EPA-600/2-77-144
September 1977

Environmental Protection Technology Series

DOWNFLOW GRANULAR FILTRATION OF ACTIVATED SLUDGE EFFLUENTS

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA-600/2-77-144
September 1977

DOWNFLOW GRANULAR FILTRATION
OF
ACTIVATED SLUDGE EFFLUENTS

by

Robert P. G. Bowker
EPA-DC Pilot Plant
Washington, D.C. 20032

Contract No. 68-03-0349

Project Officer

Irwin J. Kugelman
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

In an effort to achieve a high quality effluent from wastewater treatment facilities, filtration has often been considered as an important integral part of the treatment sequence. This report summarizes the investigations at the EPA-DC Pilot Plant dealing with utilization of various filter media sizes and types for treatment of activated sludge process effluents.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

The performance of downflow granular filters subjected to effluents from activated sludge processes was investigated at the EPA-DC Pilot Plant in Washington, D.C. The 0.1 m^2 (1 ft^2) filters were operated at hydraulic loadings from 0.12 to 0.37 $m^3/min/m^2$ (3 to 9 gpm/ft^2). Several media combinations were investigated, including both single anthracite and dual anthracite-sand configurations. Effluents from step aeration, plug flow, and completely mixed activated sludge systems were used as feeds.

Breakthrough of the suspended solids into the effluent occurred with both the 1.65 mm and 2.0 mm effective size (E.S.) single anthracite configurations, becoming more evident at the higher flow rates.

A dual media filter, consisting of 2.0 mm E.S. coal over 0.9 mm E.S. sand, exhibited the most desirable characteristics for filtration of the secondary effluents investigated. The advantages were longer run times and higher suspended solids loadings with virtually no deterioration of effluent quality.

A backwash study conducted at a variety of backwash flowrates showed that a 13 percent bed fluidization was achieved with the coarse media (2.0 mm E.S. coal/0.9 mm E.S. sand) at a flow rate of 1.43 $m^3/min/m^2$ (35 gpm/ft^2). This was sufficient to effectively cleanse the media.

This report was submitted in fulfillment of Contract No. 68-03-0349 by the EPA-DC Pilot Plant under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from September 1974 to May 1975, and work was completed as of July 1975.

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of the operators, technicians and laboratory staff at the EPA-DC Pilot Plant in the construction, operation and maintenance of the systems described in this report.

SECTION 1

INTRODUCTION

Achievement and maintenance of a high quality effluent from wastewater treatment facilities will continue to warrant increased utilization of downflow granular filters for removal of suspended solids. As effluent standards tighten, many wastewater treatment operations will employ some form of filtration to meet effluent suspended solids criteria.

In the design of filtration systems, three classes of parameters must be considered. These are: wastewater feed characteristics (suspended solids concentration, floc size distribution, floc strength and floc charge), filter media characteristics (media type, size distribution, shape, and depth), and operational conditions (hydraulic loading, terminal head loss, and type of media cleaning technique).

The filtration characteristics of activated sludge effluents are expected to vary with the operational parameters of the activated sludge process (D.O. level and SRT) and the process mode used (step aeration, complete mix, etc) . The original purpose of this study was to evaluate in parallel the filterability of activated sludge effluents from the three most popular process flow regimes (plug flow, complete mix, and step aeration). The activated sludge systems were to be operated under identical conditions and each of the filters was to be identical in media type, depth, and size. It was found, however, that periodic upsets, primarily due to proliferation of either filamentous organisms or Norcardia sp., made it impossible to operate these three process modifications under identical conditions for long periods of time. In addition, it was found to be difficult to prepare three filters in which the media size and depth were the same (within the allowable experimental variation).

Therefore, after several runs were made, the objective of the study was modified. The new objective was to study the effect of media characteristics on the filterability of effluents from each activated sludge modification in order to determine the most effective media configuration. The filters were packed with various media and used in parallel to treat effluent from only one of the process modifications at a time.

A wide range of particle sizes has been suggested for dual media filtration of secondary effluents, effective sizes varying from 1.0 to 2.0 mm for anthracite, and 0.4 to 0.9 mm for sand. Media depths generally vary from 38 to 64 cm (15 to 25 in) for anthracite and 30 to 38 cm (12 to 15 in) for silica sand.

This study attempted to assess the value of using various sizes of filter media for removal of suspended solids from each of three secondary effluents (step aeration, plug flow, and completely mixed activated sludge). Special consideration was given to the possibility of utilizing a relatively coarse, deep bed media configuration that could maintain an effluent of suitable quality while demonstrating longer run lengths and higher suspended solids loadings.

SECTION 2

SUMMARY

The performance of downflow granular filters receiving effluents from activated sludge processes was investigated at the EPA-DC Pilot Plant in Washington, D.C. The 0.1 m^2 (1 ft^2) filters were operated at hydraulic loadings from 0.12 to 0.37 $m^3/min/m^2$ (3 to 9 gpm/ft^2). Several media combinations were investigated, including both single anthracite and dual anthracite-sand configurations. Effluents from step aeration, plug flow, and completely mixed activated sludge systems were used as filter feeds. The influent and effluent streams were monitored for suspended solids (SS), and the differential pressures across the filter media were recorded periodically. The filters were backwashed when the total head loss exceeded 2.5 m (100 in) or when breakthrough of the suspended solids was detected.

Breakthrough of the suspended solids into the effluent occurred with both the 1.65 mm and 2.0 mm effective size (E.S.) single anthracite configurations, becoming more evident at the higher flowrates.

A dual media filter, consisting of 2.0 mm E.S. coal over 0.9 mm E.S. sand, exhibited the most desirable characteristics for filtration of the secondary effluents investigated. The advantages were longer run times and higher suspended solids loadings with virtually no deterioration of effluent quality compared to more conventional media combinations.

A backwash study conducted at a variety of backwash flowrates showed that a 13 percent bed fluidization was achieved with the coarse media (2.0 mm E.S. anthracite/0.9 mm E.S. silica sand) at a flow rate of 1.43 $m^3/min/m^2$ (35 gpm/ft^2). This was sufficient to effectively cleanse the media.

Problems encountered during operation of the pilot filters included unusually low influent suspended solids concentrations, and proliferation of Norcardia organisms in the activated sludge system. The latter caused considerable difficulty in attempting to assess the filterability of the three process effluents.

SECTION 3

CONCLUSIONS

From the investigations conducted at the EPA-DC Pilot Plant at Blue Plains, the following conclusions were drawn concerning downflow granular filtration of activated sludge effluents:

1. Use of relatively coarse media (64 cm of 2.0 mm effective size (E.S.) anthracite and 38 cm of 0.9 mm E.S silica sand) produced effluent qualities similar to those from much finer media gradations at hydraulic loadings of 0.12 to 0.37 $m^3/min/m^2$ (3 to 9 gpm/ft^2).

2. The 2.0 mm E.S. coal/0.9 mm E.S. sand media exhibited run lengths and suspended solids loadings significantly higher than other finer media gradations investigated.

3. A backwash rate of 1.50 $m^3/min/m^2$ (37 gpm/ft^2) for four minutes was sufficient to effectively cleanse the 2.0 mm E.S. coal/0.9 E.S. sand media. Air scour preceeding water backwash on both coarse and fine dual media filters was needed to prevent formation of "mud balls." Although the backwash water requirement for this media was greater than for media of smaller effective sizes, the frequency of backwash was reduced to such an extent that daily water production was relatively independent of filter media sizes.

4. 64 cm of 1.65 mm effective size anthracite was inadequate to sustain a high quality effluent at hydraulic loadings greater than 0.12 $m^3/min/m^2$ (3 gpm/ft^2).

5. For the coarse filter media investigated, the potential savings in backwash water resulting from less frequent backwash was offset by the greater backwash water requirement to achieve a desired uniform level of bed expansion. Thus, the values of net water production were similar for each media at any given flowrate. Based on effluent quality and net water production, there was no advantage in using a coarser filter media. However, the lower backwash frequency and correspondingly lower manpower requirements for backwash operations were a possible economic advantage.

SECTION 4

RECOMMENDATIONS

Based on the current literature and on investigations performed at the EPA-DC Pilot Plant with respect to filtration of activated sludge effluents, the following recommendations are suggested as topics for future research:

1. Determine the optimum bed expansion for backwashing dual media filters treating activated sludge effluents.
2. Investigate the amenability of effluents from extended aeration and high-SRT activated sludge processes for treatment by dual-media filters with coarse media gradations.
3. Assess the performance of coarse, dual-media filters under hydraulic and suspended solids surges.

SECTION 5

EXPERIMENTAL APPARATUS AND OPERATION

Three filters were constructed of 35.6 cm (14 in) diameter clear plexiglass columns approximately 2.4 m (8 ft) in length, each having a lateral surface area of 0.1 m^2 (1 ft^2) (see Figure 1). Taps were provided at 7.6 cm (3 in) intervals to monitor the differential pressure across the media. A 0.14 m^3/min (5 scfm) air wash system was installed so as to dissipate, during the backwash, scum formations in the filter media. For backwashing of the filters, tap water was pumped from a holding tank upward through the media at hydraulic loadings of up to 1.42 $m^3/min/m^2$ (35 gpm/ft^2) and discharged to drain.

The support media consisted of approximately 15 cm (6 in) of 1.3 cm (0.5 in) diameter stone, above which was placed 10 cm (4 in) of 0.3 cm (.125 in) diameter garnet to prevent the overlying sand from penetrating the support media. The filter media consisted of approximately 38 cm (15 in) of sand under 64 cm (25 in) of anthracite coal, except in the studies which utilized a single anthracite media.

Process effluent from step aeration, plug flow, completely mixed, and/or single stage nitrification-denitrification activated sludge systems was pumped to a splitter box, from which it flowed by gravity to the filters at hydraulic loadings from 0.12 to 0.37 $m^3/min/m^2$ (3 to 9 gpm/ft^2). As the differential pressure increased across the filter media, the height of the water increased in the column to maintain constant flow. A maximum of 3 m (10 ft) of total head was available, although backwash operations were initiated when the head exceeded 2.5 m (8.3 ft). The backwash sequence is discussed in Section 9.

During normal pilot operation of the filters, daily influent and effluent 4-hour composites were collected and analyzed for suspended solids (SS), volatile suspended solids (VSS), chemical oxygen demand (COD), and 5-day biochemical oxygen demand (BOD). Differential pressure readings were taken prior to, and immediately following, backwash, in addition to the normal 4-hour readings. During the special studies operations, differential pressure readings were taken hourly and the influent and effluent streams sampled every two hours for suspended solids analysis.

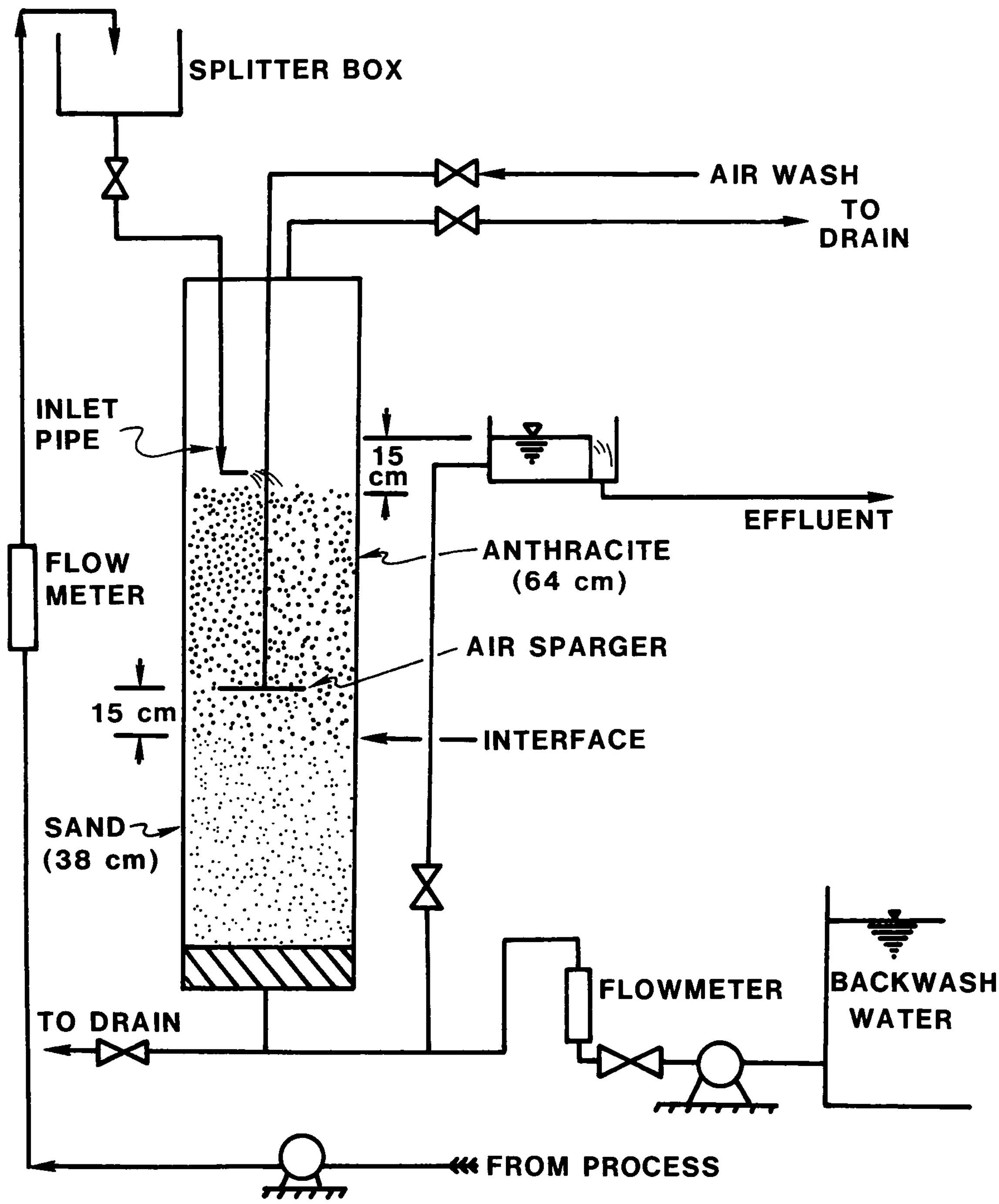

Figure 1. Schematic of Dual Media Filters

SECTION 6

EFFECT OF MEDIA CHARACTERISTICS ON FILTER PERFORMANCE

The three downflow granular filters were initially designed to contain 64 cm (25 in) of 1.3 mm effective size (E.S.) anthracite over 38 cm (15 in) of 0.65 mm effective size (E.S.) sand. However, due to widely varying run lengths produced under similar suspended solids loading conditions during the first few months of the study, it was suspected that differences in the media existed. During the period March-May, 1974, filters N, O, and P received the effluents from the step aeration, plug flow, and completely mixed activated sludge systems respectively. Thus, media comparison was not possible. To compare the performance of the filters, the effluent from the completely mixed system was fed to all three filters in June 1974. An analysis of the head loss characteristics confirmed the suspicion that filter P contained a finer gradation of media. (See Appendix, Figure A-1). Prior to replacement of the filter P media in September 1974, a sieve analysis of the existing anthracite yielded an E.S. of approximately 1.2 mm, as opposed to the 1.3 mm anthracite in filters N and O. Inspection of Appendix Figure A-1 also reveals a difference in head loss characteristics between filters N and O, which may be of great enough significance to make comparisons of filterability of the three process effluents difficult.

In addition to the difficulties in placement of identical filter media, a valve malfunction on filter O in July 1974 resulted in the loss of approximately 18 cm (7 in) of anthracite during backwash. Media replacement was not effected until September 16, 1974.

Since characterization of the filter media was not sufficient to allow effective data handling, the data from the period July 1-September 16, 1974 has been placed in the Appendix of this report.

During the week of September 16, the media in filters O and P was replaced. Filter O was packed with sand of effective size 0.8 mm and coal of effective size 1.65 mm. Filter P media was replaced with 64 cm (25 in) of 1.65 mm E.S. anthracite, with no underlying sand. It was intended that filter N media remain the same throughout the duration of the study to serve as a control. However, some media loss was experienced in November, 1974 (see Table 1).

Operation of the filters with the effluent from the completely mixed activated sludge system at 0.16 $m^3/min/m^2$ (4 gpm/ft^2) produced loadings of 0.433, 0.625 and 0.753 $kg/m^2/m$ head loss (.027, 0.039, and 0.047 $lbs/ft^2/ft$ head loss) for filters N, O and P respectively (see Table 2). Filter O accepted a

TABLE 1

CHARACTERISTICS OF FILTER MEDIA UTILIZED
DURING PERIOD
SEPTEMBER 1974-MAY 1975

	ANTHRACITE		SAND		
Filter	E.S. (mm)	Depth (cm)	E.S. (mm)	Depth (cm)	Dates
N	1.3	64	0.65	38	9/22-
O	1.65	64	0.8	38	11/5
P	1.65	64	-	-	
N	1.3	48	0.65	38	11/5 -
O	2.0	64	-	-	12/9
P	1.65	64	-	-	
N	1.3	48	0.65	38	12/9 -
O	2.0	64	-	-	1/13
P	2.0	64	0.9	38	
N	1.3	64	0.65	38	1/13-
O	2.0	64	0.65	38	5/30
P	2.0	64	0.9	38	

Uniformity coefficients:

Anthracite	1.5 - 1.6
Sand	1.4

TABLE 2

SUMMARY OF FILTER PERFORMANCE

Month	Filter	Media E.S. (mm) Coal/Sand	Flow $m^3/min/m^2$	Process Effluent Type/SRT (days)	Avg. SS in ppm	Avg. SS out ppm	Avg. % Rem.	Avg. Loading $Kg/m^2/m$ head loss
Sept. '74	N*	1.3/0.65	0.16	CM/2.0	9.6	2.9	70	0.38
	O*	1.65/0.79	0.16	CM/2.0	9.7	2.9	70	0.56
	P*	1.65/---	0.16	CM/2.0	9.7	3.5	64	0.55
Oct.	N	1.3/0.65	0.16	CM/2.0	16.5	6.6	60	0.43
	O	2.0/---	0.16	CM/2.0	15.2	6.0	61	0.63
	P	1.65/---	0.16	CM/2.0	16.5	7.5	55	0.75
Nov.	N*	1.3/0.65	0.20	STEP/3.7	5.6	2.1	62	0.32
	O*	2.0/---	0.20	STEP/3.7	6.8	3.4	50	---**
	P*	1.65/---	0.20	STEP/3.7	6.9	2.9	57	---**
	N*	1.3/0.65	0.20	PLUG/4.7	6.3	3.7	41	0.38
	O*	2.0/---	0.20	PLUG/4.7	6.8	4.4	35	---**
	P*	1.65/---	0.20	PLUG/4.7	7.3	4.4	40	---**
	N*	1.3/0.65	0.20	CM/4-7	42.5	1.1	97	1.19
	P*	1.65/---	0.20	CM/4-7	37.3	5.0	87	---**
	N*	1.3/0.65	0.29	CM/4-7	43.7	5.1	89	1.83
	N*	1.3/0.65	0.37	CM/4-7	28.9	2.9	91	1.27

* "special study" (short duration)
** run terminated before 2.5 m (100 in.) total head loss

TABLE 2 (con't)

SUMMARY OF FILTER PERFORMANCE

Month	Filter	Media E.S. (mm) Coal/Sand	Flow $m^3/min/m^2$	Process Effluent Type/SRT (days)	Avg. SS in ppm	Avg. SS out ppm	Avg. % Rem.	Avg. Loading $Kg/m^2/m$ head loss
Dec. '74	N*	1.3/0.65	0.12	CM/8.1	21.0	0.5	97	2.26
	O*	2.0/---	0.12	CM/8.1	21.8	2.3	89	---**
	P*	2.0/0.9	0.12	CM/8.1	21.0	0.5	97	3.56
	N*	1.3/0.65	0.20	CM/8.1	16.0	1.4	91	1.19
	O*	2.0/---	0.20	CM/8.1	17.8	4.9	73	1.97
	P*	2.0/0.9	0.20	CM/8.1	17.4	1.4	92	1.89
	N*	1.3/0.65	0.29	CM/8.1	30.8	1.4	95	2.00
	O*	2.0/---	0.29	CM/8.1	32.0	15.0	53	---**
	P*	2.0/0.9	0.29	CM/8.1	34.2	4.7	86	3.29
	N*	1.3/0.65	0.37	CM/8.1	34.7	6.1	83	1.88
	O*	2.0/---	0.37	CM/8.1	42.7	19.9	47	---**
	P*	2.0/0.9	0.37	CM/8.1	35.6	9.0	73	2.61
	N*	1.3/0.65	0.20	STEP/3.5	13.2	2.9	77	1.01
	O*	2.0/---	0.20	STEP/3.5	13.3	4.5	66	---**
	P*	2.0/0.9	0.20	STEP/3.5	13.4	2.9	78	1.70

* "special study" (short duration)
** run terminated before 2.5 m (100 in.) total head loss

TABLE 2 (con't)

SUMMARY OF FILTER PERFORMANCE

Month	Filter	Media E.S. (mm) Coal/Sand	Flow $m^3/min/m^2$	Process Effluent Type/SRT (days)	Avg. SS in ppm	Avg. SS out ppm	Avg. % Rem.	Avg. Loading $Kg/m^2/m$ head loss
Dec. '74	N*	1.3/0.65	0.29	STEP/3.5	16.7	9.4	52	0.46
	O*	2.0/---	0.29	STEP/3.5	14.4	9.2	44	---**
	P*	2.0/0.9	0.29	STEP/3.5	14.4	6.5	58	0.93
Jan. '75	N*	1.3/0.65	0.12	CM/6-7	16.3	2.1	87	2.21
	O*	2.0/0.65	0.12	CM/6-7	16.5	2.5	84	2.08
	P*	2.0/0.9	0.12	CM/6-7	15.6	2.1	86	3.70
	N*	1.3/0.65	0.20	CM/6-7	8.8	0.9	89	1.35
	O*	2.0/0.65	0.20	CM/6-7	9.2	1.0	88	1.79
	P*	2.0/0.9	0.20	CM/6-7	8.7	0.9	89	2.31
	N*	1.3/0.65	0.29	CM/6-7	32.6	8.5	74	1.94
	O*	2.0/0.65	0.29	CM/6-7	27.1	7.9	71	1.17
	P*	2.0/0.9	0.29	CM/6-7	31.[illegible]	9.8	69	2.31
	N*	1.3/0.65	0.37	CM/6-7	32.3	10.8	66	1.46
	O*	2.0/0.65	0.37	CM/6-7	39.3	14.5	63	1.46
	P*	2.0/0.9	0.37	CM/6-7	29.5	12.1	56	2.20
Mar.	N	1.3/0.65	0.20	CM/3.0	17.6	6.5	63	1.37
	P	2.0/0.9	0.20	CM/3.0	18.9	5.4	71	1.88

* "special study" (short duration)

** run terminated before 2.5 m (100 in.) total head loss

44% higher loading than filter N with virtually no loss of effluent quality. The poor removal efficiencies listed in Table 2 for this period are believed to result from the nature of the influent suspended solids. A review of the SVI data for the completely mixed activated sludge system during this time reveals values between 600 and 800 ml/gm. This indicates either a poorly formed floc or presence of filamentous type organisms. In either case, it appears that general filterability was less than desirable.

Filter P, containing only anthracite, performed comparatively well, yielding a 55 percent removal efficiency and a loading of 0.753 $kg/m^2/m$ head loss (.047 $lbs/ft^2/ft$ head loss).

In November 1974 the media in filter O was replaced with 64 cm (25 in) of anthracite having an effective size of 2.0 mm. As would be expected, filter N produced the highest quality effluent, followed by filters P and O. Unfortunately, extremely low influent suspended solids concentrations did not allow effective evaluation of filter performance. Since the atypical influent characteristics resulted in a very slow build up of total head loss, operation of all three filters was curtailed when filter N head loss reached 2.5 m (100 in). Thus, loadings are not calculated for filters O and P during November.

In December, filter P media was replaced with anthracite of effective size 2.0 mm under which was placed silica sand of effective size 0.9 mm. Studies were conducted using the completely mixed system effluent at hydraulic loadings of 0.12, 0.20, 0.29 and 0.37 $m^3/min/m^2$ (3, 5, 7 and 9 gpm/ft^2), and with the step aeration system effluent at 0.20 and 0.29 $m^3/min/m^2$ (5 and 7 gpm/ft^2). The performance data (percent removal, solids loadings, and net water production) are given in Table 2.

The filter P media appeared to offer considerable advantage over the media in filters N and O. In general, the quality of the effluent was similar to that from the 1.3 mm E.S. coal/0.65 mm E.S. sand combination, with run lengths being 27 to 55 percent higher. Consequently, the total solids capture per run was significantly greater. The removal efficiency of filter O (2.0 mm effective size anthracite) was reasonably good at low flowrates, but deteriorated rapidly as the flowrate was increased (see discussion of flowrate effects in Section 7). Figure 2 shows the increase in total head loss as a function of solids captured for the three filters, operated at 0.20 $m^3/min/m^2$ (5 gpm/ft^2) with the effluent from the completely mixed activated sludge system.

Figure 3 reveals the head loss distribution through the media during the 0.20 $m^3/min/m^2$ (5 gpm/ft^2) run with the completely mixed process effluent. During the months of November and December, it was noted that a portion of the anthracite had been lost from filter N at some time during the backwash operation. This accounts for the relative vertical position of the filter N head loss curve. From inspection of the three curves, it is apparent that the greatest head loss drop occurs across the top few centimeters of the media. In comparing the two dual media filters, N and P, it appears that filter N demonstrates a greater proportion of head loss drop across the surface. It is likely that this condition is due to a greater accumulation

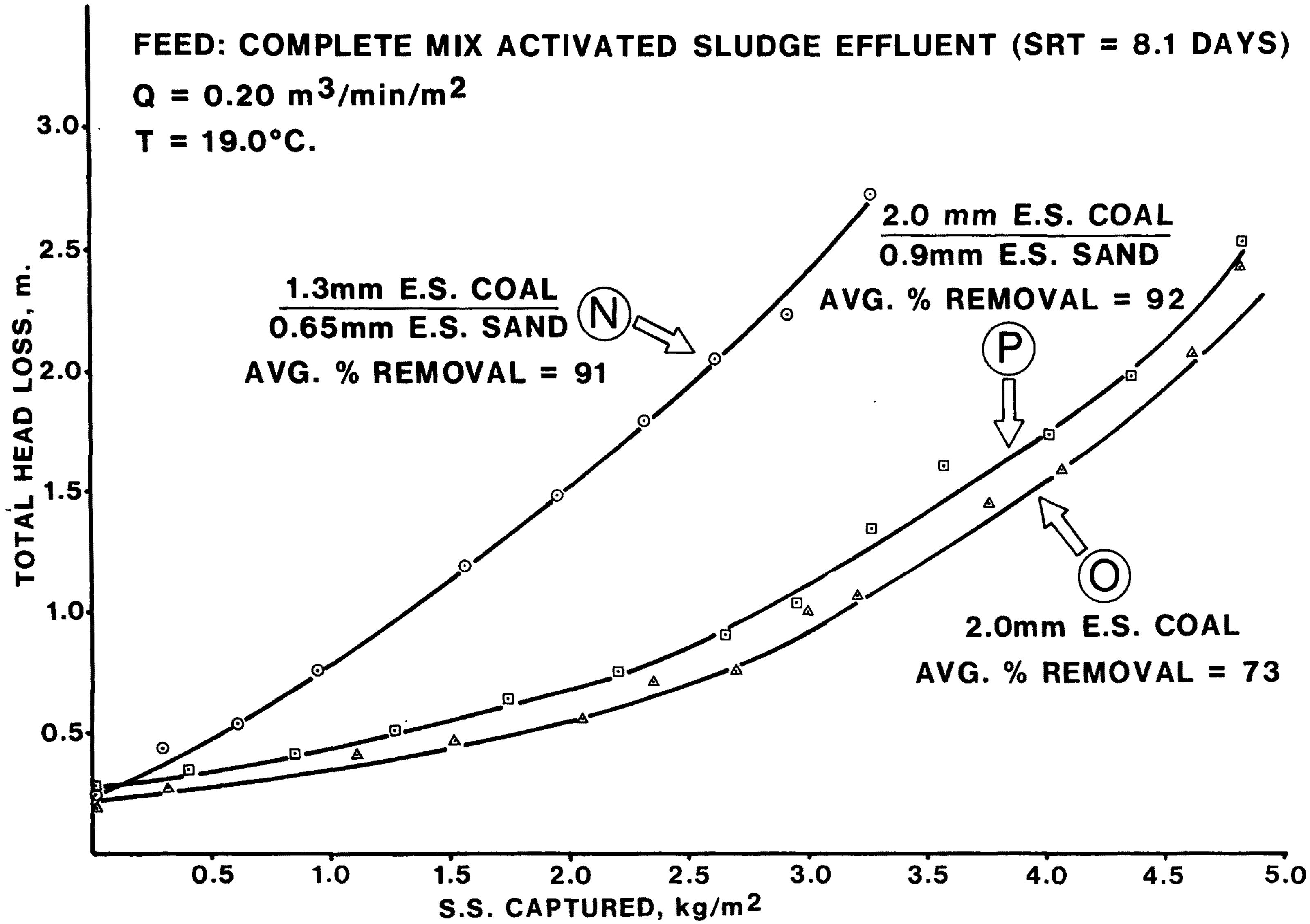

Figure 2. Head Loss as a Function of Solids Capture, December 1974

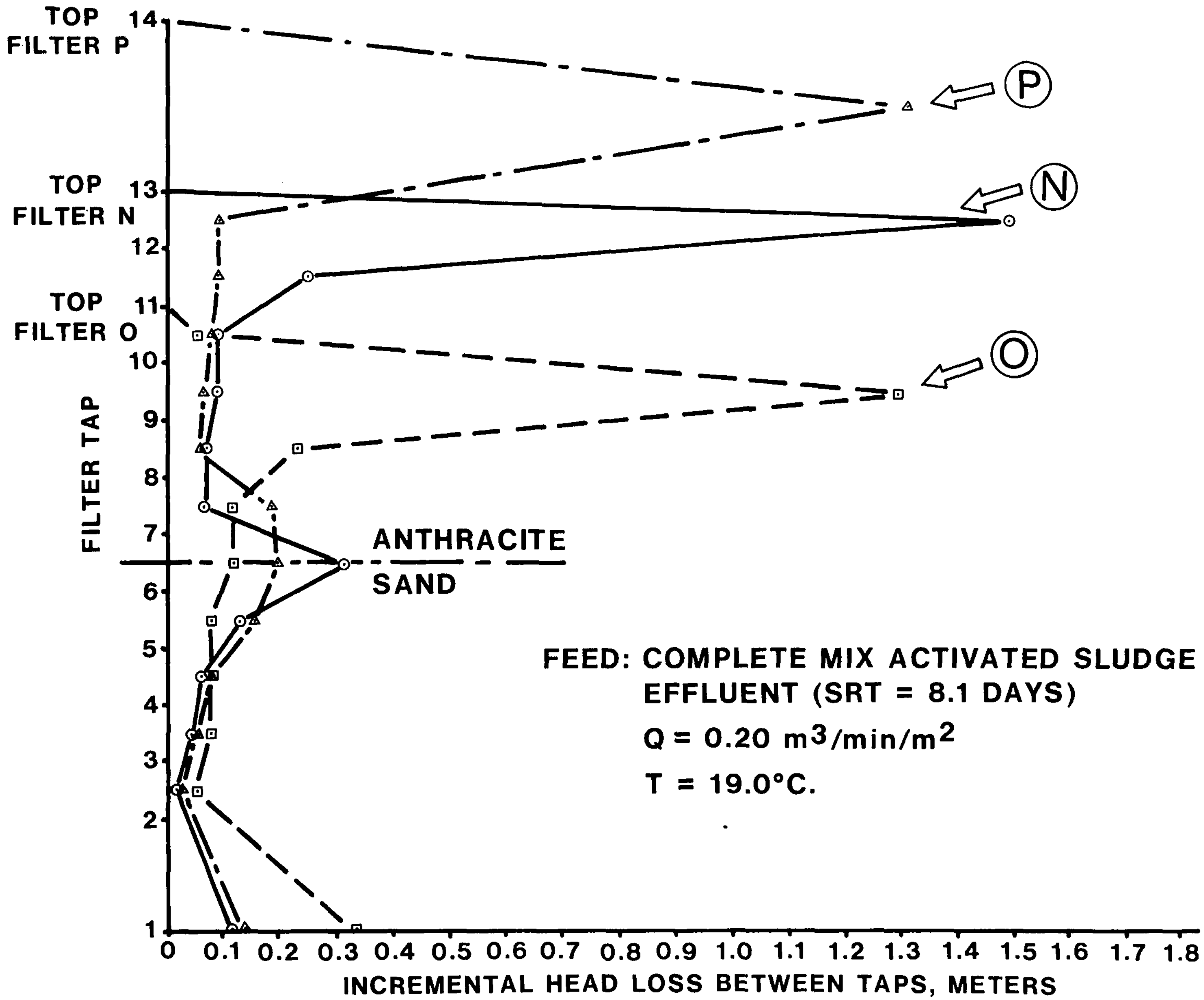

Figure 3. Differential Head Loss Characteristics, December 1974

of suspended solids at the surface of filter N, as the effective size of the upper media is 1.3 mm for N vs. 2.0 mm for P. In addition, filter N shows a sharper, more defined head loss drop across the sand-coal interface (between taps 6 and 7), which would indicate less penetration of the suspended solids into the sand. This becomes more evident during the January 1975 study, discussed below.

It was concluded from previous work that the 2.0 mm effective-sized anthracite in filter O was unsuitable for filtration of secondary effluents. Consequently, in January 1975, 38 cm (15 in) of sand having an effective size of 0.65 mm was placed beneath the existing anthracite. In addition, since filter N had experienced some loss of anthracite, new material of the same effective size was placed to a depth of 64 cm (25 in). The completely mixed activated sludge system effluent was used to feed the filters at hydraulic loadings of 0.12, 0.20, 0.29, and 0.37 $m^3/min/m^2$ (3, 5, 7, and 9 gpm/ft^2).

Figure 4 demonstrates the head loss vs. suspended solids captured for filters N, O, and P at a hydraulic loading of 0.20 $m^3/min/m^2$ (5 gpm/ft^2). Filter P absorbed a loading 72 percent higher than that for filter N and 29 percent higher than the filter O loading. At this same flowrate, the removal efficiencies are 89, 88, and 89 percent for filters N, O, and P respectively. For filter P this translates into run lengths that are 72 and 32 percent greater than those for filters N and O, with virtually no deterioration of effluent quality. This same observation holds generally true at the higher flowrates, although a slight reduction in effluent quality is realized.

Figure 5 shows the incremental head loss between taps for filters N, O and P at the hydraulic loading of 0.20 $m^3/min/m^2$ (5 gpm/ft^2). Here, the differences in head loss distribution are quite pronounced. Note that virtually all of the head loss for filter N occurs across the media surface, while for filters O and P, considerable head loss occurs throughout the bulk of the media. This indicates a greater "mat" accumulation of solids on the filter N media surface, with a deeper solids penetration in the other filters. Figure 5 also shows a greater head loss distribution at the sand-coal interface for filter O, with a relatively small drop across the top. This is most likely due to the greater degree of media intermixing at the interface, which results in a more gradual head loss distribution through the media. Since the difference in media effective sizes is quite large (2.0 mm vs. 0.65 mm), the head loss drop at this interface is significant.

The relationship between the effective sizes of anthracite and sand have often been cited as playing an important role in the performance of dual media filters (2, 3, 4, 6), since the degree of media intermixing is largely dependent upon this factor. In general, a sharp sand-coal interface is not desirable, since a solids mat may be formed at this boundary. The ratio of the 90 percent finer coal size to the 10 percent finer sand size (D_{90}) coal/ (D_{10}) sand, is often used as a parameter to predict the degree of media intermixing, a ratio of 4 generally resulting in substantial intermixing, and a ratio of 2 to 2.5 producing a sharp interface (2).

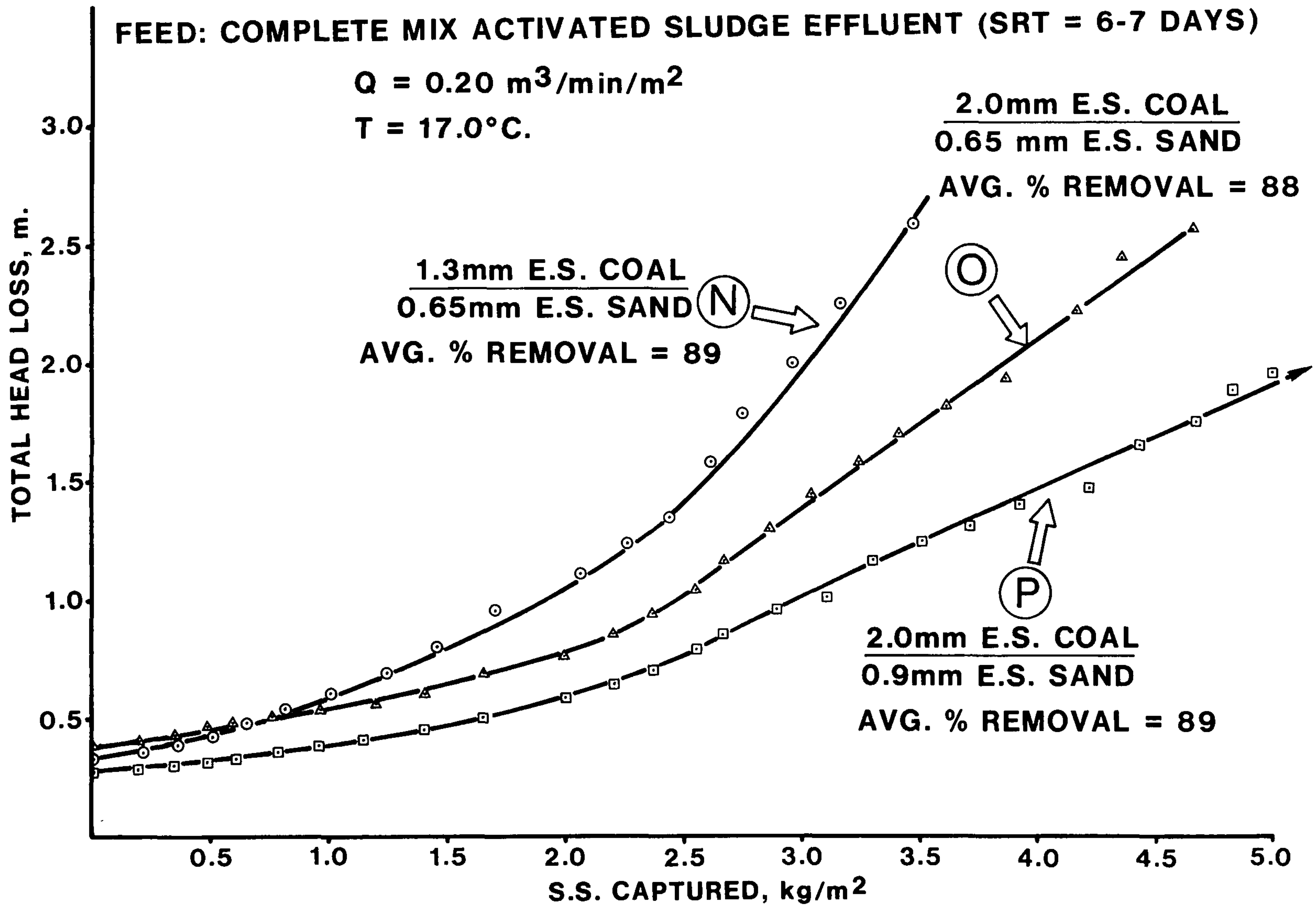

Figure 4. Head Loss as a Function of Solids Capture, January 1975

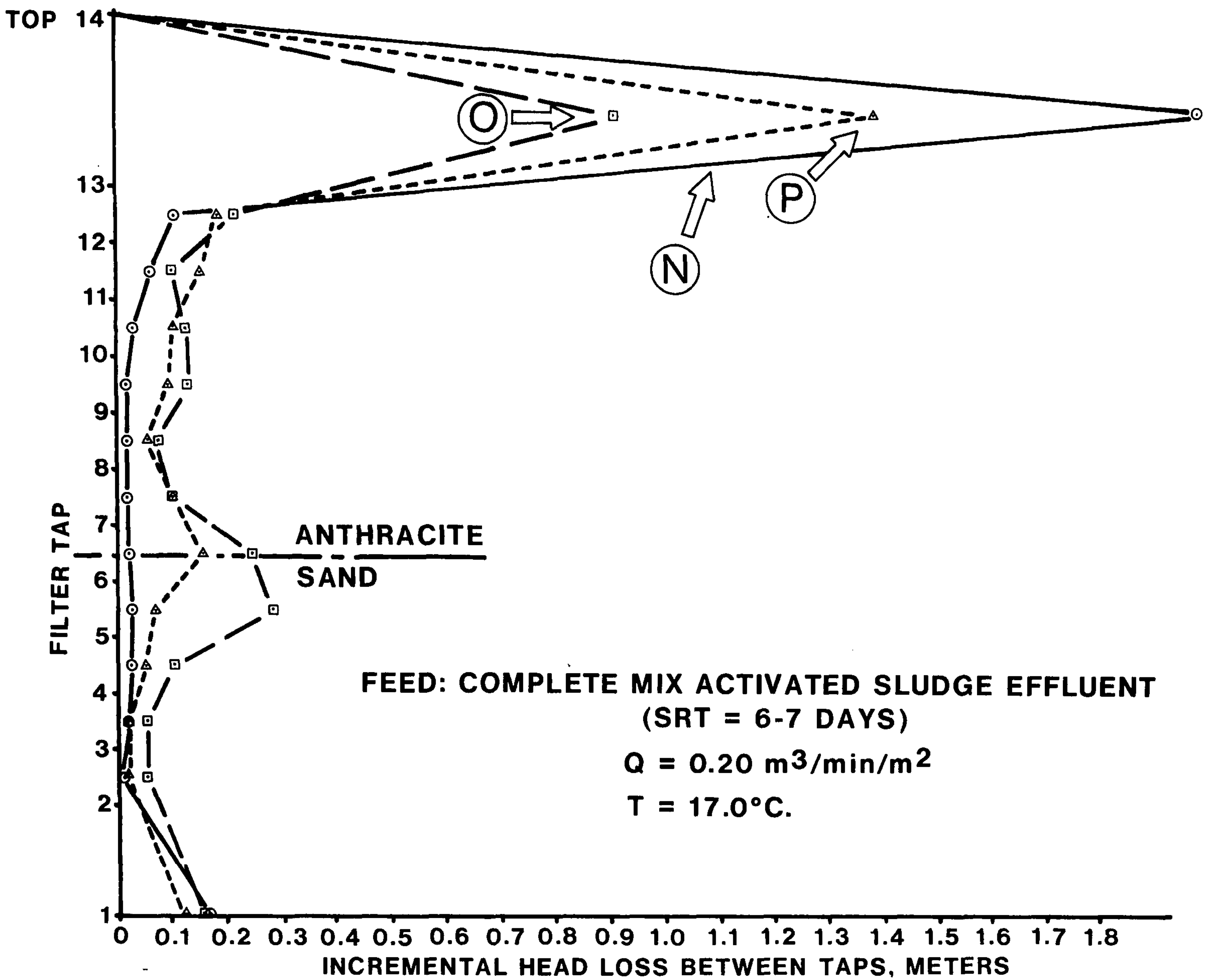

Figure 5. Differential Head Loss Characteristics, January 1975

Table 3 lists the "intermix quotients" for the media combinations used in this study.

TABLE 3

INTERMIX QUOTIENTS FOR DUAL MEDIA CONFIGURATIONS

Effective size of coal, mm (D_{10})	(D_{90}) coal mm	Effective size of sand, mm (D_{10})	$\frac{(D_{90})\ \text{coal}}{(D_{10})\ \text{sand}}$
1.3	2.75	0.65	4.2
1.65	3.0	0.8	3.8
2.0	4.2	0.9	4.6
2.0	4.2	0.65	6.4

The first three combinations listed above are believed to be within the working range of values required to achieve a reasonable degree of intermixing. Even the relatively high ratio of 4.6 provided desirable run length and effluent quality characteristics. However, the 6.4 value resulted in excessive media intermixing. Attributable to this condition were short run lengths, similar to those for the 1.3 mm coal/0.65 mm sand combination, and an effluent of poorer quality than that from the 2.0 mm coal/0.9 sand configuration, the latter of which produced run lengths at least 32 percent greater. Thus, there appeared to be no benefit from further investigation of a 2.0 mm coal/0.65 mm sand media for filtration of secondary effluents.

SECTION 7

EFFECT OF FLOWRATE ON FILTER PERFORMANCE

During the months of December 1974 and January 1975, the filters were operated at a variety of flowrates, ranging from 0.12 to 0.37 $m^3/min/m^2$ (3 to 9 gpm/ft^2). The parameters of particular importance in assessment of flow rate effects were effluent quality (possibility of suspended solids breakthrough at elevated flowrates), solids loading (a function of removal efficiency and run length), and net water production.

The data for December 1974 are plotted in Figures 6, 7, 8, and 9. At this time, the media effective sizes were as follows: N--1.3 mm coal/0.65 mm sand, O--2.0 mm coal only, P--2.0 mm coal, 0.9 mm sand. Note that even at the lowest hydraulic loading of 0.12 $m^3/min/m^2$ (3 gpm/ft^2) filter O experienced a suspended solids breakthrough, as shown by the drop in removal efficiency. At the higher flowrates, this breakthrough becomes more evident.

With the addition of 38 cm (15 in) of 0.9 mm effective sized sand to the 2.0 mm effective sized anthracite (filter P), the susceptibility of the media to solids breakthrough was greatly reduced. Only at the 0.28 and 0.37 $m^3/min/m^2$ (7 and 9 gpm/ft^2) loading did a reduction in removal efficiency occur. In addition, it is questionable whether the performance of the 1.3 mm/0.65 mm E.S. media in filter N would be significantly better than filter P, since the removal efficiencies appear quite similar.

During November 1974, studies were conducted at elevated flowrates to determine the breakthrough characteristics of the single anthracite media contained in filters O (E.S. = 2.0 mm) and P (E.S. = 1.65 mm). Figures 10 and 11 prove conclusively that such media are unable to sustain an acceptable removal efficiency at high flowrates of 0.28 and 0.37 $m^3/min/m^2$ (7 and 9 gpm/ft^2).

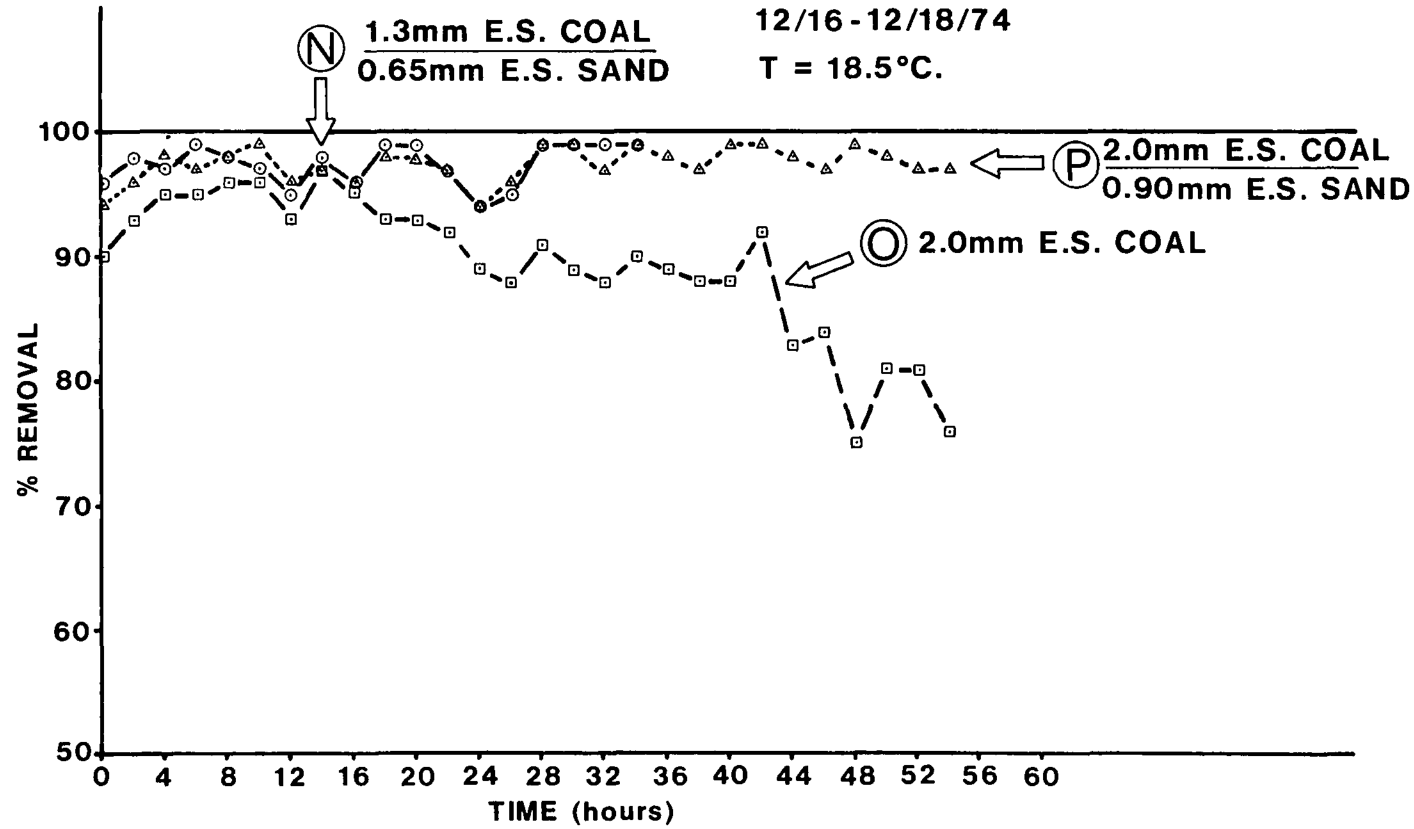

Figure 6. Removal Efficiency at 0.12 $m^3/min/m^2$
Feed: Complete Mix Activated Sludge (C.M.A.S.) Effluent

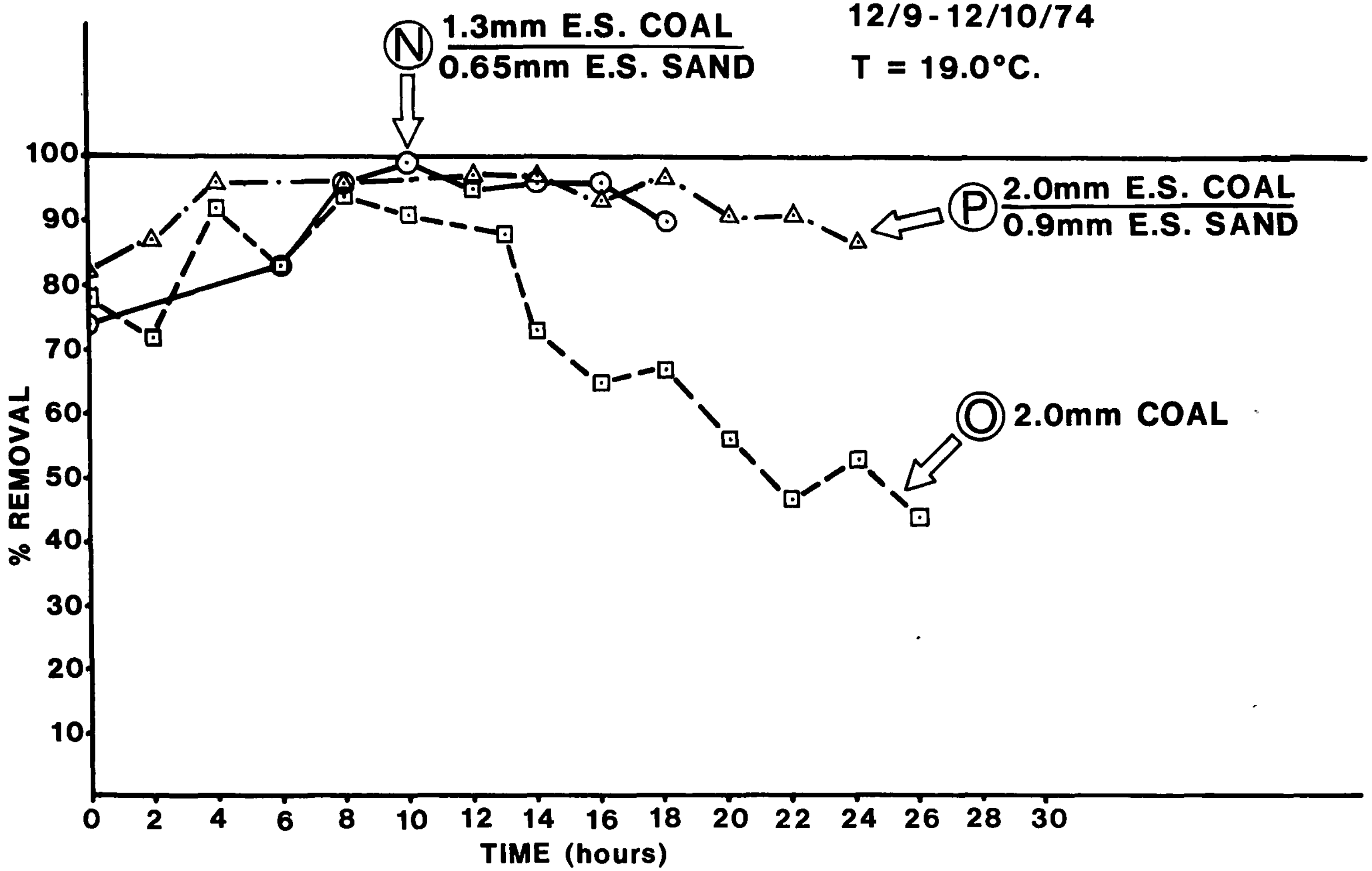

Figure 7. Removal Efficiency at 0.20 $m^3/min/m^2$
Feed: C.M.A.S. Effluent

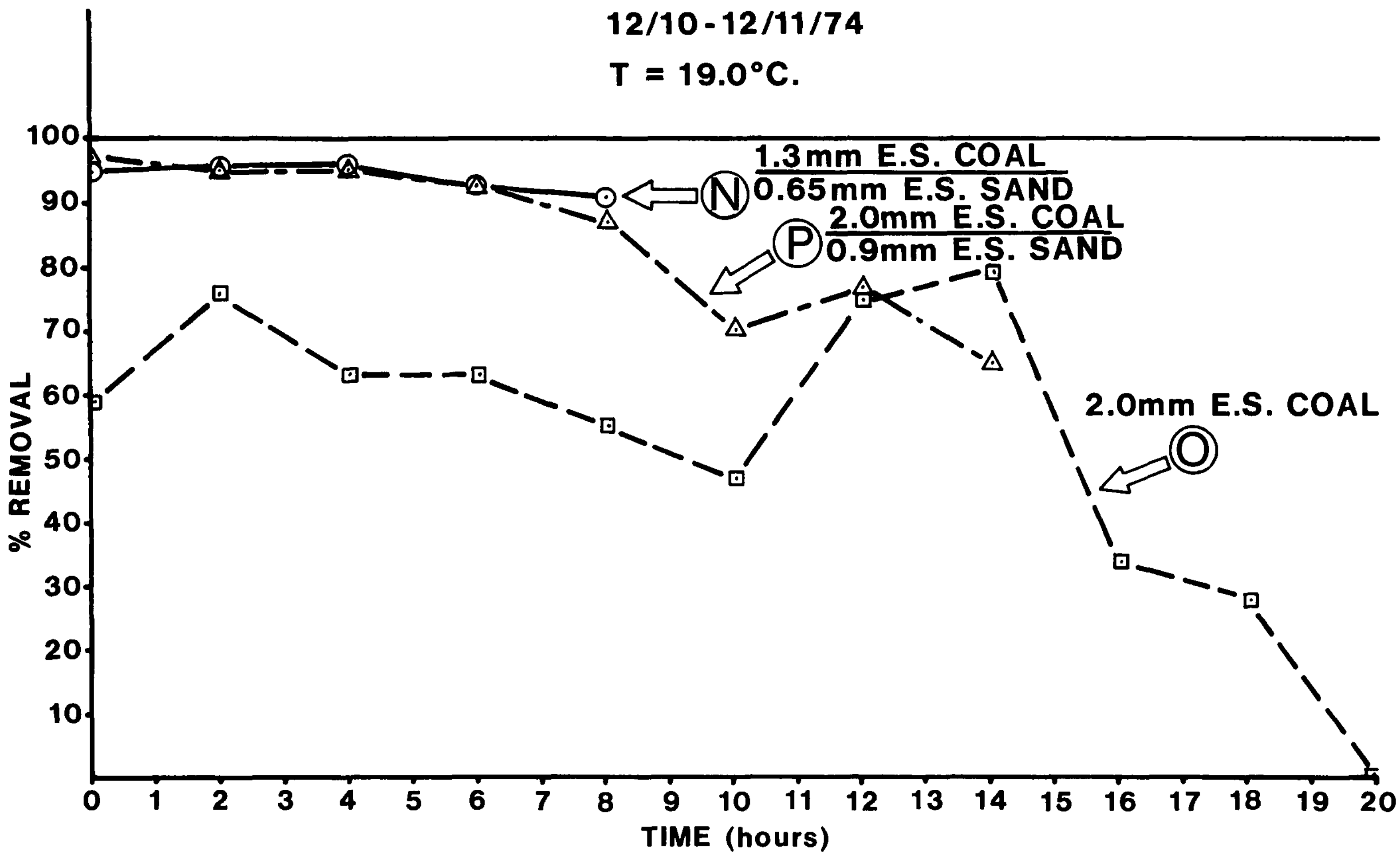

Figure 8. Removal Efficiency at 0.29 $m^3/min/m^2$
Feed: C.M.A.S. Effluent

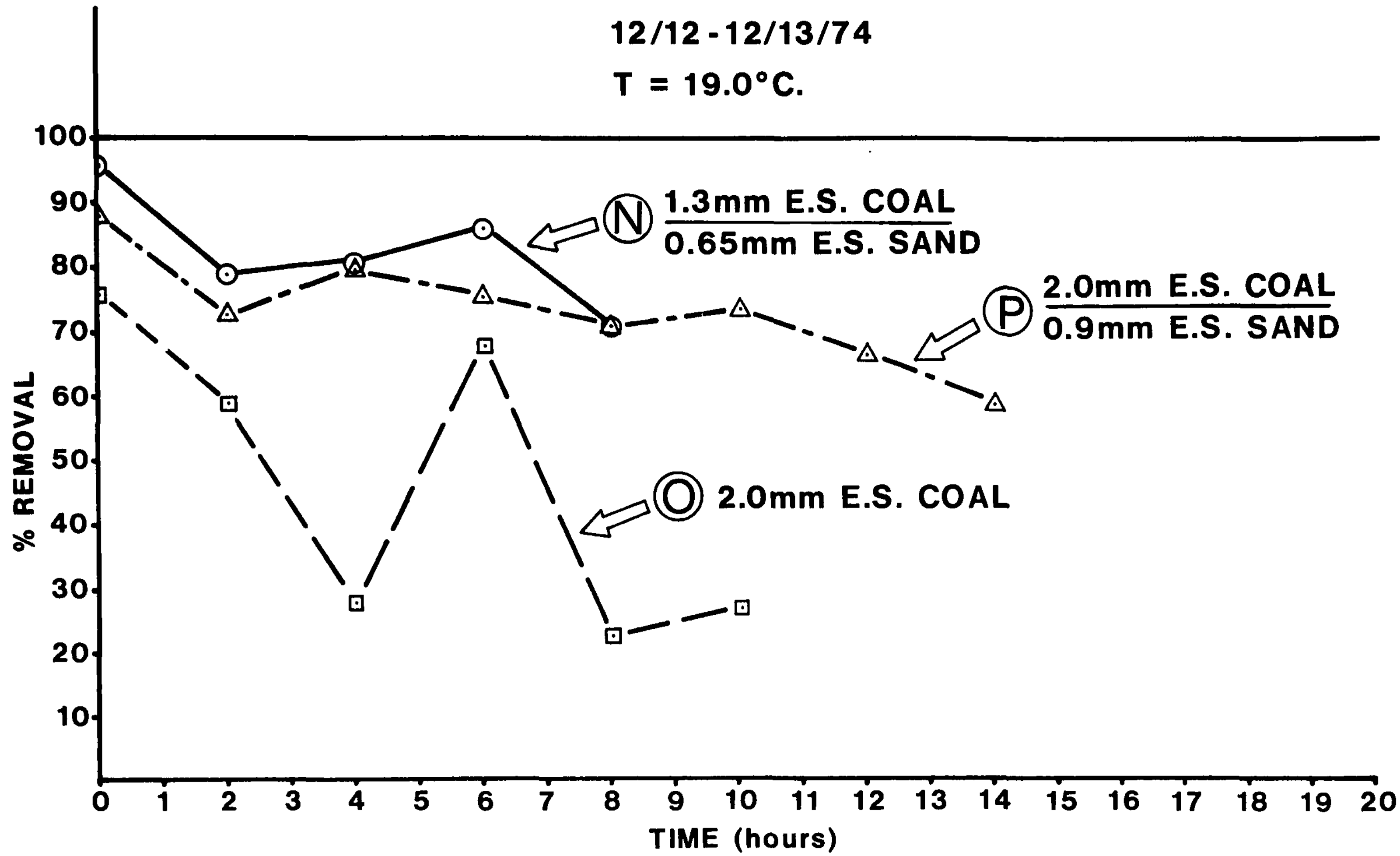

Figure 9. Removal Efficiency at 0.29 $m^3/min/m^2$
Feed: C.M.A.S. Effluent

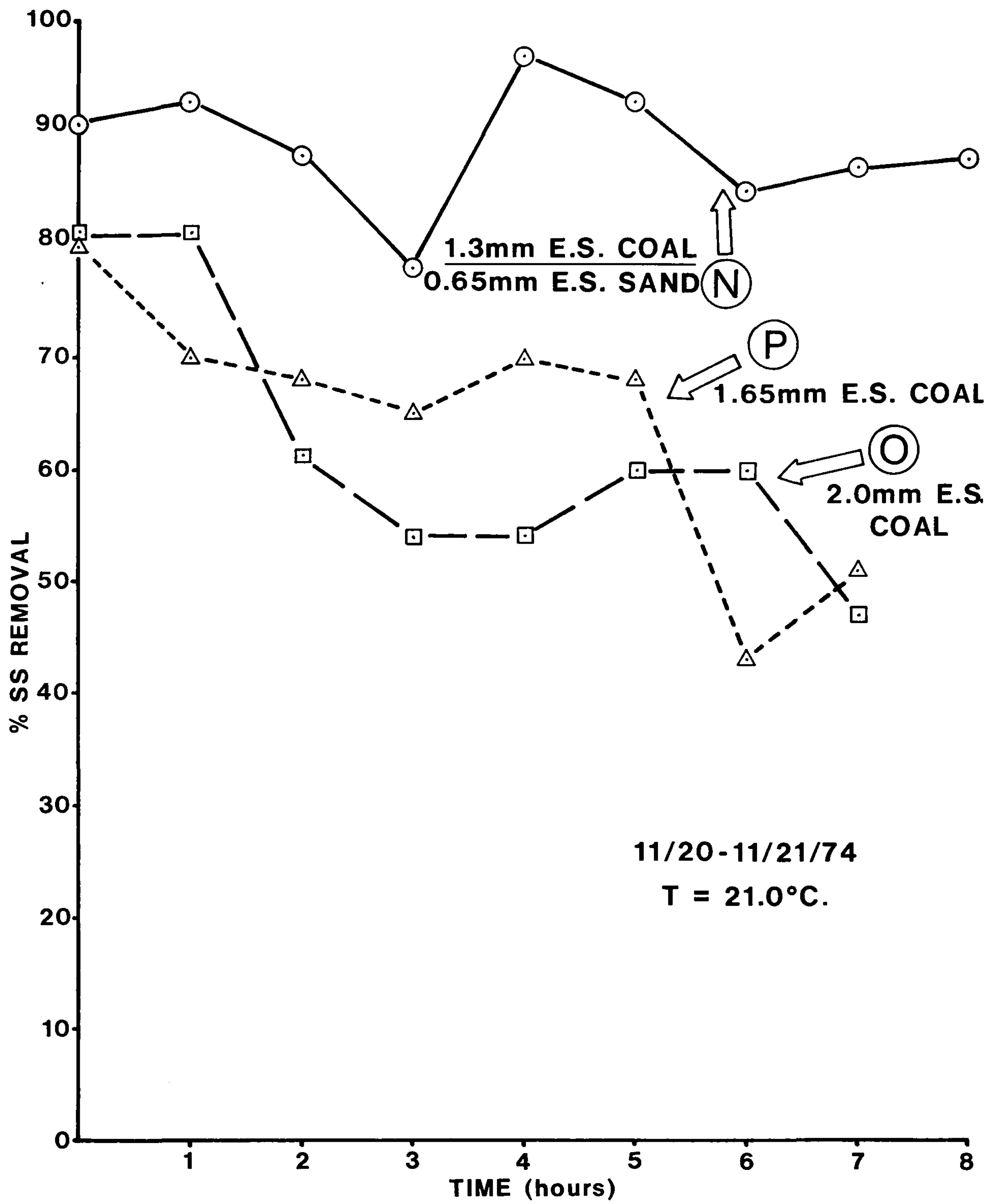

Figure 10. Removal Efficiency at 0.29 $m^3/min/m^2$

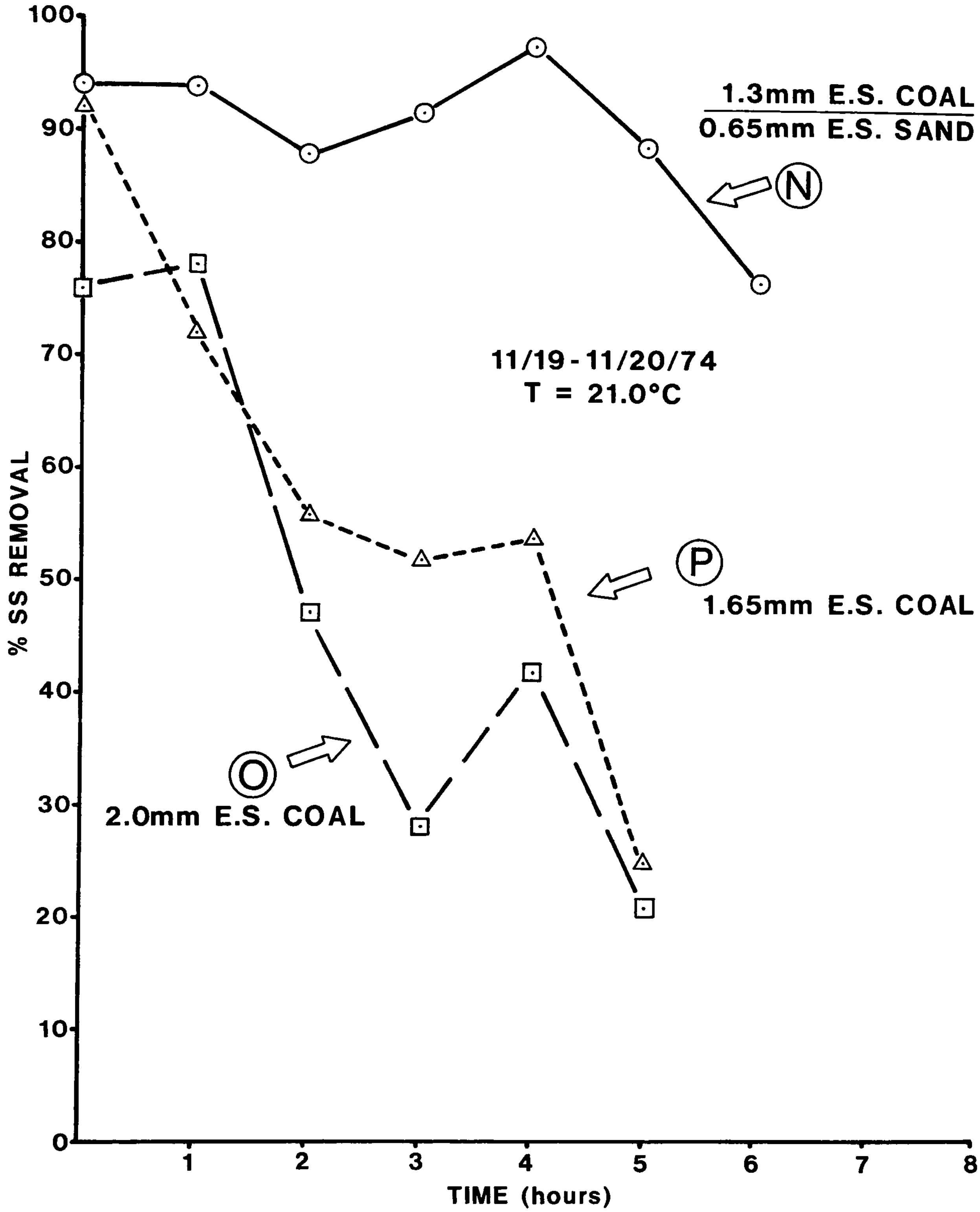

Figure 11. Removal Efficiency at 0.37 $m^3/min/m^2$

SECTION 8

EFFECT OF PROCESS EFFLUENT ON FILTER PERFORMANCE

One of the most important and most elusive parameters affecting filter performance is the nature of the influent suspended solids, as characterized by concentration, floc size distribution, floc strength, and floc charge (4). For a typical domestic waste, these characteristics should be dependent on the type of treatment process preceeding filtration, the process operational parameters (solids retention time or F/M), and the overall process performance, perhaps the most critical factor of all. The filtration work at the EPA-DC Pilot Plant substantiated the importance of process performance in assessing filterability of activated sludge effluents.

Two factors related to process performance made it difficult to establish a relationship between filterability and either process type or SRT. The first was that the performance of the activated sludge systems was such that the concentrations of suspended solids in the effluent were often between 5 and 10 ppm. This made effective evaluation of filter performance extremely difficult, since considerable error is introduced in determining filter removal efficiency. Process effluents of this nature do not require filtration. In some cases, the low suspended solids values were due to excellent process performance and a low sludge volume index (SVI); during other times, Norcardia proliferation in the system formed a scum on the clarifier surface, which acted as a filtering mat prior to discharge of the effluent over the weirs. The presence of the Norcardia mat also caused variations in the effluent solids due to sloughing of the scum into the effluent trough.

To compare the filterability of process effluents, the data from filter N are presented, since the effective sizes of the media remained the same throughout the study (1.3 mm coal/0.65 mm sand). Investigation of process type and SRT requires that the other variables be relatively constant, i.e. flowrate, influent suspended solids concentration, and SVI. SVI is used here merely as an indicator of process stability.

Table 4 indicates the performance of the filters in terms of loading and percent removal. Also given are the influent and effluent suspended solids concentrations, the flowrate, the type of process and SRT, and the SVI.

Without a complete characterization of the effluent suspended matter, the SVI indicates little with respect to filterability. A low SVI would generally indicate a well-formed floc which could be easily captured during filtration. However, a high SVI could be indicative of either a poorly flocculated

TABLE 4

SUMMARY OF FILTER N DATA

Media E.S.: 1.3 mm coal/0.65 mm sand

PROCESS/SRT	DATES	FLOW $m^3/min/m^2$	SS in ppm	SS out ppm	% REMOVAL	LOADING $kg/m^2/m$ head loss	SVI ml/gm
Step/4.5	7/1-7/31/74	0.12	12.5	2.6	79	0.90	145
Step/5.9	8/1-8/27/74	0.12	6.7	2.2	67	0.79	141
Step/5	9/1-9/19/74	0.12	8.2	2.9	65	0.72	124
CM/8.1	12/16-12/18/74	0.12	21.0	0.5	97	2.26	216
CM/6-7	1/20-1/23/75	0.12	16.3	2.1	87	2.21	306
Step/3.7	11/5/74	0.20	5.6	2.1	62	0.32	100
Plug/4.7	11/6/74	0.20	6.3	3.7	41	0.38	291
CM/4.7	11/7/74	0.20	42.5	1.1	97	1.19	374
CM/8.1	12/9-12/10/74	0.20	16.0	1.4	91	1.19	256
Step/3.5	12/18-12/20/74	0.20	13.2	2.9	77	1.01	163
CM/6-7	1/3-1/5/75	0.20	8.8	0.9	89	1.35	247
CM/3.0	3/16-3/26/75	0.20	17.6	6.5	63	1.38	79

effluent which would pass the filters, or a filamentous ridden effluent which could rapidly plug the media surface. Although SVI is a useful parameter in assessing activated sludge process performance, it is a poor measure for characterizing the effluent suspended solids with respect to filterability.

Correlation of SRT and/or type of activated sludge modification with filter performance could not be established with the limited and variable data available from this study.

SECTION 9

FILTER BACKWASHING

The initial design for the backwash operation of the filters in March 1974 consisted of (1) a 0.12 $m^3/min/m^2$ (3 gpm/ft^2) surface wash and 0.61 $m^3/min/m^2$ (15 gpm/ft^2) low flow backwash for two minutes, (2) a 1.14 $m^3/min/m^2$ (28 gpm/ft^2) high flow backwash for ten minutes, and (3) a 0.61 $m^3/min/m^2$ (15 gpm/ft^2) low flow backwash for one minute. However, during this month, it was observed that 2.5-5.0 cm (1-2 in) diameter "mud-balls" formed in the media which could not be removed by this backwash sequence. As a result, an air scour system was installed to dissipate the scum, which was thought to result from Norcardia proliferation in the activated sludge systems. The backwash sequence was then modified to read as follows:

(1) 1 min. of air scour at 1.5 $m^3/min/m^2$ (5 $scfm/ft^2$).

(2) partial filter drainage to top of media.

(3) 1 min. air scour with 2 min. low flow, 0.4 $m^3/min/m^2$ (10 gpm/ft^2) backwash.

(4) 10 min. of high flow, 1.2 $m^3/min/m^2$ (30 gpm/ft^2) backwash.

The installation of the air wash system greatly reduced "mud ball" formation and resulted in a well scoured media after backwash. However, several incidents of mud ball formation were encountered which required addition of chlorine to the filters. This had the effect of dissipating biological scum formation in the media and on the filter walls.

During Janurary 1975, a series of studies was initiated to investigate the backwash characteristics of the filter media. The effective sizes of the media were as follows: N-- 1.3 mm coal/0.65 mm sand, O-- 2.0 mm coal/0.65 mm sand, P-- 2.0 mm coal/0.9 mm sand. The parameters of interest were (1) backwash rates required for bed fluidization, and (2) extent of particle removal during backwash.

Figures 12 and 13 demonstrate percent bed expansion as a function of flowrate. Unfortunately, bed expansion studies were conducted only on filters N and P, since a previous rupture of the filter O walls necessitated replacement with opaque PVC pipe, making observation of the contents impossible.

The filter N media was able to achieve a high degree of expansion at relatively low flowrates. At a backwash rate of 1.22 $m^3/min/m^2$ (30 gpm/ft^2),

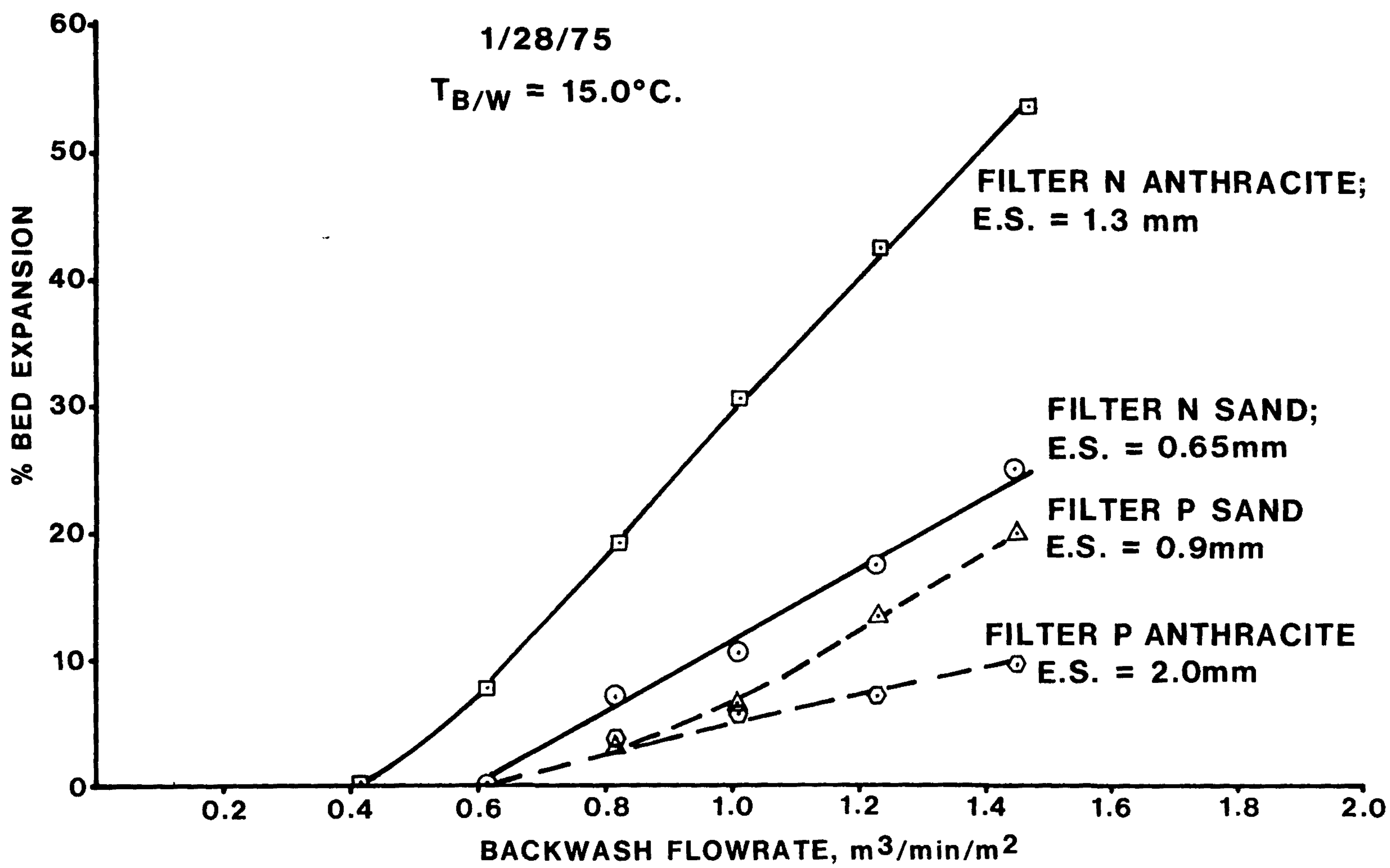

Figure 12. Extent of Sand, Anthracite Bed Expansion during Backwash

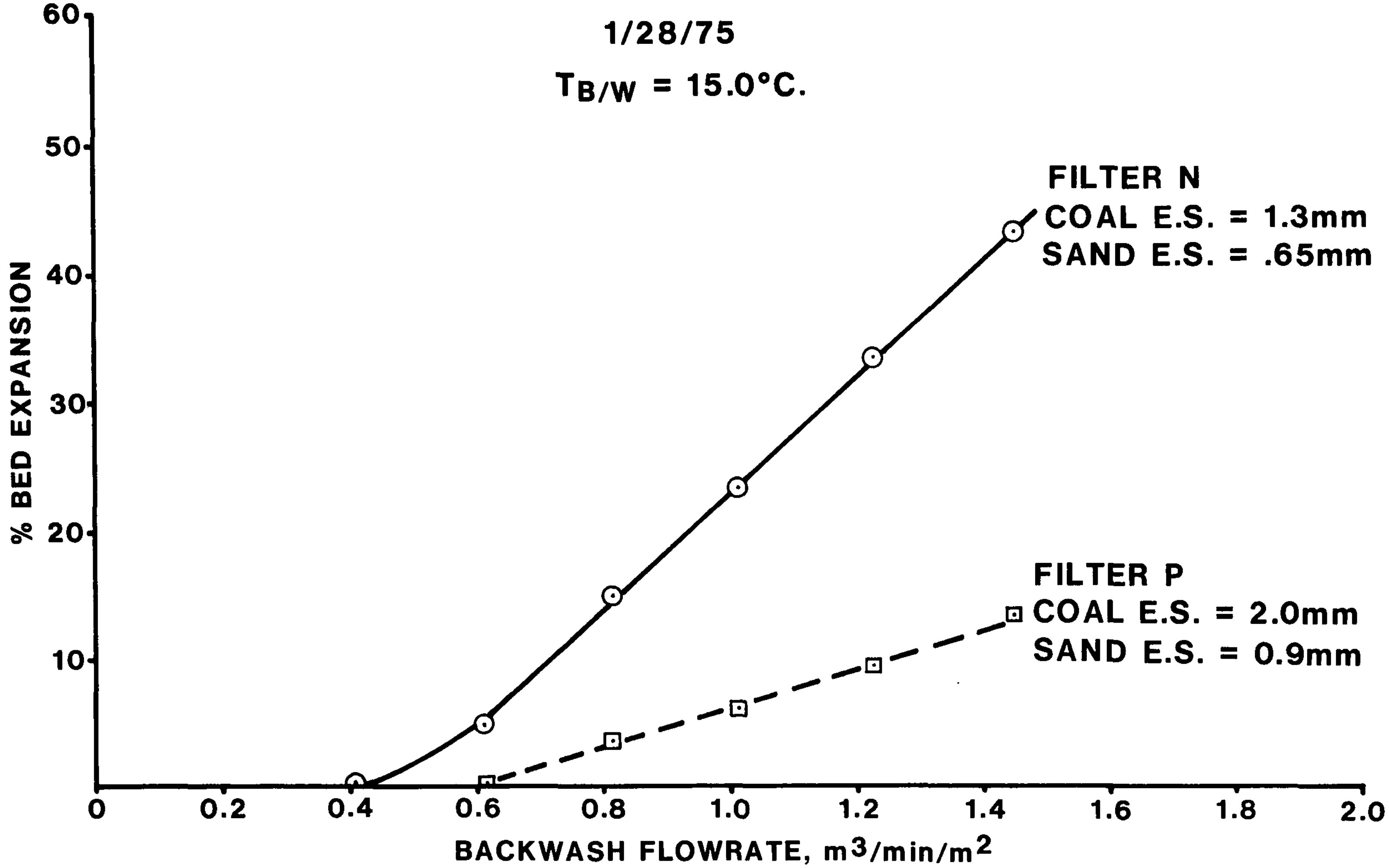

Figure 13. Extent of Total Bed Expansion during Backwash

the percent total bed expansions for filters N and P were 34 and 10 percent respectively. At 1.43 $m^3/min/m^2$ (35 gpm/ft^2) these values became 43 and 14 percent. Optimum bed expansion values have not been determined for dual and multimedia filters (5). In general, a 10-20 percent expansion is recommended to release the entrapped particles, particularly at the sand-coal interface (6). For filter P, the relatively high degree of mixing at this interface may have had a beneficial effect on backwash efficiency, since less localized plugging at the interface occurred. In general, few situations were encountered at this relatively low bed expansion which prevented removal of solids during the backwash operation. However, some plugging of the air scour system occurred which often required an increase in the air flowrace to purge the sparger.

To determine the required duration of backwash to effectively clean the media, and to perform a mass balance on the suspended solids through the filters, backwash studies were conducted on all three filters. These consisted of operating the filters to 2.5 m (100 in) head loss and backwashing the filters on the normal cycle. During the first three minutes of backwash; the backwash water was sampled every 30 seconds, after which time samples were collected every minute and analyzed for suspended solids. The concentration of suspended solids in the filter backwash water vs. time is presented in Figures 14, 15 and 16.

During the first three minutes of backwash at 1.22 $m^3/min/m^2$, approximately 98 percent of the solids were removed from the media, and after five minutes, the media was completely clean. An attempt to account for the suspended solids entrapped during filtration by examination of the backwash curves was largely successful. Theoretically, the mass of solids captured in the media during the filtration cycle should be equal to the mass of solids removed during the backwash cycle. By comparing the area under the backwash curves with calculations from influent and effluent suspended solids concentrations, flowrate, and run length, it was found that the values were within 10 percent agreement, the value from the backwash curve in all cases the larger (see Figures 14, 15 and 16).

To effectively cleanse the media in filter P, a backwash rate of 1.43 $m^3/min/m^2$ (35 gpm/ft^2) for approximately four minutes was required. This represents a total water usage of 5.7 m^3 per m^2 of surface area (140 gal/ft). Normally, 3 to 4 m^3 per m^2 (75-100 gal/ft^2) is required for the smaller media sizes. However, the additional backwash water requirement for the larger media is negligible, since the frequency of backwashing is reduced considerably.

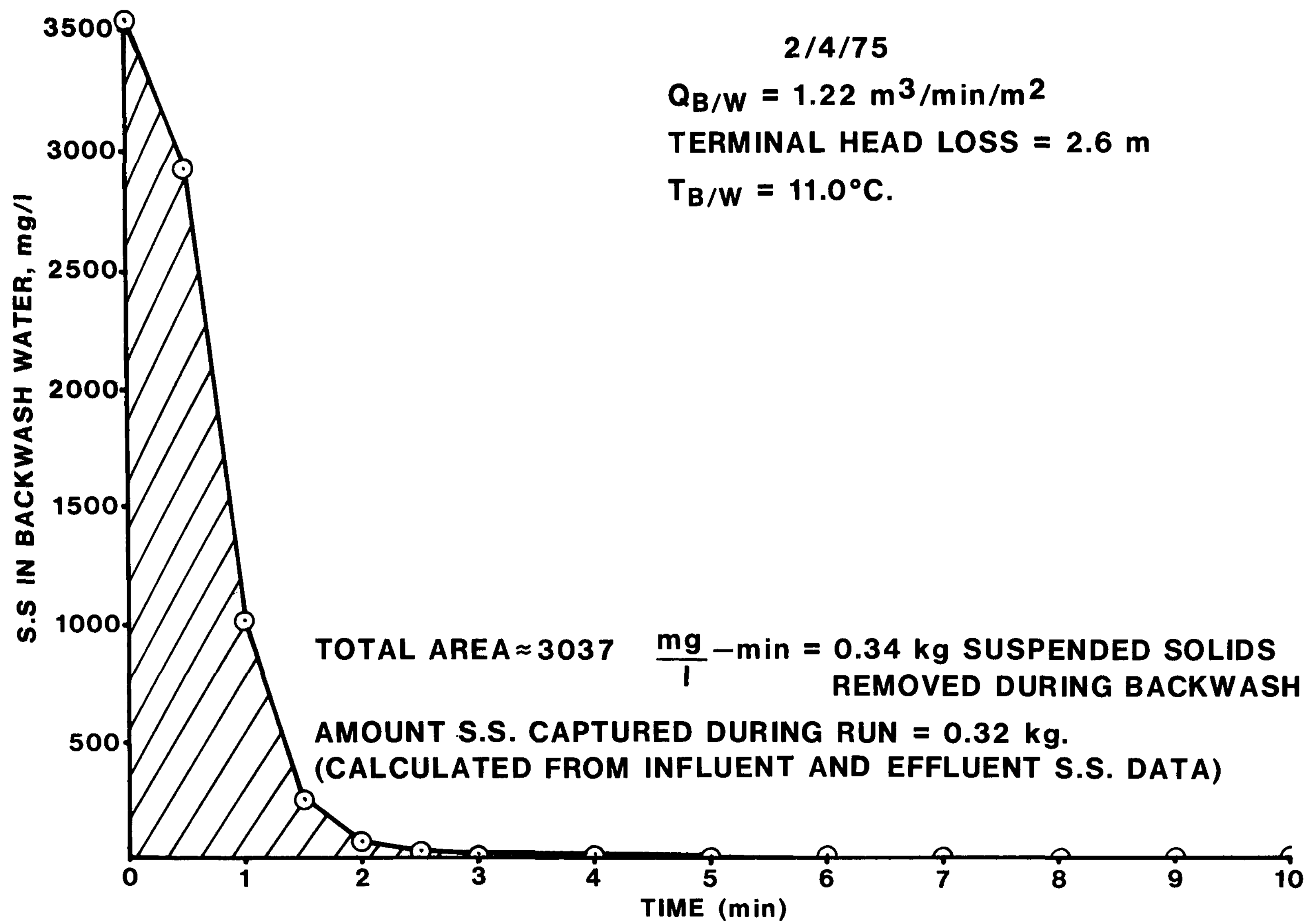

Figure 14. Removal of Entrapped Solids during Filter N Backwash

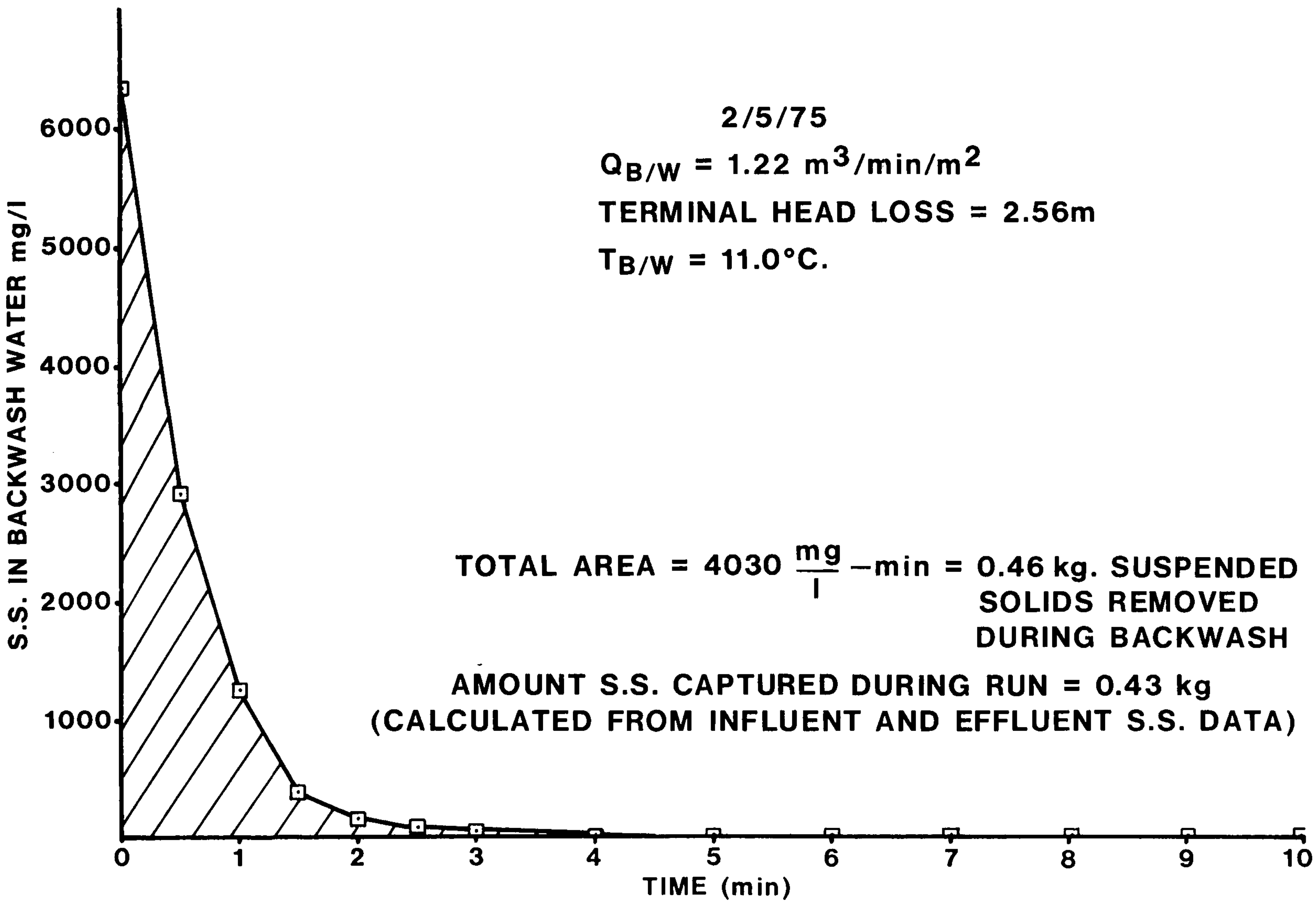

Figure 15. Removal of Entrapped Solids during Filter O Backwash

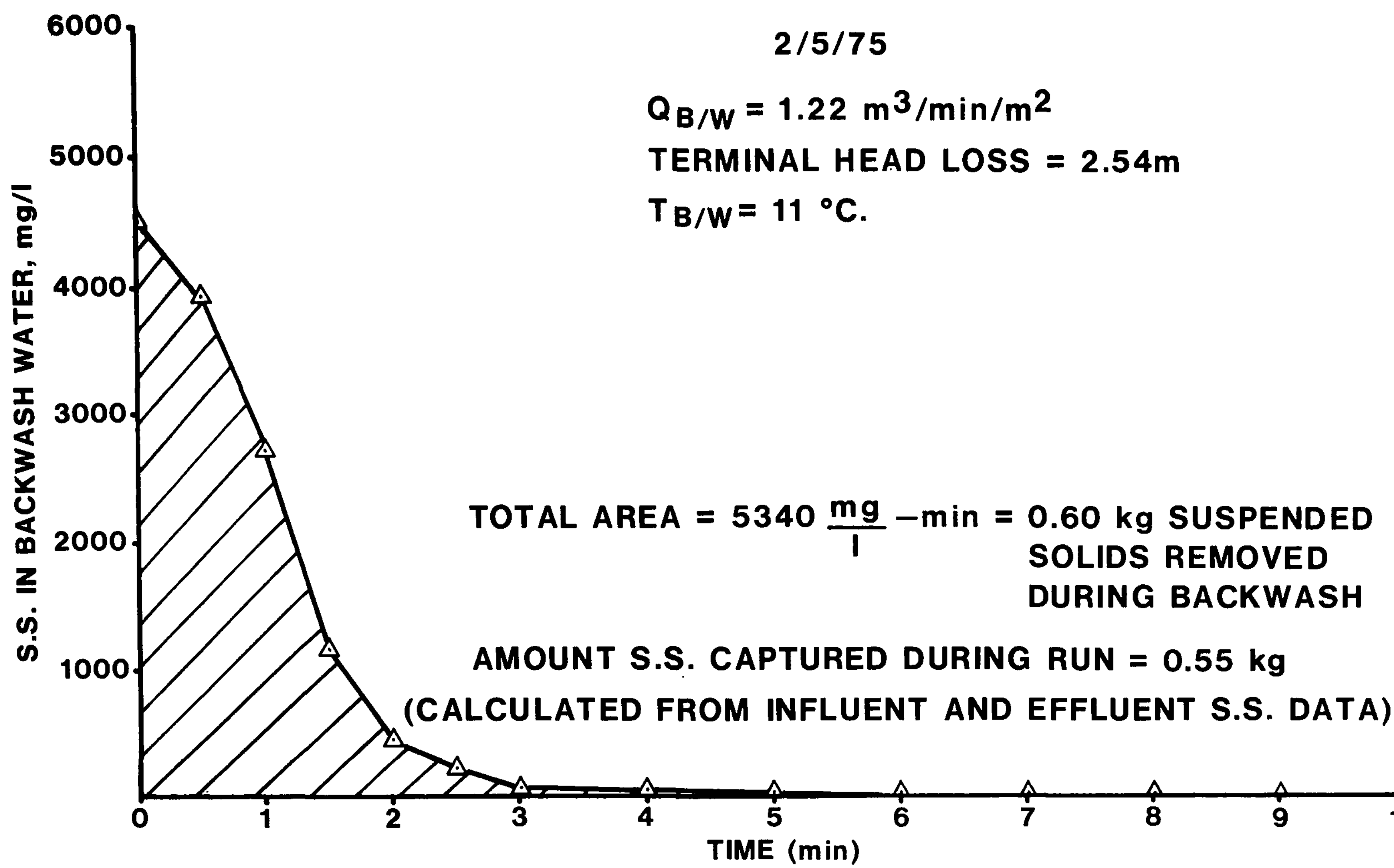

Figure 16. Removal of Entrapped Solids during Filter P Backwash

SECTION 10

PHOSPHORUS REMOVAL

In April of 1975, a limited scale study was undertaken to investigate the removal of phosphorus during downflow granular filtration.

From previous filtration work at the EPA-DC Pilot Plant (Jan. 1972-Sept. 1973) on a 3-stage activated sludge system with alum addition, it was found that higher phosphorus removals were effected by dual media filtration than by 0.45 μ Millipore filtration. This somewhat perplexing observation led to an attempt to duplicate the phenomenon with the dual media filters. The effluent from the single stage nitrification-denitrification system was chosen as a filter influent, since it had exhibited biological phosphorus uptake. If the filter removal mechanism was, in fact, biological, then the necessary microorganisms would be present.

The nitrification-denitrification effluent was fed to the filters at a flowrate of 0.20 $m^3/min/m^2$ (5 gpm/ft^2). The data are presented in Table 5.

From inspection of the data, it can be seen that the extent of phosphate removal was virtually negligible, at no time exceeding 7 percent. Since the influent phosphorus is almost completely in the "soluble" form, it appears that any phosphate reduction is due to removal associated with suspended solids. It is apparent that the unusual uptake mechanism experienced with the 3-stage system was not in evidence here. The reason for the failure to duplicate the results of the 1972-1973 pilot study is believed to be due to the absence of alum addition prior to filtration. It may be possible that the particle size distribution of the aluminum-phosphate floc is such that particles in the colloidal size range may pass through the 0.45 μ Millipore filter while still being removed during media filtration. Also, continual operation of the filters may result in an alum-enriched media which may effect a relatively high phosphorus removal.

TABLE 5

PHOSPHORUS REMOVAL STUDY
FILTERS N and P

			PO_4, ppm				SOLIDS, ppm			
			INFLUENT		EFFLUENT		INFLUENT		EFFLUENT	
DATE	FILTER	HEAD LOSS AT TIME OF SAMPLING, m	TOTAL	FILTRABLE	TOTAL	FILTRABLE	TOTAL	SUSP.	TOTAL	SUSP.
4/3/75	N	0.87	11.9	-	11.4	-	292	5.4	278	1.4
	P	0.47	11.5	-	11.0	-	243	4.8	289	0.7
4/7/75	N	2.54	10.9	-	10.8	-	257	4.4	260	1.75
	P	0.91	12.2	-	11.3	-	258	4.6	265	3.05
4/14/75	N	0.33	12.1	10.3	14.3	10.1	270	-	280	-
	P	0.97	11.7	14.1	12.9	13.2	263	-	263	-

SECTION 11

ENGINEERING SIGNIFICANCE

Among the most important considerations in design and operation of dual media filters are 1) maintenance of an acceptable level of effluent quality, 2) flowrate, and 3) rate of head loss development (backwash frequency). Selection of media type and size plays an important role in determining the interrelationships between the above parameters.

This study investigated the use of filter media of greater effective size (E.S.) than those used in conventional tertiary wastewater filters. It was found that such media was able to sustain an acceptable effluent quality with a reduced frequency of backwashing, thereby reducing operational requirements while increasing the volume of wastewater filtered per day.

A useful parameter for economic comparison of filtration systems is net water production, which is defined as the difference between the total daily volume of filtrate produced while the filter is in service and the total daily volume of water used for backwash. Net water production values are presented in Table 6 for the systems described in this report.

Figure 13 was used to estimate backwash flowrates required to achieve the desired level of bed expansion for each media size. The conventional media (1.3 mm E.S. coal/0.65 mm E.S. sand) required a backwash rate of 0.8 $m^3/min/m^2$ (20 gpm/ft^2) to achieve a 15% bed expansion, while the coarse media (2.0 mm E.S. coal/0.9 mm E.S. sand) required about 1.5 $m^3/min/m^2$ (37 gpm/ft^2) to attain the same level of expansion. The intermediate size employed at the beginning of the study (1.65 mm E.S. coal/0.79 mm E.S. sand) was estimated to require approximately 1.1 $m^3/min/m^2$ (27 gpm/ft^2) for backwash. A sample calculation of net water production is presented on the following page.

SAMPLE CALCULATION OF NET WATER PRODUCTION (NWP)

Assumptions:

1. 15% bed expansion during backwash
2. Duration of backwash = 10 min
3. Filter out of service 30 min per backwash

Anthracite size* mm	Backwash rate required for 15% bed expansion $m^3/min/m^2$ (gpm/ft^2)	Total water used per backwash m^3/m^2 (gal/ft^2)
1.3	0.8 (20)	8.0 (200)
1.65	1.1 (27)	11.0 (270)
2.0	1.5 (37)	15.0 (370)

NWP = (Total filtrate produced per day while filter is in service) - (Total backwash water used per day)

Example: Filter P: 2.0 mm E.S. coal/0.9 mm E.S. sand
$Q = 0.2\ m^3/min/m^2$ ($5\ gpm/ft^2$)
Run length before backwash = 16 hr

$$NWP = \left[1440\ \text{min/day} - \frac{24\ \text{hr}}{16\ \text{hr to BW}}\ (30\ \text{min/BW})\right]\ 0.2\ m^3/\text{min}/m^2$$

$$-\left(\frac{24}{16}\right)\ 15.0\ m^3/m^2\ \text{per BW}$$

$$= 257\ m^3/\text{day}/m^2$$

* The anthracite size in the dual media filters governed the backwash rate necessary to achieve the desired level of bed expansion (see Figure 12).

TABLE 6

NET WATER PRODUCTION (NWP)

Month	Filter	Media E.S. (mm) Coal/Sand	Flow $m^3/min/m^2$	Run length hr	Water req'd per backwash, m^3	NWP $m^3/day/m^2$
Sept. '74	N	1.35/0.65	0.16	15	8	210
	O	1.65/0.79	0.16	21	11	212
	P	1.65/---	0.16	25	11	215
Oct.	N	1.3/0.65	0.16	10	8	200
	O	2.0/---	0.16	17	15	202
	P	1.65/---	0.16	23	11	214
Nov.	N	1.3/0.65	0.20	18	8	270
			0.20	24	8	274
			0.20	7	8	240
			0.29	8	8	368
			0.37	6	8	456
Dec.	N	1.3/0.65	0.12	37	8	165
	P	2.0/0.9	0.12	56	15	165
	N	1.3/0.65	0.20	17	8	268
	O	2.0/---	0.20	19	15	270
	P	2.0/0.9	0.20	24	15	267
	N	1.3/0.65	0.29	11	8	381
	P	2.0/0.9	0.29	14	15	377
	N	1.3/0.65	0.37	9	8	482

TABLE 6 (con't)

NET WATER PRODUCTION (NWP)

Month	Filter	Media E.S. (mm) Coal/Sand	Flow $m^3/min/m^2$	Run length hr	Water req'd per backwash, m^3	NWP $m^3/day/m^2$
Dec. '74	P	2.0/0.9	0.37	14	15	489
	N	1.3/0.65	0.20	20	8	271
	P	2.0/0.9	0.20	35	15	274
	N	1.3/0.65	0.29	9	8	373
	P	2.0/0.9	0.29	17	15	384
Jan. '75	N	1.3/0.65	0.12	54	8	168
	O	2.0/0.65	0.12	51	15	164
	P	2.0/0.9	0.12	79	15	167
	N	1.3/0.65	0.20	36	8	279
	O	2.0/0.65	0.20	47	15	277
	P	2.0/0.9	0.20	62	15	280
	N	1.3/0.65	0.29	12	8	384
	O	2.0/0.65	0.29	10	15	361
	P	2.0/0.9	0.29	16	15	382
	N	1.3/0.65	0.37	8	8	476
	O	2.0/0.65	0.37	7	15	444
	P	2.0/0.9	0.37	15	15	491
Mar.	N	1.3/0.65	0.20	24	8	274
	P	1.3/0.9	0.20	36	15	274

Inspection of Table 6 reveals little difference in net water production between the media combinations studied at any particular flowrate. The largest recorded difference between net water production from the coarse and fine dual media filters amounted to approximately 3.2%. The diminutive magnitude of this difference is due to the fact that the conservation of backwash water from less frequent backwash of the coarser media is offset by the greater quantity of water utilized per backwash to achieve the same degree of expansion. If the values of net water production for filter P (2.0 mm E.S. coal/0.9 mm E.S. sand) are recalculated using the same water requirement per backwash as filter N, the net water production from the two filters still differs by less than 6%. In general, backwash water requirements using the data from Table 6 vary from 4 to 10% of total filter throughput.

Despite the similar net water production from both conventional and coarse dual-media filters, the use of larger-sized anthracite and sand may offer an economic advantage due to the reduction in backwash frequency. Although little savings in backwash water requirements are realized, the total man-hours necessary for backwash operations may be reduced substantially. In addition, the use of larger media may make it possible to operate at higher flow rates with an acceptable backwash frequency. Obviously this will reduce capital costs.

During this study, the dual media filter consisting of 2.0 mm E.S. coal over 0.9 mm E.S. sand produced a high quality effluent under a variety of hydraulic and solids loading conditions. However, several areas are in need of further investigation. Of particular interest is the performance of such a filter under the combined conditions of hydraulic surge and high suspended solids loadings (> 30 mg/l). In addition, research should be conducted on the amenability of coarse, dual-media filters for treatment of effluents from activated sludge processes employing high solids retention times, as in extended aeration processes.

From the research described in this report, it appears that dual-media filters employing media of greater effective size than conventional filter media may have application for filtration of effluents from secondary wastewater treatment facilities. Such filters appear capable of sustaining an effluent of acceptable quality while reducing the frequency of backwash operations.

REFERENCES

1. Baumann, E.R., and J.Y.C. Huang, "Granular Filters for Tertiary Wastewater Treatment." JWPCF, 46: 1958 (1974).

2. "Wastewater Filtration-Design Considerations," EPA Technology Transfer Seminar Publication, July 1974.

3. Cleasby, J.L., and C.F. Woods, "Intermixing of Dual Media and Multimedia Granular Filters," JAWWA, April, 1975, p. 197.

4. Metcalf and Eddy, Inc., Wastewater Engineering, McGraw-Hill, New York, 1972.

5. Weber, W.J., Jr., Physicochemical Process for Water Quality Control, Wiley-Interscience, New York, 1972.

6. Young, J.C., "Filtration of Effluents from Biological Treatment Plants," General Filter Co., Ames, Iowa.

APPENDIX

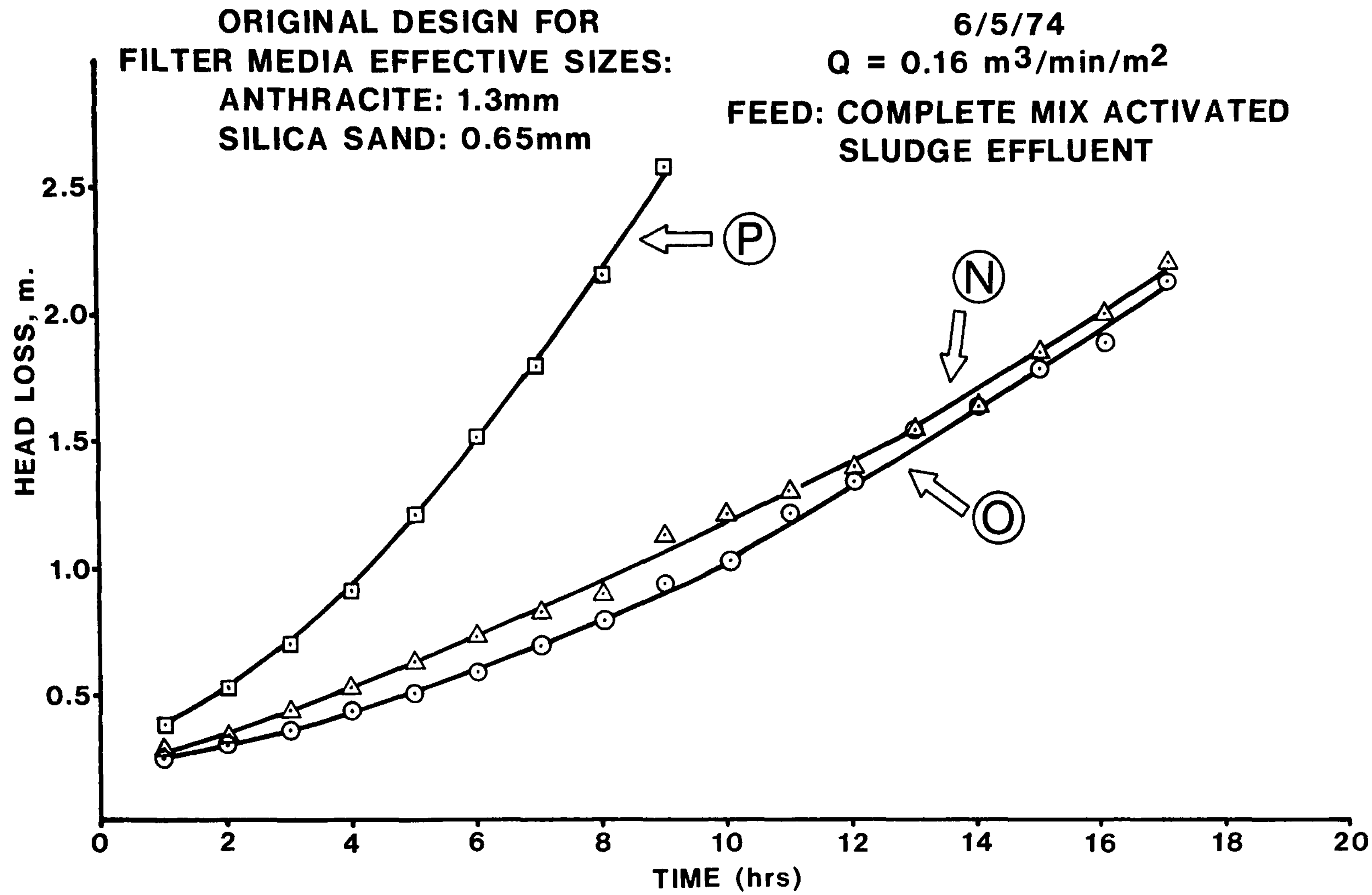

Figure A-1. Differences in Head Loss Characteristics Caused by Inconsistencies in Filter Media

TABLE A-1

SUMMARY OF FILTER PERFORMANCE DURING PERIOD OF INCONSISTENT FILTER MEDIA

Month	Filter	Media E.S. (mm) Coal/Sand	Flow $m^3/min/m^2$	Process Effluent Type/SRT (days)	Avg. SS in ppm	Avg. SS out ppm	Avg. % Rem.	Avg. Loading $Kg/m^2/m$ head loss
July 1974	N	1.3/0.65	0.12	STEP/4-5	12.5	2.6	79	0.90
	O	1.3/0.65	0.12	PLUG/4-5	11.4	4.6	60	0.90
	P	∿ 1.2/0.65	0.12	CM/2.3	11.2	2.3	79	0.77
Aug.	N	1.3/0.65	0.12	STEP/5.9	6.7	2.2	67	0.79
	O	1.3/0.65	0.12	PLUG/2.9	8.6	3.5	59	0.75
	P	∿ 1.2/0.65	0.12	CM/2.1	7.1	1.8	74	0.80
	N*	1.3/0.65	0.16	CM/2.1	20.4	2.3	89	0.67
	O*	1.3/0.65	0.16	CM/2.1	19.7	2.6	87	0.85
	P*	∿ 1.2/0.65	0.16	CM/2.1	17.7	2.0	90	0.88
	N*	1.3/0.65	0.24	CM/2.1	16.0	2.2	86	0.53
	O*	1.3/0.65	0.24	CM/2.1	16.2	1.6	90	0.66
	P*	∿ 1.2/0.65	0.24	CM/2.1	21.0	2.2	89	0.77
Sept.	N	1.3/0.65	0.12	STEP/5.0	8.2	2.9	65	0.72
	O	1.3/0.65	0.12	PLUG/2.5	5.4	2.8	48	0.72
	P	∿ 1.2/0.65	0.12	CM/2.0	11.0	2.8	75	0.85

* "special study" (short duration)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-77-144	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE DOWNFLOW GRANULAR FILTRATION OF ACTIVATED SLUDGE EFFLUENTS		5. REPORT DATE September 1977 (Issuing Date)
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Robert P.G. Bowker		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Government of the District of Columbia Department of Environmental Services EPA-DC Pilot Plant 5000 Overlook Avenue S.W. Washington, D.C. 20032		10. PROGRAM ELEMENT NO. 1BB043
		11. CONTRACT/~~GRANT NO.~~ 68-03-0349
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory--Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Irwin J. Kugelman (513-684-7631)

16. ABSTRACT

The performance of downflow granular filters subjected to effluents from activated sludge processes was investigated at the EPA-DC Pilot Plant in Washington, D.C. The 0.1 m^2 (1 ft^2) filters were operated at hydraulic loadings from 0.12 to 0.37 $m^3/min/m^2$ (3 to 9 gpm/ft^2). Several media combinations were investigated, including both single anthracite and dual anthracite-sand configurations. Effluents from step aeration, plug flow, and completely mixed activated sludge systems were used as feeds.

Breakthrough of the suspended solids into the effluent occurred with both the 1.65 mm and 2.0 mm effective size (E.S.) single anthracite configurations, becoming more evident at the higher flow rates.

A dual media filter, consisting of 2.0 mm E.S. coal over 0.9 mm E.S. sand, exhibited the most desirable characteristics for filtration of the secondary effluents investigated. The advantages were longer run times and higher suspended solids loadings with virtually no deterioration of effluent quality.

A backwash study conducted at a variety of backwash flowrates showed that a 13 percent bed fluidization was achieved with the coarse media (2.0 mm E.S. coal/0.9 mm E.S. sand) at a flow rate of 1.43 $m^3/min/m^2$ (35 gpm/ft^2). This was sufficient to effectively cleanse the media.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sewage Treatment Filtration	Filter Media Activated Sludge Effluents Suspended Solids	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 56
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977—757-056/6523