



Some synergisms in the laboratory degradation of a polypropylene geotextile



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HIGHLIGHTS

- Degradation tests were carried out for a polypropylene geotextile.
- Two agents that individually did not cause damages, together caused degradation.
- Thermo-oxidative resistance was affected by sodium hydroxide and iron nitrate.
- Weathering resistance was affected by cadmium and copper nitrate.

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ABSTRACT

This paper studies the existence of synergisms between some degradation agents of geotextiles. For that purpose, a polypropylene geotextile (stabilised with Chimassorb 944) was exposed to some degradation tests: immersion in liquids (water, sulphuric and nitric acids, sodium hydroxide and metallic ion solutions), thermo-oxidation and artificial weathering. The geotextile was (1) exposed individually to each degradation agent (single exposure) and (2) exposed successively to some combinations of two agents (multiple exposures). Results showed that, in some cases, the combined action of two degradation agents was more damaging than the sum of the individual effects of each agent. The most relevant examples of this included: (1) immersion in sodium hydroxide and thermo-oxidation, (2) immersion in iron nitrate and thermo-oxidation and (3) immersion in cadmium or copper nitrate and artificial weathering.

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1. Introduction

Geosynthetics are polymeric materials used in the construction of many civil engineering infrastructures, like waste landfills, roads, railways, tunnels, retaining structures, dikes, reservoirs, dams or coastal engineering structures. These relatively-new materials offer many advantages when compared to more traditional ones: ease of use and application, low cost, environmental-friendly and good integration with the landscape. Geotextiles are the most applied geosynthetics due to their ability to perform multiple functions (separation, protection, reinforcement, drainage or filtration).

Abbreviations: C944, Chimassorb 944; E_{ML} , elongation at maximum load; PP, polypropylene; RTS, retained tensile strength; TO, thermo-oxidation; TS, tensile strength; UV, ultraviolet.

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In their applications, the geosynthetics can be in contact with many degradation agents, such as: liquids (acids, bases, water or leachates), high temperatures, oxygen, weathering agents, biological agents, static loads (creep) or abrasion [1,2]. The installation process can also cause some damage [3,4]. An extended exposure to these agents can have a negative impact on the physical, mechanical and/or hydraulic properties of the geosynthetics, affecting their performance and reducing their lifetime [1,2].

The contact with liquids can induce the degradation of the geosynthetics in different ways: absorption of liquids, extraction of additives (such as stabilisers) or chemical reactions (like hydrolysis) [5,6]. Polyethylene and polypropylene (PP) (two polymers often used for the production of geosynthetics) have a quite good resistance against water [7,8] and other liquids [7–9]. Polyesters are sensitive to alkaline solutions [9–11] and polyamides can be affected by acids [8,10].

Like other polymeric materials, geosynthetics are prone to oxidation. The effects of this process can include loss of brightness, colour changes, embrittlement and reduction in mechanical strength [12–15]. The oxidation process of polyolefins (like PP) occurs following a complex chain-reaction mechanism [14,16,17]. This process can be initiated by free-radicals, which can be produced by heat (photo-oxidation) or by ultraviolet (UV) radiation (photo-oxidation) [14,16]. In the absence of UV radiation, the oxidation of PP is usually very slow at room temperature. However, this type of degradation cannot be neglected when considering materials for long-term use.

The exposure to solar radiation (mainly due to UV radiation) and other weathering agents can cause serious damage to geosynthetics [18–20]. These materials are buried in most applications (and thus protected from UV radiation) but in some cases they can be exposed for a long period of time. The UV resistance of geosynthetics can be enhanced by adding chemical additives (such as UV stabilisers and/or antioxidants) to their composition [14,18]. Without proper stabilisation, some polymers (like PP) have a relatively poor UV resistance, which makes them unsuitable for most outdoor applications [14].

The expected lifetime of geosynthetics can reach hundreds of years in some applications (such as waste landfills). During this period, the materials must perform correctly their functions (for that, minimum values of some key-properties must be maintained). Being impossible to determine the long-term properties of the geosynthetics before construction, it is necessary to predict their evolution through time. These predictions are normally carried out based on laboratorial tests, where the materials are exposed (often under accelerated conditions) to degradation agents.

The extrapolation of the laboratory behaviour to reality is often a difficult task. Many standards available for degradation tests of geosynthetics (for example [21–23]) do not indicate any relation between test conditions and expected lifetime. Their purpose resides in establishing minimum levels of resistance against degradation.

The existing studies (examples include [9,13,15,20,24]) about the durability of geosynthetics consider mostly the isolated action of the degradation agents, not contemplating the interactions that can occur between them. The standards available for degradation tests of geosynthetics (for example [21–23,25]) and the documents with design recommendations (for example [26,27]) also consider the isolated action of each agent. However, in real situations, the materials will hardly be under the action of only one agent. Therefore, the damage suffered by the geosynthetics will always be the combined effect of the different agents. This combined effect is not necessary equal to the sum of the effects of the individual agents, since interactions (synergisms or antagonisms) may occur between them.

This work studies the resistance of a PP geotextile against degradation and the interactions than can occur between some degradation agents: liquids (water, sulphuric and nitric acids, sodium hydroxide and metallic ion solutions), thermo-oxidation and artificial weathering. The interactions that may exist between or with these agents are a topic that needs research. Indeed, no previous studies with geosynthetics were found in literature considering such type of interactions. This work aims to contribute to the identification of synergisms in the degradation of geosynthetics.

2. Experimental description

2.1. Geotextile

This work used a non-woven needle-punched geotextile (white colour) made from PP fibres with 0.2% (percentage in weight) of the additive Chimassorb 944 (C944). C944 is a UV stabiliser belonging to the HALS (hindered amine light stabilisers) family. The PP fibres had a linear mass of 8 denier and a length of 75 mm. The main characteristics of the geotextile can be found in Table 1.

The sampling process (for the different degradation tests) was carried out according to EN ISO 9862 [31]. The specimens (machine direction of production) were cut from positions evenly distributed over the full width and length of the geotextile (supplied in a roll), but not closer than 100 mm to the edges. For the same degradation test, the specimens were taken from different longitudinal and transverse positions. Each test was carried out with, at least, 5 specimens 50 mm wide and 400 mm long (number and dimensions of the specimens according to EN 12226 [32]).

2.2. Degradation tests

Initially, the geotextile was exposed separately (single exposure) to some degradation tests: immersion in liquids, thermo-oxidation and exposition to weathering (test descriptions in the following points). Then, the geotextile was exposed successively to some combinations of two of the previous tests (multiple exposures). Table 2 summarizes the degradation tests performed.

The basic principles of the degradation tests (and the evaluation of the changes occurred in the tensile properties of the geotextile) followed the guidelines of EN 12226 [32]. Like for many standard degradation tests of geosynthetics, it is hard to find a relation between the degradation conditions employed in this work and real field conditions.

2.2.1. Immersion tests

The geotextile was immersed, at 90 °C, in deionised water, in sulphuric acid (H₂SO₄) and in sodium hydroxide (NaOH). These tests were performed in a thermostatic bath (GFL, model 1003) and lasted for 14 days.

Immersion at room temperature (≈20 °C) were carried out in cadmium(II) nitrate (Cd(NO₃)₂·4H₂O), copper(II) nitrate (Cu(NO₃)₂·3H₂O) and iron(II) nitrate (Fe(NO₃)₂·9H₂O) (the oxidation states of the metallic ions (+2) will be omitted throughout the text). Metallic ions (like cadmium, copper or iron) are often found in soil environment or in residues. The pH of the metallic ion solutions was adjusted to pH ≈2 by the addition of nitric acid (HNO₃) (in absence of acidification, the formation of cadmium, copper or iron hydroxide could occur). For being used to acidify the metallic ion solutions, an immersion test was also performed to evaluate the isolated effect of nitric acid. The experimental conditions of the immersion tests carried out in this work are summarized in Table 3.

The specimens that were subsequently exposed to thermo-oxidation or to weathering (multiple exposures) were not washed after immersion (in order to be contaminated with remains of the solutions) and were allowed to dry at room temperature in the dark. The subsequent thermo-oxidation and weathering tests were carried out in a short period of time (a few days or weeks) after the drying process. When needed, the specimens were stored at room temperature in a dry and dark place.

2.2.2. Thermo-oxidation tests

The thermo-oxidation tests consisted in exposing the geotextile at 110 °C in an oven (Heraeus Instruments, model T6120) with a normal oxygen atmosphere (21% O₂) and without forced air circulation. The specimens were suspended in the oven, spaced and not touching each other. The exposition time lasted for 56 days.

With exception for the longer exposition time, the used methodology was the same as method A of EN ISO 13438 [25] (this standard stipulates an exposition time of 14 or 28 days, depending on the intended use of the geosynthetics). The choice for a longer time pretended to increase test harshness and thereby enhance the effects of thermo-oxidation.

2.2.3. Artificial weathering tests

The artificial weathering tests consisted in exposition to UV radiation, water spray and condensation, trying to represent, respectively, the effects of sunlight, rain and moisture. These tests were performed in a laboratory weatherometer (Q-Panel Lab Products, model QUV/spray).

The UV radiation was provided by fluorescent lamps (type UVA-340). The water used to simulate rain (flow of 5 L min⁻¹, water at room temperature) was treated microbiologically (UV disinfection) and purified by reverse osmosis, followed by deionisation on ionic exchange columns. The water spray step causes a fast

Table 1
Main characteristics of the geotextile (reference specimens).

Chemical composition	99.8% PP, 0.2% C944 (w/w)
Mass per unit area ^a (g m ⁻²)	502 (±25)
Thickness ^b (mm)	3.81 (±0.08)
Tensile strength ^c (kN m ⁻¹)	26.6 (±1.4)
Elongation at maximum load ^c (%)	71.6 (±3.2)

In brackets are the 95% confidence intervals.

^a Determined according to EN ISO 9864 [28] (10 specimens).

^b Determined according to EN ISO 9863-1 [29] (10 specimens).

^c Determined according to EN 29073-3 [30] (machine direction of production).

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