**PILOT TESTS FOR THE USE OF AFITEX GEOCOMPOSITES IN SLUDGE BASINS OF MEA PROCESSING UNITS**

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**Abstract**

The enrichment of the phosphate ore is currently carried out at the OCP plant by the washing, grinding and flotation process. This type of treatment generates fine and coarse rejections where the sludge fraction (100 to 110 g / L), usually composed of schlamms (<40 µm) and flotation rejects (<125/160 µm), is thickened in decanters to separate water.
About 80-83% of water is generally recovered at the decanter and then recycled to the treatment units. The rest is transferred to the dikes in the form of sludges having a solid concentration ranging from 300 to 350 g/l.
From the dikes, approximately 10 to 12% of water is recovered and then recycled to the treatment units. An important part of this water (about 6 to 8%) remains unrecovered and can be a water that:

- evaporates due to strong sunlight and high temperatures.
- seeps into the soil,
- remains trapped in the sludges.

In order to increase the recovery of the water contained in these sludges, this work was undertaken following the collaboration of the OIK, R&D and AFITEX teams. The main objective is to carry out pilot basin tests to develop and assess the good functioning of a range of drainage's geocomposites for a better recovery of the water from the dikes and a good stability of the walls of the basins.
The results of these tests highlighted several interests of the Draintube (geocomposite) compared to the traditional solution of the natural basin.

- Solid percentage less than 1% in the recovered filtrate. This makes it reusable at the treatment units,
- protection of dikes from erosion and instability at the basin slope;
- at the bottom of the basin:
  - ✓ optimized drainage;
  - ✓ recovery of 20% more filtrate than with the traditional basin;
  - ✓ limitation of surface evaporation of the basin;
  - ✓ drying up a large volume of sludge over a short period of time.

- Preservation of groundwater by limiting infiltration through ponds.

## 1. INTRODUCTION

Phosphate mining at the OCP Mrah laundromat leads to the production of 24,000 m3 of sludge every day. This sludge contains between 70 and 80% water. A significant portion of this water is not recycled in the mine; This water is then lost in the environment:

♣ Water evaporates due to strong sunshine and summer temperatures.

♣ Water seeps into the underlying soil, potentially polluting the environment. Infiltration losses in a 50 ha basin would be in the order of 2000 m3 per day. Thus, between 5 and 10% of the water contained in the mud would be lost at the level of the bottom and slopes of the basins.

♣ Water remains in the mud, trapped by the electrochemical interactions with the solid particles. Thus, the mud does not consolidate and remains weak, which can cause instabilities in the dikes.
Furthermore, the recovery of water in the basins takes place via recovery pipes. The height of the overflow must be adjusted at all times according to the amount of supernatant and the water demand of the laundromat. This work of adjustment of the height of overflow is perilous (dangerous workplace). Finally these chimneys are expensive to build.
Finally, the ponds are also used to store water. When the wind blows over this layer of open water, a swell develops and Erodes the dikes.

## 2. PROJECT OBJECTIVE

OCP has chosen to be forward-thinking and to integrate social, environmental and economic issues at all levels of its activity, and its water strategy is to reconcile industrial growth with the preservation of water resources.
Access to water is a vital issue for the OCP Group's industrial strategy.
In 2008, a global industrial transformation strategy was put in place by mobilizing a large investment of 145 billion DH with a view to doubling its mining production capacity and triple that of transformation to 2025.
The effort to increase production capacity is naturally accompanied by an increase in water requirements from 66 million m3 / year to more than 158 million in the future. (1)
Currently, at the khouribga site, 50 million m3 per year are used. "5 million m3 already come from domestic water purified by the Khouribga wastewater treatment plant, and 45 million m3 per year will be taken from the Aït Messaoud dam."
According to the OCP plan, 60% of the water consumed by the OCP industrial installations will be of unconventional origin by 2025.Thus it is necessary to increase the recovery of the water contained in the sludge in order to limit the consumption of fresh water and to limit the footprint of the storage basins.
This project is part of the OCP strategy leveraging "OPTIMIZATION OF WATER UTILIZATION ON THE CHANNEL OF THE VALUE" (2)
The objective of this project is to develop and then validate the proper functioning of a range of drainage geocomposites to answer the problems raised in the context of the project.
Faced with these problems, AFITEX has developed a new range of geocomposites (GCP) specially designed for OCP laundry sludge.
These geocomposites meet the following requirements:

- ♣ Retention of solid particles in the basin.
- ♣ Free circulation of water to mini-drains.
- ♣ Transport of water in the GCP plan over a long distance (100 m).
- ♣ Waterproofing against soil-support to limit infiltration.
- ♣ Maintains characteristics over time = UV resistance and chemical resistance.

## 3. MATERIAL AND METHODS

3.1 The development project is divided into 3 main stages:
- Preliminary filtration tests
- Filtration / drainage tests and installation of a UV resistance test
- basin pilot tests

### 3.2 Laboratory tests

These tests were carried out in March 2015, initially the sludge was characterized in terms of granulometry and dryness (water content). Five filtration tests were then carried out to demonstrate that the laundry sludge is filterable. Geotextiles used to filter this mud are made of polyester, polymer more resistant to UV than polypropylene commonly used in geosynthetics.
10 filtration / drainage tests and a chemical resistance test to the OCP sludge were carried out. Six different geocomposites (GCPs) were tested in an innovative device with OCP laundry sludge. The testing the GCP in a configuration as close as possible to the experimental device comprises 8 cells hich have the advantage of reality. The GCP is placed at the bottom of the cell.

Figure 1: Cells used for laboratory testing

The mini-drain passes through the front wall of the cell. About 10 liters of sludge are deposited on the GCP and the expulsion of the filtrate is followed over time (quantity and dryness)

### 3.3 UV resistance tests

UV resistance test is carried out in parallel with the filtration / drainage tests. The geotextiles are exposed to the sunfor 5 months.54 samples of 6 different GTX are now exposed to the Khouribga sun. Every 15 days for 4.5 months, 6 GTX are lifted and sent to the Afitex laboratory for mechanical testing. Six GTX samples will remain in the OCP sludge for 15 days and then sent to the laboratoryfor the same tests and estimate whether the chemistry of the sludge is likely to rapidly degrade the GTX Thus the evolution of the mechanical parameters can be followed. The results of this test will be useful for sizing the GTXs for the actual mud ponds. Indeed, these basins are filled in a few months and the slopes will have to keep their properties all that time.

### 3.4 basin pilot tests

On the test site, right next to the pumping station of Mrah, two ponds were built side by side:

- a traditional control basin with a water recovery chimney.
- a test pool covered with GCP and without a chimney.

Each basin has the following dimensions:

- The bottom of the basins has an area of 19 m by 60 m.
- The height of the dikes is 6 m. The basins are mostly dug in the ground.
- The slope of the dikes is 1 / 2.5: the slopes are 15 m wide and have a slope of 16.2 m.
- The width of the top of the dikes is 5 m to allow circulation between the basins.
- The area of the basins is 4500 m².


Figure 2: Excavation of basins

#### 3.4.1 Traditional control basin:

The traditional control basin is composed only of a chimney for the recovery of the supernatant waters. The bottom and slopes of the basin are not protected or sealed.


Figure 3: View of the control pond with the recovery chimney

#### 3.4.2 Calculating the geocomposites of the test basin

The layout describes the layout of the geocomposites hich are placed on the basin dedicated to the test. They were installed under the supervision of Afitex. The geocomposite sheets are 3.90 m wide, the longest rollers will be 62 m.
Considering the developed surface of the basin , the 10 cm coverings between the sheets and the coverings between the bottom and the slope, Afitex will have to provide about 5,500 m² of GCP to cover this test basin.
It is essential that the basins are identical so that the results can be exploited. Dimensional tolerances are:

- 1 m in width
- 2 m in length
- 0.5 m in height
- Surfaces must be smooth and compacted to avoid punching of the geofilm.

In addition, 3 reserve tubes (D 200 mm) were placed


Figure 4: Installation of drainage geocomposites on the bottom of the test pool and placement of the collectors.

in the continuity of the bottom (1% slope) before backfill embankment.

### 3.4.3 Connection of mini-drains to collector drains ( figure 5)

All the mini-drains of the geocomposites are connected directly to the collector drains by the Quick Connect system. The installation of the drainage connector makes it possible to drain optimally and without loss of fluid with a simple installation by clip

Figure 5: Quick Connect Device Diagram.

### 3.4.4 Deposit of the mud (figure 6)

The sludge is deposited in the basin by an overflow channel (200 mm tube cut lengthwise) which allows the sludge to be deposited over the entire width of the basins. The 2 following pictures present the 2 basins at the start of the filling.
Collection of the water of the test basin
The geocomposites will simultaneously collect the water from the bottom and slopes as well as the supernatant water. The water will reach the mini-drains by crossing the GTX acting as a filter and then circulating freely in the draining sheet. Then the mini-drains will lead the water to 150 mm collectors. Ideally these collectors will be PE-HD in order to be tolerant to deformation. The mini-drains will be connected to these collectors by simple clipping using the Quick-connect system.
We have chosen to install two collectors in order to dissociate the flows of water coming from the different zones of the basin (bottom and slope) and thus toevaluate the behavior of the geocomposites in each of these zones. In the following figure the different zones are identified as well as the location of the collectors. It is essential to install the reserve tubes (D200 mm) before the embankments of the dikes.
These tubes will allow the collectors to pass under the downstream dam after the installation of the GCPs.

Figures 6: Depositing the  mud

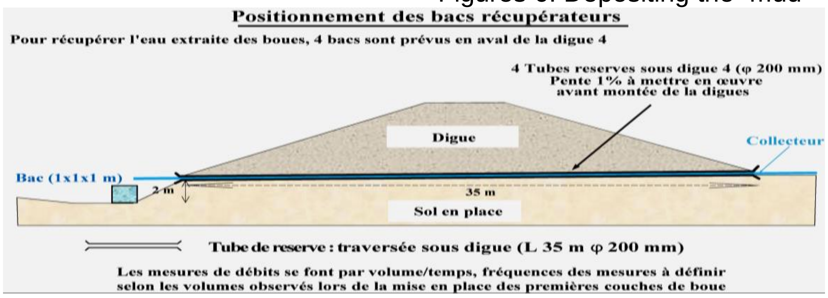



Figure 7:Section of the downstream dike at the level of a collector bushing

OCP will have to acquire before the end of May

- ♣ 420 m of HDPE tube D 150 mm plus the length necessary to reach the pumping station
- ♣ 6 plugs adapted to the tube.
- ♣ 2 equal tees of 90 ° adapted to the tube.
- ♣ 3 valves adapted to the tube.

The collectors will arrive at retention tanks of about 1000 l which will allow to measure the quantity of water extracted by the GCP in a first time. These bins will be downstream of the dike and located lower than the bottom. Secondly, after analysis of the first water recovery, the collectors will be dumped into a drainage basin where the outlets will still be accessible for measurements throughout the

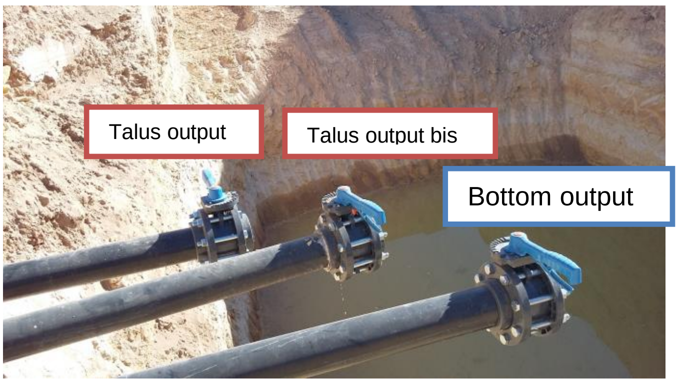



Figure 8: Detail of the outlets of the three collectors at the level of the drainage basin.

experiment.

### 3.4.5 Collecting water from the traditional control Basin (figure 9)

The control basin has a multi-stage recovery chimney to recover the supernatant water without harvesting the sedimented particles at the bottom of the basin.

Figure 9: Control basin recovery chimney.

### 3.4.6 Following experience

#### 3.4.6.1 . Amount of filtrate

The procedure for measuring the volume of water collected by PCGs is as follows:

♣ Each collector ends in a graduated tank of minimum 1000 liters (then in the drain basin afterwards).

♣ Every day, or as soon as the tank is full, the valve upstream of the tank is closed, and the tank is emptied with the pump to the main pumping station.

♣ The upstream valve is reopened and the water flows again from the manifolds to the tanks.

The measurement of the water collected by the chimney of the control basin is identical.

Figure 10: Measurements using the desiccant scale

#### 3.4.6.2 Filtrate quality

In order to determine the quality of the filtrate and thus to evaluate the retention capacity of the GCPs, a 10 ml test piece will be taken daily at the outlet of the collectors. The dryness of these samples will be measured using a desiccant scale. Moreover, at the beginning of the experiments, and then more episodically, the passing particles can be characterized in size using the laser granulometer present in the mineralogy laboratory. Study of water levels in the two basins:
A filling of the basins over 2.5 months, the two basins are filled, to approximately equal height.

## 4. RESULTS

### 4.1 Results of the preliminary filtering test

The characteristic mud comes from a sample taken on March 26 at 15h.
The median particle size constituting the collected sludge is between 30 and 40 µm and the dryness is between 20 and 30%. Preliminary filtration tests show that the laundry sludge is filterable: the retention is excellent (only 30 g of particle pass through the geotextile per square meter). After 10 minutes of filtration, the filtrate becomes clear in all tests. Six different geocomposites (GCPs) were tested in an innovative device with OCP laundry sludge. The tests lasted 48 hours and led to significant drying of the sludge. The dryness increased from 21 to 39%, which corresponds to an extraction of about 60% of the water contained in the mud. Thus the volume of sludge was reduced by about 50%. At the same time the resistance of the mud was increased. The tests show that the GCPs generally succeed in retaining the particles; The best performing geotextiles (GTX) in retention are the thermolized GTXs; Having a lower porosity, they retain the particles on their surface while the simply needled products see the particles penetrate deep enough into the GTX.A clear differential settlement occurs during the experiments: the mud lying against the filter wall densifies rapidly. Then, as the surface of the mud descends, the far part of the filter wall descends more quickly. At the end of the experiment there is adifference in height of nearly 3 cm. This slope has the effect of migrating the supernatant away from the filter wall.

Figure 11: Surface condition after filling, after 8 h and after 22 h

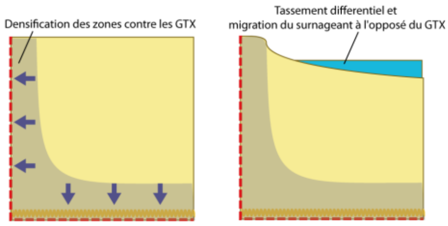



Figure 12: Initial Densification and Migration of Supernatant

In the field, all the embankments will be covered by GCP. Thus this phenomenon will lead to the migration of the supernatant towards the center of the basin, far from the GCP. This will impede water recovery. In order to limit this inconvenience it is necessary to play on the method of filling:

♣ By filling with a lower flow, in order to force the development of a slope downstream.

♣ Filling alternately by the left upstream corner and the right upstream corner

## 4.2 Resistance of GTX to UV

### 4.2.1 Resistance aux UV

The results have made it possible to choose the best filters for the two Geocomposites Draintube. The two filters presented below are those which have been retained.
Curve reading: The degradation of the product follows a reversed logarithmic law.
The red curve is the limit below which the tested product no longer meets the requirements. Its values are calculated according to the formula :

Figure 13: UV exposure panels

$$Ts = a \ln \frac{1}{te} + b$$

With

Ts: tensile strength
A and b: constants
Te: exposure time

The green curve is the actual aging curve of theproduct for a 4-month exposure in Khouribga.

**C300 black**

Composition: Black fibers
After a 4-month exposure at the Khouribga site, it was observed that the product had a degradation of 43.57%

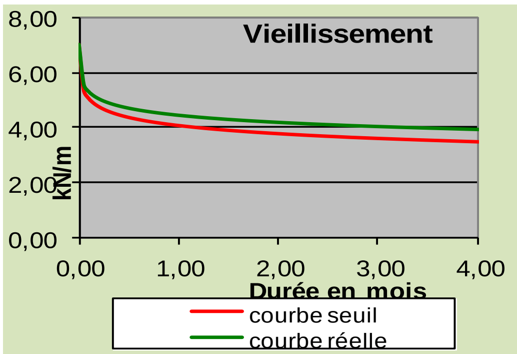



Figure 14: Aging curve of the BLACK C300 filter used in the composition of the Draintube FT2 D20 PE UV BLACK

**ND 200 PG**

Composition: Fibers POLYESTER
After a 4-month exposure at the Khouribga site, it was observed that the product had a degradation of 35.50%.
The Draintube will be optimally used for a maximum of 3 months. On a 50 ha basin, the bottom is filled in about 1.5 months so the Draintube must be able to hold at least 50% of its characteristics for 3 months. The choice of the two previous filters corresponds to this parameter.

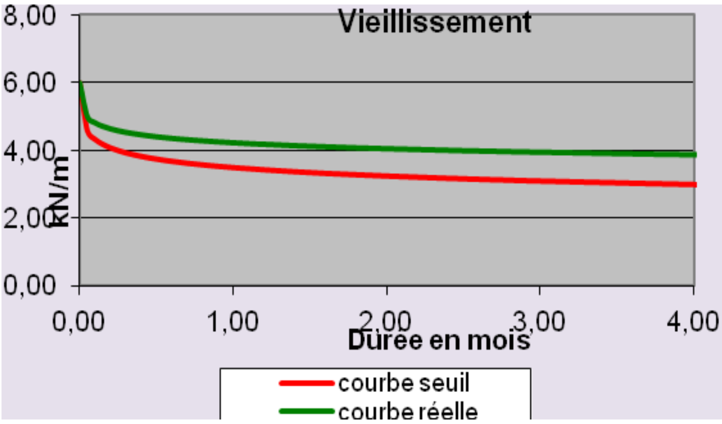


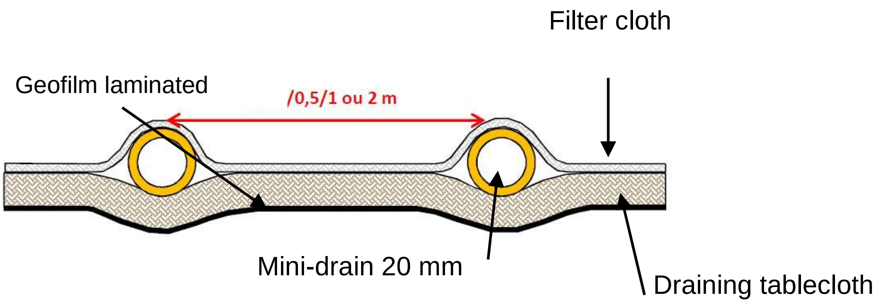

Figure 15: Aging curve of the PG filter used in the composition of the Draintube PG2 D20

4.2.2 Description of developed geocomposites

Following preliminary filtration tests and filtration / drainage and UV resistance tests, two geocomposites were developed to cover the test pool described in the next chapter.
The geocomposites proposed by AFITEX include from bottom to top:

- ♣ A 500 / 1000th geofilm bonded to the GTX ⟶ fight against infiltrations
- ♣ A needle-punched geotextile (GTX) ⟶ draining sheet and geofilm protection
- ♣ A polyester GTX defined from the preliminary tests ⟶ filtering sheet

♣ Mini-drains of 20 mm inserted in the GCP every 50 cm ⟶ transport of water




The drainage geocomposites proposed by AFITEX will maximize the recycling of water within the mine because they are composed of an assembly of several geosynthetics with precise functions:
♣ The draining core of the geocomposite consisting of mini-drains regularly positioned on all the dikes will allow the supernatant water to be evacuated rapidly towards the bottom. By limiting its residence time to the surface of the basin, evaporation will be limited.
♣ Infiltration will be limited by geofilm, an impermeable barrier of 500 microns thick.
♣ By draining the bottom of the basin, the mud will consolidate. This will lead to the expulsion of water, an increase in mechanical parameters and a limitation of the footprint on the ground.
♣ The GCP will combat erosion, limiting the deleterious impact of the swell on the dikes.
♣ The GCP will remove the recovery stacks. The mini-drains arranged on the dikes will collect the supernatant water and lead it outside the basin. Thus the GCP eliminates a hazardous workstation and saves the cost of building the chimney.
Two geocomposites have been developed to match the bottom and slopes of the basin. The following paragraphs describe the filter sheet, the only element that differs between the two products.
The second geocomposite is a Draintube FT2 D 20 PE UV BLACK, placed in slope of the basin and therefore partly subjected to UV rays is composed of a black UV-resistant filter cloth.
Quantity: 4 800 m² (4,500 m² + coverings)

## 4.3 basin pilot tests

### 4.3.1 Analysis of slope stability

From the first fillings, in the traditional control basin, we find disorders at the level of the slope that receives the arrival of the sludge. These disorders are not present at the arrival of the sludge on the slope of the control basin because it is protected by the draining geocomposite.

Figures 16: Sludge arrival disorders on the slope of the natural and stability at the test basin.

Instabilities are also visible on the remaining slopes of the control basin.

Figures 17: Disorders at the slope of the natural control basin.

There is no evidence of similar slope instability in the test basin.
Because the drainage geocomposite provides protection to the slopes, they are not subject to erosion due to the buoyancy of water in the basin and to the weather.

Figure 18: No disorder found on the test pool.

### 4.3.2 Analyzing the amount of the filtrate

The quantity of recovered filtrate is important both in the control basin and in the test basin. No precise measurements have been made on the previous tests carried out in the laboratory, the DRAINTUBE range has been selected which has resulted in a recovery of more than 20% of water compared to the current situation.
Furthermore, the geocomposite for the drainage of the slopes and the bottom of the basin drains adequately the filtered water because, when the valves are opened, a large quantity of water is discharged, even after stopping filling the basin, and until 2 months later.
We can deduce from this that the sludge present at the bottom of the basin is not yet completely solidified and drying is a process that takes place over the long term.

### 4.3.3 Analysis on the quality of the filtrate

The filtrate samples at the outlet from the slope collectors and from the bottom of the test pond made it possible to evaluate the percentage of impurity in the filtrate for subsequent reuse of the filtrate in the

washing of the phosphates. The synthesis of the analyzes is summarized in the graphs below month by month:
The basins are filled to more than 80% of the solid sludge residues. The results of water withdrawals at the outlet of water downstream in the Draintubes basin show that generally the percentage of impurities is less than 1% And are judged by the OCP to be acceptable for washing phosphate. We also observe a different behavior in the test basin compared to the control basin:If a discharge is taken at the same time as the feeding of the mud basin is in progress, the water is charged with particles at the outlet 1 to 1.20%). It should be left to stand overnight to recover clear water with a percentage of impurities <1%. In March, when the reservoir is no longer filled, the water coming out of the collectors is directly clear.


Figure 19: Opening of the collector of the bottom of the test basin.

It should also be noted that the feeding is done on a single point with a plate jet. OCP recommends flowing over a wide flat surface so as not to mix the entire pond and thus not disturb sedimentation in place.

### 4.3.4 Analysis of sludge drainage

The drying of the sludge within the two basins is an element that identifies itself in the long term (4 to 5 years). In the case of a traditional OCP basin, filling over 3 to 4 months then results in a decantation at rest for 5 years. In the first few months, the supernatant water is recovered gradually until the surface of the basin is completely drained. The cores showed that after 5 years, the first 3 meters are made of a mud sufficiently solid for embankment. The lower the depth, the more the mud is liquid, so it is not yet dry enough for an embankment.
In the case of the test basin with the Draintubes, the following method is envisaged:
The presence of the Draintube on the bottom and the slopes of the basin allows a drainage of the sludge from the bottom of the basin. To this is added the natural drying of the sludge on the surface of the basin which acts as a compression effort due to the weight of the dry mud on the Draintube. The cumulative process of deep water drainage and the stress applied above accelerates the process of dewatering the sludge at depth.
Thus, the two basins under experimentation will be subjected to coring in the next 4 years in order to estimate the quantity of sludge sufficiently dried for reuse in fill. Laboratory tests have already demonstrated the effluent efficiency of sludge with the Draintube, which makes it possible to obtain a greater quantity of dried sludge over a shorter time.

### 4.3.5 Analysis of the infiltration of water into the soil

The Draintube has a geofilm that provides a seal to the device. All the effluents are therefore concentrated in the basin and do not infiltrate through the dikes. The pollution of the surrounding groundwater is therefore eliminated.
Several configurations of the Draintube can provide different degrees of protection against infiltration. In the case of the Draintube FTP, the combination by needling of a geofilm ensures controlled water passage and controlled infiltration between 5% and 10%. The test described in appendix 1 describes the process.

## 5. **CONCLUSIONS**

### 5.1 Preliminary tests in laboratory

Preliminary filtration tests show that the laundry sludge is filterable: the retention is excellent (only 30 g of particle cross the geotextile per square meter). After 10 minutes of filtration, the filtrate becomes clear in all the tests
- All tested GTXs have sufficient retention with respect to the dryness of the filtrate (equal to 0 for all the tests): none of the first filtrates (collected between 4 to 6 minutes after the filling) contains particles.

Moreover, none of the tests show particles having penetrated the mini-drain. Retention according to these criteria is therefore very satisfactory for all the GTXs tested.

## 5.2 Resistance of GTX to UV

A UV resistance test is carried out in parallel with the filtration / drainage tests. Geotextiles are exposed to the sun for 5 months
54 samples of 6 different GTX are now exposed to the Khouribga sun. Every 15 days for 4.5 months, 6 GTX will be lifted and sent to Chartres for mechanical testing. In addition, six GTX samples will remain in the OCP sludge for 15 days and then sent to Chartres for the same tests and estimate whether the chemistry of the sludge is likely to degrade the GTX quickly. The results show that the geocomposite loses up to 43% of its mechanical capacity at the end of 4 months, which is less than the estimated theoretical loss of 50%. The geocomposites are sufficiently dimensioned to withstand UV over the duration of operation of the basin

## 5.3 basin Pilot test

The basin pilot test revealed several interest in the Draintube compared to the traditional solution of the natural basin:
- On embankments: dikes are protected from erosion and instability.
- On the bottom: optimized drainage, recovery of 20% more filtrate than with the traditional basin, limitation of the evaporation on the pond surface and drying of a greater volume of sludge over a reduced time.

The recovered filtrate has a percentage of impurity of less than 1%, which makes it reusable.
The use of the Draintube in the
- to stabilize the slopes of erosion,
- to recover the filtrates for reuse in the production process,
- better control of the inlets and outlets of the basin (better flow management with opening and closing of valves) to optimize yields,
- to obtain a larger volume of dried mud,
- to preserve the ground water by limiting the infiltration through the dykes.

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