Long Term Behaviour of a Geotextile as a Filter in a 24-Year Old Earth Dam: Valcros

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ABSTRACT : In 1970; an endless filament non-woven geotextile was used for the first time in a large dam (the Valcros dam in France). The geotextile acts as a filter on the upstream slope between the rocks and earth fill and on the down stream slope around the main drains. As made previously in 1976, some samples were taken from the geotextiles in 1992. The tests performed show the durability of the endless filament non-woven geotextile (1) in its filtration function and (2) in its mechanical behaviour.

1. INTRODUCTION

In 1970, for the first time, a continuous filament needle-punched non-woven geotextile was used in an earth dam to perform major functions (Giroud et al., 1977). (1) Filter underneath the rocks on the upstream slope of the dam, (2) filter around the downstream drain of the dam. The geotextiles used were continuous filament needle-punched polyester non-woven geotextile of Bidim type with different mass per unit area.

Downstream of the dam, the originality of the construction in 1970 was using a geotextile around the downstream gravel drain instead of a traditional sand filter. A geotextile of 1450 m² with mass per unit area of 300 g/m^2 was used to wrap around 195 m^3 of gravel of grain size 8 / 13 mm. between 1970 and 1976, flow measurements were taken and revealed a mean flow rate of 155 l/h (3,7 m^3 / day). The flowing water observed was always perfectly clear. Only one significant incident occurred in the first year : erosion of the left bank of the valley caused an accumulation of fine particles (silts and clays) which blocked the outlet and penetrated the downstream part of the drain. In 1976, no deposit of fine particles was noted in the downstream observation well, nor was any seepage observed on the downstream facing, thereby indicating that the drain was performing correctly.

Between 1970 and 1976, three different types of protection were tested on the upstream facing : (1) a traditional protection with 25 cm blocks on 15 cm of 6 / 40 mm gravel; (2) a geotextile with a mass per unit area of 850 g/m^2 fixed to the ground with pins; (3) a geotextile laid in strips with a 40 cm overlap and covered by 25 cm blocks. Since the experimental zone 2 was reconstructed in 1977 using the same arrangements as in zone 3, only zone 3 was considered in 1992.

From the observations made in 1976, the following conclusions were drawn :

- the polyester geotextile exposed to the sun for 6 years had lost up to half its strength while in the soil the loss was very limited and resulted from mechanical wear from the ground at time if installation;
- the permeability of the geotextile used around the downstream drain was practically identical to that of the clean geotextile;
- the permeability of the geotextile used upstream decreased by a factor of ten, but this was not very serious and did not affect the performance of the structure.

2. OBSERVATION PROGRAM IN 1992

As in 1976, two observation sites were identified : one upstream of the dam, close to the water level, and the other downstream above the toe drain.

Upstream, a 4 m by 3 m area was cleared of rocks at the limit of the water level, situated that day at 20 cm below the maximum level of the reservoir.

This section was therefore well exposed to waves. The side of the geotextile in contact with the rocks was covered with 50 to 100 mm of top soil, and grass had started to grow. The roots of a few bushes had succeeded in passing through the geotextile.

The geotextile showed the imprint left by the rocks. There was no top soil in the imprint.

the side of the geotextile in contact with the dam suffered

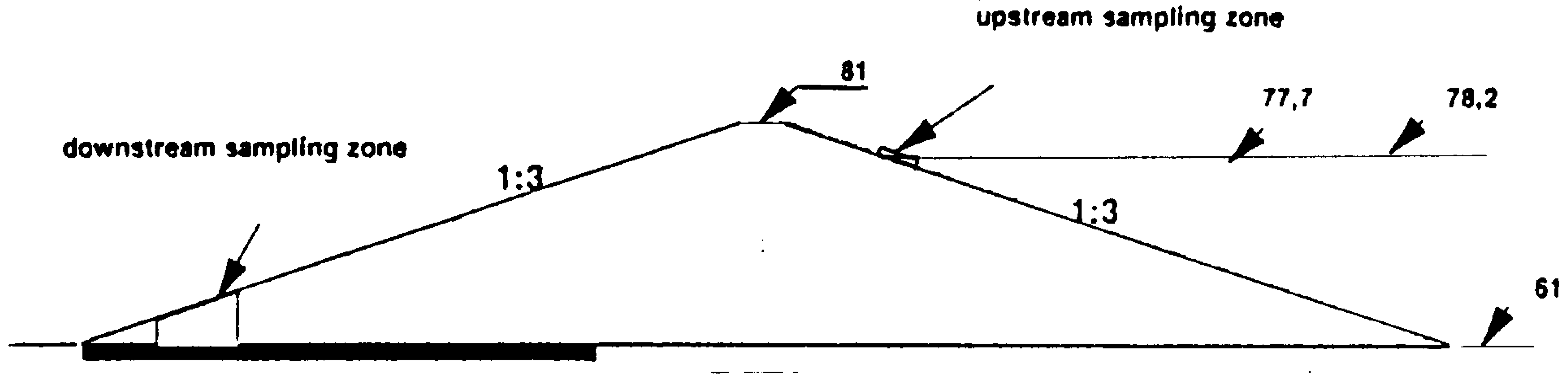

Figure 1 : Cross section of the Valcros dam showing the place of recoveries

little pollution or colouring from the soil. The soil underneath the geotextile was smooth but very small ducts or channels could be observed, the origin of which is thought to be earthworms. It is not considered to be evidence of erosion of the soil underneath the geotextile.

With regard to the overlap, the contact surfaces of the geotextile strips were perfectly clean. This confirms that there is no soil movement between the two geotextile strips.

Downstream, a 4 m deep pit was dug to reach the main drain. The opening of the excavation (4,5 m long and 5 m wide) was made at the overlap point in the geotextile used as a protective filter for the drain. Samples were taken from the geotextile sheeting above and underneath the gravel drain.

These samples showed little sign of pollution. those taken from the upper side were relatively dry, despite a wet zone observed upstream of the excavation.

Given the position of the pit in relation to the dam, it is unlikely that the filter acts effectively as a filter at this location. It seems likely that it acts more as separator. It only acts as a filter for water infiltrating after rainfall. The sample taken from the underneath the gravel drain, was saturated since the water level in the drain was 120 mm.

As in 1977 (Giroud et al. 1997), water from the drain was laden with fine particles, the origin of which was the accumulation of silt and clay from the accidental erosion of the left bank which blocked the drain outlet.

The water is clear the drain outlet and the measured flow rate is comparable to that measured in 1977 (131 l/h).

3. MECHANICAL TESTS

During the programme of observations in 1992, tensile tests were performed on samples taken upstream and downstream. Test specimens were cut from the samples to the format required for performing tensile tests in compliance with the French standard NF G 07001 (standard chosen in 1977), that is 5 cm by 20 cm.

before the test were performed, the surfaces of the specimens were cleaned of any soil and meticulously washed without causing any damage. The specimen were then dried and weighed.

The compared results of the tensile tests (10 samples in each direction) on new samples and on samples taken in 1976 and in 1992 are given in the Table 1.

The test results show no significant differences between the tensile characteristics observed in 1976 and 1992, the differences observed being related in particular to the presence of particles of soil trapped in the geotextile despite meticulous washing.

To reach more definitive conclusion on the durability of the geotextile, the results of chemical analyses on the fibres are needed. These analyses being conducted at the moment.

4. HYDRAULIC TESTS

Initially, only the hydraulic tests (permittivity, opening size) were performed. Actually, filtration tests are being performed.

The test specimens are cut from the samples according the format required for the tests. After the removal of any soil from the surface, some test specimens are dried, weighed, meticulously washed, dried again and then weighed again (washed), the others are used as such (polluted).

The permittivity test is performed following the French standard. Flow is under constant head and the flow velocity is 10 mm/s.

The opening size test is performed following the French standard (hydrodynamic). The opening size is determined by the d95 of the soil passing through the geotextile.

Results are given in the Table 2.

Upstream, the pollution rate (obtained from the ratio between the volume of the soil trapped and the volume of the voids in the geotextile) is greater between the blocks (≈ 17%) than under the blocks (≈ 7%), with one exception for sample n° 2. Also for this case the porosity of the geotextile remain greater than 45 %.

This result is confirmed by the permittivity values obtained on the "polluted" samples.

Note the low change of permittivity with the level of pollution rate (Fig. 2).

The particle size analysis of the soil trapped in the geotextile (Fig. 3) shows (1) a d95 of the order of 100 μ m, slightly larger (though of the same order of magnitude) than the opening size of the geotextile, (2) a grain size identical to that of the soil of the dam with a 300 μ m cut-off.

Table 1 : Comparison of the results of tensile tests on new samples and samples taken in 1976 and 1992.

tensile test NF G 07 001	upstream geotextile					downstream geotextile				
	new	1976		1992		new	1976		1992	
		mean value	CV (%)	mean value	CV (%)		mean value	CV (%)	mean value	CV (%)
strength (long direction)	710 N	760 N	5	846 N	14	860 N	680 N	15	669 N	12
strength (cross direction)	520 N	630 N	16	700 N	10	580 N	520 N	10	592 N	14
strain (long direction)	45 %	49 %	9	47 %	8	60 %	58 %	8	47 %	4
strain (cross direction)	41 %	36 %	6	44 %	6	64 %	51 %	6	50 %	13
Mass per unit area (g/m²)	400	-		474		300	-		350	

Table 2 : Hydraulic results obtained in 1992.

	upstream geotextile									
	lower part				overlap				upper part	
	n° 1		n° 2		under side		upper side			
	beneath stone	between stone	beneath stone	between stone	beneath stone	between stone	beneath stone	between stone	beneath stone	between stone
mass per unit area (g/m²)	468 ± 6	518 ± 24	531 ± 42	603 ± 58	538 ± 63	514 ± 110	485 ± 24	485 ± 6	460 ± 7	547 ± 24
pollution rate (%)	21,6 ± 2,4	9,1 ± 2,7	14,4 ± 3,5	54,8 ± 1,6	7,4 ± 2,3	16,9 ± 3,2	13 ± 9	39,6 ± 2,3	16,4 ± 3,7	36,5 ± 3,5
permittivity (washed) (s^{-1})	1,03 ± 0,17	1,21 ± 0,39	0,97 ± 0,19	1,23 ± 0,15	0,98 ± 0,08	1,46 ± 0,26	1,06 ± 0,04	1,24 ± 0,09	1,33 ± 0,16	1,16 ± 0,29
(polluted) (s^{-1})	0,42	0,30	0,27	0,38	0,68	0,81	0,30	0,36	0,39	0,29
opening size (μ m)	72	73	72		68	72	69		70	69

	downstream geotextile			
	lower part	overlap upper side	upper part	
			n° 1	n° 2
mass per unit area (g/m²)	276 ± 40	346 ± 51	328 ± 20	329 ± 15
pollution rate (%)	4,35 (gravel) 21 (soil dam)	1,9	0,8 ± 0,3	1 ± 0,2
permittivity (washed) (s^{-1})	2,7 ± 0,6	21 ± 0,2	2,2 ± 0,2	2,2 ± 0,2
opening size (μ m)	95	115	95	235

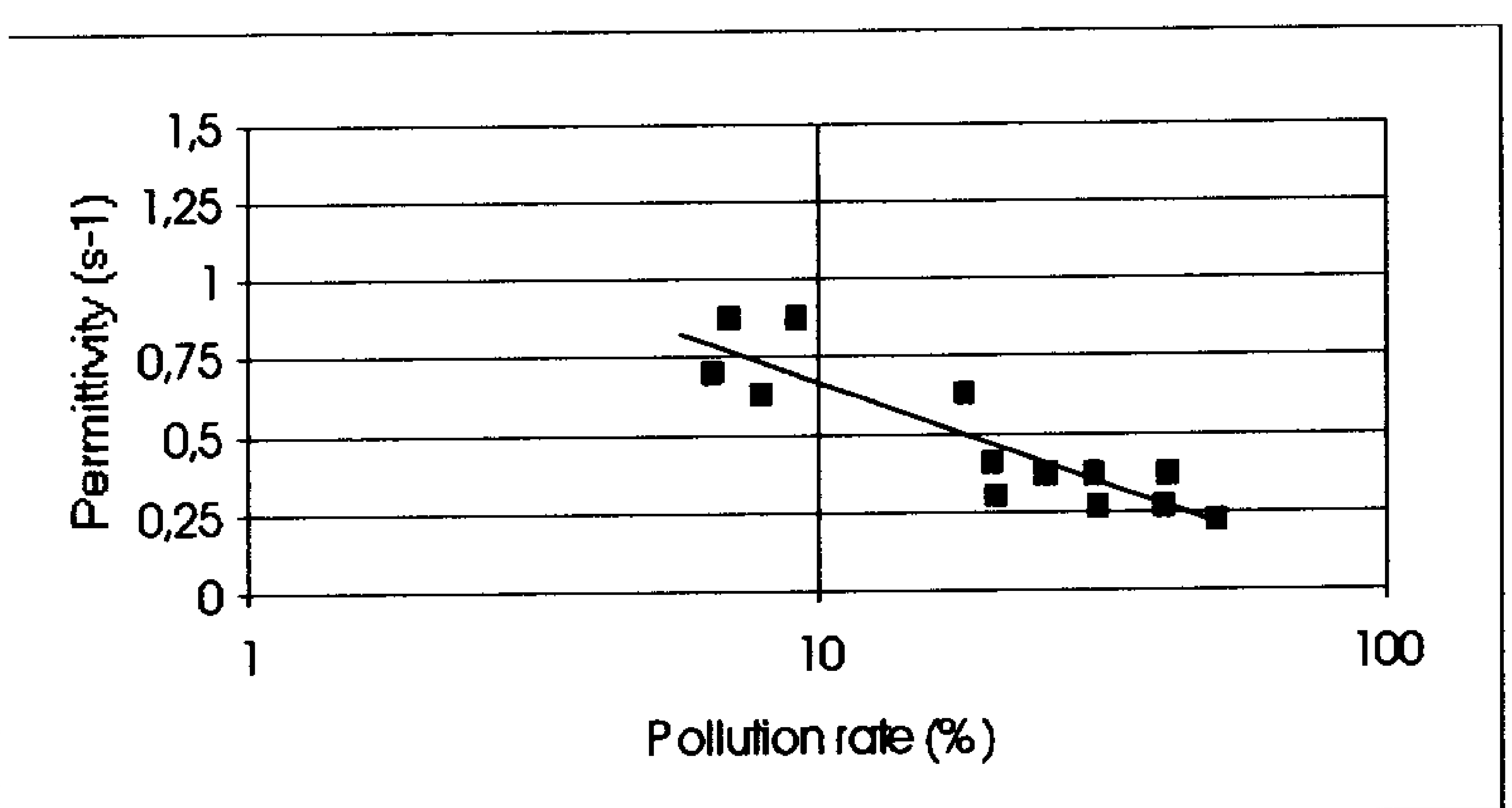

Figure 2 : Evolution of permittivity with the pollution rate.

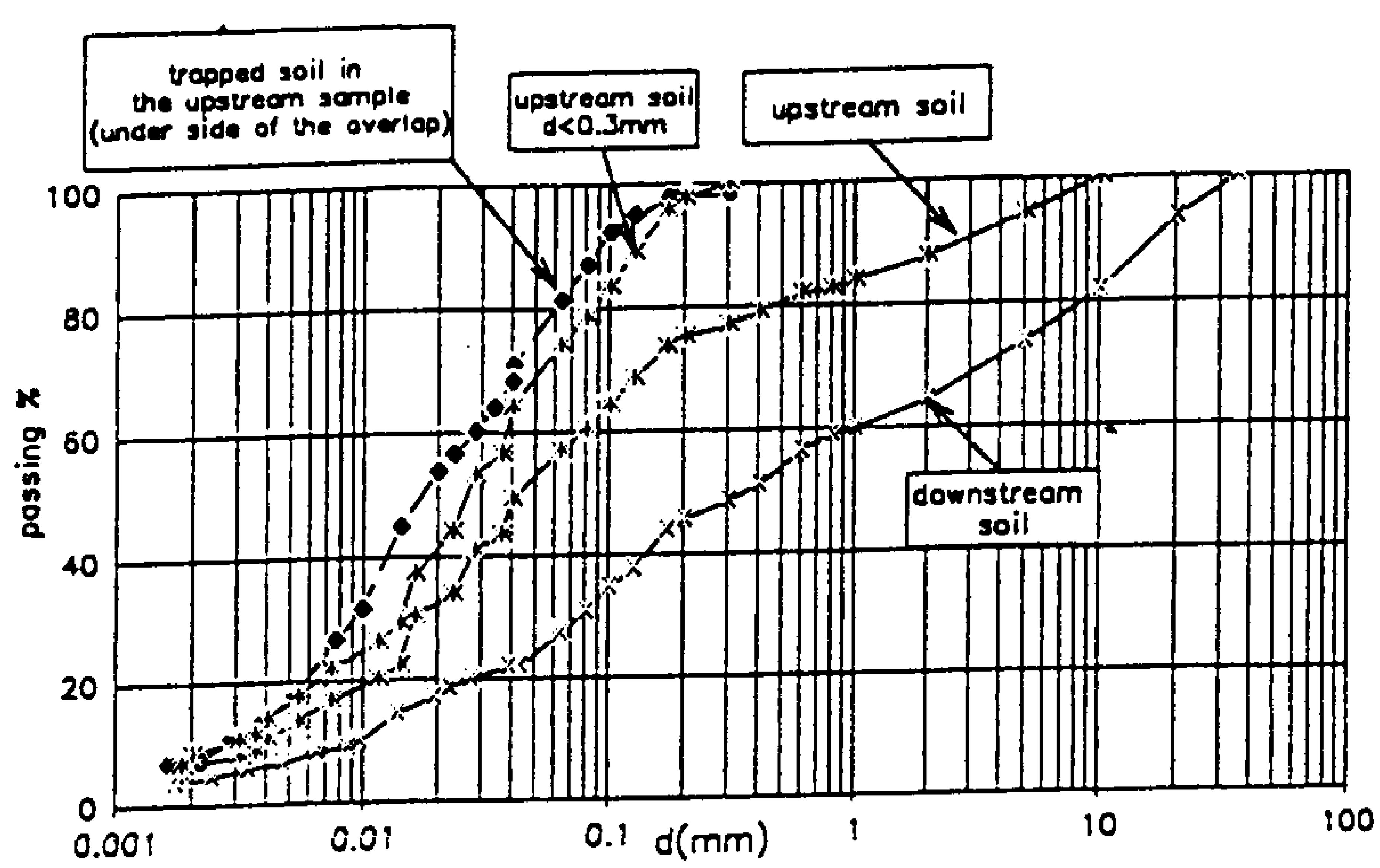

Figure 3 : Grain size distribution of soil trapped in the geotextile (upstream zone)

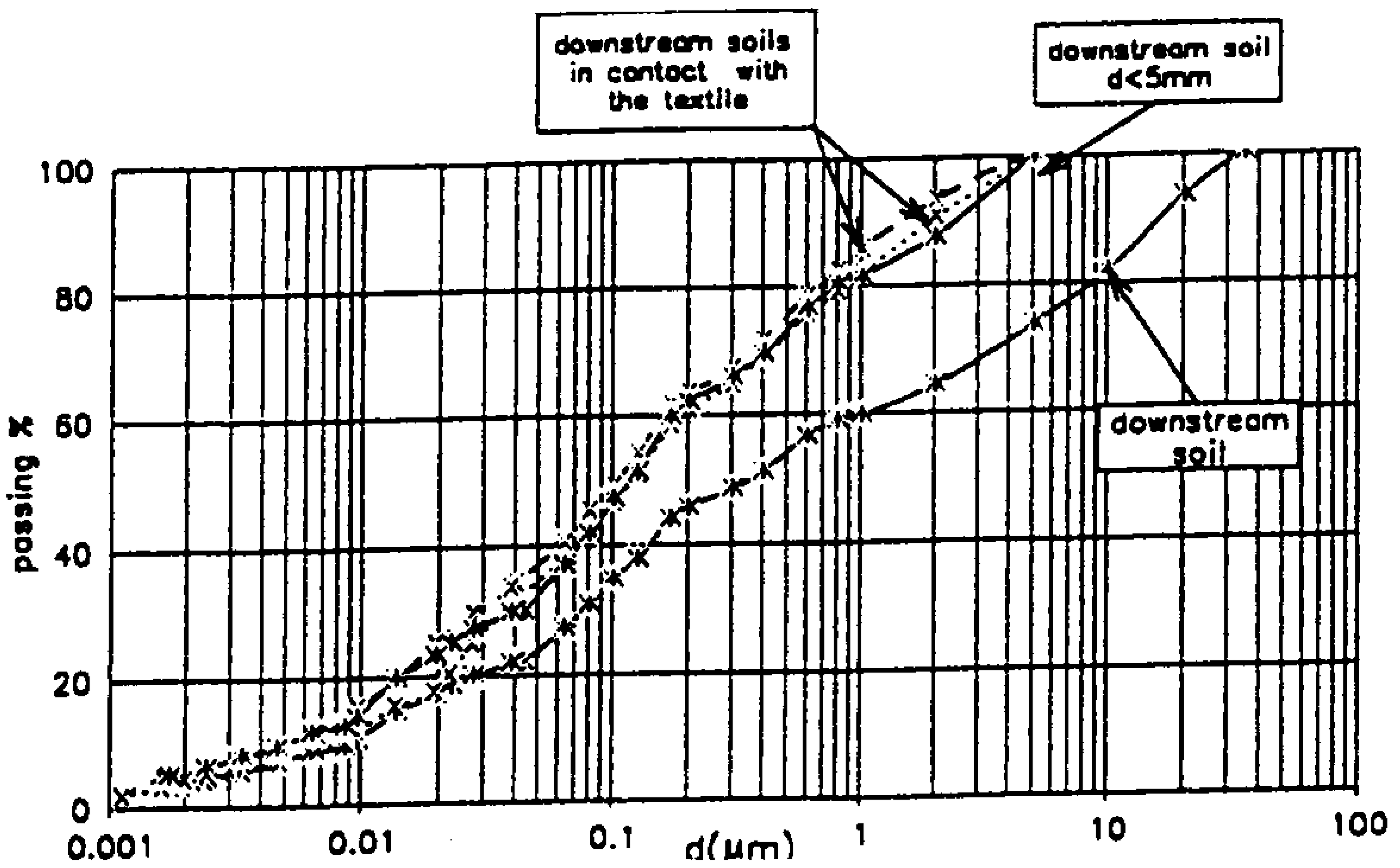

Figure 4: Grain size distribution of soil trapped in the geotextile (downstream zone)

Downstream, the pollution rate were found negligible. That can be explained by the very low flow rate in this zone.
The analysis of the soil in contact with the geotextile revealed particles with a diameter showing that these particles did not penetrate inside the geotextile (Fig. 4).

5. CONCLUSION

The main lessons to be learnt from the samples taken from the Valcros dam in 1992 are as follow :
(1) ageing : a polyester needle punched non-woven geotextile installed in soil for a period of 22 years undergoes no significant change in tensile behaviour (based on comparison of test results in 1976 and 1992);
(2) filter of downstream drain : permeability measured in 1992 are analogous to those of 1976; the filter opening size (not measured on the new product nor in 1976) measured is of the order of 100 µ m compared to a value of 95 µ m on the new product made in 1992; pollution rate remain negligible; the flow of water measured downstream of the drain is similar to that of 1976, water leaving the drain is not laden with deposits and no seepage is observed in the downstream slope of the dam indicating that the downstream drainage system as a whole, and in particular the geotextile filter, is performing correctly;
(3) filter underneath rocks in the upstream zone : the permeability level measured in 1992 is about twice the 1976 level; pollution rate observed remain relatively low; porosity remains greater than 60 %, thereby confirming the ability of the upstream geotextile to perform correctly as filter.
In conclusion, after 22 years the continuous filament needle-punched geotextile remains its efficiency as filter either under blocks upstream or around the downstream drain.

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