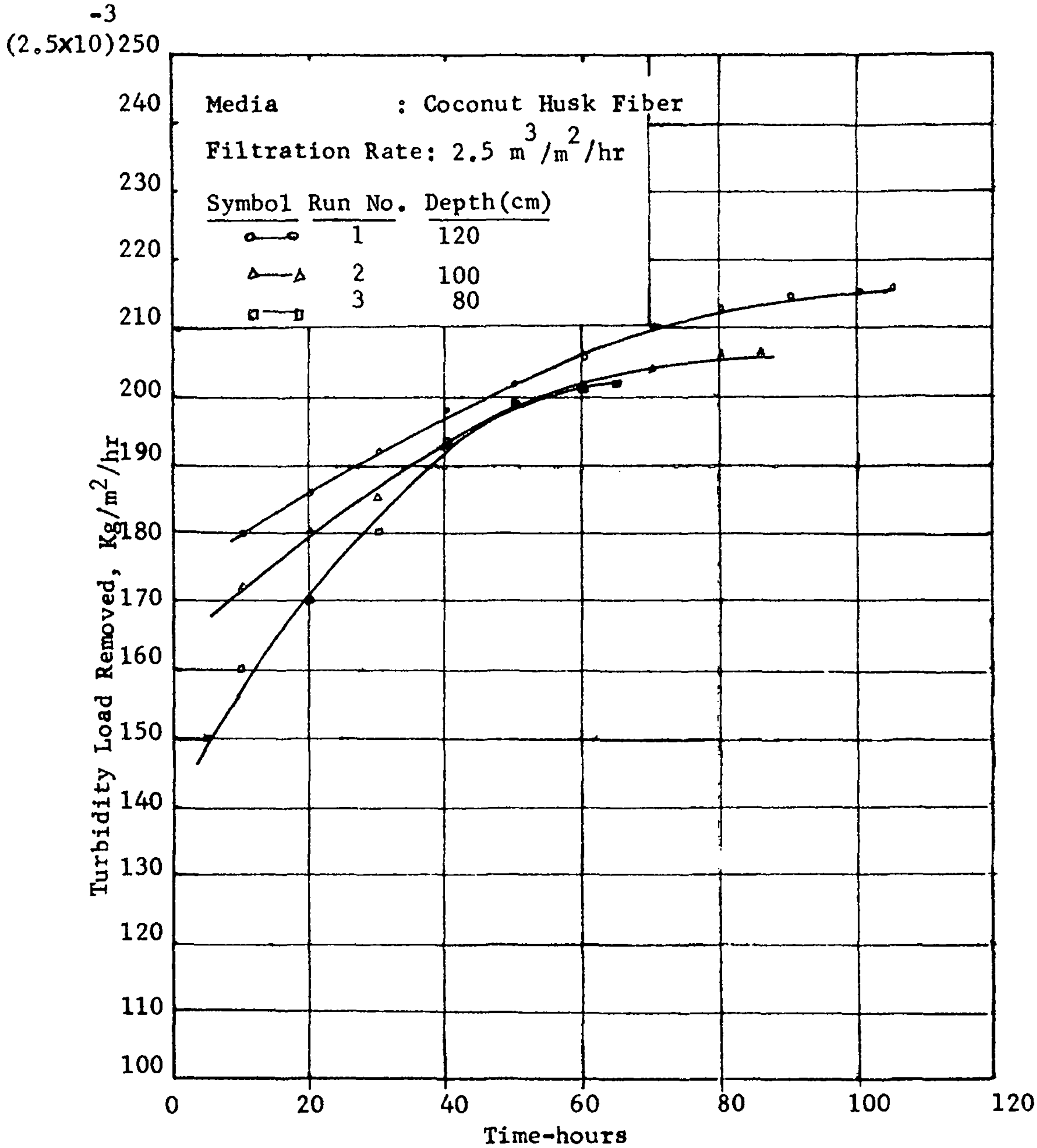


Fig.II-7- Relation of Turbidity Load Removed versus Time of Coconut Husk Fiber at 2.5 $m^3/m^2/hr$

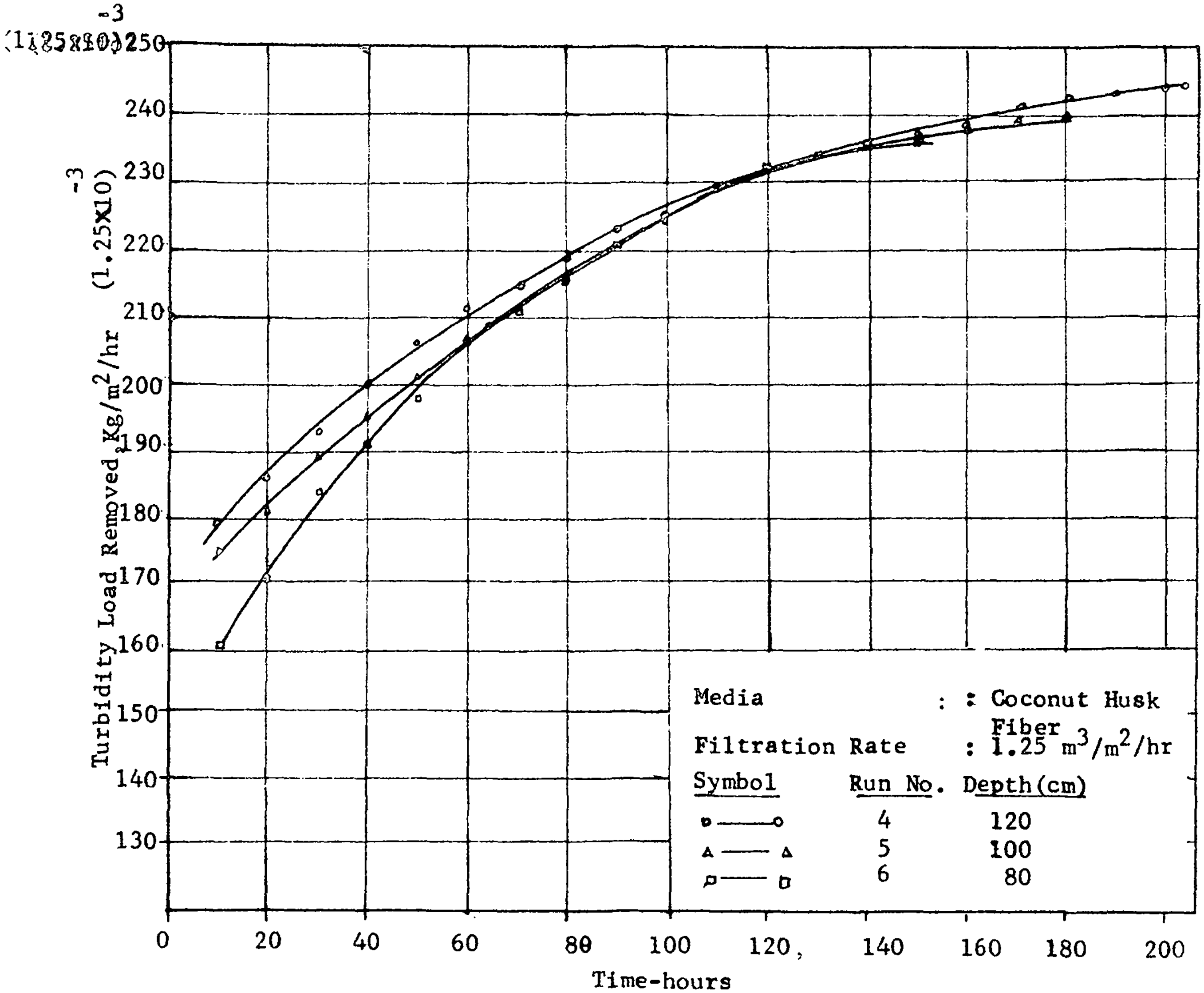


Fig.II-8- Relation of Turbidity Load Removed versus Time of Coconut Husk Fiber at 1.25 m^3/m^2/hr

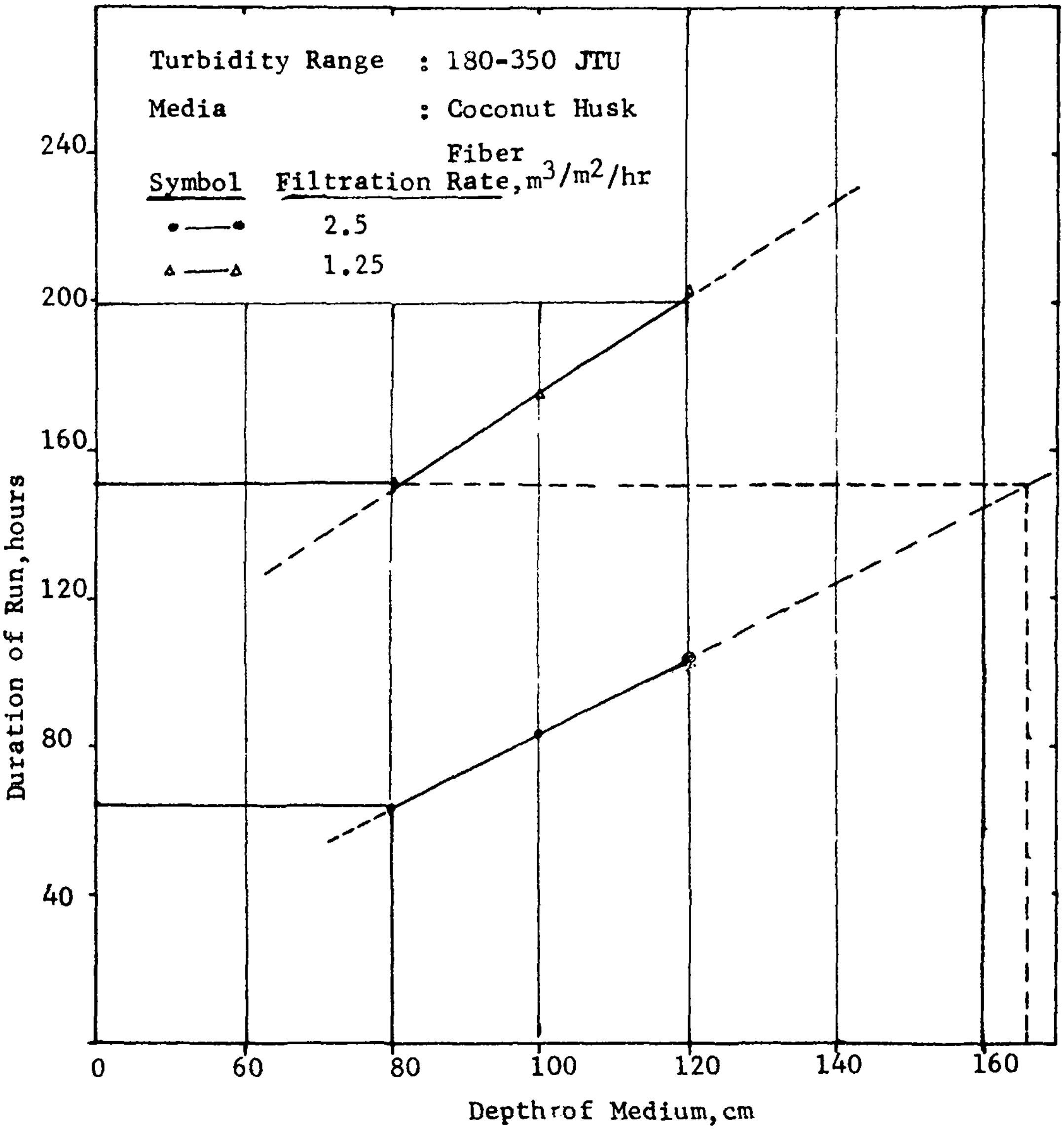


Fig.II-9- Relation of Duration of Run versus Depth of Medium at Different Filtration Rates

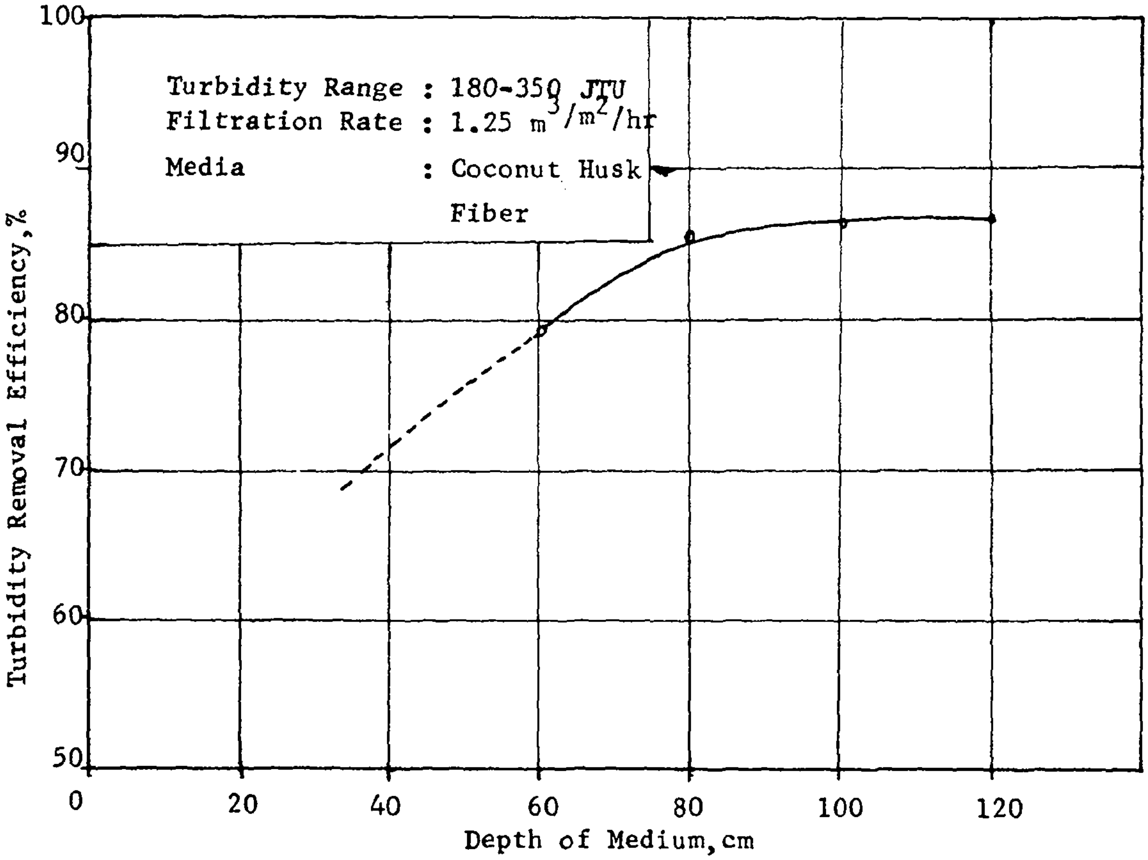


Fig.II-10- Comparison of Turbidity Removal Efficiency,% versus Depth of Coconut Husk Fiber at 1.25 m^3/m^2/hr

Run Series III : Exploratory Study of Dual Media Filter Performances Using Chao Phya River Water

A test run of dual media filter - coconut husk fiber 80 cm depth with burnt rice husk 20 cm depth was conducted at 2.5, 1.25 and 0.25 $m^3/m^2/hr$ using Chao Phya river water. Pea gravel, effective size $\frac{1}{4}$"-$\frac{3}{8}$", 80 cm of depth combined with burnt rice husk 20 cm of depth was also performed at 1.25 $m^3/m^2/hr$. Turbidity, chemical and bacteriological tests of two types of dual media at different filtration rates were studied.

Dual Media : Coconut Husk Fiber with Burnt Rice Husk

The filter performance of the dual media, coconut husk fiber 80 cm with burnt rice husk at 20 cm at three (3) filtration rates are shown in Fig III-1 to III-3. Turbidity test, coliform test, COD, NH_3-Nitrogen, organic-Nitrogen tests were conducted on the series of run.

Comparison of turbidity removal between three filtration rates showed the maximum turbidity removal at filtration rate 0.25 $m^3/m^2/hr$ and effluent turbidity of this rate was below 5.0 JTU after 60 hours of operation ($\frac{1}{3}$ of duration of run). Coliform removal efficiency at 0.25 $m^3/m^2/hr$ reached only 50% at the beginning period of run and was up to 93% after running the filter for 70 hours. Coliform removal efficiency for high rate 2.5 $m^3/m^2/hr$ reached 96% of the beginning period of run and for 1.25 $m^3/m^2/hr$ at 20th hour. Duration of run at 1.25 $m^3/m^2/hr$ was increased to twice the duration of run at 2.5 $m^3/m^2/hr$ while the length of run of 0.25 $m^3/m^2/hr$ was only 40 hours more than that of 1.25 $m^3/m^2/hr$.

It appears that the filtration rate of 1.25 $m^3/m^2/hr$ should be optimum for the dual media for turbidity removal efficiency, coliform removal efficiency and duration of run.

Removal of COD by the dual media was 30-80%, removal of organic-nitrogen was 70-100% and NH_3-Nitrogen was not found in raw water and also in effluent water. Removal efficiencies were generally higher at the lower filtration rates, except 1.25 $m^3/m^2/hr$ again approved most attractive. Dual media filters at three rates removed the colour of raw water down to less than 5 Hazen units that is accepted according to WHO Standard.

Dual Media : Pea Gravel with Burnt Rice Husk

Pea Gravel at 80 cm depth, size ¼" - 3/8" was combined with brunt rice husk 20 cm and the filter was performed at 1.25 $m^3/m^2/hr$. Even though the pea gravel did not remove the turbidity as much as combination of coconut husk fiber with burnt rice husk at the same rate, this kind of filter did remove coliform organisms at high efficiency from the beginning of run to the end of run. Its removal efficiency was in range of 99.0-99.97%. This combination of media pea gravel and burnt rice husk can be substituted for the dual media of coconut husk fiber and burnt rice husks in areas where coconut husk fiber is scarce. But two filters in series should be used as the pea gravel can be washed and used over again. The difficulty of using pea gravel instead of coconut husk fiber is the selection of size by sieve analysis. Duration of run was less than the dual media of coconut husk fiber plus burnt rice husk because the pea gravel removed all turbidities less than the coconut husk fiber thereby clogging the burnt rice husk more rapidly.

Removal of COD by the dual media was about 50%, this was 30% less than the removal by coconut husk fiber 80 cm with burnt rice husk 20 cm. Colour of raw water was removed down to less than 5 Hazen units.

Comparison of Performance between River Water and Synthetic Water

Synthetic Water - municipal tap water with added kaolin clay, at high load turbidity was run on dual media of coconut husk fiber 60 cm and burnt rice husk 20 cm of depth at filtration rate 1.25 and 0.25 $m^3/m^2/hr$. Effluent turbidity using synthetic water was always below the WHO Standard for drinking water. Using river water, the dual media of coconut husk fiber 80 cm and burnt rice husk 20 cm of depth only met the standard after 60 hours of operation at filtration rate of 0.25 $m^3/m^2/hr$. Comparison of turbidity removal efficiency between two types of water showed that the turbidity in synthetic water could be removed more easily than that in river water. Hence, long term pilot plant studies will be required to obtain fewer operating data for the dual media filter.

For coliform organism removals, efficiency of the filter untis was about the same 96-99% for both the synthetic and river waters.

Table 13 - Summary of Results in Run Series III

Run No.	Media	Depth of Media (cm)	Filtration Rate ($m^3/m^2/hr$)	Influent Turbidity Range (JTU)	Effluent Turbidity Range (JTU)	Removal Efficiency Range (%)	Color (Hazen Unit)	Coliform Removal Efficiency Range (%)	COD		Org-N (mg/l)	Amount of Filtered Water (m^3/m^2 of bed)	Duration of Run for Head 1.2 m (hour)	Rate of Head Loss (cm/hr)
									(mg/l)	(%) Removal				
1	CHF + BRH	80 20	2.5	180-400	41-17	84.0-93.2	< 5	95.37-99.88	15.4	33.3	.25	180	72	1.67
2	CHF + BRH	80 20	1.25	180-400	35-4.0	86.1-98.2	< 5	85.33-99.95	3.8	83.3	0	205	164	0.73
3	CHF + BRH	80 20	0.25	180-400	22-2.0	89.1-99.3	< 5	50.46-99.92	7.7	66.7	0	50.5	202	0.59
4	PG + BRH	80 20	1.25	180-400	40-14	84.0-94.5	< 5	99.0-99.97	11.5	50.3	0	177	142	0.84
RAW pH @ $25^{\circ}C$ = 8.3				Ave.250			40-60	750,000 - 1,100,000 MPN/100 ml	23.1		.80			

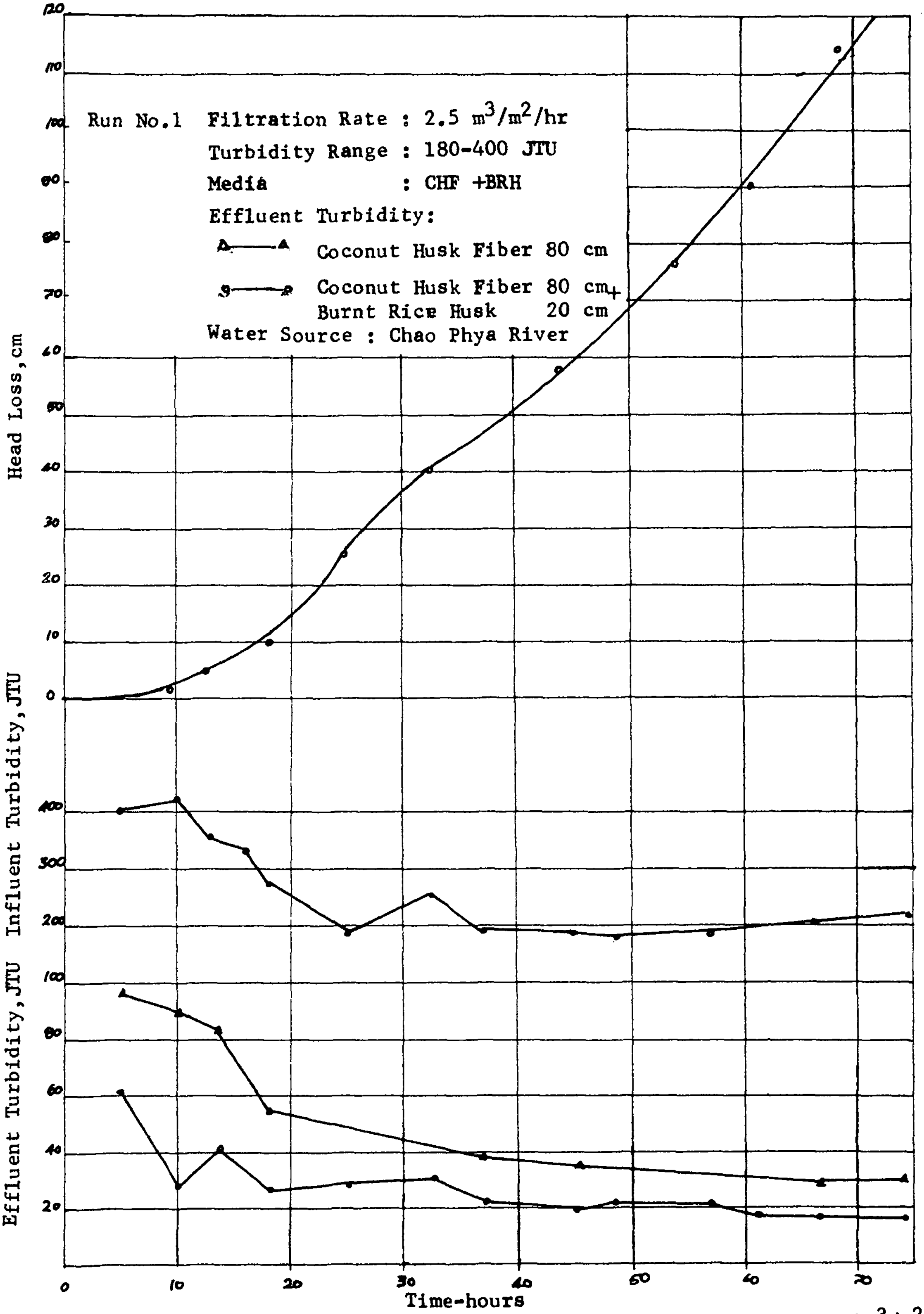


Fig.III-1- Filter Performance of Combined Media- CHF+BRH at $2.5 m^3/m^2/hr$

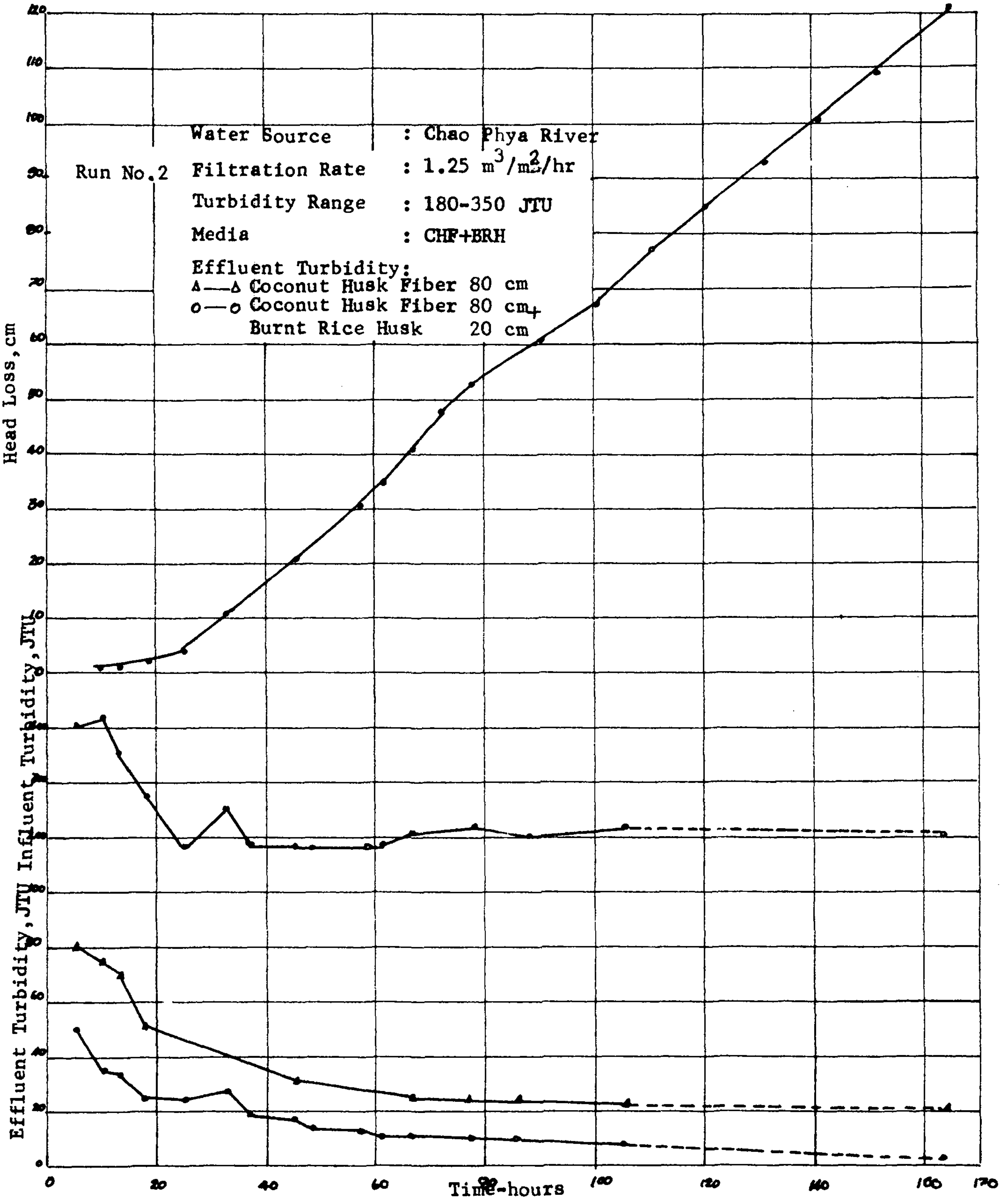


Fig.III-2- Filter Performance of Combined Media-[illegible]+BRH at 1.25 $m^3/m^2/hr$

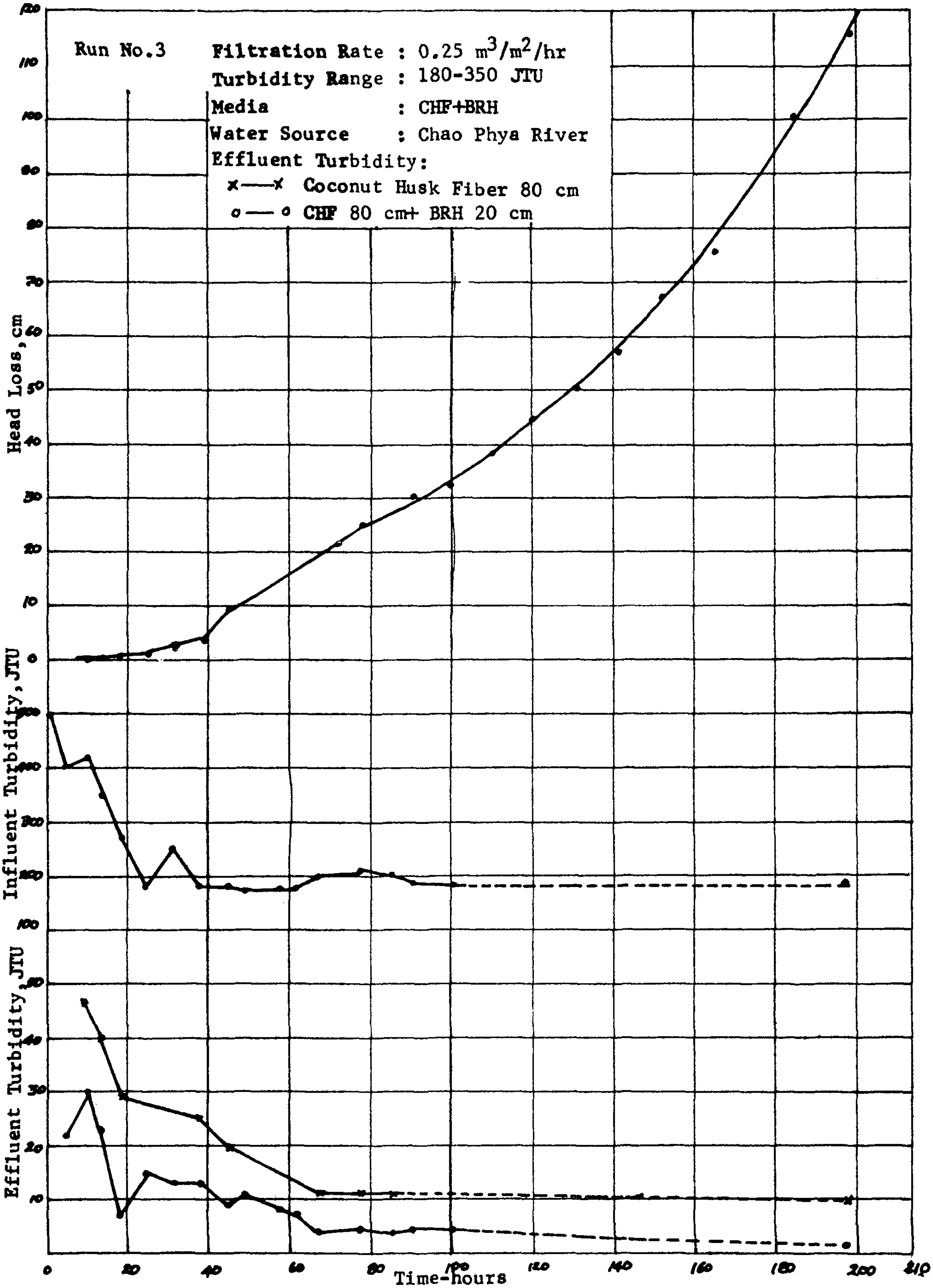


Fig.III-3- Filter Performance of Combined Media-CHF+BRH at 0.25 m^3/m2/hr

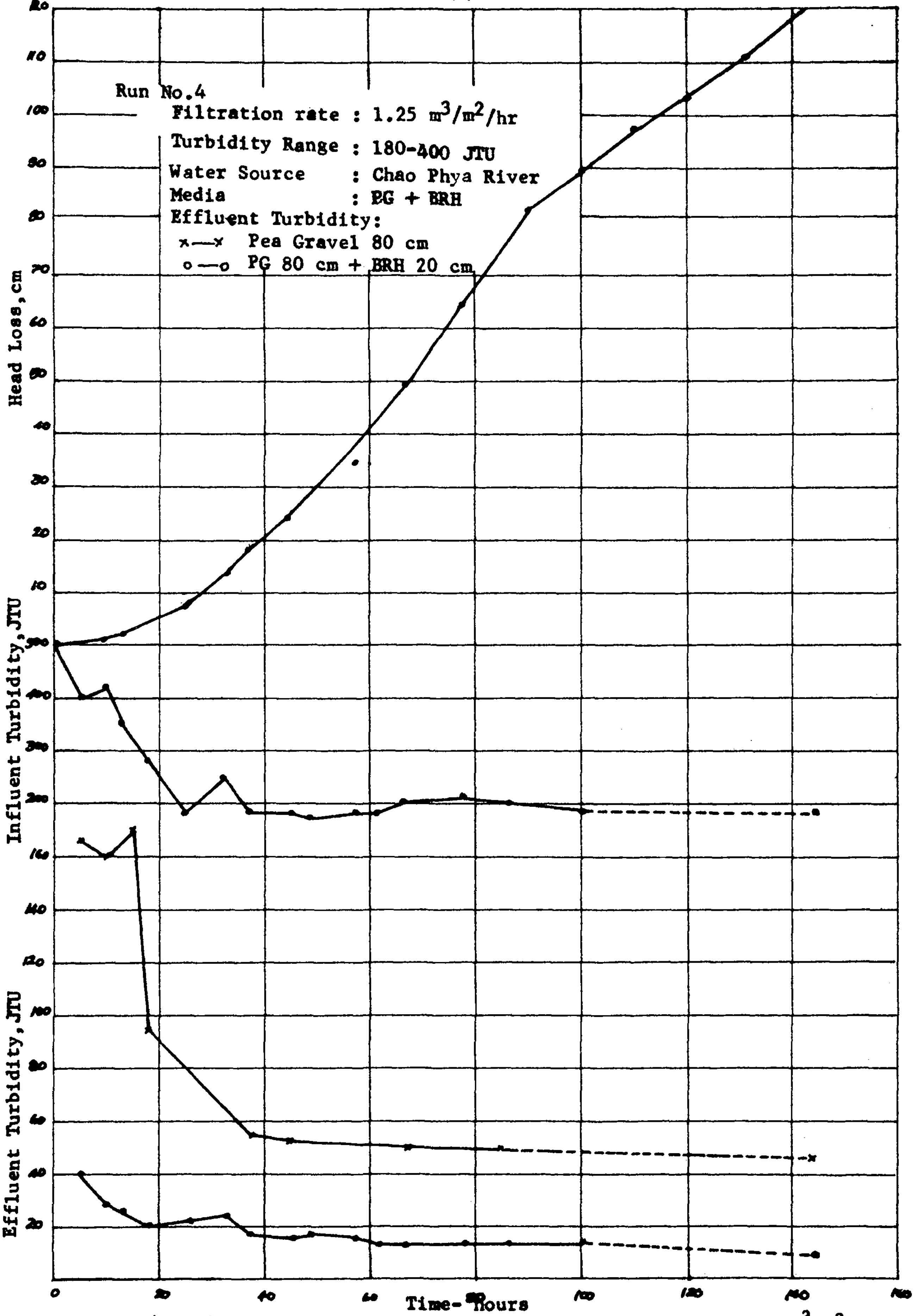


Fig.III-4- Filer Performance of Combined Media- PG + BRH at 1.25 $m^3/m^2/hr$

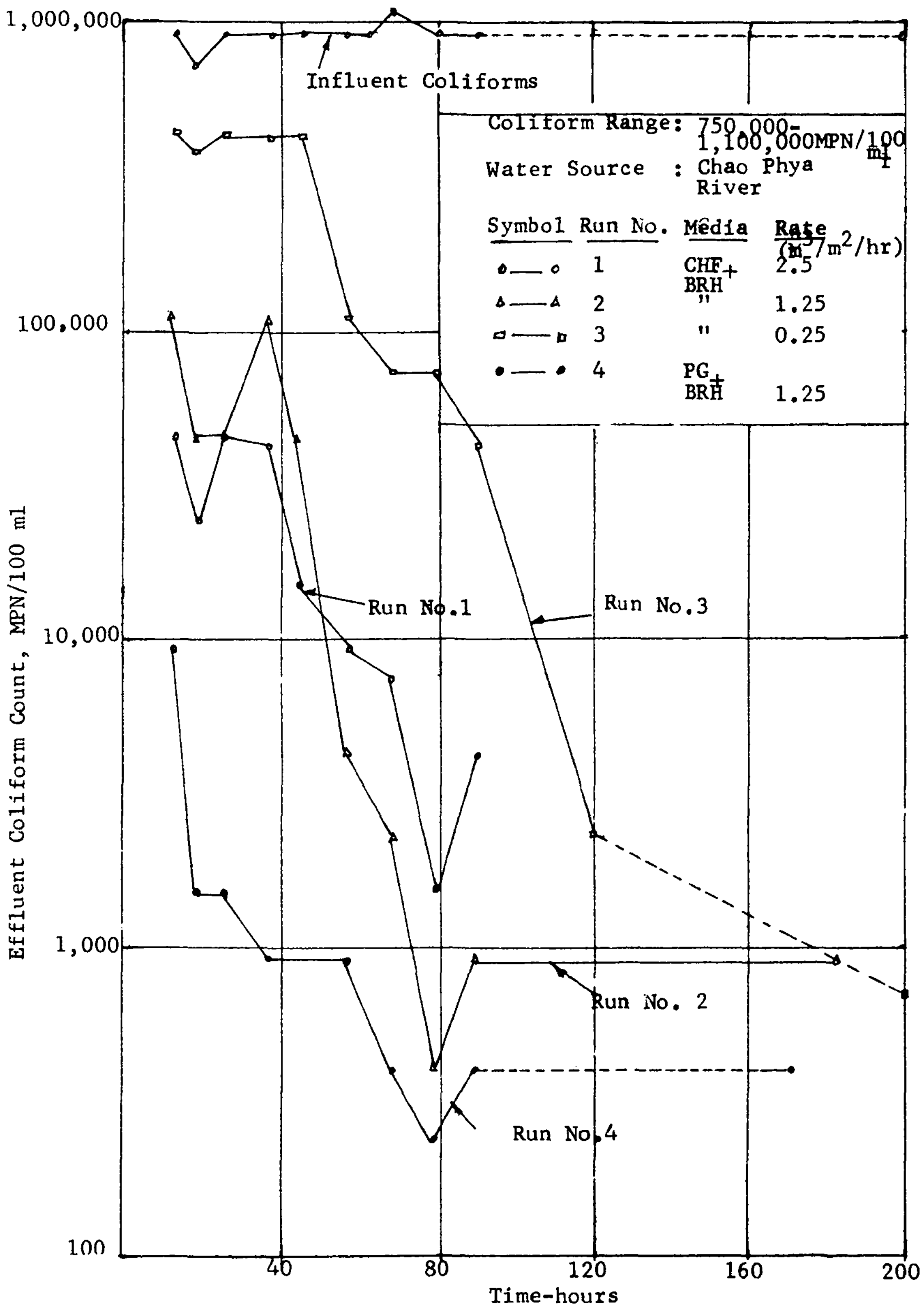


Fig.III-5- Comparison of Effluent Coliform of Combined media at different filtration rates

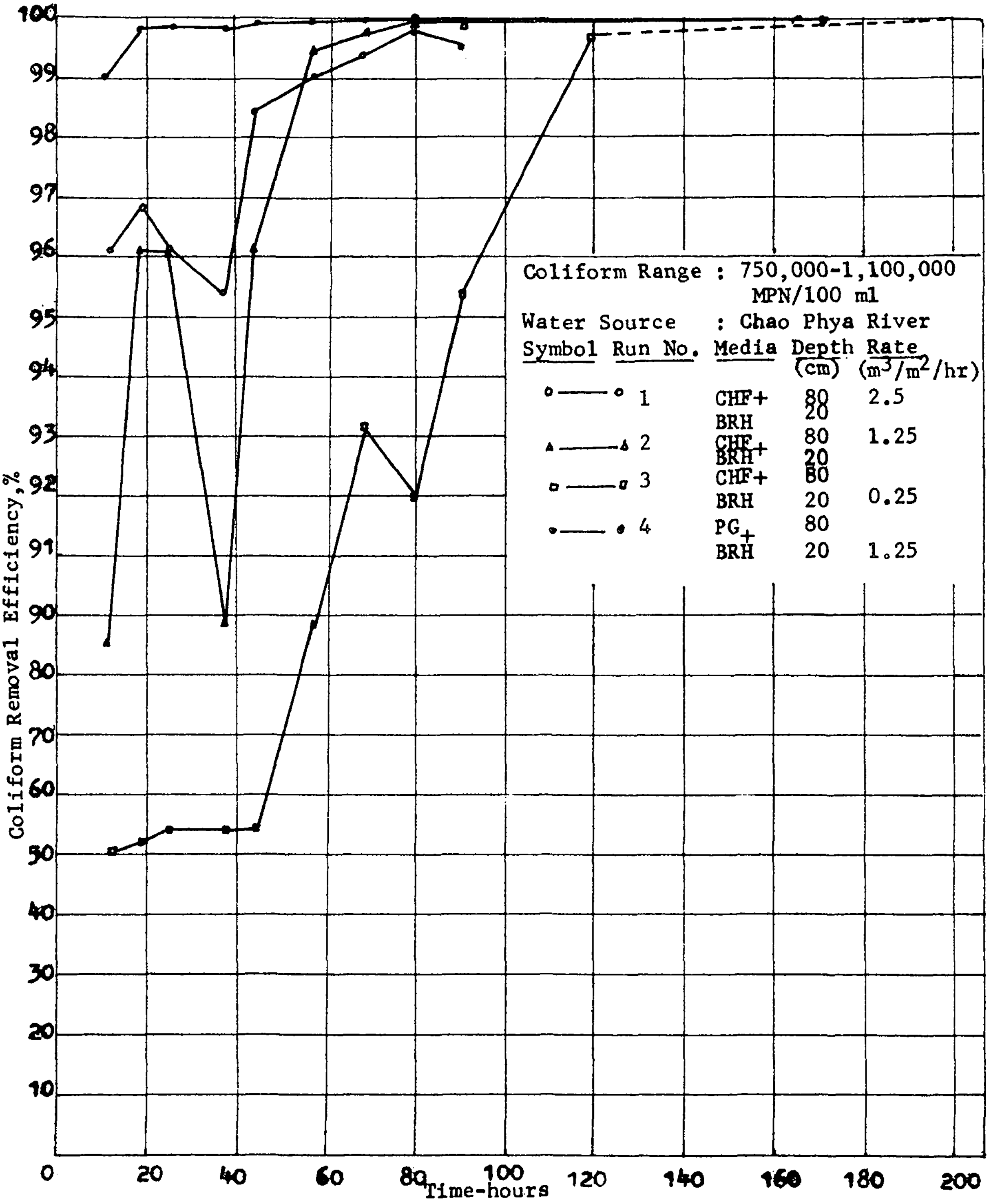


Fig.III-6- Comparison of Coliform Removal Efficiency of Combined Media at Different Filtration Rates

Run Series IV : Study on the Use of Dual Media to Treat High Rate Oxidation Pond Effluent from Flotation Unit

The Series of tests were run by using high rate oxidation pond effluent from flotation unit which was delivered from Applied Scientific Research Corporation of Thailand to the Environmental Engineering laboratory of the Asian Institute of Technology by truck. The series of runs were conducted using filter columns of coconut husk fiber at 1.25 $m^3/m^2/hr$, burnt rice husk at 0.25 $m^3/m^2/hr$ and dual media-coconut husk fiber 80 cm with burnt rice husk 20 cm at filtration rates of 1.25 and 0.25 $m^3/m^2/hr$. Laboratory tests on turbidity, coliform organisms, COD, NH_3-Nitrogen, organic-nitrogen, colour were conducted in these runs.

Comparison of Coconut Husk Fiber and Dual Media at 1.25 $m^3/m^2/hr$

Filter performance of these two runs are shown in Fig IV-1 and Fig. IV-3. Effluent turbidity of the dual media dropped rapidly to 2.2 JTU at the first hours of run and remained low throughout the run. Effluent turbidity of coconut husk fiber alone was below 5.0 JTU after 40 hours of operation. The duration of run of the dual media was decreased 19.6% from that of coconut husk fiber alone at 100 cm depth. Coliform removal of coconut husk fiber alone was only 50% at the early hours of run. It took more than half the duration of run to reach the efficiency removal of 99%. This was compared with the dual media which removed coliform organisms by 96% within a few hours because of the biological layer that developed on the interface of coconut husk fiber and burnt rice husk. Colour removal by both filters was between 80 and 90% COD removal was also high and similar amounting to about 80%. The NH_3-Nitrogen removal efficiency of the dual media was 4% higher than the efficiency of coconut husk fiber alone.

Comparison of Coconut Husk Fiber and Dual Media at 0.25 $m^3/m^2/hr$

Filter performance of burnt rice husk at depth 20 cm is shown in Fig. IV-2. Effluent turbidity for good operation was in range of 0.5-0.8 JTU. This run experienced difficulties in operation due to short circuiting along the corner of the filter column. Thus, after this filter was run for 120 hours, the effluent turbidity increased to 13.0 JTU.

For coliform removal at this rate, the results obtained were very good due to the high efficiency at the beginning of run (99.06%) and this efficiency increased with duration of run up to 99.91%.

Filter performance of the dual media at 0.25 $m^3/m^2/hr$, shown in Fig. IV-4, showed an effluent turbidity in the same range of the dual media at 1.25 $m^3/m^2/hr$. Coliform removal efficiency was only 63% in the beginning of run because at slow rate the biological layer which formed in the interface grew more slowly than at the fast rate. The high efficiency of 90.69% was reached only after 130 hours of the run.

For COD test, it was found that coconut husk fiber alone did not remove COD as high as burnt rice husk or the combination of burnt rice husk and coconut husk fiber. Colour removal was equally good for both types of filters.

Comparison of Dual Media versus Removal Efficiencies Reported by Tuntoolavest, M. (1971)

The purpose of treating high rate oxidation pond effluent from flotation unit is for re-use as drinking water. Dual media of coconut husk fiber 80 cm with brunt rice husk 20 cm of depth was conducted of filtration rate 1.25 m^3/m^2/hr and the removal efficiencies using this combination compared with the removal efficiencies of the various processes used by Tuntoolavest (1971) to treat this waste are shown in Table 15 Processes used in after alum flotation to remove algae were:

(1) addition of lime to raise the pH for air stripping of ammonia;

(2) sedimentation; and

(3) dual media filtration using anthracite and sand. The dual media of coconut husk fiber and burnt rice husks at a filtration rate 1.25 m^3/m^2/hr produced an equally good effluent in term of turbidity and organic-nitrogen removal (equivalent to removal efficiency achieved by Tuntoolavest for all three processes) COD removal was better in the coconut husk fiber plus burnt rice husk filter by a considerable amount. Very little NH_3-Nitrogen was removed as previously noted. (maximum 16%). Coliform removal also appeared to be superior in the dual coconut husk fiber and burnt rice husk filter.

Table 14 - Summary of Results in Run Series IV

Run No.	Media	Depth (cm)	Filtration Rate (m^3/m^2/hr)	Influent Turbidity Range (JTU)	Effluent Turbidity Range (JTU)	Turbidity Removal Efficiency Range (%)	Color (Hazen Unit)	Coliform Removal Efficiency Range (%)	COD		NH_3-N		Org-Nitrogen (mg/l)	Amount of Filtered Water (m^3/m^2 of bed)	Duration Run for Head Loss 1.2 m. (hours)	Rate of Head Loss (cm/hr)
									(mg/1)	(%) Removal	(mg/1)	(%) Removal				
1	CHF	100	1.25	20-60	17.5-1.2	75.5-97.2	<5	46.5-99.8	11.2	76.9	27.8	3.8	-	350	280	0.44
2	BRH	20	0.25	20-60	2.2-0.07	95.0-99.84	<5	99.1-99.9	5.6	88.5	25.0	13.5	1.0	43.4	173	0.69
3	CHF + BRH	80 20	1.25	20-60	4.5-0.40	91.8-99.07	<5	94.4-99.9	7.5	84.6	25.2	7.9	1.4	281	225	0.53
4	CHF + BRH	80 20	0.25	20-60	4.4-0.60	92.1-98.65	<5	63.5-99.85	5.6	88.5	24.2	16.2	3.2	25	340	0.35
Raw				Average = 43			30-40	240,000-750,000 MPN/100 ml	48.7		28.9		4.9			

Table 15 - Comparison of Removal Efficiencies for High Rate Oxidation Pond Effluent by Various Methods

Method	Turbidity (JTU)	COD (mg/l)	COD Removal (%)	Colour (Hazen Unit)	Org-N (mg/l)	NH_3-N (mg/l)	Coliforms (MPN/100 ml)	Coliform Removal Efficiency (%)
High Rate Oxidation Pond Effluent	NA	42.4			9.2	24.5	240^{**}	
Flotation*	NA	26.4	37.8		5.2	23.8	240^{**}	0
Lime addition + Ammonia stripping*	NA	25.8	39.2		5.1	1.1	240^{**}	0
Sedimentation*	17-24	19.2	54.3		3.2	1.1	96^{**}	60.0
Filtration*	0.10	18	57.6		2.8	1.1	38^{**}	84.2
Flotation Unit Effluent (1972)	20-60	48.7		30-40	4.9	28.9	240,000-750,000	
Dual Media							400-24,000	
Filtration through Coconut Husk Fiber	0.4-4.5	7.5	84.6	<5	1.4	25.2		
+Burnt Rice Husk at 1.25 $m^3/m^2/hr.$								94.42-99.91

* As reported in Tuntoolavest, M. Reclamation of Potable Water From High Rate Oxidation Pond Effluent, Master's Thesis, Asian Institute of Technology, Bangkok, 1971.

** Data reported by Tuntoolavest, M. It is probable that a factor of 10^3 was omitted from the reported data. In the run this year using the same pond effluent coliform concentrations were 240,000-760,000 MPN per 100 ml.

NA = not analysed.

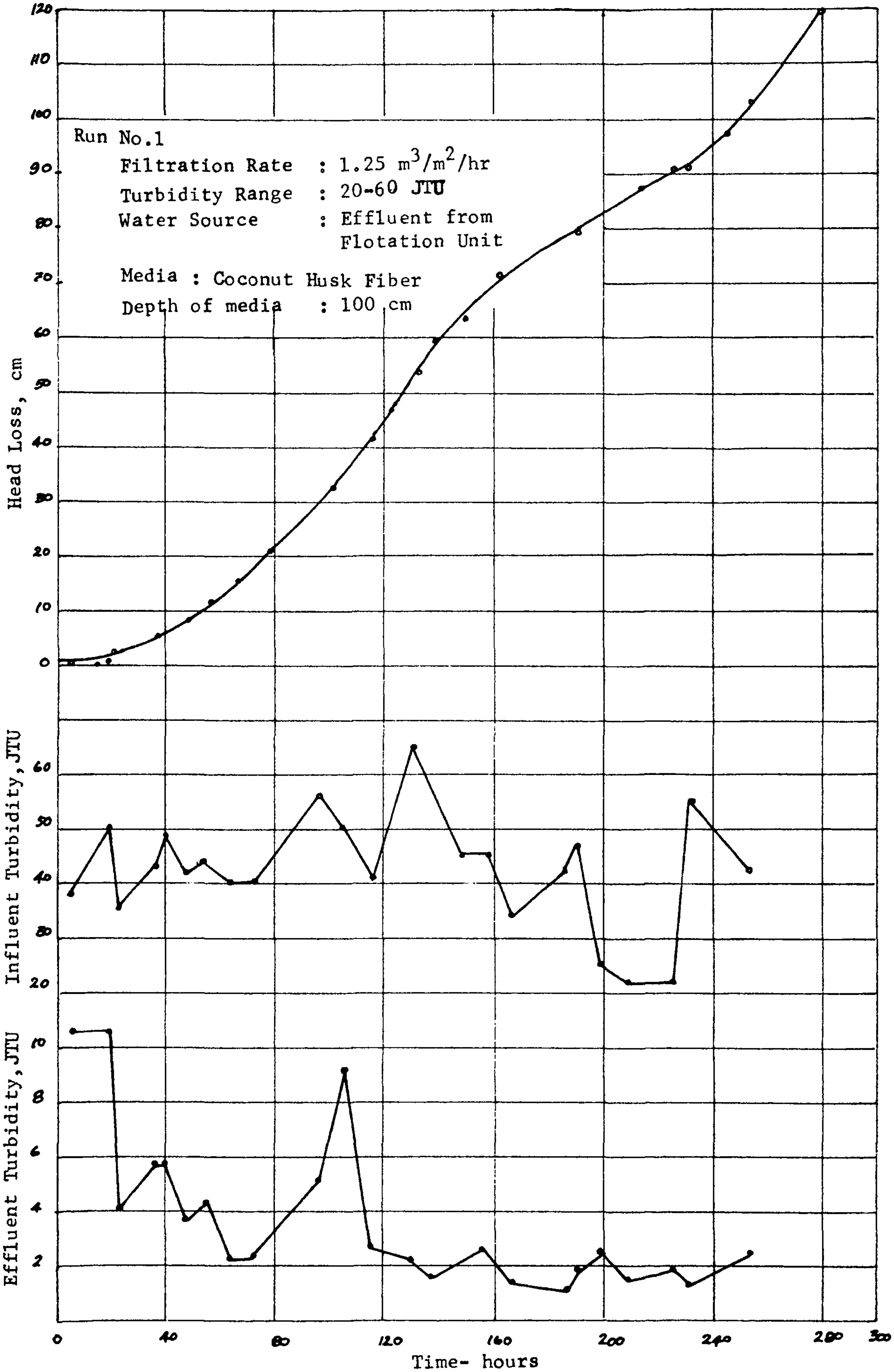


Fig.IV-1- Filter Performance of Coconut Husk Fiber at 1.25 $m^3/m^2/hr$

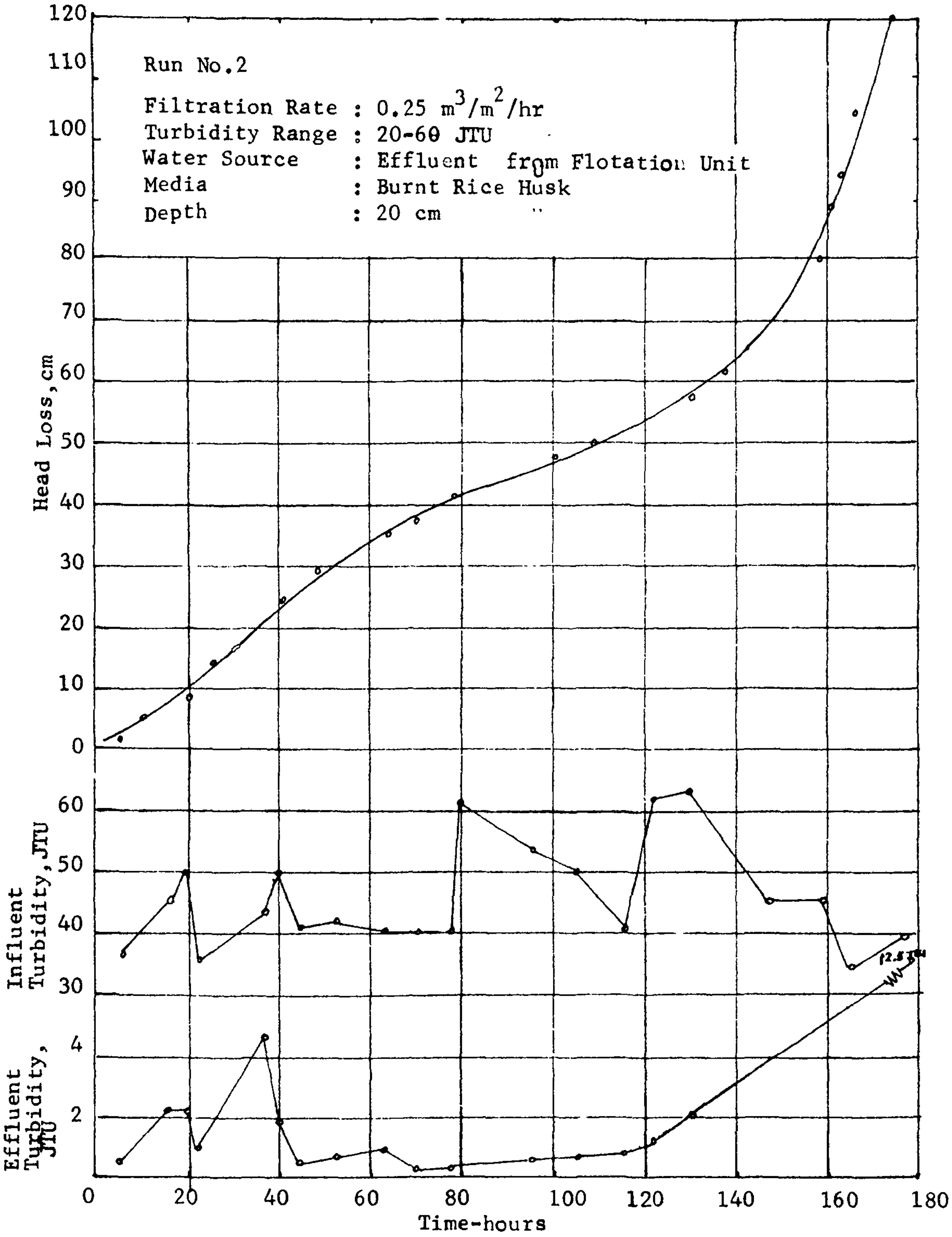


Fig.IV-2- Filter Performance of Burnt Rice Husk at 0.25 m^3/m^2/hr

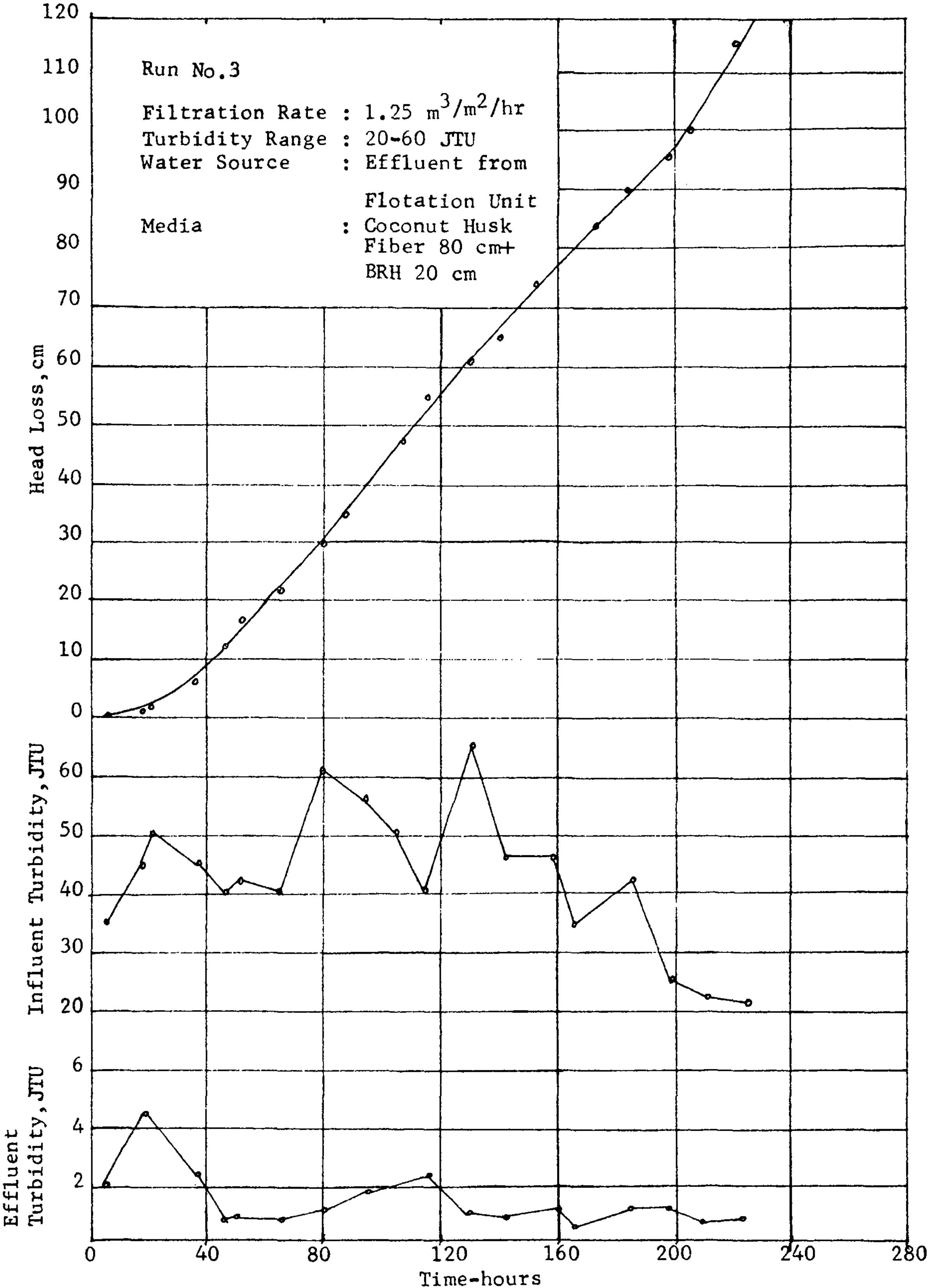


Fig.IV-3- Filter Performance of Combined Media- CHF+BRH at 1.25 $m^3/m^2/hr$

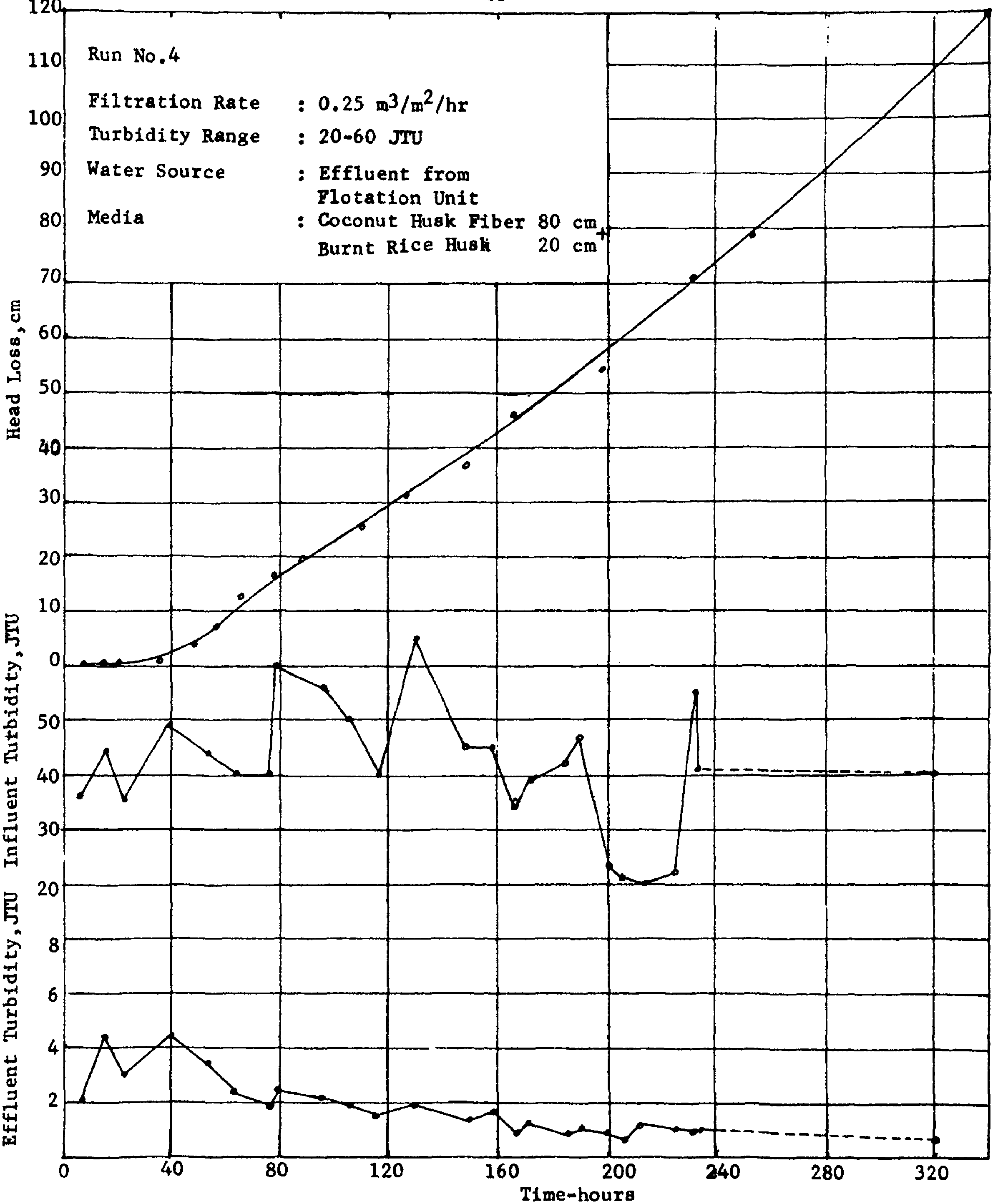


Fig.IV-4- Filter Performance of Combined Media- CHF+ BRH at $0.25 m^3/m^2/hr$

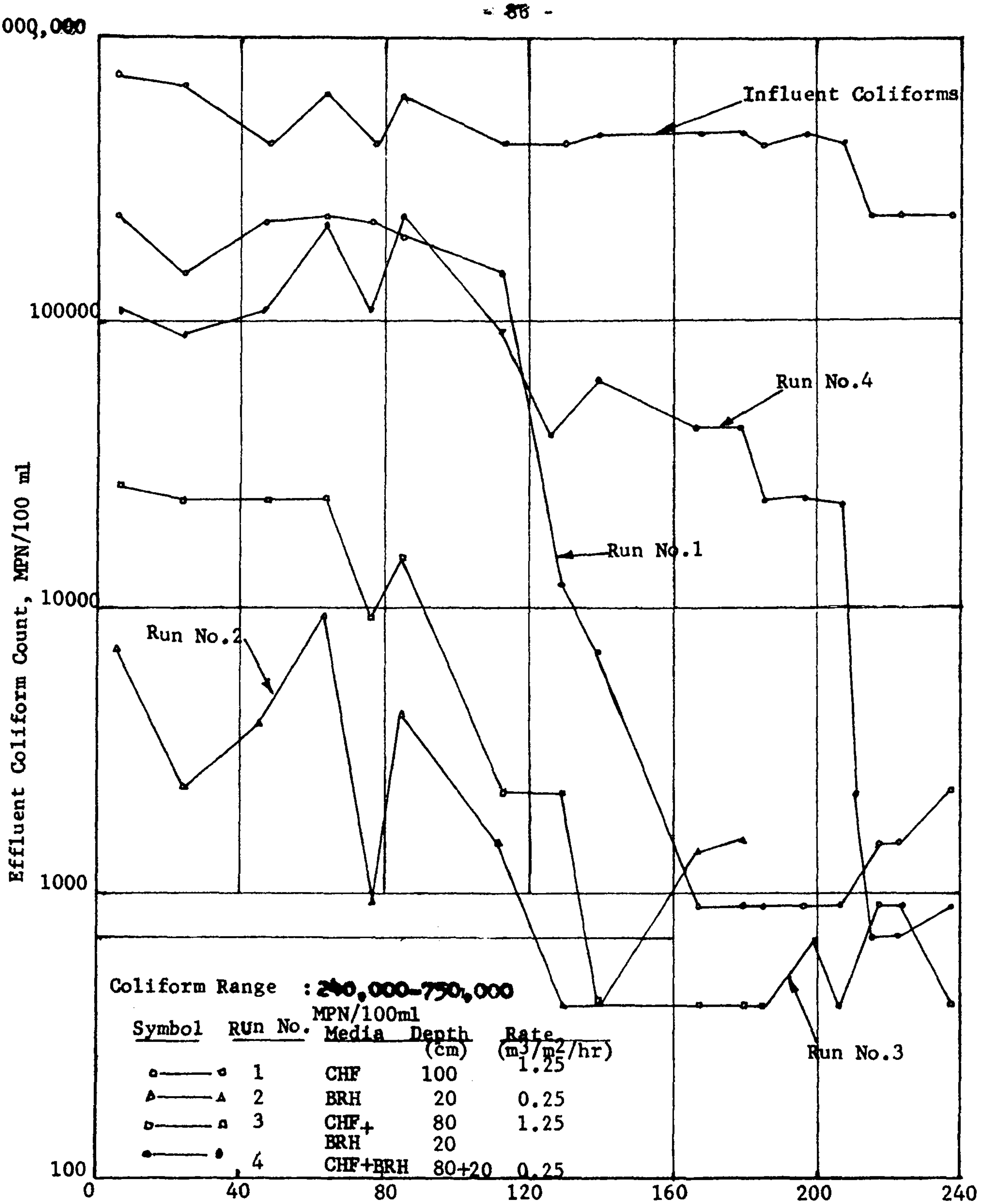


Fig.IV-5- Comparison of Effluent Coliform of Combined media and Single media at 1.25 and 0.25 $m^3/m^2/hr$

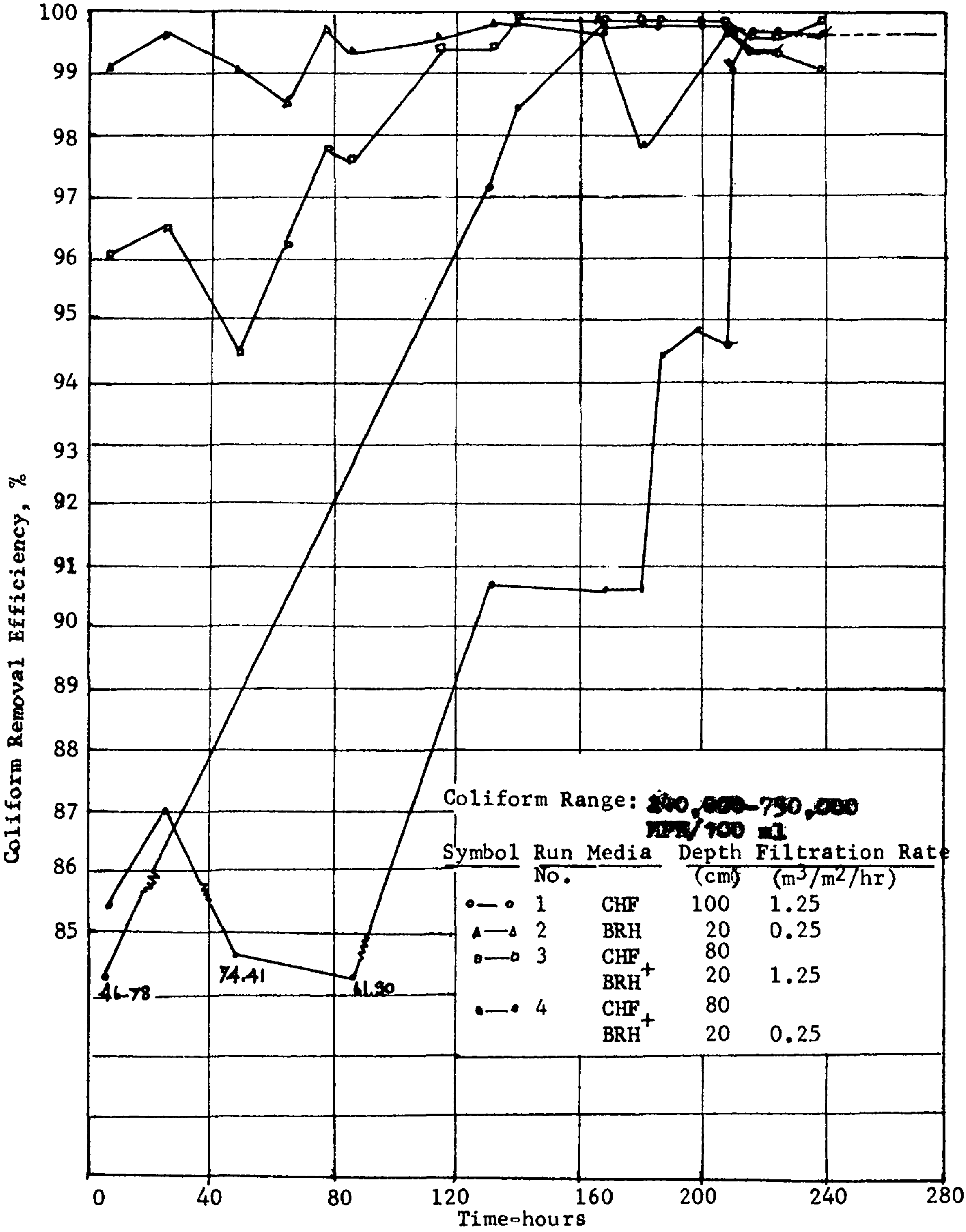


Fig.IV-6- Comparison of Coliform Removal Efficiency of Combined Media and Single Media at 1.25 and 0.25 $m^3/m^2/hr$

Summary of Results

Run Series I

a) Coliform removal efficiency for sand, effective size 0.30 mm. and uniformity coefficient 2.66, of depth 80 cm at filtration rate 0.25 and 0.10 m^3/m^2/hr, influent turbidity 15-40 JTU, was upto 99% after the 100th hour of operation and it reached 99.997-99.998% at the end of runs. Average effluent turbidity at both rates was 0.90 JTU.

b) Duration of run at filtration rate 0.10 m^3/m^2/hr was only 17 hours longer than at 0.25 m^3/m^2/hr.

c) Sand at filtration rate 2.5 m^3/m^2/hr gave the effluent turbidity less than WHO Standard of 5.0 JTU - about 1.0 JTU but this rate was not desirable because of too rapid build up in head loss of 1.2 meters.

d) Sand at filtration rate 1.25 m^3/m^2/hr had the duration of run three times the rate of 2.5 m^3/m^2/hr and effluent turbidity was less than 0.5 JTU after 30 hours of operation.

e) Comparison of total turbidity removed and amount of water filtered versus filtration rates showed that total turbidity removed was maximum at filtration rate 1.25 m^3/m^2/hr.

f) Burnt rice husks at 0.25 and 0.10 m^3/m^2/hr were investigated at depth 80, 40 and 20 cm. to determine the effect of different depth of media on turbidity and coliform removal efficiencies. Average effluent turbidity at both filtration rates of three different levels was less than 0.40 JTU.

g) Coliform removal efficiency of burnt rice husk 80 cm depth at 0.25 and 0.10 m^3/m^2/hr reached 99% in 24 hours operation. At 40 cm depth, the same removal efficiency was obtained in 78 hours, and at 20 cm depth in 146 hours.

h) Burnt rice husks of 80 cm depth at 2.5 and 1.25 m^3/m^2/hr had the average effluent turbidity less than 0.20 JTU. Filtration rate 2.5 m^3/m^2/hr should not be considered because of too rapid end of run. Duration of run at 1.25 m^3/m^2/hr was nearly four times that at 2.5 m^3/m^2/hr.

i) Total turbidity removal, amount of water filtered at 2.5, 1.25, 0.25 and 0.10 m^3/m^2/hr of burnt rice husks 80 cm depth was compared with sand of the same depth and at the same filtration rates. Burnt rice husks had the turbidity removal efficiency more than sand at any filtration rates and also showed the maximum at filtration rate 1.25 m^3/m^2/hr.

Run Series II

a) Coconut husk fiber of 120 cm. depth at 2.5 $m^3/m^2/hr$ and 1.25 $m^3/m^2/hr$ removed turbidity more than that of 100 and 80 cm. Depth of media had the effect to duration of runs and also turbidity removal.

b) At filtration rate 1.25 $m^3/m^2/hr$, minimum depth of coconut husk fiber was 80 cm because turbidity removal efficiency was much different at depth below 80 cm.

c) At the same depth of medium, duration of run at 1.25 $m^3/m^2/hr$ of coconut husk fiber was nearly twice the length of run at 2.5 $m^3/m^2/hr$.

d) A dual media filter comprised of 60 cm coconut husk fiber and 20 cm of burnt rice husk at 1.25 $m^3/m^2/hr$ and 0.25 $m^3/m^2/hr$ removed turbidity more than using coconut husk fiber alone at a depth of 120 cm. Turbidity removal by the dual media filter at both rates were nearly the same but at the rate of 1.25 $m^3/m^2/hr$ the duration of run indicated that the amount of water filtered, m^3/m^2 of bed, was four times that of the slow rate.

Run Series III

a) Dual media of coconut husk fiber 80 cm with burnt rice husk 20 cm of depth at 2.5 and 1.25 m^3/m^2/hr can remove coliform organisms better than the slow rate of 0.25 m^3/m^2/hr while the turbidity removal was better at the lower filtration rate.

b) Duration of run at filtration rate 1.25 m^3/m^2/hr was twice that at 2.5 m^3/m^2/hr while the length of run at 0.25 m^3/m^2/hr was only 40 hours longer than that at 1.25 m^3/m^2/hr.

c) COD removal of dual media was maximum at filtration rate 1.25 m^3/m^2/hr. Thus, the filtration rate 1.25 m^3/m^2/hr was the most attractive rate of dual media.

d) Dual media - pea gravel, effective size ¼ - 3/8", 80 cm of depth and burnt rice husks of 20 cm depth showed the highest coliform removal efficiency of 99% after only ten hours of operation. COD was removed by 50% by this dual media.

Run Series IV

a) Dual media of coconut husk fiber 80 cm with burnt rice husks 20 cm of depth, at filtration rate 1.25 m^3/m^2/hr showed coliform removal efficiency of 96% within a few hours operation while at filtration rate 0.25 m^3/m^2/hr the efficiency was only 63%. Effluent turbidity at both rates was always below 5.0 JTU.

b) Coconut husk fiber at 100 cm depth at filtration 1.25 m^3/m^2/hr cannot be used alone to treat this waste.

c) Burnt rice husks at 20 cm depth at 0.25 m^3/m^2/hr showed coliform removal efficiency of 99% at the beginning of run but the duration of run was only half of that of dual media at the same rate.

d) Comparison of removal efficiencies between dual media at 1.25 m^3/m^2/hr and several conventional processes used by Tuntoolavest (1971) showed that this dual media produced an comparable quality in terms of turbidity, coliform removal, organic-nitrogen, colour and COD.

V CONCLUSIONS

Experimental studies using coconut husk fiber, burnt rice husk, pea gravel and sand under various configurations and water qualities were conducted. Conclusions from these experiments can be summarized as follows:

1. Burnt rice husk at any depth of media - 80, 40, and 20 cm - at filtration rate of 0.1 - 0.25 $m^3/m^2/hr$ had the same removal efficiency of turbidity with different depths. At a depth of 80 cm and filtration rate 0.10 - 0.25 $m^3/m^2/hr$ the coliform removal efficiency reached 99.3 - 99.8% at the beginning of run while at 40 cm of depth it was not obtained until 78 hours of operation and at 20 cm of depth not until 148 hours. These periods of time are equivalent to 13 and 24 villages days of filter operation period of 6 hours. Depth of 80 cm should be preferred to other depths for high coliform removal efficiency where it is unlikely that chlorination will be practised in the village. The removal efficiency of coliform at depth 80 cm was 99.8% at the first 24 hours of operation. The percentage is expected to be 99.9 or 99.99% for treating village raw water.

2. At any constant filtration rate the greater the depth of coconut husk fiber the greater the turbidity removal and the longer the duration of run. Duration of run at any constant depth at a filtration rate 1.25 $m^3/m^2/hr$ was twice that at filtration rate of 2.5 $m^3/m^2/hr$. The minimum depth of using coconut husk fiber alone should not be less than 80 cm.

3. A dual media filter comprising coconut husk fiber of 80 cm depth and burnt rice husk of 20 cm depth at filtration rate 2.5 and 1.25 m^3/m^2/hr removed coliform organisms better than the slow rate of 0.25 m^3/m^2/hr. However, the maximum efficiency at the first 40 hours of operation was only 96% which was still too low for potable water supply.

4. A filter depth of 20 cm of burnt rice husk is enough in a dual media filter for village water supply where chlorination will be used thereafter.

5. A dual media filter comprising pea gravel effective size ¼"-3/8", of 80 cm depth and burnt rice husk 20 cm depth, at filtration rate 1.25 m^3/m^2/hr had the same efficiency to remove turbidity as dual media of coconut husk fiber plus burnt rice husk and the coliform removal was as high as 99% after ten hours of operation. This type of dual media can be substituted in areas where the coconut husk fiber is limited. The difficulty of using pea gravel is that pea gravel from stock gravels cannot be used without prior sieve analysis to obtain proper size.

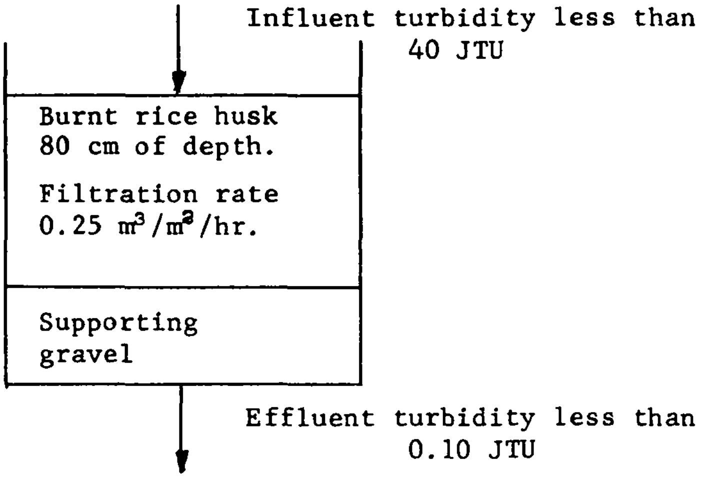
6. Comparison of turbidity removal efficiency between high load turbidity synthetic water and Chao Phya River water at the same range of influent turbidity, showed that the turbidity in tap water with added kaolin clay could be removed more easily than that in river water. Effluent turbidity of dual media using synthetic water was always better than the WHO standard for drinking water. Using river water, the dual media only met the standard at the filtration rate of 0.25 m^3/m^2/hr. Coliform organism removals by the various media showed the same range

of efficiencies 96-99% for both types of water.

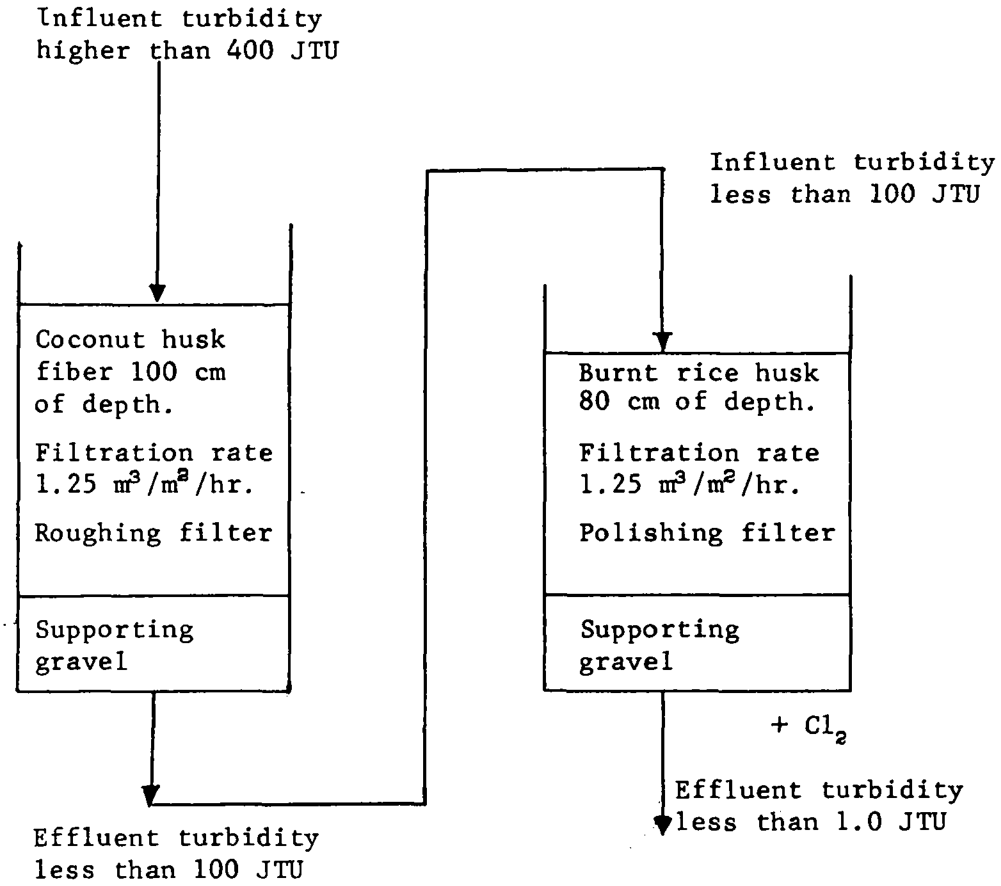
7. A dual media filter of coconut husk fiber 80 cm plus burnt rice husk 20 cm at filtration rate of 1.25 m^3/m^2/hr provides the same length of run as coconut husk fiber 80 cm depth alone (between 150 and 160 hours of operation before a head loss of 1.2 meters is reached). Turbidity and coliform removals in the mixed media filter were higher than in single coconut husk filter. Thus a dual media filter is recommended over a single medium filter of coconut husk fiber alone.

8. For ground water or surface water of low turbidity (less than 40 JTU), it appears that a single media filter of burnt rice husk will be satisfactory. The single burnt rice husk filter provides high efficiency to remove coliform and turbidity because a biological layer on the surface of the medium itself can be well formed. The duration of run at a filtration rate of 0.25 m^3/m^2/hr varied between 190 to 210 hours or approximately 35 days of equivalent village filter operation.

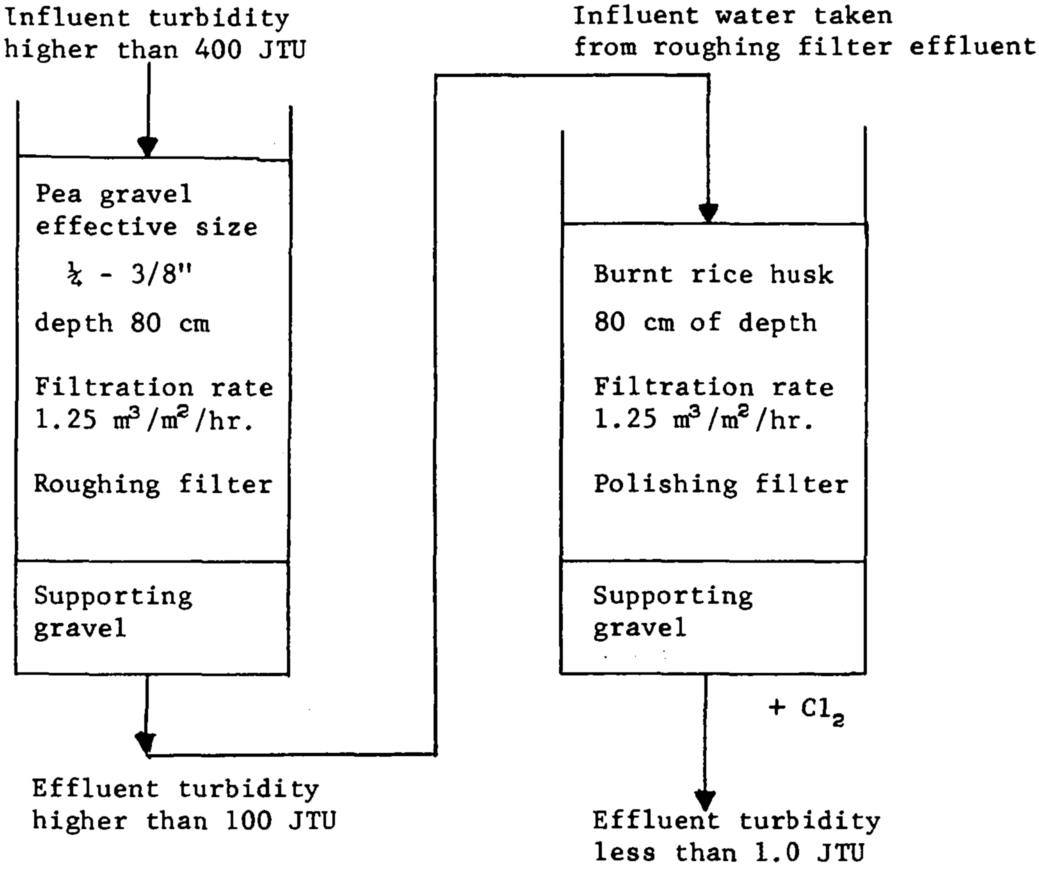
The configuration recommended is as follows:



9. For water of high load turbidity (higher than 400 JTU), series filtration will be applicable to treat this type of water. Coconut husk fiber of 100 cm, depth should be used as the roughing filter and at filtration rate 1.25 $m^3/m^2/hr$ and burnt rice husk of 80 cm depth as the polishing filter at 1.25 $m^3/m^2/hr$. This series filter can be used to obtain a coliform removal efficiency of 99.8% in few hours of operation while the dual media filter reaches 96% removal only after 40 hours operation. The configuration recommended is as follows:



The alternative where coconut husk fiber is limited is to use pea gravel as the roughing filter and burnt rice husk as polishing filter medium. The configuration recommended is as follows:



10. As a polishing or tertiary process for waste water treatment and renovation, the dual media filter produced an effluent of comparable quality to that obtained by several conventional tertiary processes, except for NH_3-nitrogen removal which was inadequate. Duration of run averaged almost 300 hours before a head losses of 1.2 meters was reached. Algae, turbidity and coliform removals were greater than 90%. The dual media and coliform removals were greater than 90%. The dual media filter appears promising as a tertiary waste treatment process.

11. Advantages of the use of burnt rice husk and coconut husk fiber over use of available sand are concluded as follows:

a. The cost of filter media is very low. Only transportation cost of burnt rice husk from the mill to series water treatment plant is considered because burnt rice husk is free of charge. The cost of fibrous material shredded from the coconut husk is also low.

b. Duration of runs using burnt rice husk is always longer than that of sand. The length of run for coconut husk fiber even at high turbidity loading is almost 200 hours of operation.

c. For burnt rice husk at any depth and filtration rate, the efficiencies of turbidity and coliform removals are higher than that of sand.

VI RECOMMENDATIONS FOR FUTURE WORK

From the above studies it appears that depth of burnt rice husk of 40 cm. in dual media filter with coconut husk fiber reduced to 40 cm. instead of 80 cm. might have a coliform and turbidity removal efficiency higher than dual media of coconut husk fiber 80 cm. plus burnt rice husk 20 cm. It is expected that the head loss build up would not be adversely affected in this configuration. Experimental studies using this combination should be tested.

Further study should also be made at the Pilot Plant Scale utilizing both filter media combinations:

(i) A dual media filter of coconut husk fiber and burnt rice husk.

(ii) A dual media of pea gravel and burnt rice husk.

(iii) Series filtration of using coconut husk fiber as a roughing filter and burnt rice husk as apolishing filter.

Lastly, the dual media filters should be tested as potential waste treatment processed for various industrial and municipal wastewaters.

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