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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	lb/in	pound per inch
cm/s	centimeter per second	lb/in^2	pound per square inch
ft	foot	m	meter
ft^3	cubic foot	m^3	cubic meter
g	gram	mL	milliliter
gal	gallon	mL/s	milliliter per second
in	inch	mm	millimeter
kg	kilogram	oz/yd^2	ounce per square yard
L	liter	pct	percent
lb	pound	yr	year
lb/ft^3	pound per cubic foot		

PROPERTIES OF FILTER CLOTHS FOR SEEPAGE CONTROL IN COAL MINE WASTE EMBANKMENTS

By Robert C. Gabler, Jr.[1]

ABSTRACT

Three filter cloth fabrics commonly used in drains for coal waste embankments were tested by the Bureau of Mines for clogging behavior and deterioration under simulated field conditions. The objective was to provide guidelines for the mining industry for the proper selection and use of filter cloths to assure safer embankments at mine waste disposal sites.

The filter cloths were tested with three coal waste samples in standpipes used to simulate coal mine waste disposal environments. Two of the cloths showed a tendency to become clogged with fines from the wastes. One waste caused clogging by precipitating an iron-silicon compound on the test cloths. No apparent cloth deterioration resulted from exposures to the simulated coal waste environments. (The exposures ranged from 2 to 12 months.)

In other tests, exposures to waters in the pH range of 2 to 12 and to reagents used in coal-preparation plants resulted in insignificant or no deterioration, as measured by tensile strength. However, long exposures to sunlight (ranging from 4.6 to 6 months) caused major deterioration in two of the cloths (86- and 98-pct losses in tensile strength) and slight deterioration in the third cloth (9-pct loss in strength).

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INTRODUCTION

Disposal of the 3 billion tons (2.7 billion metric tons) of waste material generated annually from coal mining and processing is generally accomplished by pumping the fine-material slurry behind embankments built of coarse waste material. Mine waste embankments require controlled seepage of water for stability. If seepage is inadequate, the pore-water pressure cannot be controlled; as a result, the dam becomes saturated, and dam failure is possible. However, if the flow is too fast, waste particles in the dam wash away; and this, too, can result in failure. Filter cloth is used in coal waste disposal dams to control seepage and thus provide safer dams. However, failure of the filter material to perform as it is supposed to can lead to both of the problems cited above: Saturation can occur if the filter cloth becomes plugged, and washout can occur if the filter cloth decomposes.

Filter cloths have long been used in road construction, in levees, and in bulkheading to control seepage while avoiding piping of soil particles during drainage. Use of filter cloths for coal mine waste embankments has been increasing, yet there has been little evaluation of the materials used for this application. Sciulli (1),[2] in a report on the use of filter cloth in coal mine waste disposal, stated,

> "The construction industry has led the way in developing this relatively new product; however, theory, laboratory testing, and specifications have not kept pace. More and more designers are specifying filter fabric with little or no knowledge of how it actually works and what precautions, if any, should be taken. The use of filter fabrics was introduced around 1976 as a drainage component in coal refuse disposal facilities; unfortunately, there has been no formal testing of the fabric with mine-waste products."

Sciulli concluded that most methods currently used to measure various properties of fabrics do not simulate field conditions. He also concluded that most fabric-system failures were attributable to design errors, poor installation techniques, and improper storage of the fabric. He further concluded that future use of filter fabrics in the mining industry depends upon the documentation of existing installations using fabrics; the ability of designers, manufacturers, and practicing engineers to confidently specify fabrics in terms of their physical properties; the development of appropriate tests for fabrics suitable for use in coal waste disposal; and the cost of suitable fabrics.

In a related study of filter fabrics for use with soils, Koerner and Ho (2) concluded that long-term flow was the most appropriate means of evaluating a particular soil-fabric performance. Raumann (3) reported that even though fabrics with long-term stability to sunlight can be considered for severe exposure in temporary applications, filter cloths should not be exposed to sunlight for permanent installations. Guglielmetti (4), in studies on soil-fabric systems, concluded that the soil is usually the controlling factor of flow in tests and in the field.

This report describes the preliminary results of Bureau of Mines tests on the three filter cloth fabrics most widely used by the southern West Virginia coal mining industry. It adds to the information available on filter cloth properties that are important for coal waste disposal applications. The study reported on is significant in that it is the first formal investigation in which filter cloths were tested in the presence of coal waste samples under simulated field conditions.

[2] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Armco, Inc., Montcoal, WV; Island Creek Coal Co., McDonald Fork, WV; and Mine Safety and Health Administration (MSHA) personnel in obtaining and supplying samples of coal wastes, cobbles, and settling-pond waters. E. I. Du Pont de Nemours and Co., Inc., Wilmington, DE; Carthage Mills, Cincinnati, OH; and Celanese Fibers Marketing Co., Charlotte, NC, supplied the filter cloth samples. The Maryland State Highway Administration, Bureau of Tests, conducted the tensile strength tests. Assisting in the arduous task of putting up and taking down the test standpipes were Robert L. Stoll, formerly chemical engineer, Avondale Research Center, Bureau of Mines, Avondale, MD, now patent examiner, U.S. Patent and Trademark Office, Washington, DC; Heidi C. Triantafillou, formerly chemist, Avondale Research Center, now student nurse, University of the District of Columbia, Washington, DC; and John G. Groetsch, Jr., chemical engineer, Avondale Research Center. The author also acknowledges the assistance of personnel from MSHA's Bruceton (PA) Safety Technology Center and Denver (CO) Safety and Health Technology Center; they provided guidance and tested samples--both of which were necessary to make this project successful.

TEST METHODOLOGY AND PRELIMINARY RESULTS

Two types of tests were conducted. In one, standpipes were used to study clogging and deterioration of filter cloths by the coal waste environment. The standpipe arrangement was used to simulate a cross section through a disposal site including the settling pond, settled slurry (fine waste), dam material (coarse waste), and a filter cloth drain. Clogging was evaluated by visual examination of the filter cloths and by measuring the flow rates through the cloths with a falling-head permeameter before and after exposure to the simulated waste environment. Cloth deterioration was determined by visual examination and by tensile strength testing using American Society for Testing and Materials (ASTM) standard D1682-64 (5).

In the second type of test, filter cloths were exposed to stressing factors such as sunlight, pH, and coal-preparation reagents. The filter cloth samples were then examined visually and tested for tensile strength by ASTM standard D1682-64.

MATERIALS

Waste Samples

Three samples of coal waste and associated materials were used to test the filter cloths. (The cloths tested are described in the following section.) Two of the waste samples were from the Armco, Inc., operations near Montcoal, Raleigh County, WV. One of the Armco samples was neutral to slightly alkaline, and the other was acidic. The third sample, an acid to neutral waste, was obtained from the Island Creek Coal Co.'s Coal Mountain No. 9 preparation plant in Wyoming County near McDonald Fork, WV. Samples of rock cobbles and settling-pond waters were also obtained from each site. Low-carbonate untreated well water from Kent Island, MD, that was similar in composition to West Virginia river and ground water was used for makeup water.

Density and soil characteristics of the three coal wastes are described in table 1. Bulk density was measured by using the as-received waste sample to fill a cylindrical container (0.403-ft^3, or 0.0114-m^3 capacity) and weighing. Compacted density was determined by compacting the material in the cylinder with a flat-ended steel tamper to give compaction similar to that produced in the test standpipes. The compacted densities were 23 to 27 pct higher than the as-received bulk densities, indicating similar compaction behavior for all three wastes. During field observation of actual waste-dam construction, wastes were compacted

TABLE 1. - Densities and soil characteristics of sample coal wastes

Source and type	Density, lb/ft^3		Soil type[1]	pH
	Bulk	Compacted		
Lower Big Branch, Armco, Inc.:				
Coarse......................	70.1	87.4	GW	Acidic.
Fine........................	62.7	NAp	CL	Do.
Schumate, Armco, Inc.:				
Coarse......................	70.7	89.9	GM	Neutral to slightly alkaline.
Fine........................	76.3	NAp	SM	Do.
Island Creek Coal Co.:				
Coarse......................	66.4	81.8	GW	Slightly alkaline to acidic.
Fine........................	51.5	NAp	ML	Do.

NAp Not applicable.
[1]CL Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
GM Silty gravels, gravel-sand-silt mixtures.
GW Well-graded gravels and gravel-sand mixtures; little or no fines.
ML Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.
SM Silty sands, sand-silt mixtures.

by making multiple passes with heavy equipment over lifts (about 2 ft, or 0.61 m high) of freshly deposited coarse waste.

Acidity or basicity was determined by measuring the pH of the simulated setting-pond waters after several months' operation of the standpipes. The pH values ranged from 2.7 to 3.5 for the (Armco) Lower Big Branch wastes, 6.90 to 7.65 for the (Armco) Schumate wastes, and 3.5 to 7.6 for the Island Creek wastes. Particle-size distributions for the three wastes (table 2) were determined by MSHA's Bruceton Safety Technology Center using ASTM standard D422-63 (6).

The Island Creek fines contained a larger percentage of fine particles than

TABLE 2. - Particle-size distributions in sample coal wastes, percent passing through sieve

Sieve size, mm	Lower Big Branch	Schumate	Island Creek	Sieve size, mm	Lower Big Branch	Schumate	Island Creek
Coarse sizes:				Fine sizes--Con.			
76.2..........	100	87	NAp	0.84.........	97.5	35	97.5
50.8..........	82	77	100	0.42.........	86	24	95
25.4..........	57	59	96	0.149........	60	18	78
19.1..........	44	54	88	0.074........	53	16	67
12.7..........	32	50	80	0.05.........	NAp	NAp	66
7.9..........	22	47	61	0.04.........	NAp	15	NAp
4.8..........	15	41	36	0.03.........	NAp	NAp	63
2.0..........	9	27	13	0.02.........	NAp	13	60
0.84.........	4.5	17	6	0.01.........	47	12	55
0.42.........	3	11	3	0.007........	NAp	NAp	49
0.149........	2	7	2	0.006........	NAp	9	NAp
0.074........	0	5	0	0.005........	NAp	NAp	44
Fine sizes:				0.003........	37	7	35
7.9..........	NAp	100	NAp	0.002........	NAp	5	27
4.8..........	NAp	85	NAp	0.001........	NAp	3	15
2.0..........	100	56	100				

NAp Not applicable.

TABLE 3. - Physical properties of tested filter cloths[1]

Fabric	Mirafi 140S	Polyfilter-X	Typar 3401
Thickness..........mils..	[2]30	16	15
Weight..........oz/yd^2..	3.5	7.2	4
Equivalent opening size, U.S. standard sieve size number..........	80	70	70-100
Grab (tensile) strength[3]........lb/in..	150	380	135
Grab elongation[3]..........pct..	70	10-35	62
Burst strength..........lb/in^2..	125	540	200
Water permeability coefficient...cm/s..	0.07	0.035	0.02

[1]Manufacturers' data. [2]Varied considerably; see text.
[3]Determined in accordance with ASTM standard D1682-64.

the other two wastes; for example, 55 pct was smaller than 0.0004 in (0.01 mm). This difference may not be significant, although the immediate concern was the extent to which the fines might settle in voids within the coarse fractions and thus lead to clogging.

Filter Cloths

The three filter cloths tested, Typar 3401, Mirafi 140S, and Polyfilter-X,[3] were the cloths in widest use by the coal mining industry in southern West Virginia as determined from a survey in November 1980. The cloths were supplied by their manufacturers. Their physical properties are summarized in table 3.

Typar 3401 is a nonwoven spunbonded polypropylene fabric that is gray in color. It is described by its manufacturer as a "uniform sheet of preferentially oriented continuous filaments manufactured by an integrated process of fiber spinning and bonding." This fabric has been shown by Bureau studies and those of Raumann (3) to degrade under exposure to sunlight (ultraviolet light).

Mirafi 140S is a white nonwoven heat-bonded fabric composed of polypropylene and polyethylene fibers oriented into a stable network (manufacturer's description). The manufacturer specifies that Mirafi 140S is nonbiodegradable, resistant to acids and alkalies in the pH range of 3 to 12, and free of chemical treatment or coatings that might significantly reduce permeability or porosity. However, the manufacturer also states that the fabric deteriorates when exposed to sunlight; it is therefore shipped in black plastic wrappers. One property observed in this study and by the Maryland State Highway Administration, Bureau of Tests, was that the thickness of this fabric was quite variable from extremely thin to overly thick (fig. 1).

Polyfilter-X is a black woven fabric manufactured from monofilament yarns. The yarns consist of at least 85 pct polypropylene and contain stabilizers and inhibitors to make the filaments resistant to ultraviolet light and heat deterioration.

SIMULATION OF DISPOSAL-SITE CONDITIONS: STANDPIPE TESTS

Tests were carried out in vertical 6-in-diam standpipes, each simulating a cross section through a typical mine waste disposal site. This cross section is shown schematically in figures 2 and 3. In figure 2, the cross section line goes through pond water, settled fine slurry waste, coarse waste (the dam), and a filter cloth drain. Figure 3 shows how the disposal-site simulation was set up in the laboratory. Over the filter cloth and cobbles, each standpipe contained the following elements:

[3]Reference to specific products does not imply endorsement by the Bureau of Mines.

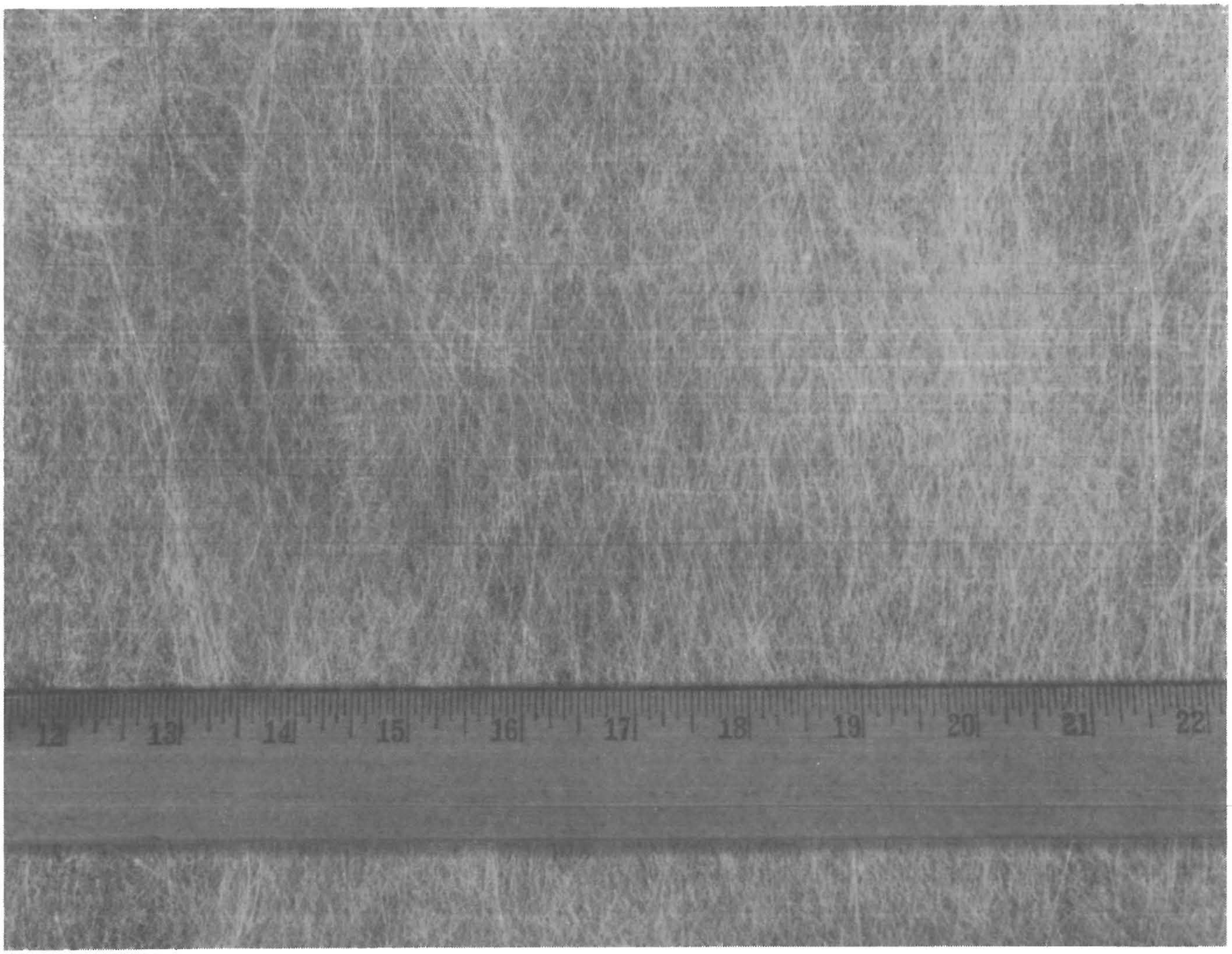

FIGURE 1. - Mirafi 140S filter cloth showing thin and thick sections.

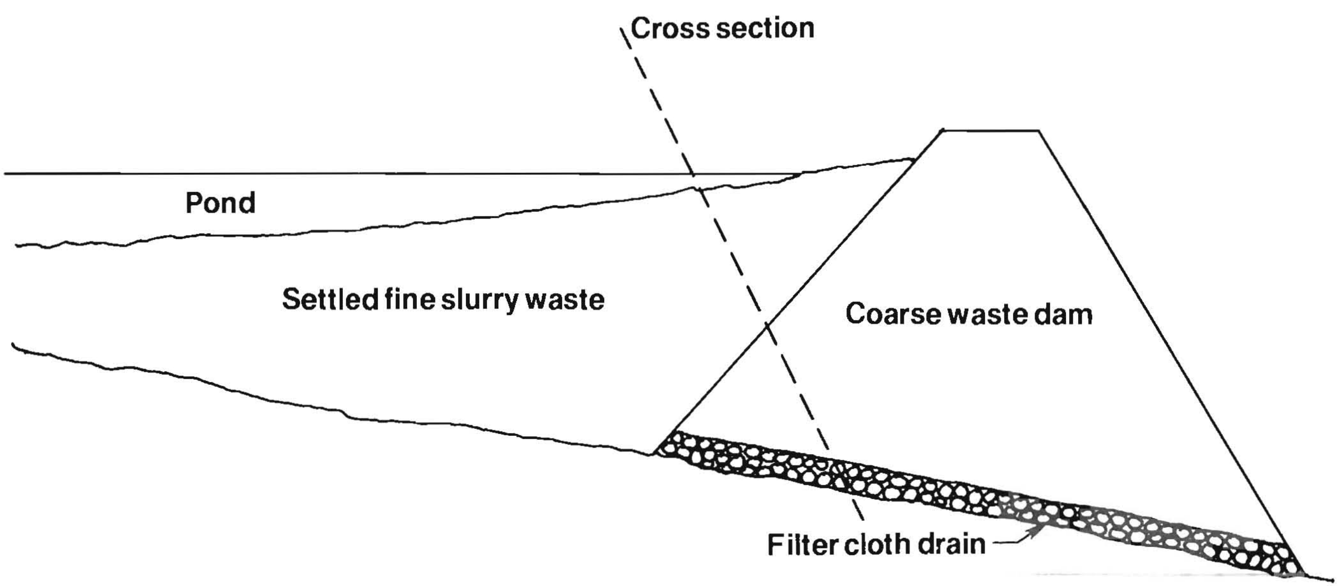

FIGURE 2. - Typical coal waste disposal site showing cross section simulated for testing.

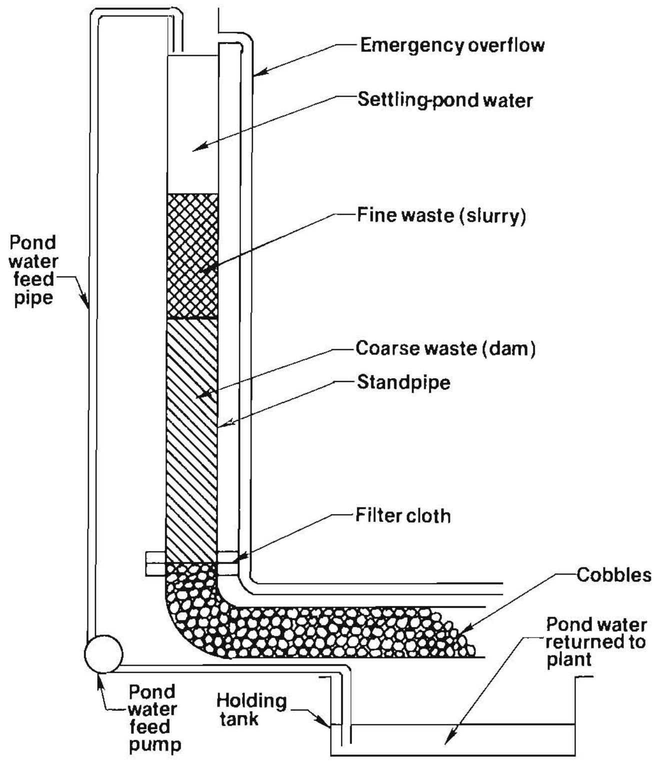

FIGURE 3. - Schematic drawing of test standpipe.

1. Coarse waste--8 ft (2.4 m) deep,

2. Fine waste--3 ft (0.9 m) deep, and

3. Water head over the fine waste--variable from 0.5 ft (0.2 m) deep to a maximum of 3.3 ft (1 m) deep.

The filter cloths tested with the Armco wastes were those in use at the Armco sites during field visits. The Island Creek Coal Co. was not using filter cloth drains at its disposal site; however, Typar 3401 filter cloth was selected for the standpipe test with the Island Creek waste. Thus, each cloth was tested with a specific waste, as follows:

Waste sample	Filter cloth
Island Creek......	Typar 3401.
Schumate..........	Mirafi 140S.
Lower Big Branch..	Polyfilter-X.

In each standpipe, the sandstone cobbles were set in place first. The filter cloth was then installed in a pipe flange so that it covered the cobbles and rested on them. The coarse waste was then applied in lifts about 2 ft (0.61 m) high (consistent with observed industry practice). Each lift was compacted using a 5-1/2-in-diam (14-cm-diam) 30-lb (13.6-kg) flat tamper, until no further compaction was possible, before the next lift was placed. The fine slurry waste was placed on top of the coarse waste, and pond water was pumped into the standpipe over the fine slurry waste. After flowing through the standpipe, the water was collected in the holding tank (fig. 3) and recycled back to the top as necessary to maintain a water head. This simulated industry practice, wherein decanted water from the slurry pond is returned to the plant to reslurry more fine waste for pumping to the pond.

The simulations using the Schumate wastes were a special case: Since it was observed during field visits that the embankment, or coarse waste section at the Schumate disposal site is actually composed of coarse and fine wastes mixed 1:1, coarse and fine wastes were so mixed in the coarse waste sections of the standpipes filled with the Schumate wastes.

Clogging Behavior

For the clogging tests, standpipes were allowed to operate for 2, 4, 6, 8, and 12 months. At the time this report was written, 18 standpipes had been taken down for examination--six for each waste. Each standpipe was disassembled, and the filter cloth was carefully examined to determine if a filter cake had been formed. Only three of the 18 cloths examined had any significant filter cake: A 3/8-in (9.5-mm) filter cake after a 2-month test with Typar 3401 cloth and Island Creek waste, a 1/4-in (6.4-mm) filter cake after a 6-month test with Mirafi 140S cloth and Schumate waste, and a 1/4-in (6.4-mm) filter cake after an 8-month test with Mirafi 140S cloth and Schumate waste. After removal from the standpipe, each filter cloth was carefully washed in running water to remove any loose material on the surface; it was then examined visually and microscopically for signs of clogging by the wastes.

All Typar 3401 samples (used with Island Creek waste) showed some degree of clogging by coal waste both on the surface and in the cloth. In addition, all the Typar samples were clogged with a precipitated yellowish-red material identified by energy-dispersive X-ray techniques as being composed mainly of iron and silicon. The amount of this precipitated material appeared to vary with both pond water pH and time of exposure.

In addition to the visual and microscopic examinations, each filter cloth sample was measured for flow rate in a falling-head permeameter; the post-exposure flow rates were then compared to the rate for a clean, unused sample of the same cloth. The flow rate and pond-water pH data are shown in table 4. The flow rates in the standpipes using the Island Creek waste and Typar 3401 fabrics were affected by both pH and length of service. The Island Creek waste material was shipped in three containers, but all the material was collected at a single site. However, some portions were slightly alkaline, some neutral, and some were acidic, even within the same containers. Visual observations showed less of the precipitated iron-silicon material on cloth samples from acidic standpipe setups. The acidic 6-month sample yielded a higher flow rate and had less pecipitated material than the neutral 6-month sample. The latter sample was completely clogged with the precipitated iron-silicon compound (fig. 4*C*), and of the 18 cloth samples examined, it was the most clogged. After 8- and 12-month exposures to neutral-pH wastes, visual examination of the used filter cloths showed less of the precipitated material, and flow rates (table 4) were increasing rather than decreasing. The reason for this apparent anomoly is not known.

All the Mirafi 140S samples (from the Schumate waste setups) had large areas of clear, unclogged cloth. Figure 5 shows a new piece of cloth and portions of a used cloth with clear, unclogged areas; clogged areas; and waste trapped within the thickness of the fabric. The clogging generally caused only a slight drop in flow rate (table 4), with most values within the spread of the normal range. The cloth sample that yielded the lowest flow rate--one of the two 6-month samples--had a filter cake but appeared to be no more clogged than the other samples when it was washed and examined before the flow rate was measured. The 8-month sample, which also had a filter cake, had a flow rate in the normal range (but near the lower limit of the normal range). The 12-month sample had a flow rate below the normal range. No precipitated material similar to that from the Island Creek waste was found with the Schumate waste on any filter cloth examined.

TABLE 4. - Flow rates for new and used filter cloths as measured in falling-head permeameter

Exposure, months	Typar 3401 (Island Creek)		Mirafi 140S (Schumate)		Polyfilter-X (Lower Big Branch)	
	Flow rate, mL/s	Pond water pH	Flow rate, mL/s	Pond water pH	Flow rate, mL/s	Pond water pH
0	173± 17	NAp	260± 40	NAp	220± 17	NAp
2	NA	3.4	236	7.3	331	3.6
4	108	7.1	229	7.1	268	4.1
6	83	4.2	149	7.7	303	3.7
6	.14	7.0	241	7.6	280	2.8
8	96	7.1	223	7.2	255	2.7
12	129	7.0	205	7.0	310	3.3

NA Not available. NAp Not applicable.

FIGURE 4. - Unused and used Typar 3401 cloth samples (magnified). *A*, New cloth.

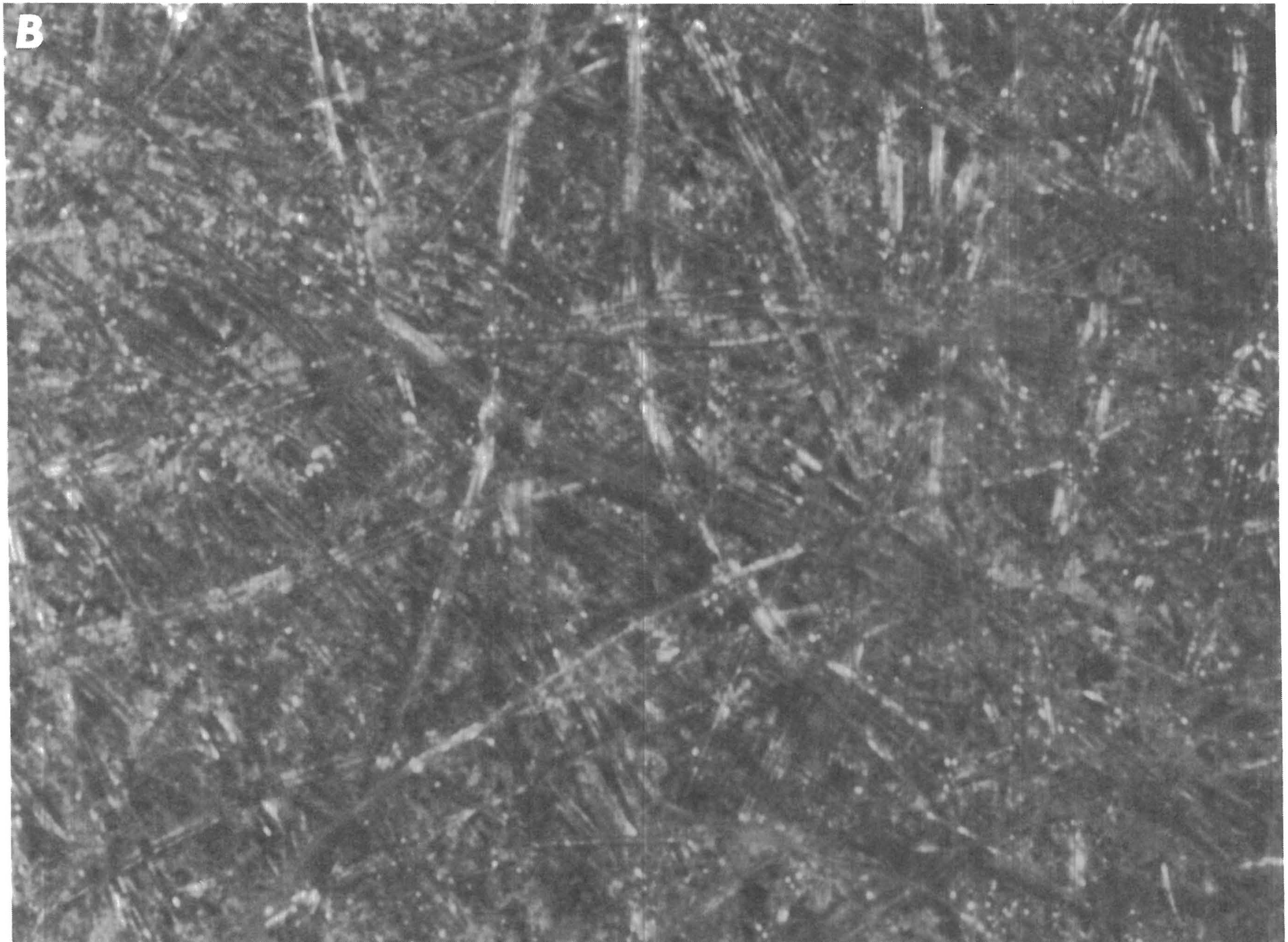

FIGURE 4. - Unused and used Typar 3401 cloth samples (magnified)—Continued. *B*, Cloth partially clogged with coal wastes.

FIGURE 4. - Unused and used Typar 3401 cloth samples (magnified)—Continued. *C*, Cloth completely clogged with precipitated material.

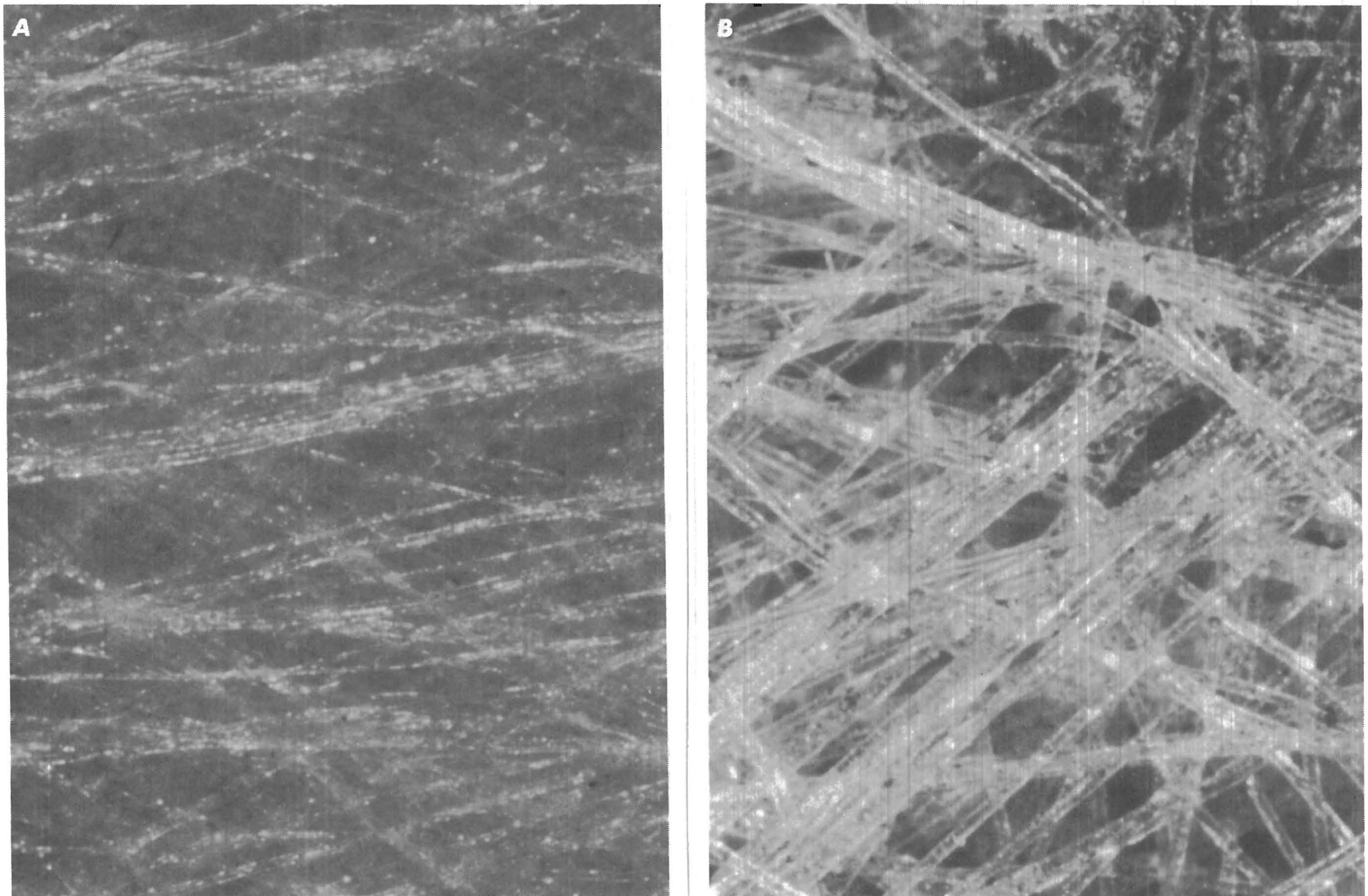

FIGURE 5. - Unused and used Mirafi 140S cloth samples (magnified). *A*, New cloth; *B*, unclogged area.

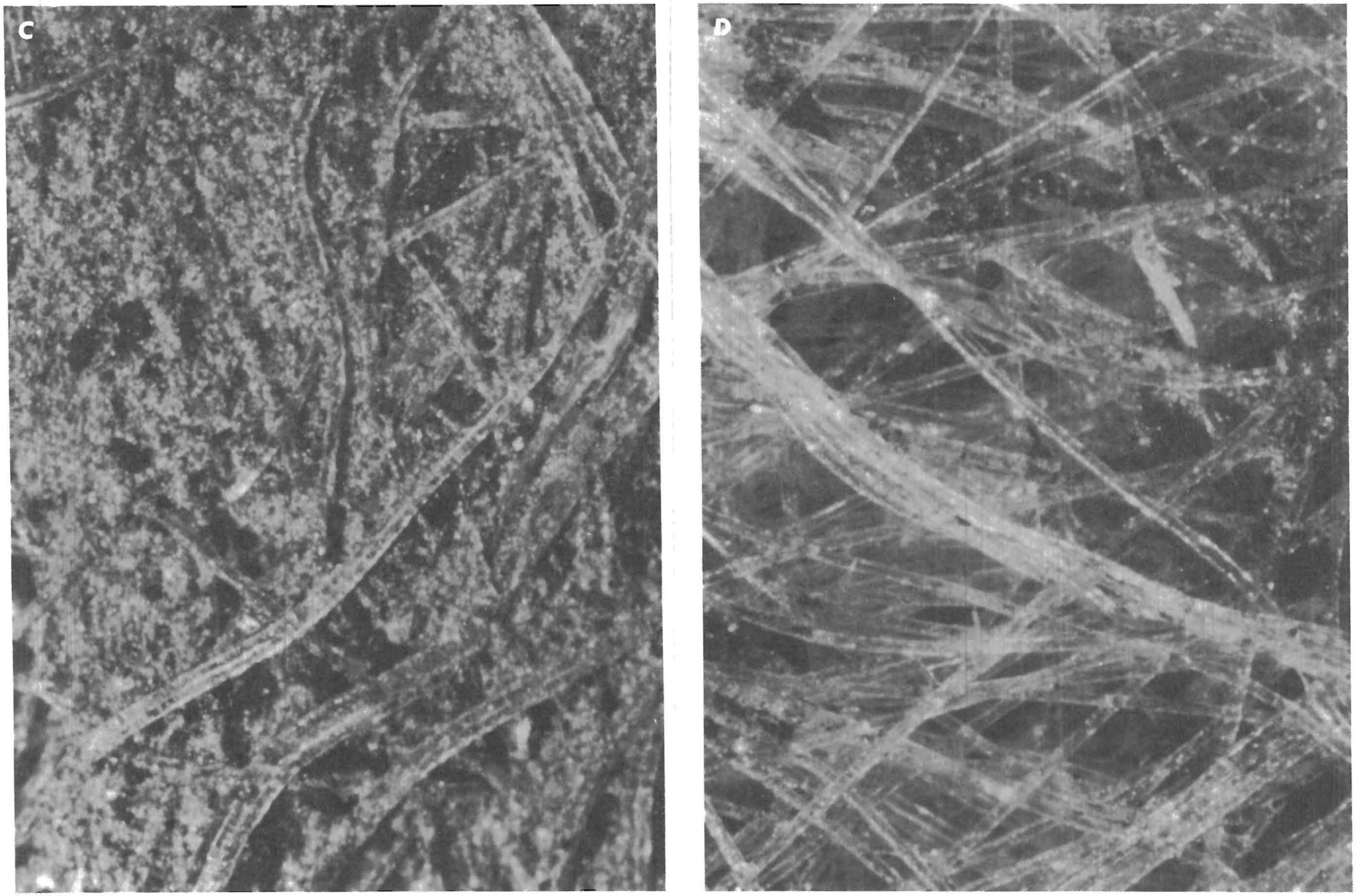

FIGURE 5. - Unused and used Mirafi 140S cloth samples (magnified)—Continued. *C*, Clogged area; *D*, waste trapped within fabric.

All the Polyfilter-X cloth samples (tested with the Lower Big Branch wastes) were free of filter cakes and clogging. Figure 6 shows clean, unused cloth and a typical piece of used cloth. The flow rates were significantly higher--about 31 pct--for the used cloths as compared to the unused cloth (table 4). It appeared that the weave was opened slightly on the used cloths (as shown in figure 6), either by the weight of the waste column or by the force generated during compaction. This could account for the increased flow rates.

Flow rates through all the standpipes were monitored once a week since startup. As of the writing of this report, flow rates had dropped significantly with time in 35 of 43 standpipes set up. All but two of the remaining eight standpipes, in which flow rates were higher or the same, had been in operation for less than 6 months. The falling flow rates in 35 of the standpipes were probably due to settling of the fines within the waste column, and not clogging of the filter cloths. To determine the cause of falling flow rates with time, three standpipes were modified so that the filter cloths could be removed and replaced without disturbing the waste column. Tests using these modified standpipes were not completed at the time this report was prepared, but the theory was that if the flow returned to or near to the original levels after replacement with a new filter cloth, this would indicate that the original cloth was clogged; if the flow remained low, this would indicate the column was clogged.

Cloth Deterioration

Six samples each of Typar 3401 (used with Island Creek waste), Mirafi 140S (Schumate waste), and Polyfilter-X (Lower Big Branch waste) were removed from the standpipes after periods of 2 to 12 months. No broken fibers or other signs of failure were noted in visual examination of samples of filter cloths from disassembled standpipes. All samples were tested for tensile strength using ASTM D1682-64 at the Maryland State Highway Administration's Bureau of Tests laboratory in Brooklandville, MD. All the (used) samples tested were within the normal ranges for unused, unstressed filter cloth fabrics of the same type. The samples thus showed no deterioration in tensile strength or other signs of deterioration after exposure to the simulated coal mine waste environments.

EXPOSURE TESTS

Effects of Pond-Water Solution Chemistry

Tests were conducted to determine the effects of pond-water solution chemistry on each of the filter cloths. Specifically, the effects of pH and of coal-preparation reagents were investigated.

For each test, three sets of ten 4- by 8-in (10.2- by 20.3-cm) pieces were cut from each filter cloth, five along the length of the roll and five across the width of the roll, as specified by ASTM D1682-64 for tensile strength measurement. All solutions and filter cloths were kept in a light-free closed cabinet during the course of the tests so that sunlight would not alter the test results.

pH

The pH tests were run for periods of 2, 4, and 6 months, with pH of the solutions ranging from 2 to 12. The solutions were prepared using commercial pH buffers. After removal from the solution, all samples were washed, air dried, and then tested for tensile strength. There was no measurable deterioration of any of the cloths. This finding was in agreement with claims by the manufacturers of the cloths.

Coal-Preparation Reagents

Four reagents were selected from a list of the most commonly used coal-preparation reagents. For each test, 3 sets of 10 pieces of filter cloth were used as described in the section, "Effects of Pond-Water Solution Chemistry."

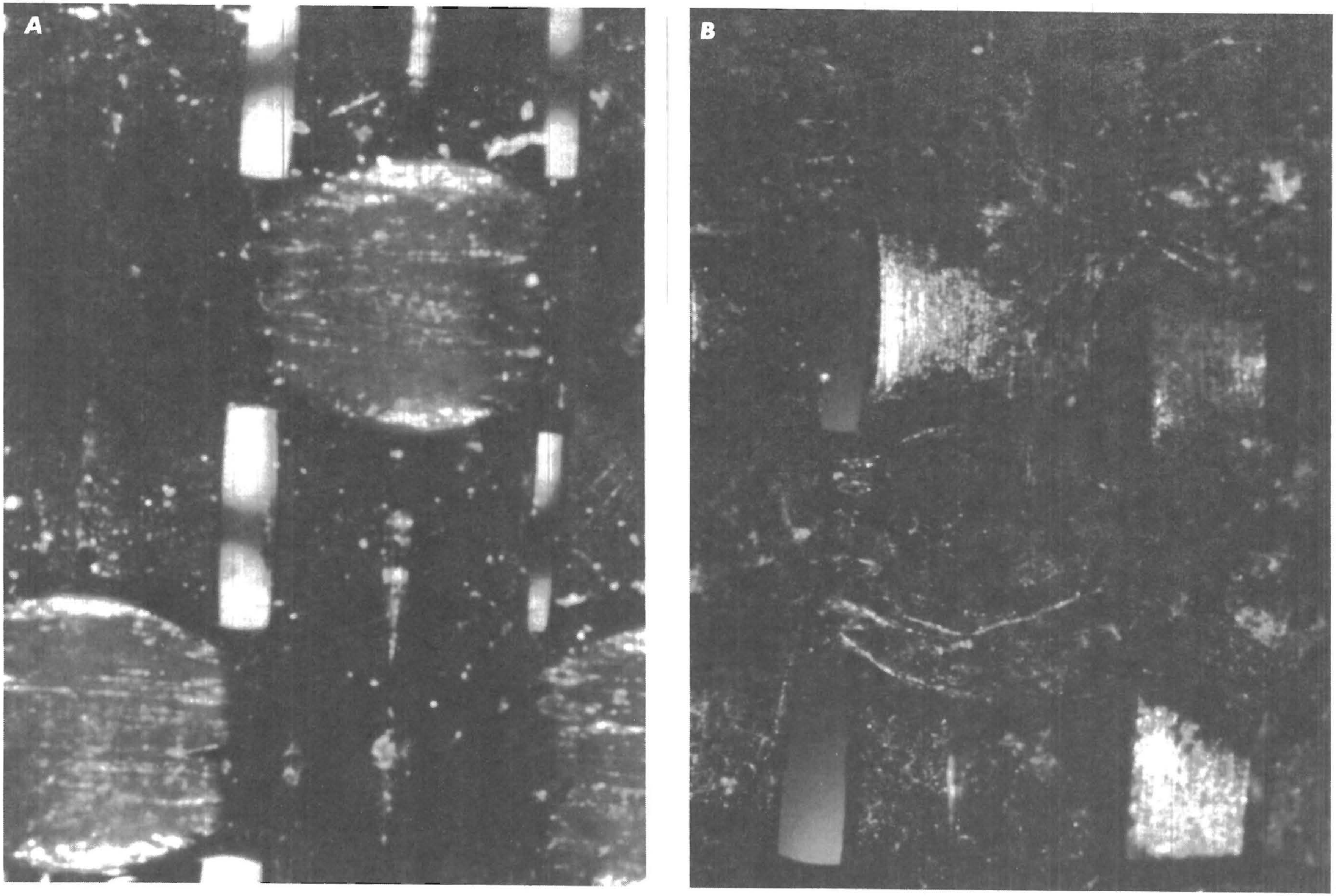

FIGURE 6. - Unused and used Polyfilter-X cloth samples (magnified). *A*, New cloth; *B*, used but unclogged cloth.

Two flocculants from the Cyanamid Co., Superfloc 214, a high-molecular-weight (10 to 15 million gram molecular weight units) anionic polyacrylamide-type flocculant, and Superfloc 330, a highly cationic polyamine-type flocculant, were tested in aqueous solutions. Also tested were two Dowell Chemical Co. reagents, M 150 frother and M 210 conditioner, which are used in froth flotation. Since both Dowell chemicals are used together in a diesel fuel solution in the flotation tank, tests were set up in (1) diesel fuel alone, (2) diesel fuel with M 150 frother, (3) diesel fuel with M 210 conditioner, and (4) diesel fuel with both reagents. The solution compositions for the six test setups are listed in table 5. The different solvent volumes were required because the water solutions were placed in covered 0.26-gal (1,000-mL) polyethylene beakers and the diesel fuel solutions were placed in 1-gal (3.785-L) wide-mouthed closed glass bottles. Results for 1- , 2- , and 3-months tests are listed in table 6.

TABLE 5. - Components of coal-preparation reagent test solutions

Solvent and test number	Reagent and quantity
1,000 mL water:	
Test 1.........	Superfloc 214, 0.35 g.
Test 2.........	Superfloc 330, 0.35 g.
2,200 mL diesel fuel:	
Test 3.........	None.
Test 4.........	Dowell M 150, 65 mL.
Test 5.........	Dowell M 210, 55 mL.
Test 6.........	Dowell M 150, 65 mL, plus Dowell M 210, 55 mL.

TABLE 6. - Tensile strengths of filter cloths after exposure to coal-preparation reagents, pounds per inch

Exposure time, months	Typar 3401		Mirafi 140S		Polyfilter-X	
	Length[1]	Across[1]	Length[1]	Across[1]	Length[1]	Across[1]
NORMAL RANGES FOR UNUSED CLOTH						
0.......	103-157	150-180	105-154	120-166	462-509	286-368
DIESEL FUEL						
1.......	119	167	86	101	474	288
2.......	110	167	104	104	471	258
3.......	133	159	97	110	508	299
DIESEL FUEL PLUS DOWELL M 210 CONDITIONER						
1.......	126	148	73	125	465	279
2.......	119	170	105	112	452	294
3.......	131	156	83	128	433	293
DIESEL FUEL PLUS DOWELL M 150 FROTHER						
1.......	140	153	101	122	431	276
2.......	133	156	101	119	457	286
3.......	145	161	97	106	446	277
DIESEL FUEL PLUS M 210 CONDITIONER AND M 150 FROTHER						
1.......	94	156	93	116	446	264
2.......	133	162	98	122	406	263
3.......	140	147	92	125	466	279
WATER PLUS CYANAMID SUPERFLOC S214						
1.......	104	173	136	148	509	294
2.......	123	170	137	140	515	286
3.......	129	150	123	136	498	287
WATER PLUS CYANAMID SUPERFLOC S330						
1.......	137	150	137	144	495	290
2.......	104	169	116	139	495	296
3.......	124	151	130	136	504	294

[1]Direction of sample on roll of filter cloth.

All samples from the aqueous-solution flocculant tests had tensile strengths in the normal range, indicating no deterioration. The Typar cloth was not affected by the diesel fuel or any of the diesel fuel-reagent combinations, except that one slightly low value was noted in the test with diesel fuel plus both reagents. The Mirafi cloth showed tensile strengths from low normal to those representing an average 7-pct loss of strength after exposure to diesel fuel with or without reagents. The Polyfilter-X cloth showed tensile strengths from low normal to those representing about a 2-pct average loss of strength. It is believed that the small losses of tensile strength in the Mirafi and Polyfilter-X cloths were due to softening of the polypropylene and polyethylene fibers by the diesel fuel. However, in preparation-plant practice, the diesel fuel and reagents are present in the froth flotation baths only at the parts-per-million levels listed in table 7. The concentrations likely to be encountered by filter cloths in waste drains are so low that no significant effects would be expected.

TABLE 7. - Compositions of normal flotation baths containing Dowell reagents (7), parts per million

Ratio	Diesel fuel	M 150	M 210
4:5:1.....	5-25	6-12	1-3
9:5:1.....	16-25	6- 9	1-2

Effects of Sunlight Exposure

Cloth samples were prepared for sunlight exposure tests using the test rack shown in figure 7. Half the rack held nine flat panels (three for each cloth) to test the effect of complete exposure to sunlight. The other half held samples in rolls eight layers deep to test the effect of sunlight on rolls of filter cloth used to simulate rolls left exposed in the field. (During visits to waste disposal sites, cloth rolls left exposed to sunlight were frequently observed.) Each flat sample (12 by 22 in, or 30.5 by 55.9 cm) was oriented so that the short dimension was in the direction of the length of the roll. All roll samples were lengths taken from the overall length of the roll. Thus, each flat or roll sample yielded five 4- by 8-in (10.2- by 20.3-cm) pieces, each originally oriented such that its long axis was parallel to the length of the roll. Samples were taken for tensile strength testing after 2- , 4- , and 6-month exposures to sunlight.

Again, tensile strength tests were conducted by the Maryland State Highway Administration, Bureau of Tests, using a modification of ASTM standard D1682-64. The standard procedure requires 5 specimens transverse to the roll and 5 parallel to the roll. However, the procedure was modified because only 5 samples parallel to the roll were available from each test.

Flat Cloths

All three fabrics were affected by sunlight exposure (table 8). Polyfilter-X, with its stabilizers and inhibitors to protect against ultraviolet light deterioration, was affected the least. Its tensile strength even after 6 months' exposure had only deteriorated by about 9 pct. The tensile strength of Mirafi 140S showed little change after 2 months but dropped 61 pct after 4 months and 86 pct after 6 months; at 6 months, the cloth had become somewhat brittle. Typar 3401 experienced the most severe deterioration: no measurable loss in strength after 2 months, a 76-pct loss in strength after 4 months, and a 98-pct loss after only 4.6 months. The Typar sample had to be removed from the test rack at 4.6

TABLE 8. - Tensile strengths of flat panels after exposure to sunlight, pounds per inch

Exposure time, months	Typar 3401	Mirafi 140S	Polyfilter-X
0........	103-157	105-154	462-509
2........	125	125	454
4........	25	41	433
6........	[1]2	15	419

[1]Sample had to be removed after 4.6 months because of deterioration.

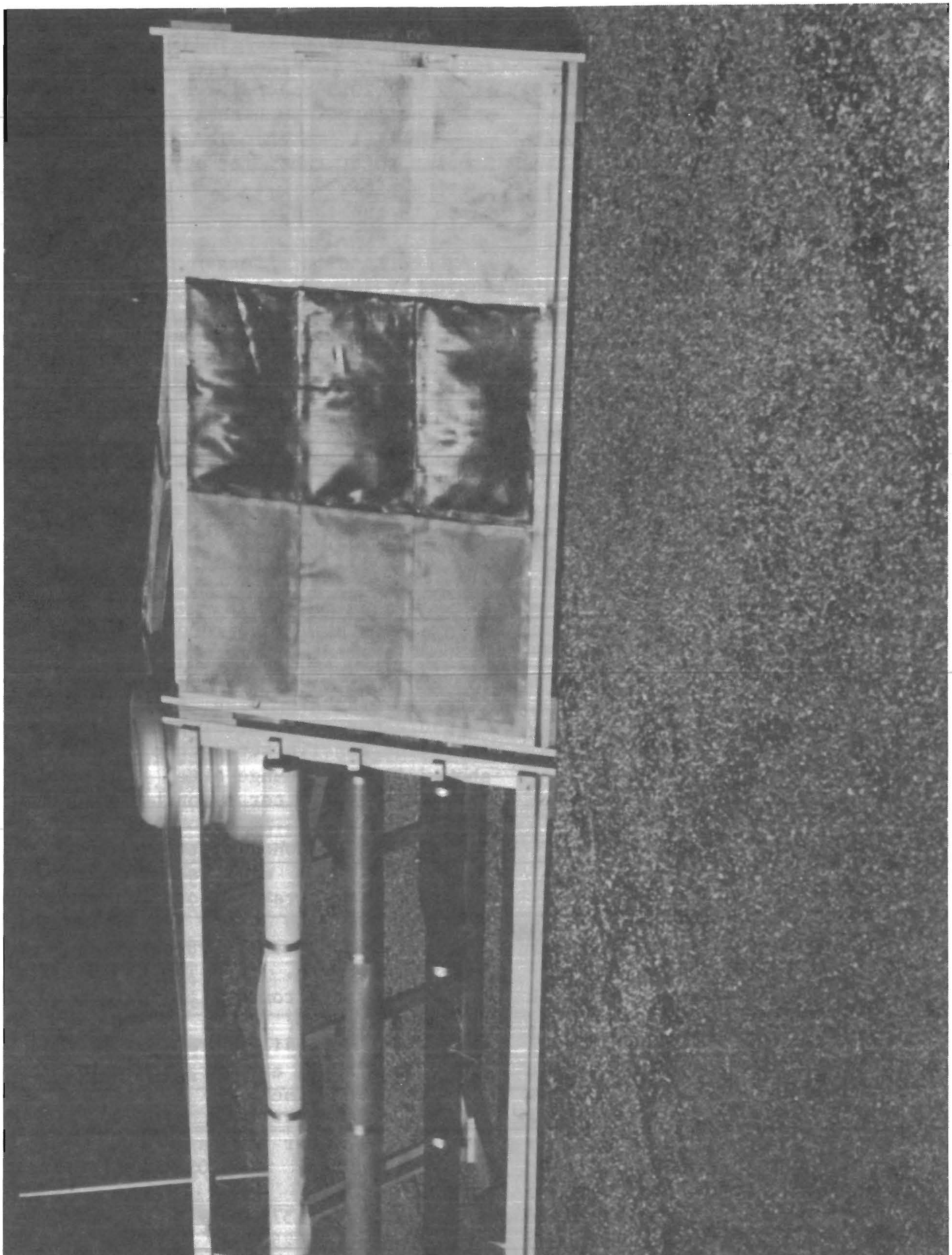

FIGURE 7. - Rack used for sunlight exposure tests.

months; it had become extremely brittle and was breaking and crumbling. Figure 8 shows a piece of Typar 3401 before the sunlight exposure and the sample after 4.6 months exposure to sunlight.

Cloth Rolls

Originally, only the top four layers of each roll sample were tested for tensile strength (table 9). However, the data for Mirafi 140S indicated that significant deterioration was evident down to layer 4 and possibly deeper into the roll after only 2 months' exposure to sunlight. Thus, this filter cloth was tested down to the bottom of the roll for 2- , 4- , and 6-month exposures. These tests showed significant deterioration down to the bottom of the roll (layer 8) in all except the 6-month sample. The tensile strength of layers 7 and 8 of the 6-month sample were near the bottom limit for Mirafi 140S, but because of the wide normal tensile strength range, the strength values for these layers may actually have been normal high values that had deteriorated slightly but still appeared in the normal range.

TABLE 9. - Tensile strengths of rolls after exposure to sunlight, pounds per inch

Exposure time, months	Layer	Typar 3401	Mirafi 140S	Polyfilter-X
0.......	NAp	103-157	105-154	462-509
2.......	1	92	56	458
	2	127	63	462
	3	120	72	478
	4	122	83	477
	5	NT	94	NT
	6	NT	104	NT
	7	NT	101	NT
	8	NT	NT	NT
4.......	1	121	58	439
	2	135	76	467
	3	122	72	469
	4	128	76	465
	5	NT	87	NT
	6	NT	99	NT
	7	NT	84	NT
	8	NT	89	NT
6.......	1	21	39	438
	2	109	51	455
	3	145	68	461
	4	148	76	477
	5	NT	91	NT
	6	NT	92	NT
	7	NT	111	NT
	8	NT	111	NT

NAp Not applicable. NT Not tested.

The data for Typar 3401 indicated that the somewhat opague gray color of the fabric absorbs most of the ultraviolet radiation in the top layer, allowing no measurable deterioration below this level. The 4-month sample showed no measurable signs of deterioration in its top layer, whereas the top layer of the 2-month sample lost a slight amount of its tensile strength and the top layer of the 6-month sample lost about 80 pct of its strength.

Polyfilter-X, with its stabilizers and inhibitors, showed only a slight loss of tensile strength. The top layer of the 2-month sample lost only a slight amount of tensile strength, and the top layers of the 4- and 6-month samples each lost 5 pct of their strength. The second layer of the 6-month sample lost only a slight amount of its strength, and the strength of the third layer of that sample was nearly equal to the lower limit of the normal range.

These data indicate that none of these fabrics should be left outside on the job and then used. Rolls of Typar 3401 and Polyfilter-X would probably be usable after the top two or three layers were removed and discarded after sunlight exposure, but complete protection would be preferable. However, the test results indicate that rolls of Mirafi 140S should not be used for waste drain applications after even brief exposures to sunlight.

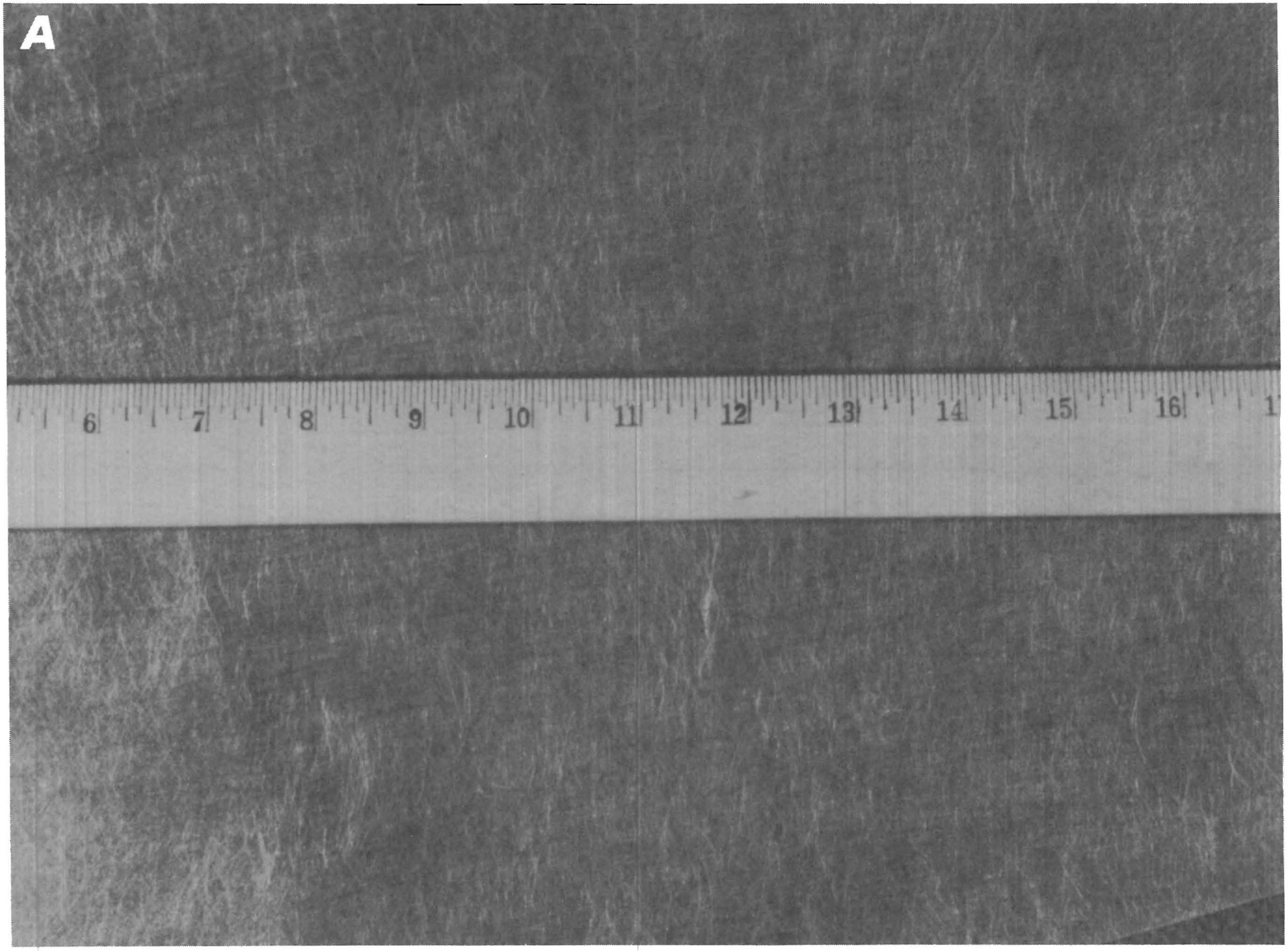

FIGURE 8. - Effect of 4.6-month sunlight exposure on Typar 3401 filter cloth samples. *A*, New cloth.

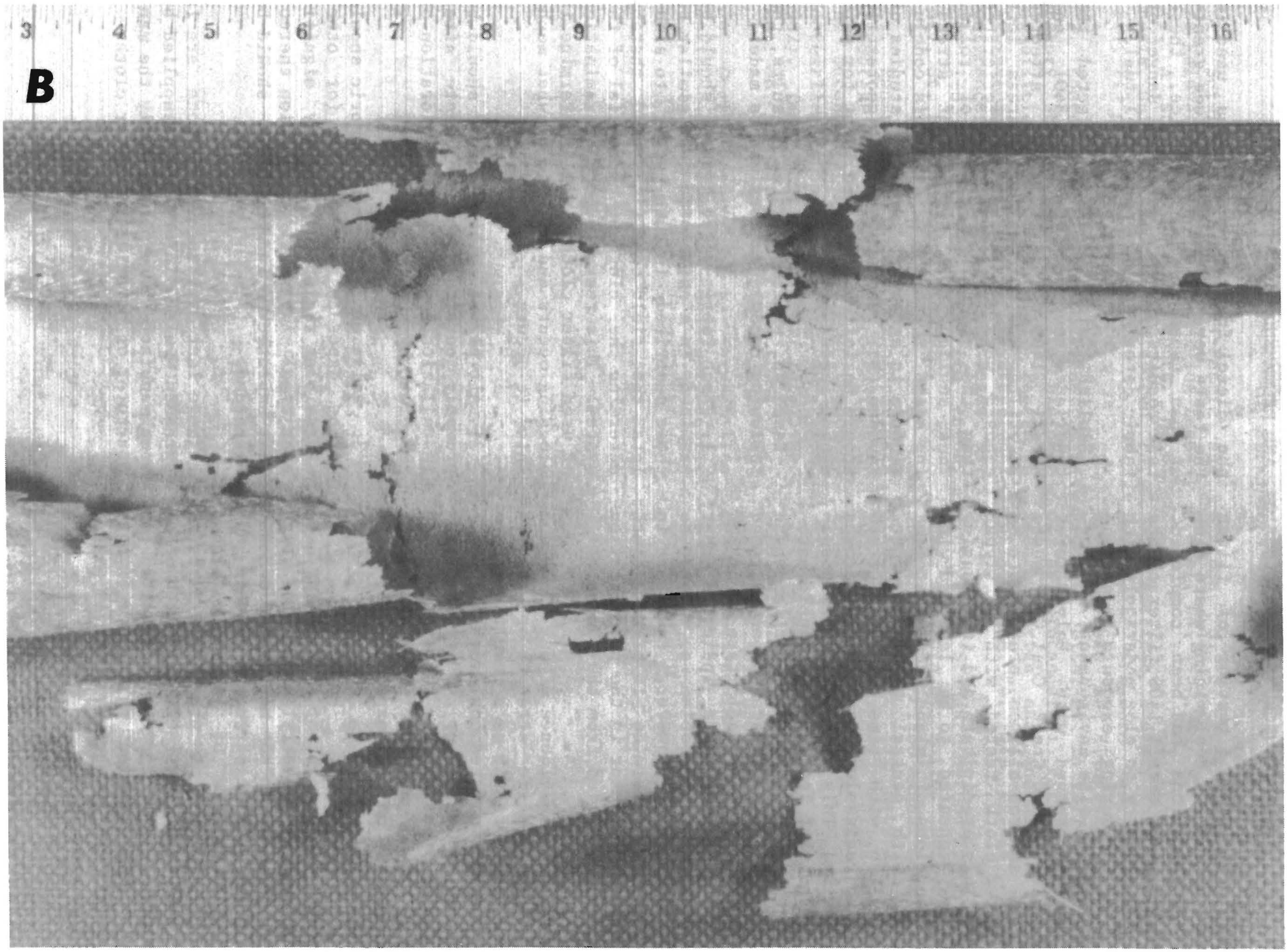

FIGURE 8. - Effect of 4.6-month sunlight exposure on Typar 3401 filter cloth samples—Continued. *B*, Sample after exposure.

CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

Some preliminary testing of filter cloths for use in coal mining waste disposal applications has been completed. Typar 3401 and Mirafi 140S filter cloths showed a tendency to clog moderately with coal wastes during exposure to a simulated disposal site environment; no clogging was observed with Polyfilter-X cloth. The Island Creek Coal Co. waste produced an iron-silicon precipitate on the filter cloth tested with it (Typar 3401). This precipitate and its clogging potential appeared to be lessened with acidic portions of Island Creek waste and enhanced with neutral to alkaline portions. Also, with time, the precipitate seemed to redissolve, freeing the cloths of clogging. This dissolution was possibly a result of leaching of soluble material from the limited amount of waste material in the test standpipes followed by leaching of the precipitate from the filter cloth. No data indicated that this precipitation problem is related to Typar 3401 cloth; however, tests are in progress to determine if filter cloth material is a factor in the precipitation of dissolved solids from the leachate.

There was no evidence of any decrease in fabric tensile strength or visible damage to any fabric as a result of exposure to the simulated coal waste environment for periods of up to 1 yr. Cloths exposed to pond waters ranging from pH 2 to 12 showed no deterioration in tensile strength during exposures of up to 6 months.

Aqueous solutions of commonly used flocculants of polyacrylamides and polyamines resulted in no measurable deterioration of tensile strength even at concentration orders of magnitude higher than would be used in practice. Exposure to diesel fuel by itself and with other flotation bath reagents resulted in slight deterioration of the Mirafi 140S and Polyfilter-X fabrics. However, since the diesel fuel concentrations used in the tests were orders of magnitude greater than those used in practice, these test results did not indicate a danger of fabric deterioration from diesel fuel.

Sunlight significantly affected the tensile strength of Typar 3401 and Mirafi 140S and slightly affected Polyfilter-X. Large flat areas left exposed were more strongly deteriorated than the exposed surfaces of rolls. Thus, sunlight is a significant stressing agent to the fabrics. This conclusion is in agreement with the studies of Raumann (3), who stated, "No geotextile should be left exposed to light for permanent installations."

Based on preliminary test results, the following recommendations can be made:

1. Each fabric-waste system should be examined in a standpipe test similar to those described in this report to simulate the field conditions and thereby determine the clogging potential of the system. This test, including examination of used filter cloths, will determine if clogging occurs and, if so, by what mechanism it occurs.

2. All filter cloth drains should be promptly covered with coal waste after installation to prevent deterioration of the cloth by sunlight.

3. Rolls of filter cloth fabric should not be exposed to sunlight (or other ultraviolet radiation) for any significant time. Any roll or portion thereof left unprotected in the field should be discarded.

These last two recommendations are in agreement with information supplied by some manufacturers, particularly the manufacturer of Mirafi 140S filter cloth.

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