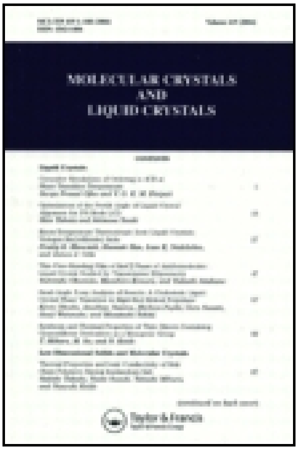

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Evaluation of Clay Added Nonwovens as Filter in Waste Landfill

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In this, study, the yellow clays were added to the nonwoven geotextiles to improve the removal effects of the toxic and organic components of the leachate solutions which are very dangerous to the men's health. 4 types of functional nonwoven geotextiles were manufactured with the different composition of yellow clays. We applied these functional nonwoven geotextiles to the waste landfill fields as a filtration material of leachate solutions and tested tensile properties before/after application. Chemical and biological resistances of these nonwoven geotextiles were also evaluated and the amounts of absorptions of toxic and organic components were compared to the simply manufactured polyester nonwoven geotextiles.

Keywords: leachate solutions; polyester nonwoven geotextiles; tensile properties

INTRODUCTION

Nonwoven geotextiles are widely used to the geotechnical and environmental fields as materials which have the functions of reinforcement, protection, separation, filtration, drainage etc. [1–2].

In Korea, nonwoven geotextiles of polyester or polypropylene fibers are used in the protection and filtration fields for waste landfills as shown in Figure 1. But for this, most of nonwoven geotextiles are simply composed of fibers which have no special function to improve these properties.

For treatment of leachate solutions in the waste landfills, it is very important to eliminate the toxic and organic components of the leachate solutions [3].

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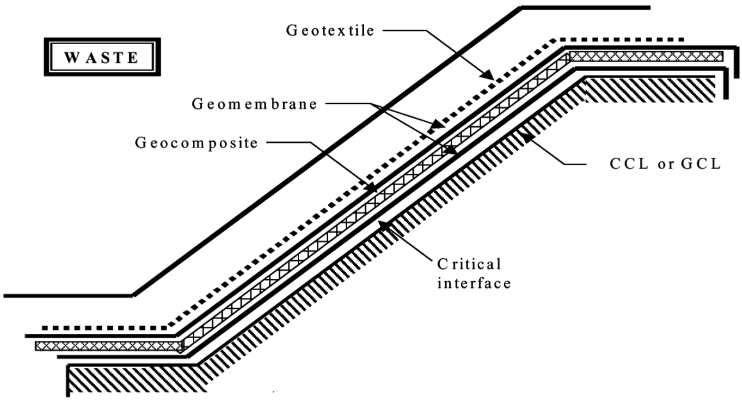


FIGURE 1 Schematic diagram of typical waste landfill liner system in Korea.

But there is no function for the simply manufactured nonwoven geotextiles and it is needed to manufacture the functional nonwoven geotextiles which can absorb the above mentioned toxic and organic components to be harmful to the men's health.

However, it is very difficult to manufacture this functional nonwoven geotextiles because of difficulty of the addition the functional materials to the inside of nonwovens [4].

In this study, the yellow calys were added to the polyester nonwovens to improve the removal effects of the toxic and organic components components of the leachate solutions which are very dangerous to the men's health. 4 types of functional polyester nonwoven geotextiles were manufactured with the different composition of yellow clays.

Not only morphologies, tensile properties, chemical and biological resistances but also the amounts of adsorptions of toxic and organic components for these nonwoven geotextiles were evaluated and compared to the simply manufactured polyester nonwoven geotextiles.

Besides this, hydraulic properties by clogging were examined to consider the effects of environmental application properties.

EXPERIMENTAL

Preparation of Geotextiles

12 denier polyester staple fibers which have 2∼3% yellow clay are used to manufacture the polyester functional geotextiles by needle punching method and three different punching patterns were applied

TABLE 1 Specifications of Polyester Functional Geotextiles

Geotextile	Composition	Raw fiber	Manufacturing method	Weight (g/m^2)	Clay content (%)
Functional nonwoven geotextile	FGT-1	Needle Punching	12denier Polyester Staple Fiber	272	2∼3%
	FGT-2			463	
	FGT-3			784	
	FGT-4			1514	
Typical nonwoven geotextile	GT-1			284	Not available
	GT-2			480	
	GT-3			756	
	GT-4			1546	

to manufacture these geotextiles such as ↑, ↑ and ↓ punching path mechanism.

Table 1 shows the specifications of the polyester functional geotextiles and in this study, typical polyester geotextiles were used to compare the performance difference with clay added geotextiles.

Table 2 shows the components of clay added polyester fiber and from this, it is known that the amount to be added is $2 \sim 3\%$.

Evaluation of Performance

Tensile properties of nonwoven geotextiles were tested with ISO 10319:1993 Geotextiles – Wide-Width Tensile Test to minimize the deviation between index and performance tests.

Modified EPA 9090 Test Method that was proposed by American Environment Protection Agency was adapted to test chemical resistance of geotextile was applied to test the chemical resistance. The chemical resistance of nonwoven geotextiles in waste leachate solution was evaluated by comparing the strength retention before/after the immersion duration at 25°, 50°, 80° and 180 days with ASTM D 4632.

AATCC 30 – Fungicides, Evaluation on Textile: Mildew and Rot Resistance of Textile, Test 1 – Soil Burial Method was applied to estimate the biological resistance in the waste landfill site. As same as

TABLE 2 Component of Clay added Polyester Fiber

Component	Loss	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O
Amount	97.54	1.80	0.07	0.11	0.13	0.01	0.01	0.02	0.01

chemical resistance, the biological resistance of nonwoven geotextiles was evaluated by comparing the strength retention before/after burial.

ASTM D4751–99a Standard Test Method for Determining Apparent Opening Size(AOS) of a Geotextile was applied to compare the AOS and ASTM D1987-95(2002) - Standard Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters was applied to examine the permittivity of nonwoven geotextiles before/after burial in the waste landfill site.

Finally, the adsorption efficiency was estimated the amounts of toxic and organic components to be remained within the nonwoven geotextiles through ICP analysis.

RESULTS AND DISCUSSION

Composition of Waste Landfill

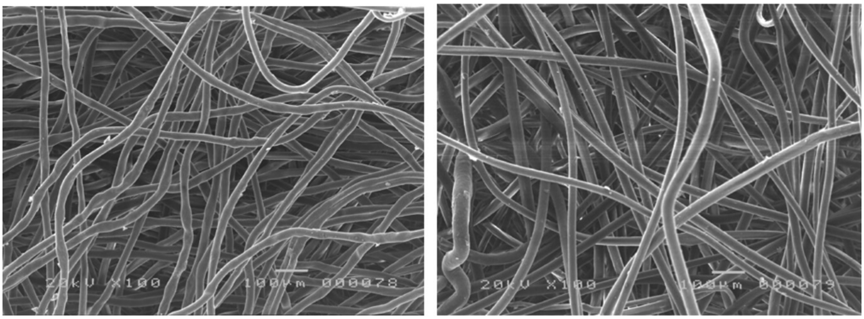
Table 3 shows the composition of the real leachate solution for the waste landfill site in Gwangju, Korea(Rep.) where the food wastes were mainly filled up. In here, it is seen that pH value of the leachate solution means weak alkaline state and toxic components, e.g., Cd and Pb etc., and many kinds of organic components were contaminated.

Morphology of Nonwoven Geotextiles

Figure 2 shows the morphologies of nonwoven geotextiles to be used in this study. It is seen that clay added nonwoven geotextile FGT-2 shows the coarser surface than the typical nonwoven geotextile, GT-2 for the similar weight and this is due to the clay addition. But it can not be seen that there is no significant difference between two nonwoven geotextiles.

TABLE 3 Chemical Composition of Leachate Solution in Korean Waste Landfill Site

pH	8.34	Ni (mg/l)	0.2
COD (mg/l)	2200.0	Fe (mg/l)	43807.7
TS (mg/l)	214.1	Mn (mg/l)	1.6
Na (mg/l)	2441.9	Cr (mg/l)	0.2
Zn (mg/l)	0.5	Mg (mg/l)	107.7
Cd (mg/l)	<0.1	Cu (mg/l)	0.1
K (mg/l)	1481.9	Ca (mg/l)	94.3
Pb (mg/l)	0.1	Cl^- (mg/l)	9040.0
Alkalinity (mg $CaCO_3$/l)	9050.0		



(a) **FGT-2** (b) **GT-2**

FIGURE 2 Scanning electronic microscope photographs of nonwoven geotextiles.

Tensile Property

Table 4 shows the tensile strength of two kinds of nonwoven geotextiles. For two type geotextiles – FGTs and GTs – tensile strengths in the both directions, MD and CMD increased with weight but tensile strains decreased with weight. This is very traditional trend as shown in the tensile property of nonwoven geotextiles.

Chemical Resistance

Table 5 shows the tensile strength retention of polyester nonwoven geotextiles before/after immersion into the leachate solution.

Tensile strength and strain retentions of two type polyester nonwoven geotextiles – FGTs and GTs – show the same tendency with

TABLE 4 Tensile Properties of Polyester Nonwoven Geotextiles

Geotextile \ Tensile property	Strength (kg)		Strain (%)	
	MD	CMD	MD	CMD
FGT-1	23.6	31.7	88.2	85.1
FGT-2	86.4	187.6	82.7	78.3
FGT-3	238.5	382.3	80.3	70.2
FGT-4	340.2	568.7	78.4	65.7
GT-1	31.5	40.2	90.3	82.3
GT-2	92.3	201.8	98.2	74.5
GT-3	250.8	397.6	92.8	65.7
GT-4	350.3	581.2	89.4	60.1

(where MD, CMD mean the machine and cross machine directions, respectively.)

TABLE 5 Chemical Resistance by Tensile Property Retention of Polyester Nonwoven Geotextiles

Geotextile \ Retention (%)	Tensile strength			Tensile strain		
	25°C	50°C	80°C	25°C	50°C	80°C
FGT-1	85.3	74.7	43.6	80.2	63.3	36.4
FGT-2	86.8	75.2	44.1	78.2	68.4	38.4
FGT-3	85.2	74.8	45.4	78.4	67.5	38.1
FGT-4	85.8	75.1	45.8	81.3	68.7	41.7
GT-1	84.3	75.3	44.2	82.4	70.3	42.2
GT-2	85.7	76.2	45.3	83.1	73.2	43.4
GT-3	85.8	75.3	45.8	81.7	71.2	44.2
GT-4	86.1	75.5	46.6	82.2	72.7	42.8

temperature and this value decreased with temperature. This result is observed very clearly in 80°C and this is due to the hydrolysis effect of polyester under higher temperature and alkaline state.

Biological Resistance

Tensile strength retentions of polyester nonwoven geotextiles between before/after burial in the waste landfill were examined and Table 6 shows the tensile strength retention to explain the biological resistance.

Clay added polyester nonwoven geotextiles, FGTs show smaller tensile strength retention than the typical polyester nonwoven geotextiles, GTs. It is assumed that this means FGT was influenced by the components of the leachate solutions in a greater or less because of

TABLE 6 Biological Resistance by Tensile Strength Retention of Polyester Nonwoven Geotextiles

Geotextile \ Retention (%)	Tensile strength
FGT-1	93.2
FGT-2	94.4
FGT-3	94.3
FGT-4	95.3
GT-1	97.3
GT-2	98.1
GT-3	97.5
GT-4	97.8

TABLE 7 Allowable Tensile Strength of Polyester Nonwoven Geotextiles by ΠRF

Geotextile \ Tensile property	ΠRF	Strength (kg) at MD – refered to Table III
FGT-1	1.4	16.8
FGT-2	1.3	66.4
FGT-3	1.3	183.5
FGT-4	1.2	283.5
GT-1	1.2	26.3
GT-2	1.2	76.9
GT-3	1.2	209.1
GT-4	1.2	291.9

clay component. But this does not mean that fungi and bacteria can attack these geotextiles.

For problems dealing with geotextile strength for the waste landfill, the formulation of the allowable values takes the following equations:

$$T_{allow} = T_{ult}\left[\frac{1}{RF_{CR} \times RF_{BR}}\right] \tag{1}$$

$$T_{allow} = T_{ult}\left[\frac{1}{\Pi RF}\right] \tag{2}$$

where T_{allow} = allowable tensile strength, T_{ult} = ultimate tensile strength, RF_{CR} = reduction factor for chemical resistance, RF_{BR} = reduction factor for biological resistance, and ΠRF = value of cumulative reduction factors.

Therefore, the tensile strength of the polyester nonwoven geotextiles could be calculated by using the Eqs. (1) and (2). Table 7 shows the values of cumulative reduction factors and the allowable tensile strengths of these nonwoven geotextiles.

Hydraulic Property by Clogging Effects

Clogging in nonwoven geotextile means the tendency to lose water permeability due to soil particles that have either lodged in the geotextile openings, e.g., AOS or have built up a restrictive layer on the surface of geotextiles.

In general, AOS does not decrease if clogging is not occurred within the nonwoven geotextile.

TABLE 8 AOS of Polyester Nonwoven Geotextiles Before/After Burial

Geotextile		FGT-1	FGT-2	FGT-3	FGT-4	GT-1	GT-2	GT-3	GT-4
AOS (mm)	A	0.11	0.08	0.07	0.06	0.15	0.13	0.11	0.10
	B	0.08	0.08	0.08	0.07	0.13	0.12	0.12	0.11

(where A, B mean before and after burial, respectively.)

Table 8 shows AOS values of two type polyester nonwoven geotextiles before/after burial in the waste landfill site.

Clay added polyester nonwoven geotextiles, FGTs have smaller AOS values than the typical polyester nonwoven geotextiles and this means more significant clogging occurrence for FGTs. Therefore, toxic, organic and some floating components in the leachate solution can be easily adsorbed to the clay added polyester fiber surface. After burial, AOS values of FGTs decreased due to the increase of adsorption components but some of them were eliminated by the simple washing the nonwoven geotextiles.

Table 9 shows the permittivities of two type polyester nonwoven geotextiles before/after burial in the waste landfill site. As shown in the biological resistance and AOS, permittivities of the clay added polyester nonwoven geotextiles, FGTs were smaller than those of the typical polyester nonwoven geotextiles due to the clogging effects of FGTs.

Table 10 shows the strength retention of polyester nonwoven geotextiles before/after clogging and the same tendency as considered in Tables 7–9 was observed. The clay added polyester nonwoven geotextiles, FGTs show smaller tensile strength retention than the typical polyester nonwoven geotextiles, GTs.

As same as the Eqs. (1) and (2) for strength reduction, the allowable permittivity takes the following equations:

$$q_{allow} = q_{ult}\left[\frac{1}{RF_{SC} \times RF_{CR} \times RF_{BR}}\right] \qquad (3)$$

TABLE 9 Permittivity of Polyester Nonwoven Geotextiles Before/After Burial

Geotextile		FGT-1	FGT-2	FGT-3	FGT-4	GT-1	GT-2	GT-3	GT-4
Permittivity (l/min/m^2)	A	0.87	0.79	0.67	0.59	0.98	0.84	0.72	0.62
	B	0.76	0.68	0.61	0.54	0.91	0.78	0.69	0.60

(where A, B mean before and after burial, respectively.)

TABLE 10 Strength Retention of Polyester Nonwoven Geotextiles After Clogging

Geotextile	FGT-1	FGT-2	FGT-3	FGT-4	GT-1	GT-2	GT-3	GT-4
Strength retention (%)	86.3	87.4	88.3	88.5	92.4	92.8	93.1	93.2

$$q_{allow} = q_{ult}\left[\frac{1}{\Pi RF}\right] \quad (4)$$

where q_{allow} = allowable permittivity, q_{ult} = ultimate permittivity, RF_{SC} = reduction factor for soil clogging, RF_{CR} = reduction factor for chemical resistance, RF_{BR} = reduction factor for biological resistance, and ΠRF = value of cumulative reduction factors.

Hence, the permittivity of the polyester nonwoven geotextiles could be calculated by using the Eqs. (3) and (4). Table 11 shows the values of cumulative reduction factors and the allowable permittivity of these nonwoven geotextiles.

Adsorption Efficiency

Table 12 shows the adsorption efficiency of toxic and organic components by the polyester nonwoven geotextiles. This value was obtained as the percentage through ICP analysis and clay added polyester nonwoven geotextiles, FGTs showed the excellent adsorption efficiency to compare with the typical polyester nonwoven geotextiles, GTs.

TABLE 11 Allowable Permittivity of Polyester Nonwoven Geotextiles after clogging by ΠRF

Tensile property / Geotextile	ΠRF	Permittivity (l/min/m^2) – refered to Table VIII
FGT-1	1.4	0.54
FGT-2	1.3	0.52
FGT-3	1.3	0.47
FGT-4	1.2	0.45
GT-1	1.2	0.76
GT-2	1.2	0.65
GT-3	1.2	0.57
GT-4	1.2	0.50

TABLE 12 Component Adsorption of Polyester Nonwoven Geotextiles

Geotextile \ Adsorption efficiency (%)	Component							
	Na	K	Fe	Mg	Ca	Cl	Cd	Pb
FGT-1	83.2	86.3	34.8	83.2	84.5	81.7	95.7	92.6
FGT-2	84.4	86.5	34.3	84.4	84.7	83.5	94.5	92.3
FGT-3	85.3	87.5	35.6	85.3	85.8	83.3	95.2	91.7
FGT-4	85.2	86.8	35.4	85.2	86.1	84.1	95.6	91.8
GT-1	56.8	61.2	35.3	56.8	57.4	54.7	35.7	36.3
GT-2	57.8	63.2	35.8	57.8	58.3	56.3	37.3	38.2
GT-3	57.6	63.7	36.8	57.6	57.9	56.9	37.2	37.9
GT-4	58.2	64.5	36.2	58.2	58.4	57.2	37.9	38.3

CONCLUSION

Clay added functional polyester nonwoven geotextiles, FGTs were manufactured to apply to the waste landfill. Typical polyester nonwoven geotextiles, GTs having the similar weights were used to compare the performance with FGTs. Tensile strengths in the MD and CMD increased with weight but tensile strains decreased with weight for both polyester nonwoven geotextiles. Chemical resistance by strength and strain retentions of FGTs and GTs showed the same tendency with temperature and this value decreased with temperature. For biological resistance, FGTs showed smaller tensile strength retention GTs. Permittivities of FGTs were smaller than those of GTs due to the clogging effects of FGTs. Clay added polyester nonwoven geotextiles, FGTs showed the excellent adsorption efficiency to compare with GTs.

Finally, the further study is in progress to investigate the detailed adsorption effects with various nonwoven geotextiles which have the different fiber composition.

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