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Methods Used for Testing the Bio-Colmatation and—Degradation of Geotextiles Manufactured in Romania

Méthodes utilisées pour la détermination du biocolmatage et de la dégradation des géotextiles fabriquées en Roumanie

Four polypropylene fabrics, a polyester textile and a material prepared from residues of different synthetic polymeric textiles were studied. More than 1400 geotextile samples were incubated in 8 media (distilled water, media for culturing iron bacteria, desulfovibrios and levansynthesizing bacteria, liquid mineral medium, sea water, compost and soil) for 5-17 months. The results indicated that some colmatation occurred in the geotextiles incubated in cultures of iron bacteria, desulfovibrios and levansythesizing bacteria. But this bio-colmatation should be a slow phenomenon, not affecting the filtering-draining capacity of geotextiles, as no important modifications appeared in their permeability. The geotextiles are not toxic for the aquatic and soil microorganisms. Some water soluble substances from geotextiles can even promote the development of microorganisms. However, none of the geotextiles showed any sign of biodegradation. Tensile strength and infrared spectroscopy also indicated that the mechanical properties and structure of geotextiles remained unchanged.

Les auteurs ont étudié quatre types de géotextiles non-tissés (deux en polypropylène, un en polyester et un d'un mélange des polymères synthétiques) et deux tissus en polypropylène. Plus de 1400 échantillons ont été incubés dans huit milieux (eau distillée, milieu pour la cultivation des ferrobactéries, désulfovibrions et bactéries synthétisant le lévane, milieu minéral liquide, eau de mer, compost et sol) à une durée de 5-17 mois. Les résultats obtenus, ont montré qu'il y a un certain biocolmatage apparu dans les géotextilex incubées dans les cultures des ferrobactéries, des désulfovibrions et des bactéries synthétisant le lévane. Mais ce biocolmatage est un phénomène lent, qui n'affecte pas la capacité filtrante-drainante des géotextiles parce qu'on ne se produit pas des modofícations importantes dans leur perméabilité. Les géotextiles ne sont pas tóxiques pour les microorganismes aquatiques et terricoles. Certaines substances hydrosolubles des géotextiles peuvent même stimuler le développement des bacteries. D'ailleurs, aucune des géotextiles n'a montré des signes de biodégradation. Les propriétés mécaniques et la structure des géotextiles ont resté les mêmes.

INTRODUCTION

Microorganisms can damage the geotextiles by colmatation and degradation. Both inorganic and organic compounds produced by microorganisms can cause the colmatation of geotextiles. Biodegradation of geotextiles like that of other synthetic polymers depends, first of all, on their chemical structure. For understanding the recalcitrance (1) of the polyalkene-type geotextiles to biodegradation, the findings by Albertsson et al. (2-4) are of major importance. Working with carbon-14 labeled polyethylene films and powders they have shown that only the carbon of the low molecular weight fractions is converted to $^{14}CO_2$; the polymer is resistant to biodegradation. According to literature data reviewed for example by Higgins and Burns (5), evidence has been obtained for the biodegrability of many polyesters, but in most cases the rates of biodegradation are extremely low, being measured in months or years rather than days. This is presumably true also for the polyester-type geotextiles.

In this paper the results of testing six types of geotextiles, manufactured in Romania are described for their microbial colmatability and degradability under laboratory conditions. The studied geotextiles comprised four polypropylene fabrics, one polyester and a material prepared from residues of different synthetic polymeric textiles. The used methods made possible the observation of geotextiles colmatation by microbially produced ferric hydroxide, ferrous sulfide and polysaccharide (levan) as well as the microbial metabolization and co-metabolization of biodegradable materials.

MATERIALS AND METHODS

Tested Geotextiles.

The six types of tested geotextiles comprised both nonwoven and woven fabrics also differing in respect of their functionality and hydraulic properties.

MADRIL$^{(R)}$M is a nonwoven polypropylene fabric; its fibers have a fineness of 0.66 tex and a length of 60 mm and are mechanically bonded by needlepunching.

MADRIL$^{(R)}$V differs from MADRIL$^{(R)}$M only by fineness (1.9 tex) of its fibers and length (100 mm).

MADRIL$^{(R)}$P is a nonwoven polyester textile; its fibers of 0.44 tex fineness and of 60 mm length are mechanically bonded by needlepunching.

TERRASIN is the nonwoven prepared from residues of different synthetic polymeric textiles. The fineness of its fibers varies between 0.4 and 2.5 tex and the length between 30 and 60 mm. The fibers of Terrasin are bonded mechanically by needlepunching and chemically by Romacryl (an acrylate based binding agent manufactured in Romania).

ALPHA M is a woven polypropylene fabric with fibrillated yarns whose fineness is 229 tex (warp) and 268 tex (filling); its denseness is of 58 yarns/10 cm (warp) and 86 yarns/10 cm (filling).

ALPHA G, like Alpha M, is a woven polypropylene textile; its yarns are fibrillated in warp (fineness 267 tex) and multifilamentary in filling (fineness 297tex). The denseness of Alpha G is of 109 yarns/10 cm in warp and of 108 yarns/10 cm in filling.

Incubation Media

The geotextile samples were incubated in 8 media.

1.Distilled water served as control medium (D.W.).

2.For culturing iron bacteria the nutrient medium recommended by Fedorov (6) was used. This medium is prepared from fallen leaves which are extracted with hot tap water. The dark-colored extract is filtered, then diluted with water to render its color pale yellow.Finally,iron chippings are added to the diluted extract (5 g iron/1000 mL extract); pH=6.5 (M.I.B.).

3.Desulfovibrios were cultured in a variant of the van Delden medium (Allen (7)) consisting of 2 g peptone, 1 g K_2HPO_4, 1.5 g $MgSO_4$. 7 H_2O, 5 g Na lactate,0.25 g $FeSO_4$. 7 H_2O in 1000 mL tap water; pH= 7,(M.D.).

4.For the cultivation of levan-synthesizing bacteria the method of Kiss and Drăgan-Bularda (8) was applied but the synthetic basal medium was replaced by beef extract. Composition of the medium: beef extract (Difco) 3 g,sucrose 100 g and tap water 1000 mL; pH = 7 (M.L.B.).

5.The liquid mineral medium (Schlegel (9))used was prepared from 1 g NH_4Cl, 0.5 g K_2HPO_4, 0.2 g $MgSO_4$.$7H_2O$, 0.01 g $CaCl_2$, 1 mL Hoagland solution of microelements and 1000 mL tap water; pH = 7 (L.M.M.).

6.Water collected from the Black Sea (S.W.).

7.The compost applied was obtained from different plant residues in the Botanical Garden of Cluj-Napoca (C).

8.The used soil is a fertile alluvial soil from the vicinity of Cluj-Napoca (A.S.).

Experimental Variants.

Five discs and three strips (from Madril M,V,P or Terrasin) or three squares and three strips (from Alpha M or G) were put in a 2 L glass jar containing one of the six liquid media or introduced into a 10 L Mitscherlich vessel filled with compost or soil.Thus, 352 individual geotextile samples were necessary for a testing period. As the experiment comprised 4 testing periods,a total of 1408 samples were used.

The distilled and sea water in which geotextile samples were immersed,and the compost and soil in which similar samples were placed were not inoculated with microorganisms. In other words,the geotextile samples were submitted only to the action of the spontaneous microflora present in these four media.

The media for iron and levan-synthesizing bacteria and the liquid mineral medium, after immersion of geotextile samples,were inoculated with mixed populations of microorganisms from compost,alluvial soil and mud (the mud was collected from the Gheorghieni lake in Cluj-Napoca). The geotextile samples immersed in the medium of levan-synthesizing bacteria were inoculated also with the cell suspension of a Bacillus species very active in synthesis of levan. The geotextile samples introduced into the medium of desulfovibrios were inoculated only with lake mud. The experimental variants on liquid media were incubated at room temperature,while those with compost and soil,in the open air.

During incubation macro- and microscopic examinations and qualitative chemical analyses were carried out. The presence of Fe^{2+} and Fe^{3+} in the culture of iron bacteria and that of free H_2S in the culture of desulfovibrios was checked. The levan formed was analyzed by means of paper chromatography (8). The water evaporated during incubation was replaced by distilled water.

The incubation periods lasted 5, 8, 12 and 17 months. In the end of the first incubation period the geotextile samples of this period were removed from the liquid media,compost and soil,then dried at 60°C for 24 hours and finally examined to determine their permeability and tensile strength. The geotextile samples of the other incubation periods were transferred to fresh media and inoculated the same as in the beginning of the experiment. This procedure was repeated in the end of the next incubation periods,excepting the last one (the 4th). Of course, the geotextile samples incubated for 8,12 and 17 months were also submitted to permeability and tensile strength determinations.

Determination of geotextile samples normal permeability (k_n) was carried out :

a) by the Bourdillon method (10),applied on a set of 5 discs of nonwoven fabrics, and

b) by means of a device (figure 1) for measuring the apparent filtration velocity on single samples of both nonwoven and woven geotextiles.

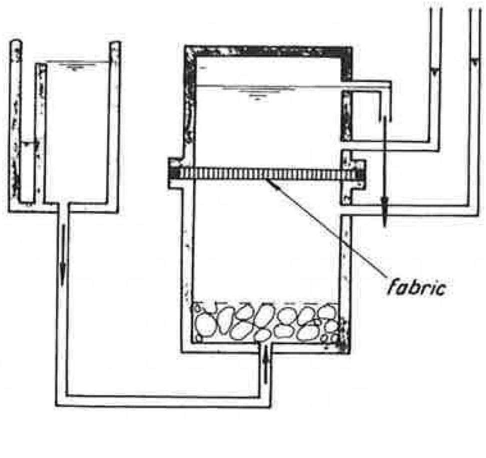

Fig.1. Device for measuring the apparent filtration velocity

For the determination of tensile strength the French standard method (11) was applied.

The geotextile samples incubated for 17months were examined also by infrared spectroscopy,using a SPECORD 75 IR type apparatus and working in the wave number ($\bar{\nu}$) range of 400-2200 cm^{-1}.

RESULTS

A. Macro- and Microscopic Examinations and Qualitative Chemical Analyses.

The results will be presented in the incubation media and the geotextile types description order.

1.Distilled water. In the distilled water in which Madril M samples were immersed no spontaneous microflora developed during the first 12 months of incubation. But by the end of the last incubation period (17 months) a scarce development of bacteria was observed. Similar observations were made in the case of Madril V, too.During the first and last incubation periods bacteria were found, although in small number, in the distilled water in which Madril P samples were placed. In the case of Terrasin samples numerous bacteria developed in the water during the whole incubation period. In addition ,transparent sediments appeared on the surface of Terrasin samples after 8 months of incubation. The sediments turned blackish by the end of 17 month incubation period.Excepting the first 5 months of incubation, a slight development of bacteria always took place in the distilled water with Alpha M and Alpha G samples.

Development of bacteria in the distilled water in which geotextile- samples were incubated can be explained by solubilization of some substances serving as nutrients for bacteria. In the case of Madril P samples, the initial solubilization occurring in the first incubation period was followed by an other solubilization surprisingly taking place in the last incubation period. However, the solubilization did not affect the basic structure of geotextiles as none of the tested geotextile types showed any visible degradation during their 17-month incubabation in distilled water.

2. Medium for iron bacteria. Abundant growth of filamentous iron bacteria occurred in this medium in each incubation period and in the presence of each geotextile type. Ferrous and ferric ions were constantly found in the culture liquid. Brown and black sediments covered step by step the surface of geotextiles. Figure 2 is the microscopic image of these sediments on the fibers of a Madril V sample kept in culture of iron bacteria for 12 months. Formation of sediments was not, however, associated with any visible degradation of the geotextiles.

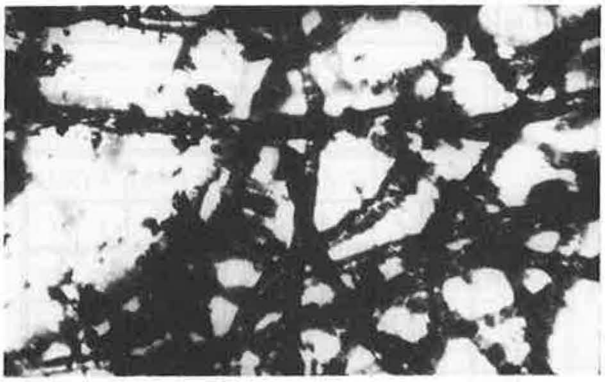

Fig.2. Sediments on geotextile fibers incubated in culture of iron bacteria

Fig.3. Sediments on geotextile fibers incubated in culture of desulfovibrios

3. Medium for desulfovibrios. These bacteria always developed in the presence of each geotextile type. The reaction for free H_2S in the culture liquid was intensely positive for 8 months but the formation of FeS took place during the whole incubation period. FeS sedimented on the geotextile fibers and yarns in form of black patches. Figure 3 shows the sediments on Madril V fibers after their 17-month incubation in culture of desulfovibrios. The desulfovibrios, like the iron bacteria, caused sediment formation, but they did not bring about any visible degradation of the geotextiles.

4. Medium for levan-synthesizing bacteria. Besides the abundant development of bacteria, a scarce growth of microfungi also accurred in each incubation period and in the presence of each geotextile type. The culture liquid constantly contained free levan during the first 8 months of incubation (figure 4). Later, free levan was not detected in the culture liquid. Instead, the sedimentation of a viscous brown material on the surface of fibers and yarns intensified. A picture of the sediments appearing on Madril M fibers following their 12-month incubation in culture of levan-synthesizing bacteria is presented in figure 5. The sediment formation was not accompanied, in this medium either, by visible decomposition of the tested geotextile types.

5. Liquid mineral medium. Both bacteria and microfungi constantly developed in this medium in the presence of each geotextile type. Their development should be attributed to some organic substances solubilized from the geotextile samples. However, there is no sign of degradation of any of the tested geotextile types.

6. Sea water. In each incubation period scarce development of bacteria occurred in sea water without any observable changes in the tested geotextile types.

7. Compost. During incubation, the pores of the geotextile samples were gradually blocked with fine compost particles. At the same time, some samples were perforated by the roots of weeds growing in the vessels. Nevertheless the geotextile basic structure remained unchanged even in the end of the 17-month incubation period.

8. Alluvial soil. The observations made are similar to those described above in the case of compost.

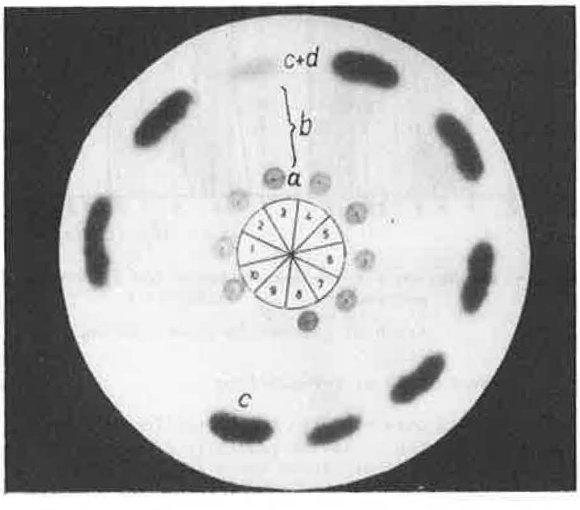

Fig.4. Bacterial levan formation in presence of geotextiles. 1-4: Cultures with Madril M samples, 5-8: Cultures with Madril V samples, 9: Sucrose solution, 10: Levan solution, a: Levan, b: Oligofructosides, c: Sucrose, d: Fructose.

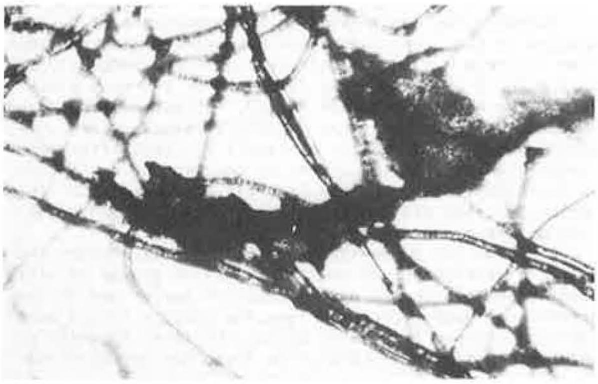

Fig.5. Sediments on geotextile fibers incubated in culture of levan-synthesizing bacteria

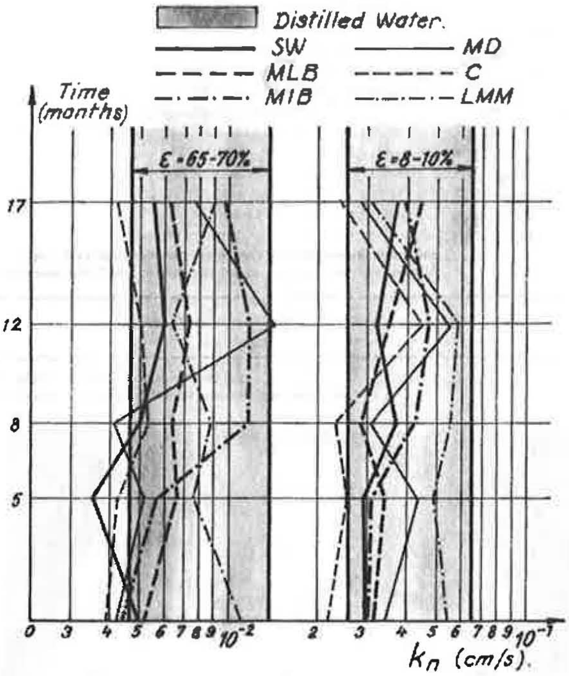

Fig.6. Incubation time-dependent variation of normal permeability (k_n) of Madril V

: Strain of geotextile under loading

B. Determination of Permeability

The results obtained with the Bourdillon method (10) have shown that the normal permeability of the geotextile samples incubated in different media for 5-17 months varies only within the ranges found for the nonincubated and distilled-water-incubated samples. These findings are exemplified in figure 6 in the case of Madril V.Similar results were obtained when the apparent filtration velocity was measured.The mean values registered with geotextile samples incubated in the six liquid media for 17 months,and the minimum and maximum values found with geotextile samples kept in compost and alluvial soil also for 17 months are presented in table 1.One can see from this table that no important changes occurred in the filtration velocity in the case of geotextile samples incubated in the liquid media. The minimum values were found in geotextile samples which were not perforated by roots of weeds growing in compost or alluvial soil,while the perforated samples gave the maximum values.

Table 1.Apparent velocity of filtration (cm/s)

	INCUBATION MEDIA									
	DW	MLB	MD	SW	MIB	LMM	C		AS	
							min.	max.	min.	max.
MADRIL® M	0,23	0,19	0,24	0,24	0,24	0,23	0,06	0,2	0,12	0,27
MADRIL® V	0,25	0,20	0,25	0,28	0,26	0,25	0,14	0,19	0,09	0,26
MADRIL® P	0,23	0,19	0,23	0,25	0,23	0,20	0,19	0,28	0,24	0,3
TERRASIN	0,25	0,23	0,24	0,25	0,25	0,22	0,11	0,24	0,19	0,28
ALPHA M_1	0,45	0,37	0,41	0,45	0,44	0,42	0,42		0,43	
ALPHA G_2	0,36	0,37	0,35	0,37	0,41	0,39	0,38		0,34	

Table 2. Mechanical characteristics of some geotextiles incubated in different media for 5 months (i) and 17 months (f)

		F_G (KN)		ε (%)			F_G (KN)		ε (%)	
		i	f	i	f		i	f	i	f
MADRIL® M	DW	2,51	2,47	92	90	TERRASIN	0,67	0,75	73	75
	SW	2,49	2,38	91	88		0,85	0,94	56	63
	LMM	2,55	2,47	94	89		0,77	0,82	55	50
	MIB	2,49	2,35	77	82		0,89	0,8	53	55
	MD	2,54	2,45	80	75		0,91	0,96	53	58
	MLB	2,52	2,49	90	90		0,89	0,87	55	57
	C	2,38	2,41	88	90		0,89	0,98	49	64
	AS	2,37	2,43	90	86		0,76	0,93	52	53
MADRIL® P	DW	1,81	2,21	62	63	ALPHA M	0,89	0,88	21	26
	SW	1,93	2,1	62	58		0,82	0,92	22	24
	LMM	2,22	2,10	59	59		0,91	0,89	22	24
	MIB	2,10	2,18	56	57		0,99	0,93	26	25
	MD	1,74	2,07	55	54		0,93	0,81	22	23
	MLB	1,98	1,96	63	66		0,83	0,81	23	23
	C	1,92	2,26	59	52		0,03	0,91	26	24
	AS	1,89	2,07	54	53		0,72	0,76	22	23

Since these determinations did not reveal any important modifications in permeability, the bio-colmatation macro- and microscopically observed should be a very slow phenomenon which does not affect the filtering-draining capacity of the geotextiles.

C. Determination of Tensile Strength

Some of the values of tensile strength and elongation of geotextiles incubated for 5 and 17 months are given in table 2. They prove that the microorganisms developed in media with geotextile samples did not cause any modifications in these mechanical properties of geotextiles. This finding is valid for each of the tested geotextile types. The small variations are undoubtedly due to the anisotropy characteristic for fabrics.

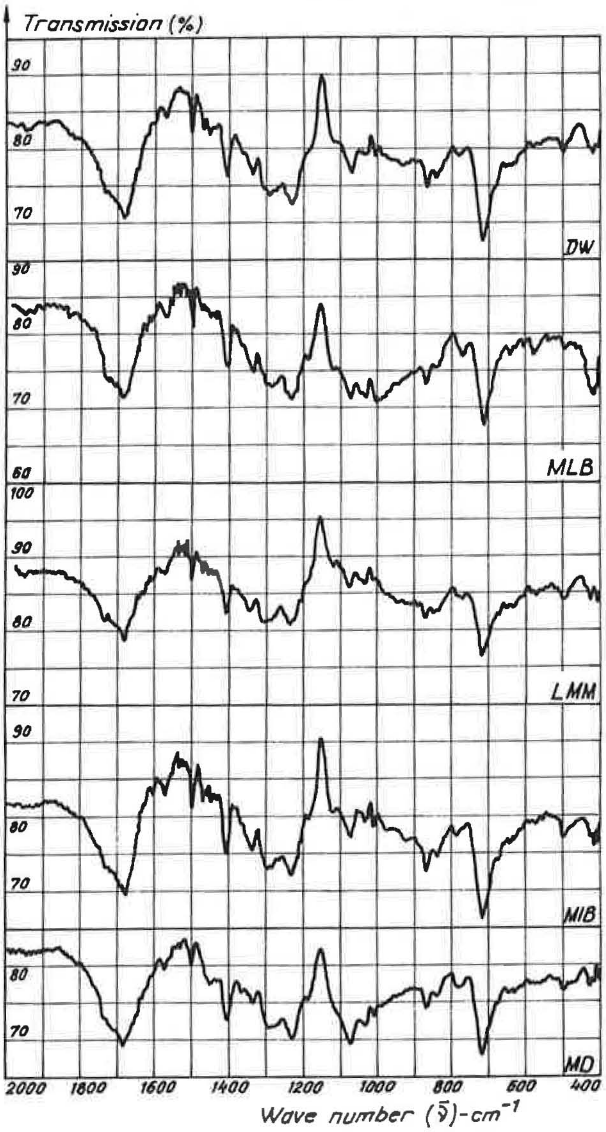

Fig.7. Spectrograms of Madril P fibers incubated in different liquid media

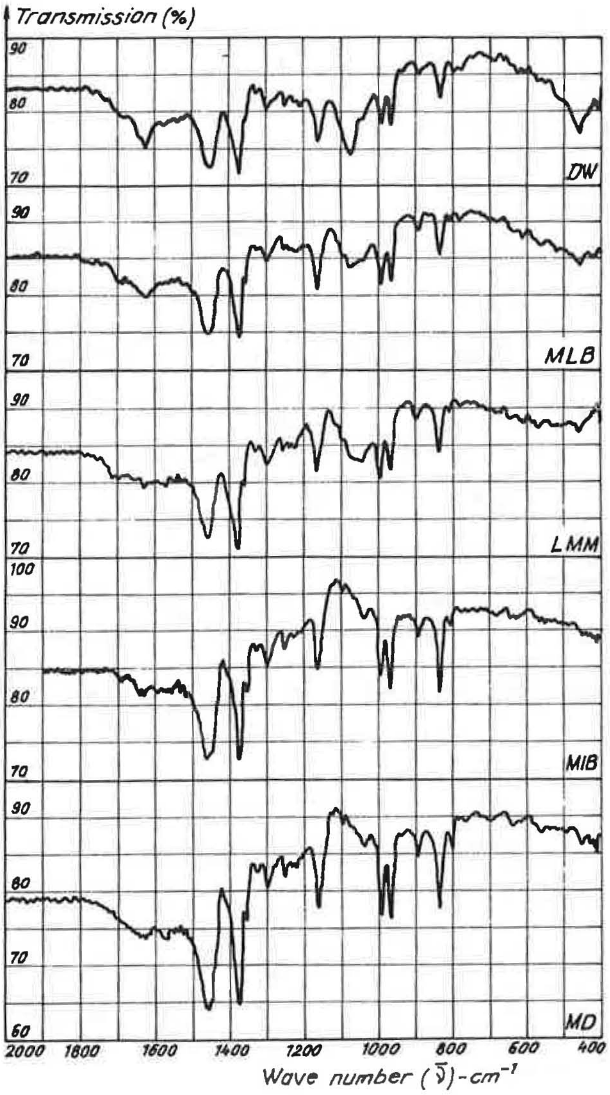

Fig.8. Spectrograms of Madril V fibers incubated in different liquid media

D. Infrared Spectroscopy

The results recorded by infrared spectroscopy indicate that the fibers of the tested geotextiles did not undergo any structural modifications, as the peaks on spectrograms of geotextile samples remained the same in all incubation media. The spectrograms registered with fibers of Madril P and V and Terrasin following their 17-month incubation are shown in figures 7-9.

CONCLUSIONS

1. Some colmatation occurred in the six geotextile types tested when they were incubated in cultures of iron bacteria, desulfovibrios and levan-synthesizing bacteria for 5-17 months. But the bio-colmatation should be a slow phenomenon, not affecting the filtering-draining capacity of geotextiles, as no important modifications appeared in their permeability.

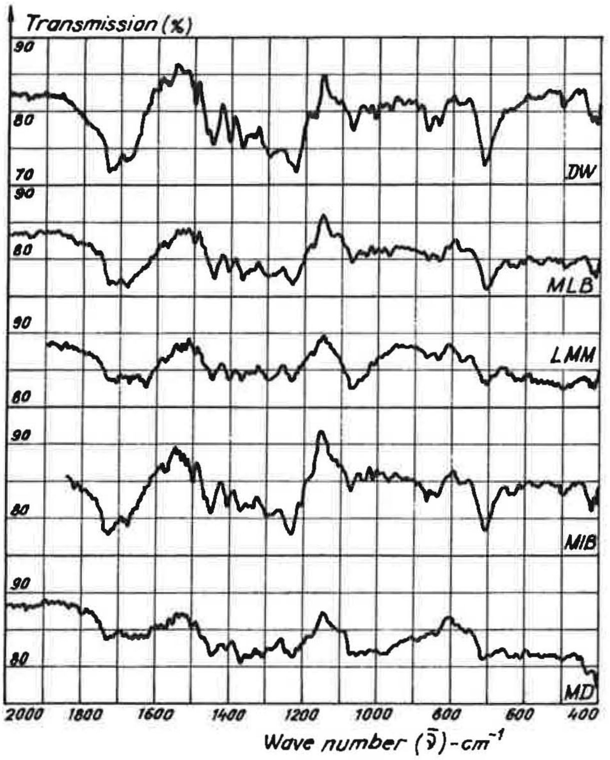

Fig.9. Spectrograms of Terrasin fibers incubated in different liquid media

2, The geotextiles are not toxic for the populations of aquatic and soil microorganisms.Some water-soluble substances from geotextiles can even promote the development of microorganisms. However,none of the six tested geotextile types showed any sign of biodegradation following their 5-17-month incubation in 8 media (distilled water;media for culturing iron bacteria,desulfovibrios and levan-sythesizing bacteria;liquid mineral medium;sea water;compost;alluvial soil). Tensile strength determinations and infrared spectrograms showed that the mechanical properties and the structure of geotextiles remained unchanged.

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