



technical documentation
of product

civil works applications

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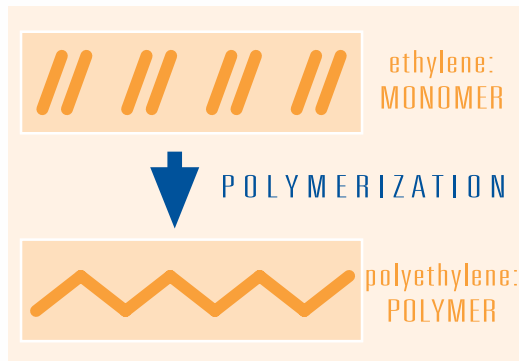
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Introduction to Polyolefins

Polymerization: polymers

Polymers are molecules with a high molecular weight that are produced by the chemical bond of small repetitive fragments called monomers. This process is called polymerization.



If we start from a very high number of ethylene molecules, instead of 4 as in the previous example, we will obtain a material that consists of a long chain with a high molecular weight. This material is the polyethylene.

Besides, if the monomer from which we initially start is propylene instead of ethylene, we will obtain a material called polypropylene through the polymerization chemical process.

MONOMER:
ETHYLENE ► POLYETHYLENE
PROPYLENE ► POLYPROPYLENE

Main types of polymers

Some polymers as proteins and DNA occur naturally.

There are two big groups of synthetic polymers depending on their behaviour under hot conditions:

- In one hand we find resins (or space-network polymers) which not only do not soften when heated but may harden even more. These materials are also known as thermostable or thermo hard materials. Examples of these material are the phenolic resins and rubber.

- On the other hand, we find polymers that soften when heated and so they are called thermoplastic polymers. When they are soft, they can be molded or extruded.

In the group of thermoplastic polymers, the following are included:

- Polyolefins. Examples: polyethylene and polypropylene.
- Vinyl polymers as the polyvinyl chloride (PVC).
- Polyesters. The best known probably is the terephthalate of polyethylene (or polyethylene terephthalate, PET).
- Chlorofluorocarbons, as Teflon.

**THERMO HARD POLYMERS:
RESINS**
(PHENOLIC RESINS - RUBBER)

**THERMOPLASTIC POLYMERS:
POLYOLEFINS**
(POLYETHYLENE - POLYPROPYLENE)
VINYL POLYMERS
(PVC)
POLYESTERS
(PET)
CHLOROFLUOROCARBONS
(TEFLON)



Polyolefins

Polyolefins are semicrystalline thermoplastic polymers with a high chemical resistance and a good electrical isolation. They can be easily transformed and have a very good price.

For all these reasons they have had a great acceptance and currently they are the most used plastics group.

The polyethylene and the polypropylene are materials belonging to this group. Other important polyolefins examples are polybutene and polymethylpentene.



Polyethylene

Polyethylene types and historical evolution.

Different types of polyethylene are manufactured depending on the method and conditions used for its synthesis.

These different types are classified depending on their packaging rate and on the final product density which is determined by the molecular structure of the polyethylene and by the way the polymer chains are ordered in space.

If the material mainly consists of a linear chain with few branches, the molecules will be able to easily approach among them resulting into a high density and a high molecular order, which means that the polymer will be highly crystalline.

LINEAR POLYMERIC CHAIN
▼
HIGH DENSITY
HIGH MOLECULAR ORDER
=
HIGH CRYSTALLINITY

In the same line, a high branching rate in chains will result in low density and crystallinity. The chemical resistance will be linked to the crystallinity rate.

LINEAR POLYMERIC CHAIN
▼
LOW DENSITY
=
LOW CRYSTALLINITY

According to this we can recognize four fundamental types of polyethylene:

- Low density polyethylene (LDPE).
- High density polyethylene (HDPE).
- Very low density polyethylene (VLDPE).
- Linear Low Density Polyethylene (LLDPE).

Low Density Polyethylene (LDPE).

It was the first variety obtained (in 1933). It is synthesized by a chemical process via free radicals at high temperatures and pressures and with initiators.

The polyethylene obtained this way has a great number of branches due to collateral radical processes.





The many branches mainly consist of butyl and ethyl groups, besides of long chains. Due to these many branches, the packaging is quite poor and therefore the polyethylene has a low density.



It is more flexible and soft than HDPE. These properties make it ideal for many applications, specially for agriculture films or packaging industry, although it is uncommonly transformed into waterproofing geomembranes.



LOW DENSITY POLYETHYLENE (LDPE)
 HIGH BRANCHING
 POOR MOLECULAR PACKAGING
 LOW DENSITY AND CRYSTALLINITY



High Density Polyethylene (HDPE).



A few years later, in 1953, a new polyethylene type was obtained at quite lower temperatures and pressures. This was possible thanks to the development of a special catalyst called the Ziegler-Natta catalyst to honour its discoverers. The polyethylene obtained in this way has a lower branching rate and therefore a high density and crystallinity.



The invention of this catalyst revolutioned the polymers and plastics industry in general. Thanks to this discovering, Ziegler and Natta shared the Nobel Prize in Chemistry in 1963.



Due to its structure, the HDPE has a high chemical resistance,



HIGH DENSITY POLYETHYLENE (HDPE)
 LOW BRANCHING
 GREAT MOLECULAR PACKAGING
 HIGH DENSITY AND CRYSTALLINITY

high mechanical features and a high gas proofing capacity, being the reference product of waterproofing geomembranes for landfills.

Linear Low Density Polyethylene (LLDPE).

It has a small number of branches but these are a little bit longer and more frequent than the ones of HDPE. Its density is between the one of HDPE and the one of LDPE. These materials are synthesized by ethylene copolymerization with 1-alkene.

The most common branches are ethyl, butyl and hexyl groups. However, other branches as the octyl group can be found depending on the copolymer used in the reactor. These resins can be considered, from a chemical point of view, as a commitment between the HDPE and the LDPE (and that is where their name comes from) and they can be transformed into geomembranes a little bit more flexible than the ones of HDPE.

Very Low Density Polyethylene (VLDPE).

Recently, a new polyethylene type with a very low density has been found. It is manufactured as the LLDPE, that is, by copolymerization with alkenes.

The difference is that the concentration of these last ones in the reactor is much higher which results in a greater occurrence frequency, limiting the molecular packaging rate. This causes a very low, almost null, crystallinity, a very low chemical resistance and an also very low density. As a result of this, it has the maximal flexibility rate and therefore the VLDPE based geomembranes are very well-suited for waterproofing drinking water supplies or roofing.

Polyethylene physical properties.

All polyethylene varieties share several common properties. Polyethylene is odourless, flavourless and, in most cases, it has been authorized for use in contact with food.

HDPE is the reference product as a geomembrane for waterproofing landfills. Boticas landfill.



Atarfil HDPE 2,00mm -S- 6,00



**VERY LOW DENSITY
POLYETHYLENE (VLDPE)**
HIGH BRANCHING RATE
VERY LIMITED MOLECULAR PACKAGING
▼
VERY LOW DENSITY AND CRYSTALLINITY
▼
MAXIMUM FLEXIBILITY

Among its physical properties, its excellent electrical isolation must be highlighted. Conductivity can be increased adding a percentage from 25 to 30% of carbon black.

At the same time, the maximal utilization temperature is determined by the melting point of the material (from 60 °C for LDPE to 95 °C for HDPE), whilst the minimal is about -50 °C (at this temperature the material becomes brittle).

POLYETHYLENE PHYSICAL PROPERTIES:

- ELECTRICAL ISOLATION
- UTILIZATION TEMPERATURE:
MAX.: +[60-95] °C
MIN.: -50 °C

Chemical resistance of different types of polyethylene

In general, it can be said that polyethylene is resistant to diluted acids, alkali, saline solutions, water, alcohol, oils and even gasoline if it is an HDPE. Underneath 60°C, polyethylene is nearly insoluble in almost any organic solvent and it has a very reduced water permeability.

However, it is not resistant to strong oxidants, specially under hot conditions. Polyethylene swells when it is in contact with some hydro carbons as these last ones enter the polyethylene molecular structure after being in contact for a long period.

In general, the chemical resistance is related to the polyethylene crystallinity rate. This means that HDPE is the most resistant polyethylene, followed by some copolymers as octhyl and hexyl. LLDPE, LDPE and VLDPE are not chemically

resistant.

Polypropylene

Structure and general properties.

The polypropylene general structure is different from the polyethylene's when there is a methyl group that repeats regularly every 2 carbons. This fact gives 3 possible polypropylene types: isotactic, syndiotactic and atactic.

The isotactic polypropylene has all the methyl groups on the same side of the molecule if the chain extends flat, whilst the syndiotactic polypropylene alternates the methyl on opposite sides. Both polypropylene types allow a good molecules packaging in space resulting in an ordered chain distribution with high crystallinity rates.

As for the atactic polypropylene, the methyl randomly appears on both sides, giving a soft and elastic polypropylene as rubber.

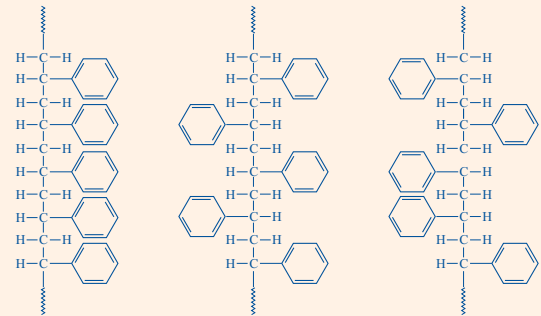
The only polypropylene industrially used for geomembranes manufacturing is the isotactic one. The spatial order of methyl makes this material highly elastic.

Other properties are its high hardness, its abrasion resistance and impact strength and its high melting point (170-190°C), plus its good tensile strength.

Polypropylene chemical resistance.

In general terms, polypropylene (as HDPE) has an excellent resistance to chemical agents.

It is very inert and only in a few specific cases it is affected by the action of some acids and organic solvents under hot conditions. It is perfectly resistant to acids as nitric acid or even bleach at high temperatures. Only very specific mixtures of several acids as acqua regia or organic solvents with very low polarity as chloroform or xylenes, may damage it. Water permeability is very limited.



Isotactic Syndiotactic Atactic

POLYPROPYLENE TYPES:

ISOTACTIC*
(ORDERED DISTRIBUTION OF THE METHYL ON THE SAME SIDE)

SYNDIOTACTIC
(ORDERED DISTRIBUTION OF THE METHYL ALTERNATING ON OPPOSITE SIDES)

ATACTIC
(RANDOM DISTRIBUTION OF METHYL)

*** THE ONLY TYPE USED IN GEOMEMBRANES INDUSTRY**



POLYPROPYLENE

PROPERTIES:

- ELASTICITY
- HIGH HARDNESS
- HIGH MELTING POINT
(170-190 °C)

RESISTANCES:

- ABRASION RESISTANCE
- IMPACT STRENGTH
- TENSILE STRENGTH

Additives ..

Polyolefins, as pure compounds, decompose gradually when they are in contact with the atmosphere due to the oxidant action of oxygen, UV radiations, etc. This is the reason why they need the incorporation of some chemical additives to preserve the polymers properties for a long period of time.

Two types of additives can be highlighted, depending on their role (or the property that we want to confer to the product):

- Additives for the process also known as antioxidant agents.
- Additives that provide resistance to UV radiations (the most used one is carbon black).



Resin, masterbatch and resin with masterbatch.



■ Characterization of a Polyolefinic Geomembranes from its

specifications ■ ■ ■

The right interpretation of the main values shown in a geomembrane specification is very important to forecast the geomembrane evolution in long terms. Being aware of the real meaning of these values, we will be able to prioritize the importance of each of them in terms of raw material quality, main material type used or quality of the manufacturing process.

Parameters that allow the identification of the raw material ..

This section includes the parameters describing the quality and properties of the raw material used for the manufacturing of the geomembrane, but not the ones describing the geomembrane's quality itself. It must be pointed out that the evaluation must be global. This means that none of the parameters on its own allows the characterization of the raw material type.

Density in white.

The density in white refers to the raw material's density without carbon black or any other antioxidant additives.

The density is related to the molecular structure and therefore with the material characteristics.

Among the polyethylene geomembranes, the high density ones have a greater molecular arrangement and therefore a higher crystallinity rate. This is due to their elongated molecules with very few branches that allow a lower intermolecular distance. As a result, they are more resistant to aggressive chemical agents and less flexible than other types of polyethylene. This is the reason why, besides their gas impenetrability, one of the main and almost exclusive applications of high density polyethylene is waste landfills waterproofing.

In order to point out the main ideas, HDPE has a crystallinity rate of 50-55%, VLDPE has null crystallinity and, between these two ones, LLDPE has a crystallinity rate that can be from

0 to 20 % depending on the copolymer used. In the same line, it has been proved that in equal conditions (others than crystallinity rates), high density polyethylene is more resistant to thermal ageing and UV radiations than other polyethylene types. This resistance is 25% higher than LLDPE's and 50% higher than VLDPE's.

Geomembrane density.

The most frequent agents affecting a geomembrane durability when exposed to the environment for long periods of time are the atmosphere oxygen and the UV radiations associated to direct sunlight. To avoid the adverse effects of this agents on the geomembrane, two types of additiives are incorporated: carbon black for UV radiations and an antioxidant element whose main role is to protect the material throughout the manufacturing process - specially right at the exit of the transformed product through the nozzle, where after being exposed to high temperatures and pressures it contacts atmospheric oxygen, not present inside the machine.

Therefore, the final density of the geomembrane is slightly increased due to the carbon black and other additives and although this does not affect the resin properties, it does significantly extend the final product durability.

Melt flow index.

The melt flow index is one of the main parameters that characterize the raw material used. It is an indirect size and

distribution measurement of molecular chains. The result of this measurement allows the verification of the polyethylene type used since, expressed in g/10min, high density polyethylene is below 0.5 if the temperature is 190° and the weight 2.16 kg or below 1.15 if the weight is 5 kg., and the rest of polyethylene types are above 1.15.

Carbon black content.

This parameter represents the percentage of carbon black in the final product. The optimal carbon black content is between 2 and 3%. Below 2% it is not considered enough for a adequate UV protection level whilst above 3% it produces brittleness in the material.

Carbon black dispersion.

This parameter controls that the carbon black is homogeneously distributed throughout the geomembrane mass avoiding the existence of areas without the right protection. In a certain way, it is a parameter more about quality than about identification since a wrong distribution of carbon black can only be due to a failure in the additive dose regulator or, as a last resort, to a bad quality product.

The test procedure consists of a comparison between the image of a sample obtained with a microscope and normalized pictures describing the homogeneity rate of carbon black distribution.



From left to right: Density, Melt Flow Index and Carbon Black Content. ◀ ◀ ◀ ◀ ◀



Parameters indicating the raw material's quality --

In this section are included the parameters describing the geomembrane durability potential when exposed to the environment. In short, they are the parameters that define the true quality of the raw material used and therefore the ones that must be directly linked to the economic assessment of the product. The main ones are the oxidative induction time for oxidation and the stress crack resistance.

Oxidative Induction Time (O.I.T.).

The time period obtained in this test (in which the material is exposed to high temperatures and oxygen) is directly related to the elapsed time before the geomembrane exposed to the environment starts to deteriorate. Thus, for values above 100 minutes, the geomembrane will not start to deteriorate before 8 years of continuous exposure to the environment.



DSC machine for tests. <<<<<<

Ozone resistance.

The ozone resistance test consists of the exposure to pressurized ozone of a folded material sample under certain test conditions in a chamber while observing if there appear any cracks in the folded area.

Since ozone is a highly oxidant agent, the non appearance of any cracks during the performance of the test indicates the ability of the material to bear hard conditions and, therefore, it is directly related to the good quality and durability of the raw material used.

Stress Crack Resistance SCR/NCTL.

It represents the time that takes a material sample to collapse when exposed to tensile forces under certain test conditions. It has a great importance since it is one of the main parameters that describe the quality of the raw material used. This quality directly affects the final product properties and durability.

In test NCTL, according to the ASTM D 5397 regulation, it represents the time that takes a material sample to collapse when exposed to tensile forces under certain test conditions, and therefore a longer time means a better quality.

In test SCR, according to ASTM D 1693 regulation, the sample is exposed to a folding oscillation while counting the hours until its breaking. Normally, for HDPE, this time length is demanded to be over 3000 hours, which means a very long, and therefore unfeasible test period. Furthermore, it has been proved that the NCTL test reflects, with more precision and reliability than SCR, the real quality of the raw material.



Stress cracking. <<<<<<

Parameters that indicate the transformation process quality --

This properties group do not directly describe the raw material's quality but they are related to the quality of the product transformation process and, in general, with the manufacturer's quality. Therefore, the raw material transformed in different machines or processes, can return very different resistance and elongation results.

Tensile strength at yield and at break.

Besides being an indicative of the product transformation quality, tensile strength is useful to verify that the tensile forces exerted on the geomembrane after installation will not exceed the acceptable limits.

In general, two representative points from the stress-strain curve obtained in the tensile strength test are chosen: yield and break. When stress forces are kept below the yield, the material recovers its shape upon the stop of the applied load action, i.e. there are no permanent strains.

The tensile strength at break is the maximal tensile force that the material can bear under certain test conditions.

The point represented by the yield is perfectly defined in some polyolefinic geomembranes as HDPE (Atarfil-HD) or LLDPE (Atarfil-LLD), whereas in others as VLDPE (Atarflex) or PP (Atarpol), this yield cannot be defined in the stress-strain diagram and only the break point is considered as representative.

Elongation at yield and at break.

Elongation at yield is the maximal recoverable strain for the material. Any strains above this value are not totally recoverable and they stay even after the applied load stops its action (plastic deformation). It is normally expressed in %.

The elongation at break is the maximal strain that can bear the material and it also represents its breaking point under certain test conditions. The high elongation values at break that can be reached by polyolefinic geomembranes prove their great capacity to adapt to imposed strains.

It is a clear indicator of the final product quality since most of the international regulations demand a minimum elongation at break value, both in manufacturing and cross directions, so it can be guaranteed that the material underwent an appropriate transformation process.

Other resistant and mechanical properties --

Tear resistance.

Whereas tensile or perforation resistance tests are unidirectional, in this test the cutting effects are also taken into account. It measures the strength that has to be applied in order to break a normalized sample according to a specific test procedure as long as the applied strength is not perpendicular to the break section.

Static puncture strength CBR.

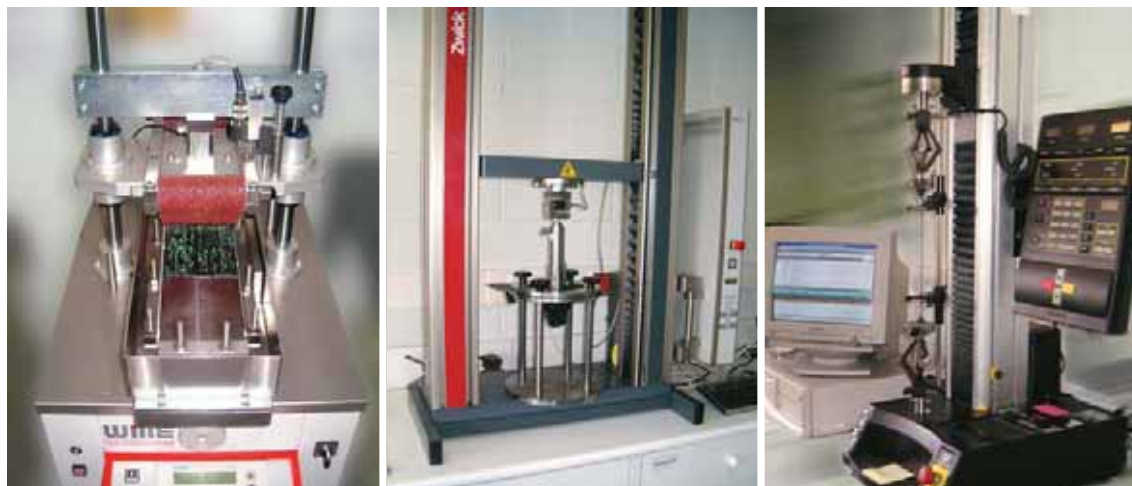
Property recently included in regulations for the EC market. It indicates the exerted strength on a normalized perforation device in order to produce the geomembrane puncture under certain test conditions.

Shore D hardness.

It measures the penetration depth of a normalized device (durometer) under certain test conditions. It depends on the elasticity module and on the material viscoelastic properties, and provides an idea of its crystallinity. There is not a simple relation among the results obtained with different durometers types.

Dimensional stability. Behaviour under hot conditions.

This parameter describes the dimensions variations of the material when exposed to different cycles of rising and falling temperatures under certain test conditions. It provides an idea of captive strains that can be produced in a non-adequate transformation process of the geomembrane.



From left to right: shear box, puncture and tensile strength. ◀ ◀ ◀ ◀ ◀



Functional properties of the geomembrane ■■

The following properties are related to the specific application of the geomembrane.

Low temperature brittleness.

This test is used to verify if there appear any cracks in synthetic sheets for waterproofing when folded at low temperatures. If no cracks appear during the test, it means that the geomembrane will have a good behaviour at low temperatures after installation. This is specially important for water lagoons applications where the geomembrane is directly exposed to the environment temperatures variations.

Water Absorption.

A geomembrane's water absorption is very low. In any case, not only it does not affect its waterproofing capacity but, in fact, it increases it making difficult the flow through the geomembrane.

Linear expansion coefficient.

It represents the proportionality coefficient between the unitary deformation of the geomembrane and the temperature variation to which it is exposed. This value is related with the crystallinity of the material. When geomembranes are exposed to the environment, temperature variations can be critical.

Therefore, determining the potential deformations of the geomembrane may be advisable, and they can be calculated thanks to this value.

Dielectric constant.

The low value of this parameter indicates that the material has good electrical isolation characteristics. Through the coextrusion process, it is possible to manufacture a geomembrane with higher electrical conductivity on one side, increasing the carbon black content of the conductive layer to 25-30%. The application of this geomembrane would be for leakages detection, as these may produce discontinuities in the electrical field created because of a power difference.

Asperity height.

In specific situations, it may be convenient to increase the

geomembrane friction surface through the texturization process. Despite the existence of different procedures to reach this increase, in general it is advisable to follow those that do not alter in any way the properties of the basic geomembrane.

Opposite to the friction angle, whose value depends on the nature of the contact area, asperity has the advantage of being an inherent parameter of textured geomembranes.

Self-extinguishing capacity.

Geomembranes can be manufactured with any self-extinguishing rates. Thus, their ignitibility is controlled in case of fire. This possibility is specially important in certain applications as tunnels.

Thickness. Tolerance. Coextrusion.

The geomembrane thickness is the parameter most commonly used to define it. The thickness control depends, among other factors, on the manufacturing system. The best thickness control is obtained with the extrusion-calendered process,



with variations under 4%. This process even allows a continuous, automatic and real-time thickness control, incorporated to the manufacturing line.

The coextrusion process also offers the possibility of producing two different colours and thickness geomembranes (one colour and thickness on each side), keeping the same characteristics as an extruded geomembrane.

■ Manufacturing Systems ■ ■ ■

Extrusion-Calendered system (EC). M1, M3 and M5 production lines ..

Atarfil has three modern manufacturing units by calendered (EC) with roll widths of 6, 6.3 and 2 m, denominated as line

M1, M5 and M3 respectively. M5 and M3 units are equipped with a coextrusion system and thickness automatic control. The M3 unit can manufacture products with different reinforcement grid types.

The EC geomembranes manufacturing system is well known in the market and it is considered the best system to get the maximal regularity in thickness. It is used in many industrial applications among which is the manufacturing of waterproofing geomembranes.

Its development is subsequent to the EE System and it mainly consists of a set of three cylinders in parallel. The lower two receive the extruded material from a flat combined extruder-head of the same width. The set of cylinders is called calender and its task is the progressive cooling and superficial finishing of the geomembrane. The heat is subsequently dispelled in a long cooling run, at the end of which there is a pulling unit and a winder.

EC SYSTEM

(MAXIMAL REGULARITY IN THICKNESS)

EC MANUFACTURING UNITS IN ATARFIL:

M1:

- 6 M. (ROLL WIDTH)

M5:

- 6,3 M. (ROLL WIDTH)
- COEXTRUSION SYSTEM AND THICKNESS AUTOMATIC CONTROL

M3:

- 2 M. (ROLL WIDTH)
- COEXTRUSION SYSTEM AND THICKNESS AUTOMATIC CONTROL
- WITH DIFFERENT REINFORCEMENT GRID TYPES

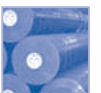
Extrusion-Extrusion system (EE). M2 production line ..

Atarfil has a machine called M2 equipped with Extrusion-Extrusion (EE) technology with a 11.6 m roll width (the widest one in the world).

The EE Extrusion-Extrusion system also known as "Extruwave" manufacturing process of geomembranes was born in Germany in the 70s decade, being probably the most ancient of all those currently in use. It is certainly the only one that was specifically and exclusively designed for the transformation of granulates into waterproof geomembranes for its application in landfills and hydraulic works.



Water Lagoon. ◀ ◀ ◀ ◀ ◀





ATARFIL has got a machine following this process since February 1999. Although at present time there are other manufacturers with this kind of system around the world, the working unit of ATARFIL is probably the most modern and well-developed one due to its technology and permanent control of quality, thickness and temperature. This unit, also manufactures the widest textured geomembrane in the world.

This system consists of an extruder counter-carriage that extends a 50 cm wide crossed stripe of extruded material on a big-diameter hot cylinder or calender that controls the temperatures distribution at the beginning and the cooling of the product at the final phase of the process.

When the counter-carriage reaches the end section of the calender, it starts its return. At the same time, in a synchronized movement, the calender turns over leaving the necessary amount of material so that the welding with the previous stripe has the minimal but enough size and thickness to warrant the geomembranes' resistance and physical properties.

As a result of this calender turnover, it is the machine itself who leads the product into the winder without causing any tensions on it as the typical pulling units used by the other two existing manufacturing systems (Extrusion-Calendered, EC and Extrusion-Blow, ES) do.

The EE technology of the Atarfil machine allows a roll width of 11.6 m, the widest in the world with any of the existing systems. Obviously, if the working conditions or size require smaller width units, this technology can also divide the roll thanks to its cutting devices. Thus, it is possible to get different combinations as: 5.8+ 5.8, or 7+ 4.6, or 9+ 2.6, ... and even make a special order of rolls divided into three or more width units.

Due to its long experience in manufacturing, this product is one of the better known and considered waterproofing existing geomembranes, and it has been approved by many European Certification Institutes.

The lack of tensions during the winding process and an optimum temperature distribution of the calender in spite of its great dimensions, favors the non-existence of any material's molecular orientation. As a result, the product is proved to be the one with better homogeneity, isotropy and alignment of the properties obtained in the manufacturing and in the cross direction.

EE SYSTEM

(MAX. HOMOGENEITY, ISOTROPY AND ALIGNMENT)

EE ATARFIL MANUFACTURING UNIT:

M2:

- 11.6 M. (ROLL WIDTH)

(THE BIGGEST WIDTH IN THE WORLD)



M1

M3



M2



M5

Finally, Atarfil's model has developed a lot the thickness regularity and control thanks to its special sensors and an ultimate extruders group. Therefore, it can be said that the over thickness is almost null in relation to the average guaranteed thickness and it is not significant at all as to cause any problems when using a welding machine.

Advantages and disadvantages of the EE & EC manufacturing systems. Comparison with other systems ..

Highlighting the advantages and disadvantages of each manufacturing system and making a comparison between them could summarize the main ideas of what it has been exposed until now.

However, most of the advantages of the EC system have already been pointed out:

- Maximal thickness uniformity that under electronic control conditions, as in the Atarfil units, may be of $\pm 4\%$.
- Maximal flatness and regularity in their superficial appearance.
- Absence of the common longitudinal splits of the ES system due to the partial folding process of the blowing column during the manufacturing process.
- Optimal product isotropy and homogeneity in manufacturing and cross direction. However, there is often a difference of 8 to 10% between the strength properties of both directions (in the cross-direction this strength is lower). This difference depends on the age of the machine, on the used resins and on the transformation parameters, but in any case it is higher than the one obtained with the ES system.

On the other hand, the advantages of the EE system are the following:

- Maximal product isotropy and homogeneity in manufacturing and cross direction, higher than the ones obtained by the EC system and even higher than the ones obtained by the ES system. In this last one, there is often a difference between the strength properties of 10-15% in both directions depending on the age of the machine, on the used resins and on the transformation parameters.
- Maximal roll alignment, as a result of the optimal distribution of temperatures and of the winding system..
- The widest smooth and textured rolls in the world: 11.6 m.

Note about textured geomembranes ..

Currently, there are two groups of textured or rough products, depending on their manufacturing system:

- Texturization obtained throughout the geomembrane manufacturing process.





- Texturization obtained from the smooth sheet using the grain thermal projection process.



A. Texturization obtained throughout geomembrane manufacturing process.

In this first group, we can find three different types of in-line texturization:



A.1. **Nitrogen blowers** over the delivery chute of the extruded material in the manufacturing process by blow (ES).



A.2. **Structured Geomembrane:** it is obtained thanks to a special cylinder relief in the manufacturing process by calendered (EC).



A.3. **Spilling of the grain** without applying any pressure on the smooth sheet **at the exit of the calender** in the EC and EE systems.



B. Texturization obtained from the smooth sheet using the grain thermal projection process.

In this group, the product undergoes a new unwinding and winding process through a texturization machine. There are three types of machines:



B.1. **Gravity drop of the product grains and then passing through a hot air curtain** that rises the sheet surface temperature to get the grain adhesion. In this case, the grain is usually of a highly fluid material to improve the adherence.



B.2. **High pressure projection of the extruded material** on a geomembrane that has previously passed through a pre-heating air curtain. In this case, the grain is also normally of a highly fluid material to improve the adherence.

B.3. **Medium pressure projection of the extruded material** using a special nozzle through which it is pressured and heated. In this case the grain can be a high density grain with a low melt flow index or a low density grain with a high melt flow index.

AATARFIL currently manufactures one or both textured sides products (TX and TXT) with the A.2 system (ATARFIL Textured-structured), the A.3 system (only in the M2 unit), and the B.3 system (with roll widths of 6 and 6.3 meters). This last one has been possible thanks to an internal Atarfil system development unparalleled in the world. To this aim, Atarfil has developed a special nozzle (currently in the process of obtaining a patent) through which the extruded material is

heated and injected simultaneously until it gets the ideal projection conditions. This system is the only one among those in the B-Group (offline manufacturing), that currently allows textured HDPE geomembranes manufacturing with HDPE grain.

All the manufacturing processes used in Atarfil are guaranteed with the correspondent certifications ISO 9001 and ISO 14001.

Comparison of the different texturization types.

Each system has advantages and disadvantages. A.1 and A.2 systems obtain the maximal texturization adherence to the geomembrane body because the product is manufactured inline without any complementary processes and its grain response to the friction cutting effort is good in short and long terms. However, this high texture quality is obtained in detriment of the resultant geomembrane properties. This fact implies some kind of a contradiction since not being compliant with the existent smooth geomembranes characterization rules, some countries have drawn up a new and less demanding regulation just for the characterization of the textured sheets. Nevertheless, the loss of properties is much higher in A.1 system than in A.2 system.

The following table provides an indication of the loss of characteristics:

Material	HDPE(1)	HDPE TXT(2)	LLDPE(1)	LLDPE TXT(2)
Tensile Strength at Yield (MN/M ²)	17	14	13	11
Tensile Strength at Break (MN/M ²)	32	17	31	11
Elongation at Break (%)	850	300/450⊗	950	450/600⊗

(1) In the A.3 and B types, the values for smooth and rough are identical to the ones of the smooth geomembrane.
 (2) In A.1. and A.2 systems. ⊗

The A.1 system has an inconvenience. It has trouble controlling the thickness inline and therefore is not able to ensure that the average thickness of the textured product is the minimum required, taking into account that the texturization "wave" is printed in the material thickness at the nozzle exit.

On the other hand, the A.2 system completely guarantees the average product thickness since it is regulated by the calender as it happens with a smooth geomembrane.

As for the A.3 system and all the ones belonging to the B-group, they ensure the minimal geomembrane thickness and that its properties are identical to the ones of the smooth geomembrane but with significant differences as the strength and the friction cutting effort in short and long terms. Particularly, they guarantee the best geomembrane properties since they do not apply any heating thermal treatment once the geomembrane has been produced to favor the textured specks adherence.

It is a proven fact that the best friction angles are obtained with the A3 system and the B-group, during the shear test due to the disordered dispersion of the grain. The maximal texturization strength in long terms is however obtained with A1 and A2 systems, as we previously pointed out, and it is reasonably high with systems A3, B2 and B3.


However, the low grain adherence to the sheet quality in the

B1 system is due to a lack of projection. Also, with the B2 system, being a product obtained using high pressure projection with a high melt flow index, the impact on the smooth sheet is usually enough to completely laminate the plastic specks. As a result, the product not only has very different characteristics compare to the ones demanded in the source material but also its adherence among materials of such different natures is low at midterm. As a result, B2 and specially B1 products do not properly bear exposure to UV radiation.

As for the welding process of these materials, the more permanent their texturization is, the less easy will be to weld them. Even in A1 and A2 systems, when a pannel is cut in cross-direction, it is advisable to polish the borders with a screw jack to get a good welding quality. In any case, the product must have two plain stripes in both sides.

Atarfil's Products Format

ATARFIL has a wide range of available product formats. The following table is provided as an orientation. For any formats not included in it, please contact us.

Thickness (mm.)	Length (m.)	ROLL WIDTH				
		2 m. 	5,8 m.	6 m.	6,3 m.	11,6 m.
		(m ²)	(m ²)	(m ²)	(m ²)	(m ²)
0.75	280	70	1,624	1,680	1,764	-
1.00	210	70	1,218	1,260	1,323	-
1.20	175	70	1,015	1,050	1,102	-
1.50	140	70	812	840	882	1,568
2.00	105	70	609	630	661	1,176
2.50	84	70	487	504	529	940
3.00	70	70	406	420	441	784

 35 m. length rolls.

Other intermedium roll width or length on request.



Chemical Resistances Table (High Density Polyethylene)

Abbreviations	Meaning
v	satisfactory
x	unsatisfactory
!	limited application possible
—	non tested
(Concentración)	
sat. sol.	saturated aqueous solution, prepared at 20°C (68°F)
sol.	solution with concentration above 10% but below saturation level
dil. sol.	dilted aqueour solution with concentration below 10%
cust. conc.	customary service concentration





Element	Concentration	Resistance at:	
		20%	60%
A			
Acetaldehyde		v	v
Acetic Acid	80 - 100%	v	!
Acetic Acid	10 - 60%	v	!
Acetic Acid	1 - 10%	v	v
Acetic Acid Anhydride	100%	v	!
Acetic Anhydride	—	v	!
Acetone	100%	!	!
Acrylic Emulsions	—	v	v
Acrylonitrile	—	v	v
Adipic Acid	sat. sol.	v	v
Aliphatic Esters	—	v	!
Allyl Alcohol	96%	v	v
Aluminium Chloride	sat. sol.	v	v
Aluminium Fluoride	sat. sol.	v	v
Aluminium Sulphate	sat. sol.	v	v
Aluminum	sol.	v	v
Aminoacetic Acid	—	v	v
Ammonia	Gas	v	v
Ammonia	sol.	v	v
Ammonium Acetate	—	v	x
Ammonium Bromide	—	v	v
Ammonium Carbonate	—	v	v
Ammonium Chloride	sat. sol.	v	v
Ammonium Fluoride	sol.	v	v
Ammonium Hydroxide	—	v	v
Ammonium Metaphosphate	—	v	v
Ammonium Nitrate	sat. sol.	v	v
Ammonium Persulphate	sat. sol.	—	—
Ammonium Sulphate	sat. sol.	v	v
Ammonium, dry gas	100%	v	v
Amyl Acetate	100%	v	v
Amyl Alcohol	100%	v	!
Aniline	100%	v	!
Aqua	—	v	v
Aqua Regia	HCL-HNO3 3/1	x	x
Aromatic Acids	—	v	v
Aromatic Hydrocarbons	—	!	x
Arsenic	—	v	v
Arsenic Acid	sat. sol.	v	v
Aspirin	—	v	v
B			
Barium Carbonate	sat. sol.	v	v

Element	Concentration	Resistance at:	
		20%	60%
Barium Chloride	sat. sol.	v	v
Barium Chloride	sat. sol.	v	v
Barium Hydroxide	sat. sol.	v	v
Barium Sulphate	sat. sol.	v	v
Beer	—	v	v
Benzaldehyde	100%	v	!
Benzene	—	!	x
Benzoic Acid	sat. sol.	v	v
Borax	sat. sol.	v	v
Boric Acid	sat. sol.	v	v
Bromine, gas dry	100%	x	x
Bromine, Liquid	100%	x	x
Bromochloromethane	—	x	x
Butadiene	—	x	!
Butane	100%	v	v
Butane, gaseous	100%	v	v
Butanediol	10 - 100%	v	v
Butyl Acetate	—	v	!
Butyric Acid	100%	v	!
C			
Calcium Bromide	—	v	v
Calcium Carbonate	sat. sol.	v	v
Calcium Chlorate	sat. sol.	v	v
Calcium Chloride	sat. sol.	v	v
Calcium Hydroxide	sat. sol.	v	v
Calcium Hypochlorite	sol.	v	v
Calcium Nitrate	sat. sol.	v	v
Calcium Sulphate	sat. sol.	v	v
Carbon Dioxide	100% dry	v	v
Carbon Dioxide	Humid	v	v
Carbon Dioxide	100%	v	v
Carbon Disulphide	100%	!	x
Carbon Monoxide	100%	v	v
Carbon Oxide	—	v	v
Chlorine, aqueous solution	sat. sol.	!	x
Chlorine, gas dry	100%	!	x
Chlorobenzene	—	!	x
Chloroform	100%	x	x
Chromic Acid	20%	v	!
Chromic Acid	50%	v	!
Citric Acid	sat. sol.	v	v
Coffee	—	v	v
Copper Chloride	sat. sol.	v	v





Element	Concentration	Resistance at:	
		20%	60%
Copper Cyanide	sat. sol.	v	v
Copper Nitrate	sat. sol.	v	v
Copper Sulphate	sat. sol.	v	v
Cresol	—	v	v
Cresylic Acid	sat. sol.	!	—
Cyclohexane	100%	v	!
Cyclohexanone	100%	v	!
D			
Dextrose	sol.	v	v
Dibutyl Ether	—	!	x
Dichloroacetic Acid	50%	v	v
Dichloroacetic Acid	100%	v	!
Dichlorobenzene	—	x	x
Dichloroethane	—	!	!
Dichloroethylene	—	x	x
Dietherphthalate	100%	v	!
Diethylene glycol	—	v	v
Dioxane	100%	v	v
E			
Ethane Glycol	100%	v	v
Ethanol	40%	v	!
Ethyl Acetate	100%	!	x
Ethyl Ether	—	!	x
Ethylbenzene	—	!	x
Ethylene Glycol	—	v	v
F			
Ferric Chloride	sat. sol.	v	v
Ferric Chloride	sat. sol.	v	v
Ferric Nitrate	sol.	v	v
Ferric Sulphate	sat. sol.	v	v
Ferrous Chloride	sat. sol.	v	v
Ferrous Chloride	sat. sol.	v	v
Ferrous Sulphate	sat. sol.	v	v
Fluoric Acid	4%	v	v
Fluoric Acid	60%	v	!
Fluorine, gaseous	100%	x	x
Fluosilicic Acid	40%	v	v
Formaldehyde	10 - 30%	v	v
Formaldehyde	30 - 40%	v	!
Formic Acid	50%	v	v
Formic Acid	98 - 100%	v	v
Fructose	sol.	v	v
Furfural	100%	!	x

Element	Concentration	Resistance at:	
		20%	60%
G			
Gas-oil	—	v	!
Gasoline	—	v	!
Glacial Acetic Acid	96%	v	!
Glucose	sat. sol.	v	v
Glycerine	100%	v	v
Glycol	sol.	v	v
H			
Heptane	100%	!	x
Hexachlorobenzene	—	v	v
Hexane	—	v	!
Hydrobromic Acid	50%	v	v
Hydrobromic Acid	100%	v	v
Hydrochloric Acid	sol.	v	v
Hydrochloric Acid	10%	v	v
Hydrochloric Acid	Concentrated	v	v
Hydrocyanic Acid	10%	v	v
Hydrogen	100%	v	v
Hydrogen Peroxide	30%	v	v
Hydrogen Peroxide	90%	v	x
Hydroquinone	sat. sol.	v	v
Hydrosulphuric Acid	—	v	v
I			
Isooctane	—	v	!
Isopropyl Ether	—	!	x
K			
Kerosene	—	!	!
L			
Lactic Acid	100%	v	v
Lanolin	—	v	v
Lead Acetate	sat. sol.	v	—
M			
Magnesium Carbonate	sat. sol.	v	v
Magnesium Chloride	sat. sol.	v	v
Magnesium Hydroxide	sat. sol.	v	v
Magnesium Nitrate	sat. sol.	v	v
Magnesium Sulphate	sat. sol.	v	v
Malic Acid	sat. sol.	v	v
Margarine	—	v	v
Mercuric Chloride	sat. sol.	v	v
Mercuric Cyanide	sat. sol.	v	v
Mercurous Nitrate	sol.	v	v
Mercury	100%	v	v





Element	Concentration	Resistance at:	
		20%	60%
Methanol	100%	v	v
Methylene Chloride	100%	x	x
Methylethylketone	100%	v	x
Milk	—	v	v
Molasses	cust. conc.	v	v
N			
Naphtha	—	v	!
Naphthalene	100%	v	x
Natural Gas	—	v	v
Nickel Chloride	sat. sol.	v	v
Nickel Nitrate	sat. sol.	v	v
Nickel Sulphate	sat. sol.	v	v
Nicotinic Acid	sat. sol.	v	—
Nitric Acid	25%	v	v
Nitric Acid	50%	v	x
Nitric Acid	75%	x	x
Nitric Acid	100%	x	x
Nitrobenzene	100%	x	x
Nitroglycerin	—	!	x
O			
Oil and Grease	—	v	v
Oleic Acid	100%	v	!
Orthophosphoric Acid	50%	v	v
Orthophosphoric Acid	95%	v	!
Oxalic Acid	sat. sol.	v	v
Oxygen	100%	v	!
Ozone	100%	!	x
P			
Perchloric Acid	20%	v	v
Perchloric Acid	50%	v	!
Perchloric Acid	100%	v	x
Petroleum	—	v	!
Petroleum Ether	—	!	x
Phenol	sol.	v	v
Phosphorous Oxychloride	—	v	!
Phosphorous Pentoxide	—	v	v
Photographic Developer	cust. conc.	v	v
Photographic Developers	—	v	v
Photographic Emulsions	—	v	v
Potassium Fluoride	sat. sol.	v	v
Potassium Bicarbonate	sat. sol.	v	v
Potassium Bromate	10%	v	v
Potassium Bromide	sat. sol.	v	v

Element	Concentration	Resistance at:	
		20%	60%
Potassium Carbonate	sat. sol.	v	v
Potassium Chlorate	sat. sol.	v	v
Potassium Chloride	sat. sol.	v	v
Potassium Chromate	sat. sol.	v	v
Potassium Cyanide	sol.	v	v
Potassium Dichromate	sat. sol.	v	v
Potassium Ferricyanide	—	v	v
Potassium Ferrocyanide	sat. sol.	v	v
Potassium Hydroxide	10%	v	v
Potassium Hydroxide	sol.	v	v
Potassium Hypochlorite	sol.	v	!
Potassium Nitrate	sat. sol.	v	v
Potassium Orthophosphate	sat. sol.	v	v
Potassium Perborate	sol.	v	v
Potassium Perchlorate	sat. sol.	v	v
Potassium Permanganate	20%	v	v
Potassium Persulphate	sat. sol.	v	v
Potassium Sulphate	conc. sol.	v	v
Potassium Sulphate	sat. sol.	v	v
Propane	Gas	v	v
Propionic Acid	50%	v	x
Propionic Acid	100%	v	!
Propylene Glycol	—	v	v
Pyridine	100%	v	!
S			
Salicylic Acid	sat. sol.	v	v
Silver Acetate	sat. sol.	v	v
Silver Nitrate	sat. sol.	v	v
Sodium Acetate	—	v	v
Sodium Benzoate	sat. sol.	v	v
Sodium Bicarbonate	sat. sol.	v	v
Sodium Biphosphate	sat. sol.	v	v
Sodium Biphosphate	sat. sol.	v	v
Sodium Bromide	sat. sol.	v	v
Sodium Carbonate	sat. sol.	v	v
Sodium Chlorate	sat. sol.	v	v
Sodium Chloride	sat. sol.	v	v
Sodium Chlorite	50%	v	v
Sodium Cyanide	sat. sol.	v	v
Sodium Ferricyanide	sat. sol.	v	v
Sodium Ferrocyanide	sat. sol.	v	v
Sodium Fluoride	sat. sol.	v	v
Sodium Hydroxide	40%	v	v





Element	Concentration	Resistance at:	
		20%	60%
Sodium Hydroxide	sat. sol.	v	v
Sodium Hypochlorite	15%Active Chlorine	v	v
Sodium Nitrate	sat. sol.	v	v
Sodium Nitrite	sat. sol.	v	v
Sodium Orthophosphate	sat. sol.	v	v
Sodium Perborate	—	v	v
Sodium Silicate	sat. sol.	v	v
Stannic Chloride	sat. sol.	v	v
Stannous Chloride	sat. sol.	v	v
Starch	sol.	v	v
Succinic Acid	50%	v	v
Sulphur dioxide, dry	100%	v	v
Sulphuric Acid	10%	v	v
Sulphuric Acid	50%	v	v
Sulphuric Acid	70%	v	!
Sulphuric Acid	80%	v	!
Sulphuric Acid	96%	!	x
Sulphuric Acid	98%	!	x
Sulphuric Acid	Fuming	x	x
Sulphuric Anhydride	—	!	!
Sulphurous Acid	30%	v	v
Sulphurous Anhydride	—	v	v
Sylver Cyanide	sat. sol.	v	v
T			
Tannic Acid	sol.	v	v
Tartaric Acid	sol.	v	v
Trichloroacetic Acid	50%	v	v
Trichloroacetic Acid	100%	v	!
U			
Urine	—	v	v
Y			
Yeast	sol.	v	v
Z			
Zinc Carbonate	sat. sol.	v	v
Zinc Chloride	sat. sol.	v	v
Zinc Chloride (II)	sat. sol.	v	v
Zinc Chloride (IV)	sat. sol.	v	v
Zinc Oxide	sat. sol.	v	v
Zinc Sulphate	sat. sol.	v	v

■ Technical Specifications. Atarfil's Product Specifications ■ ■ ■

High Density Polyethylene ..

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Atarfil HDS Coextruded. pg. 29
Atarfil TX/TXT. pg. 30
Atarfil CX Colour. pg. 31
Atarfil HDE Conductive. pg. 32

Linear Low Density Polyethylene ..

Atarfil LLD Linear. pg. 33
Atarfil LLDS Coextruded. pg. 34
Atarfil LTX/LTXT. pg. 35

Very Low Density Polyethylene ..

Atarflex. pg. 36
Atarflex S Coextruded. pg. 37
Atarflex W Translucent. pg. 38

Thermoplastic Polyolefins ..

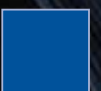
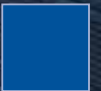
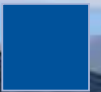
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E.V.A. (Ethyl Vinyl Acetate) ..

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Polypropylene ..

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Atarpol S Coextruded. pg. 43
Atarpol RS Reinforced. pg. 44



■ Applications ■ ■ ■

1 • WATER LAGOONS AND RESERVOIRS

2 • LAKES AND WATER TREATMENT

3 • FLOATING COVERS

4 • LANDFILLS

5 • LANDFILLS CAPPING

6 • AQUACULTURE

7 • LEACHING PADS

8 • SECONDARY CONTAINMENT

9 • CHANNELS

10 • RESERVOIRS AND TANKS

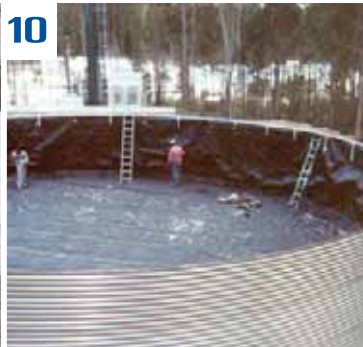
11 • TUNNELS

12 • PROTECTION AGAINST CORROSION

13 • ORNAMENTAL PONDS

14 • ROOFING

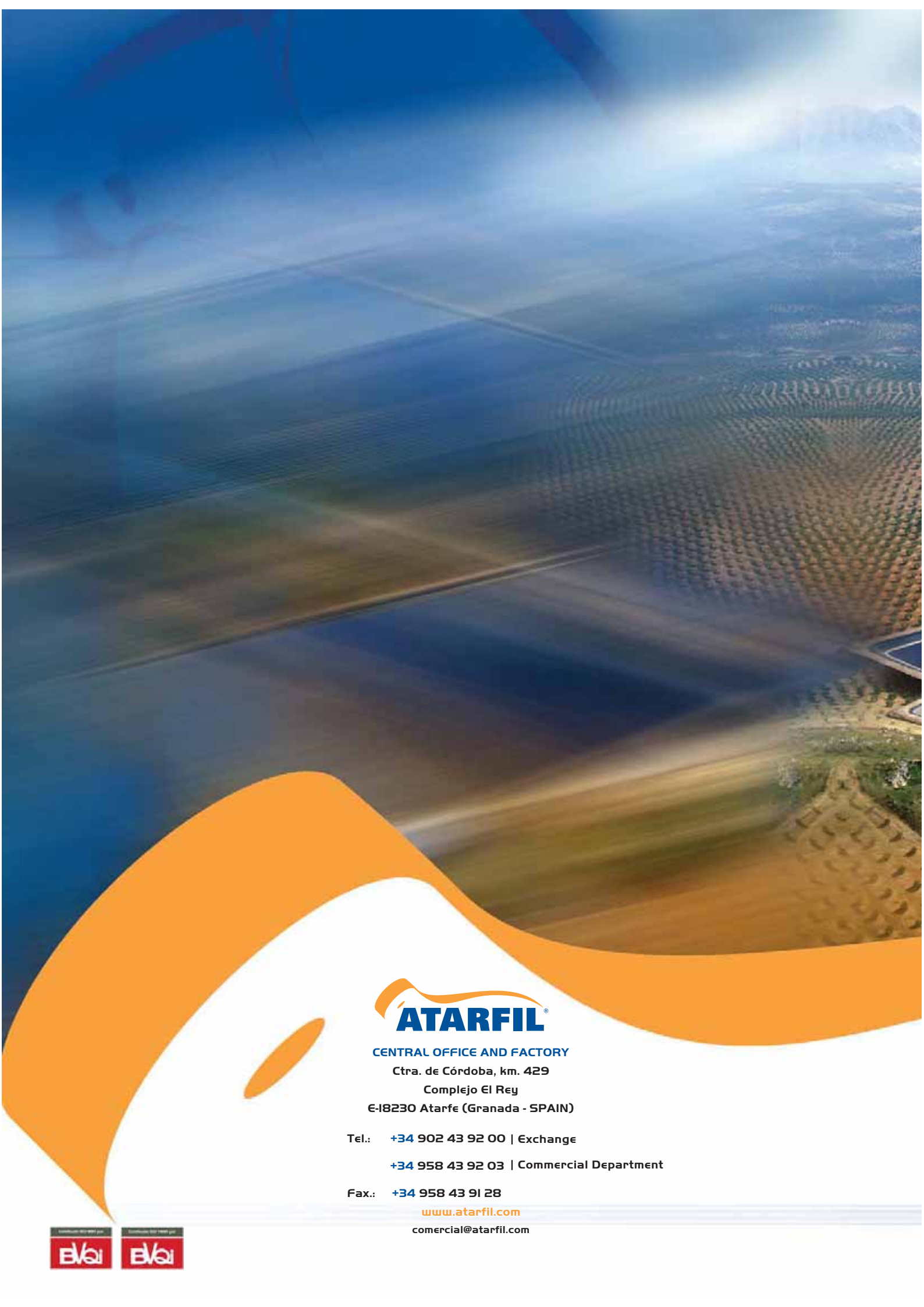




Applications

A p p l i c a t i o n s														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	WATER LAGOONS AND RESERVOIRS	LAKES AND WATER TREATMENT	FLOATING COVERS	LANDFILLS	LANDFILLS CAPPING	AQUACULTURE	LEACHING PADS	SECONDARY CONTAINMENT	CHANNELS	RESERVOIRS AND TANKS	TUNNELS	PROTECTION AGAINST CORROSION	ORNAMENTAL PONDS	ROOFING
C: COLOUR W: TRANSLUCENT S: COEXTRUDED (double layer product) TX: 1 SIDE TEXTURED TXT: 2 SIDES TEXTURED CX: 1 COLOUR SIDE TEXTURED R: REINFORCED														
Product Names in Technical Specifications														
ATARFIL HD	●	●		●	●	●	●	●	●			●	●	
ATARFIL HDS Coextruded	●	●		●		●							●	
ATARFIL TX/TXT				●	●									
ATARFIL CX Colour				●										
ATARFIL LLD Linear	●				●	●			●	●	●		●	
ATARFIL LLDS Coextruded	●					●							●	
ATARFIL LTX/LTXL					●									
ATARFLEX	●					●			●	●			●	
ATARFLEX S Coextruded	●					●			●	●			●	
ATARFLEX W Translucent										●				
ATARFLEX TS Tunnel											●			
ATARFLEX TW Tunnel											●			
ATARFLEX D						●				●				
ATARPOL	●	●			●		●			●		●		
ATARPOL S Coextruded	●	●								●		●		
ATARPOL RS Reinforced	●		●									●	●	
ATARTEC S/RS/SXG/P														●





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