# PROJECT FINAL REPORT

**Grant Agreement number:** FP7-SME-2008-1-231975

**Project acronym:** HYDRUS

**Project title:** DEVELOPMENT OF CROSSLINKED FLEXIBLE BIO-BASED AND BIODEGRADABLE PIPE AND DRIPPERS FOR MICRO-IRRIGATION APPLICATIONS.

**Funding Scheme:** Research for the Benefit of SMEs

**Date of latest version of Annex I against which the assessment will be made:** 08/05/09

**Period covered:** from 01/07/09 to 30/06/12

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the grant agreement
[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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# 1. Final publishable summary report

## 1.1. Executive summary

The main innovations claimed in **HYDRUS** are:

- **Use of bio-based materials.** A minimum 75% final product composition will be obtained from renewable resources.
- **Biodegradability in soil.**One of the main innovations of the project is the biodegradability of the final product in soil (aerobic conditions in top layer) which will reduce the cost for removal of the product after the end of its life of use. However, its biodegradable nature will not impair the mechanical, thermal and chemical resistance properties required by the target application; i.e., the pipe must withstand the normal conditions of use, but it has to biodegrade after shredded on site.
- **Development of a micro-irrigation pipe and a drip** using biodegradable materials and standard extrusion pipe line and injection moulding equipment. There is no technical information available accounting for pipe and drips production using a biopolymer as a base material. The melt flow index and the melt strength of the blend have to be adjusted to obtain similar output than when standard polyethylenes are used.
- **Development of controlled crosslinking and reactive extrusion for biopolymers at pilot plant and industrial level.** Controlled crosslinking and reactive extrusion of biodegradable materials have been tried at laboratory level but still does not have any significant industrial application. Reactive extrusion is a process that seems very promising for the blending of biodegradable materials in order to produce a final material with intermediate properties. The major challenge is to control both processes in a "selective manner", in order to achieve the desired degree of crosslinking and to avoid secondary reactions.
- **Improvement of the thermal and chemical resistance of biodegradable materials.** By means of crosslinking, the molecular weight of polymers can be increased leading to a better thermal and chemical resistance. The thermal degradation that leads to chain scission will be controlled, improving the behaviour of materials exposed to environmental conditions.
- **Fine tuning of mechanical properties.** Reactive extrusion with flexible materials or plasticizers will permit to tailor-made properties.

All the non-confidential information generated so far under the project can be found in HYDRUS website, in the open area.

The new biodegradable & bio-based product developed in the HYDRUS project may have a significant impact on the plastic and agricultural industry; providing an environmentally friendly alternatives to the current micro-irrigation systems based on conventional plastic (polyethylene). True industrial impact will require further investment, mainly aimed to optimize the actual scale-up of the drips manufacturing at scale-up level and the weldability process (manufacturing of the whole micro-irrigation system), making them suitable for a continuous fabrication stage, profitable for the SMEs involved in the production chain.

Although the project's development is aimed at specific agricultural irrigation system (according to the end-user business field and what was agreed under Annex I of the project), the compound developed (protected by an Exploitaiton Agreement under signature process among the whole consortium) plus the industrial procedure fro manufacturing pipes and drips will be able to be applied to other type of pipes (such as in gardening, animals farming and reforestation sectors) and even in other applications where concern about the environment is increasing (such as catering, packaging, surgery, hygiene, fishing, etc. sectors), provided that the specific requirements of each final product can be fulfilled/adjusted from the starting characteristics of the new material developed.

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## 1.2 Project context and objectives

**Micro-irrigation**, also known as drip irrigation or trickle irrigation is an irrigation method that **applies water slowly to the roots of plants, by depositing the water either on the soil surface or directly to the root zone**, through a network of valves, pipes, tubing, drippers and emitters.

**FIGURE 1.** GENERAL VIEW OF A MICROIRRIGATED FIELD AND AN INSERTED DRIPPER IN A MICRO-IRRIGATION PIPE.

Of the various forms of micro-irrigation, drip irrigation is the one most widely used because it can save water, reduces the use of horticultural chemicals, it is relatively insensitive to environmental effects, can reduce labour, and increases the rate of plant growth. Drip irrigation is an effective irrigation system in terms of water conservation. Using drip-irrigation, water is not wasted by irrigating areas between plants or due to run-off, excessive evaporation, wind-effects, overspray, and the like.

The use of **micro-irrigation is rapidly increasing around the world**, and it is expected to continue to be a viable irrigation method for agricultural production. According to the Food ad Agriculture Organization of the United Nations, FAO, only the 11% of the total world land area can be farmed without being irrigated, drained or otherwise improved. Micro-irrigation can be used on most agricultural crops, although it is most often used for high value crops such as vegetables, ornamentals, vines, olives, fruit crops and greenhouse plants. The numerous advantages obtained with these systems by the agricultural sector lead to a widespread use all over the world.

The main benefits that are fostering the use of micro-irrigation systems are the following:

- Low pressure and low area of irrigation.
- Reduces the water consumption until 60%, fertilizer and labour requirements due to the water is applied only to the plant's roots.
- The water-soluble fertilizer may be injected through this irrigation system, increasing the fertilizer efficiency and control.

However, they also have some limitations that burden its use by the farmers:

- **High cost to remove the product at the end of its useful life**. The cost to remove the system running above the ground is approximately 1,050 € / hectare. This cost is even higher in the case of buried pipes. After the removal of the pipes, these must be transported and disposed according to the regulations of agricultural plastics disposal.
- **Its use in combination with a mulching system also increases their removal and disposal costs**, by approximately a 30%. This is due to the fact that the mulch must be removed before the pipes can be removed and then they must be separated from each other and disposed separately.
- **Non recyclable pipes** due to its conditions of use, water and fertilizer contact and under pressure stress conditions. At the end of its life of use, it is not possible to recycle this material for other applications due to the loss of mechanical properties caused by UV radiation, the chemical attack and the presence of contaminants such as rests of sand, fertilizers and pesticides, increasing the disposal costs.

**Detailed objectives:** in order to achieve the main objective of the project, i.e. to develop **plastic pipes for micro-irrigation produced with bio-based and biodegradable material,** several specific objectives were defined:

1. Fulfil the traditional micro-irrigation systems **mechanical requirements** for their use under **normal conditions**, therefore having mechanical properties similar to those of polyethylene. The requirements of the raw materials for pipe production are well defined in standard UNE 53367:2005 and International standard ISO 8779:2001.
2. Be **processable by traditional plastic processing methods**, such as pipe extrusion. *The production of the machine using the new material will not be lower than the 85% of the maximum machine throughput using a standard material, normally polyethylene*
3. Be **completely biodegradable after its useful life** according to the standards of biodegradability in soil (ISO 17556:2003).
4. Be **harmless after biodegradation**, that is, no metabolites or biodegradation residuals will be formed, so there will not be toxic effects on the ecosystem. (OECD guideline 208, plus its modifications in Compostability Standard, EN 13432).
5. Be **thermally and mechanically resistant** in order to withstand environmental conditions. Pipes must be dimensionally and physically stable at temperatures of use **(máx. 60ºC)**, and be **chemically resistant and inert** to fertilizers and other chemical substances at moderate temperatures (between 40-60ºC) and pressures (up to 2 bars).
6. Have the required mechanical properties in order to allow to be **shredded on site (without removal)** after its lifespan **using conventional agricultural machinery.** These properties will also contribute to increase the biodegradation rate of the fabricated pipes and drips.
7. Full **mechanically recyclable** product. It will be possible to *incorporate a 20% of the industrial scrap in the fabrication of new pipes and drips with a reduction lower than 10% in mechanical and thermal properties.*
8. The new pipe/drip has to be economically viable tacking into account the full life of the product (production, installation, removing and waste management). This means at least a 5% cost reduction from the current polyethylene pipe cost including the disposal and removal cost.
9. The new pipe/drip has to fulfil the related regulatory requirements and to be environmental friendly achieving positive LCA indicators in comparison with standard polyethylene pipes.
10. **Dimensional stability** for accurate water release (to maintain its hydraulic flow versus pressure). *The hydraulic flow of the new drips at any pressure has a variation of less than 10% from the average flow.*
11. **Processability** in traditional injection moulding machines. *The production of the machine using the new material will not be lower than the 90% of the maximum machine throughput using a standard polymer, normally polystyrene.*
12. **The material used for the manufacturing of the pipes and drips will have at least a 75% of bio-based content, e. g. material obtained from renewable resources.** The use of materials based on renewable resources instead of oil-based materials will contribute to the preservation of the environment and to reduce the consumption of oil reserves, reducing also the level of $CO_2$ emissions and the greenhouse effect. The other 25% could be a biodegradable material from an oil-based source.
13. To develop an **understanding of the crosslinking process over blends of biopolymers**: properties achieved vs crosslinking ratio, interphase between crosslinking and non-crosslinking parts, etc.
14. **To overcome the lack of technical knowledge that exists about the pipe extrusion process using biopolymers in combination with an in-line crosslinking process.**

Finally, besides its technical objectives, HYDRUS project aims at **improving the EU Plastic Industry competitiveness,** in particular, but not limited to, companies focusing on the micro-irrigation market.
Although often highly ambitious in their outlook, the vast majority of these SMEs lack the resources to develop innovative materials and methods of work.

The achievement of the objectives listed above may result in an increase of the competitiveness of the participating SMEs which represent the different types of SMEs involved in the co-injected packaging supply chain:

- *Compounders* will increase their knowledge by the use of processes that until now have not been widely developed at industrial scale, such as the crosslinking and the reactive extrusion between different biodegradable materials and other additives to obtain the final formulation to be processed into pipes.

- *Pipe manufacturers* and *Manufacturers of accessories* will diversify their offer, giving their activity a more flexible profile as they will offer new products inexistent nowadays for micro-irrigation: a biodegradable pipe and accessories (such as drippers, emitters, etc.), respectively.
- The pipe produced will be used by the *micro-irrigation systems' installers* who will be able to offer their customers a new product with the advantage of its biodegradability, maintaining all the properties of current polyethylene pipes.
- *End users* such as farmers, gardeners or greenhouse farmers will benefit from the biodegradability of the new pipe which will permit the elimination of the cost of collection and removal that traditional pipes present.

**<u>As a summary</u>**

***Specific innovations*** of the project are:

- ✓ Plastic pipes (90% of the micro-irrigation system) obtained at industrial level, fulfil thermal, mechanical and chemical resistance. Drips also obtained at industrial level, in semi-automatic process.
- ✓ Renewable sources >72%.
- ✓ The micro-irrigation system obtained at industrial scale up. The weldability between pipes and drips has been achieved although working to lower production rates, which is not productive under an actual industrial process.
- ✓ New biodegradable materials developed pass the biodegradable, compostable and ecotoxicity trials in compostage conditions.
- ✓ The pipes fulfil the environmental studies, Recyclability and LCA.
- ✓ The economic report is not satisfactory due to mainly the price of the raw material.
- ✓ IPR issues: Available the final version of the Exploitation Agreement under signature process. Finally no patent application, but Industrial Secret was chosen.

**Expected final results:**

All the expected final results foreseen initially were practically achieved under the scope of the project, demonstrating the capability of the new micro-irrigation system to be obtained at industrial level, although the only inconvenient was the impossibility of manufacturing a proper industrial tailor-made mould for drips. This activity was out of the scope of the project since its beginning, and it has been proposed a continuation project (ECO-Innovation project, call 2012), to try to solve this handicap at industrial level.

1. **The new biodegradable pipe/drip for micro-irrigation systems** fulfilling the specific requirements for the application foreseen and the standards of biodegradability.

With the final formulation, with a 72 % of biodegradable material, the final compound at industrial level was obtained. These compounds were used to obtain the final products (drips and pipes) at industrial level.
It was concluded that to obtain suitable drips at industrial level it would be necessary to design and optimize the mould taking into account the flexibility and shrinkage of the new biodegradable material developed. This task was out of the scope of HYDRUS project since the beginning of the project. At the project end, the drips have been obtained in a semi-automatic way due to de-moulding problems, being impossible to reproduce the actual industrial full automatic process.

**FIGURE. 2.** MICRO-IRRIGATION PIPES OBTAINED AT INDUSTRIAL LEVEL PLACED IN-SOIL. DETAIL OF THE WATER INTAKE BY THE DRIP.

2. **The compound formulation,** including the necessary additives and polymer blends, to ensure that the properties of the final products are met.

Finally the same compound formulation was used for pipes and drips. They obtained were fully characterised. In the case of the pipes fulfil all the mechanical and chemical requirements. Note that, although the pipes do not fulfil the internal pressure requirements defined in the datasheet, the pipes do not suffer any break after their validation in soil. Regarding the drips, the requirements on dimensional stability and processability were partially achieved due to the necessity of a tailor-made industrial mould, out of the scope of this project.

3. **The reactive extrusion and crosslinking processes.** Reactive extrusion and crosslinking (in fact, branching process) of bio-based and biodegradable polymers have been developed at industrial scale level in a continuous process. The development of that process for the HYDRUS industrial application required not only the optimization of the different processing parameters and equipment used (e.g. special screw configuration, etc.) but also the selection of the crosslinking/branching agent.

## 1.3. Main scientific and technological results and foregrounds

The work in the project has been structured in seven work packages, arranged as shown in figure 1.

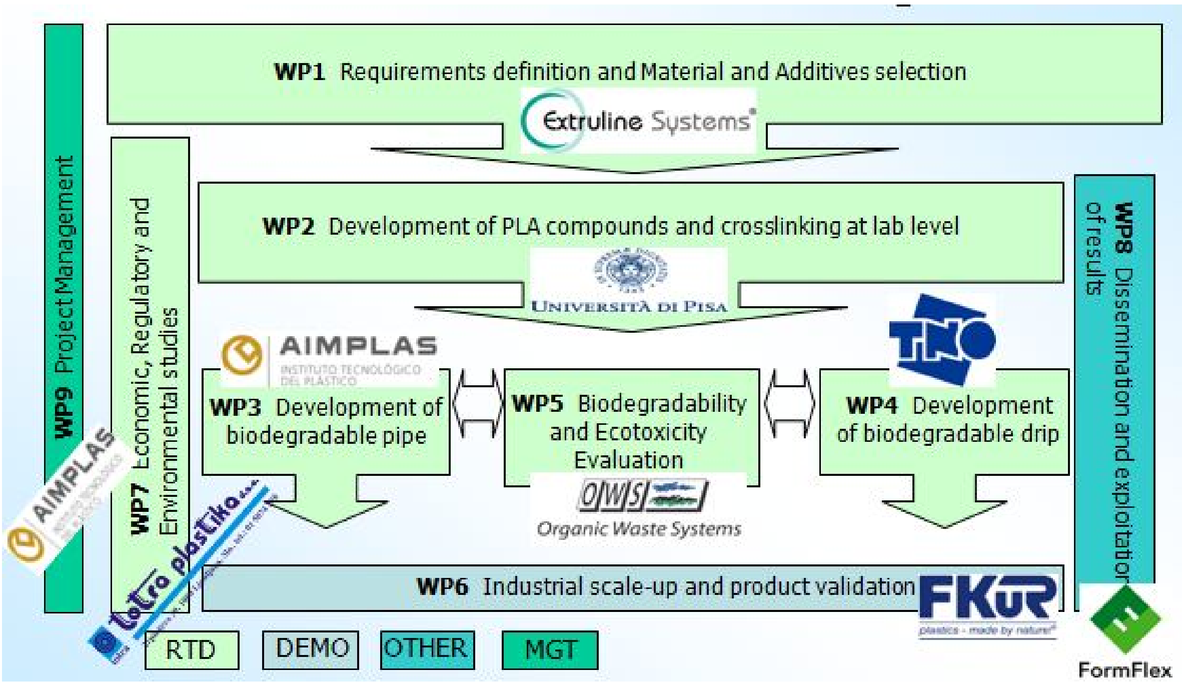



**FIGURE. 3.** GRAPHICAL PRESENTATION OF THE COMPONENTS SHOWING THEIR INTERDEPENDENCIES (PERT DIAGRAM)

The main scientific and technological results achieved are the following, presented in a WP per WP basis.

Below an explanation about the objectives, the work performed, end result obtained and degree to which the objective was reached can be found. The details have been provided in the corresponding Task reports of those TECHNICAL WORK PACKAGES and their deliverables (confidential information sent only to EC):

WP1. Definition of requirements and selection of materials. D1.

WP2. Development of the base PLA compound and study of crosslinking conditions at lab level. D2.

WP3. Development/optimisation of biodegradable micro-irrigation pipe at pilot plant level. D3.

WP4. Development/optimisation of biodegradable drip at pilot plant level. D4 and D5.

WP5. Biodegradability and Ecotoxicity Evaluation.  D6 and D7.

WP6. Industrial scale up and Product Validation. D8 and D9.

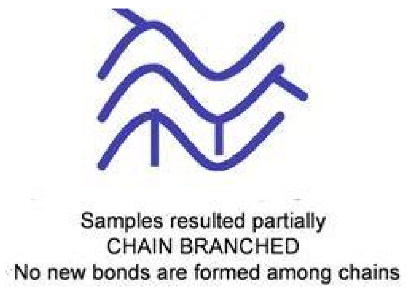
WP7. Environmental, Economic and Regulatory studies. D10, D11, D12, D13 and D14.

*Note that D15 & D16 belong to Dissemination and exploitation of results (WP7) and D17, belongs to the Project Management (WP9), not included in this description.*

# WP1. Definition of requirements and selection of materials.

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%) |
|---|---|---|---|
| **Task 1.1. Definition of requirements to a new and innovate complete micro-irrigation system (pipes and drips).**<br><br>**Task 1.2 Selection of PLA grades and additives.** | A study of the current micro-irrigation system during the product´s useful life has been carried out during task 1.1 to determine the mechanical and chemical demands derived from their manufacturing and use.<br>Besides the biodegradable material developed must:<br>- Have a high content of renewable resources, aprox. 75%.<br>- Be processing in conventional equipments ti obtain pipes and drips.<br>- Support the functionality conditions during their useful life.<br>- Be Biodegradability – Compostability according to the following test standards:<br>a) Biodegradability in soil (ISO 17556)<br>b) Biodegradability in compost (ISO 14885)<br>c) Compostability EN 13432<br><br>A study regarding the technical characteristics of the biodegradable materials available on the market and the selection of the most suitable taking into account the requirement defined and material with **fulfil compostability and biodegradation on soil.** | Three different data sheets were obtained:<br>- Datasheet for pipes.<br>- Datasheets for drips.<br>- Datasheets for common parameters.<br>And two internal procedures were developed to evaluate:<br>- Internal pressure, based on ISO 8779.<br>- Chemical resistance, to evaluate the fertilizer attack.<br><br>The materials selected were biodegradable materials with a high percentage of renewable resources with high content of PLA. | The objective was 100% successful, from the technical point of view. |
| **Contractors involved** | | | |
| ▪ **AIMPLAS**<br>▪ **BAIX**<br>▪ **METAZET**<br>▪ **EXTRULINE**<br>▪ **FKUR**<br>▪ **FORMFLEX**<br>▪ **OWS**<br>▪ **TNO**<br>▪ **TOTRA**<br>▪ **UNIPI** | *NOTA: Do not exist in the market any biodegradable material in soil with high content of PLA. The PLA is not biodegradable in soil according ISO 17556.* | | |

## WP2. Development of the base PLA compound and study of crosslinking conditions at lab level.

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%). |
|---|---|---|---|
| **Task 2.1 Selection of the best materials combinations (blends).**<br>**Task 2.2 Blend of selected materials base on PLA.**<br>**Task 2.3 Study of the reactive extrusion process.**<br>**Task 2.4 Blend optimization at lab level.**<br>**Contractors involved**<br>▪ **AIMPLAS**<br>▪ **FKUR**<br>▪ **UNIPI** | To develop the functionalised PLA compound by reactive extrusion at laboratory level using discontinuous laboratory equipment. To develop blends with the additives selected in task 1.2. This compound is the base material for the new pipe and drip manufacturing.<br>To study at laboratory level of the amount and type of additives to use and the conditions for a suitable reactive extrusion process.<br>A commercially available biodegradable PLA-based were modified using reactive extrusion process to improve the chemical resistance and the thermal stability of the final materials.<br>Moreover, a plasticizer was also added, to improve flexibility and finely tune the mechanical properties. | It has been possible to control the reaction process at laboratory and pilot plant level and to determine and to know the type of reactive extrusion: chain branching.<br>This means that macromolecular chains resulted not linked in a proper net, but only segments resulted linked to main chains, thus modifying melt viscosity and chain mobility, but not affecting the solubility of the whole sample and biodegradability.<br><br> | 100% |

**CONCLUSIONS**

The new biodegradable material fulfils all the established requirements in, chemical, thermal behaviour but the products obtained are too rigid and brittle. **It is necessary to improve its elasticity at pilot plant level in WP3 and WP4**. Table 1 and figure 1 show the results obtained.

TABLE 1. Properties of the **New Biodegradable Materials Developed** in comparison with the PE and the comercial available biodegradable materials with high content of PLA.

| PROPERTIES | BASELINE | RESULTS IN WP2 | TARGET DATA |
|---|---|---|---|
| | **COMERCIAL BIODEGRADABLE MATERIALS, HIGH CONTENT OF PLA** | **NEW BIODEGRADABLE MATERIALS DEVELOPED** | **Reference Material PE** |
| **Tensile stress at yield (MPa)** | ≈ 50 | **25 – 40** | ≈ 10 |
| **Tensile strain at yield (%)** | ≈ 1.5 | **≈ 3** | ≈ 10 |
| **Maximum strength (MPa)** | ≈ 40 | 30 – 40 | ≈ 20 |
| **Tensile strain at break (%)** | 15 – 30 | ≈ 300 | ≈ 300 |
| **Pass Chemical resistance** | NO | yes | yes |
| Nota: Properties evaluated in test specimens obtained by platen press at lab level. | | | |

**Figure 4.** Tube obtained using the new biodegradable compound. Tube aplying strain (left) and tube without aply strain (right).

## WP3. Development/optimisation of biodegradable micro-irrigation pipe at pilot plant level.

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%). |
|---|---|---|---|
| **Task 3.1 Development of the biodegradable blends.**<br>**Task 3.2 Modification of extrusion pipe machinery.**<br>**Task 3.3 Development of the micro-irrigation pipe.**<br>**Task 3.4 Mechanical characterization.**<br>**Contractors involved**<br>▪ **AIMPLAS**<br>▪ **EXTRULINE**<br>▪ **FKUR**<br>▪ **TNO**<br>▪ **TOTRA**<br>▪ **UNIPI** | Taking into account the requisites established for the current pipes and the results obtained in WP2, where the pipes manufactured at pilot plant level were still too rigid in comparison with the conventional pipes, new experimental design was carried out to modify the bio-compound developed and to decrease the rigidity of the pipes obtained at pilot plant level in the following pathways:<br>- To increase the percentage of plasticizer.<br>- To use other types of plasticizers<br>- To use other types of crosslinking agents.<br>- To use chain extenders and<br>- To use other comercial biodegradable materials as plasticizers.<br>On the other hand, different modifications were done in the conventional equipment:<br>- A new screw to increase the mixing system called “Barrier Screw”.<br>- A new die with central feeding to avoid dead zones, called “Spider die” | A new biodegradable material with high content of renewable sources (72 %) has been developed to obtain pipes in conventional equipment with the required modifications.<br>The pipes obtained fulfil all the requirements established in task 1.1 including their biodegradability.<br>Only in the case of internal pressure the pipes obtained does not fulfil the requirement established.<br><br>The pipes show small holes due to homogeneity problems.<br>This fact can be solved obtained the compound and to make the pipes at industrial level. | The objective was 100% successful. |
| CONCLUSIONS | | | |

The new biodegradable material developed in WP2 was modified to obtain suitable pipes at pilot plant level and these pipes fulfils all the established requirements in processability, chemical, thermal and **mechanical properties**. **The pipes obtained show the adequate flexibility.** Figure 2 and Table 2 show the processability a pilot plant level and the characteristics of the pipes obtained respectively.

**Figure 5**. Pilot plant equipment to obtain pipe.

TABLE 2. Properties of PIPES manufactures with the **New Biodegradable Materials Developed** in comparison with the PE pipes.

| **PROPERTIES** | **RESULTS IN WP3** | **TARGET DATA** |
|---|---|---|
| | **PIPES manufactured with new biodegradable materials developed** | **Pipes manufactured from PE** |
| **Tensile stress at yield (MPa)** | **12.9 (0.7)** | ≈ 10 |
| **Tensile strain at yield (%)** | **57 (8)** | ≈ 10 |
| **Maximum strength (MPa)** | **25.8 (1.9)** | ≈ 20 |
| **Tensile strain at break (%)** | **290 (13)** | ≈ 300 |
| **Pass Chemical resistance** | **yes** | yes |
| **Internal Pressure (23ºC, 2 bares, 24 h)** | **NO but the results are very promising.** | yes |

In brackets the standard deviation.

## WP4. Development/optimisation of biodegradable drip at pilot plant level.

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%). |
|---|---|---|---|
| **Task 4.1 Development of compound for drips.**<br><br>**Task 4.2 Manufacture and characterization of the new drip.**<br><br>**Task 4.3 Pilot plant micro-irrigation system test.**<br><br>**Contractors involved**<br><br>- **AIMPLAS**<br>- **BAIX**<br>- **METAZET**<br>- **EXTRULINE**<br>- **FKUR**<br>- **FORMFLEX**<br>- **TNO**<br>- **TOTRA**<br>- **UNIPI** | The materials developed in WP2 were processed in injection equipment to obtain the first test standards and to know their processability.<br><br>With this results and taking into account the requisites established for the current drips, new experimental design was carried out to improve the processability in injection machine of the new biodegradable materials developed. This experimental design include:<br>- Different types of mould to mimic the current mould used to obtain flat drips.<br>- Preliminary trials at industrial level<br>- Trials using processing aids.<br><br><br><br>As the materials developed at this stage, require of an improvement to obtain drips at industrial level in an automatic way, **it was decided to validate in soil only the pipes to avoid delaying the next WPs** and to study weldability preliminary trials in a parallel form.<br><br>These pipes were used in the crop of ornamental flowers "Petunia" | The drips obtained fulfil the mechanical and chemical requirements according to deliverable 1.<br><br>When the moulds used are to obtain pieces with a complicate geometry and tubular drips, **it is not possible to achieve a smooth automatically running process**, as in the case of the specimens for mechanical testing (tensile bars).<br><br>The improvement of the drip compounds have been carried out in WP6, task 6.2.<br><br>The pipes validate in soil during one month do not show differences in the mechanical behaviour before and after their validation on field.<br><br>After testing, pipes with fertilizer show a good chemical resistance without any alteration.<br><br>The tested pipes do not pass the internal pressure trials due to the folding line problem (existence of a crack).<br><br>  | The objective was 100% successful. The work to adjust and optimize the industrial process continued in WP6, task 6.2. |

**CONCLUSIONS**

The drips obtained with the biodegradable material developed in WP2 fulfils the chemical, thermal and mechanical properties but it is necessary to improve its processability . Figure 3 and Table 3 show the processability at pilot plant level.

Figure 4 and table 4 show the validation in soil of the pipes obtained in WP3.

**MANUFACTURE OF DRIPS AT PILOT PLANT LEVEL.**

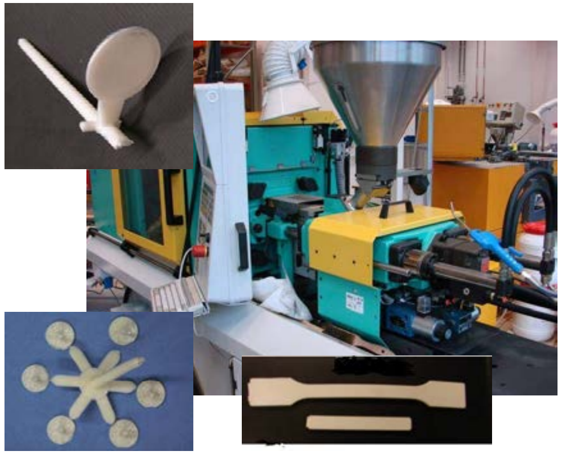


**Figure 6**. Pilot plant equipment to obtain pieces in injection process and different test specimens obtained.

TABLE 3. Mechanical properties of the **Biodegradable Materials** processed in injection equipment.

| PROPERTIES | RESULTS IN WP4 |
|---|---|
| | Test specimens used for mechanical testing (tensile and impact bars) |
| Tensile stress at yield (MPa) | ≈ 30 |
| Tensile strain at yield (%) | ≈ 3 |
| Strength at break (MPa) | ≈ 25 |
| Tensile strain at break (%) | ≈ 300 |
| Pass Chemical resistance | yes |

## PILOT PLANT MICROIRRIGATION SYSTEM EVALUATION

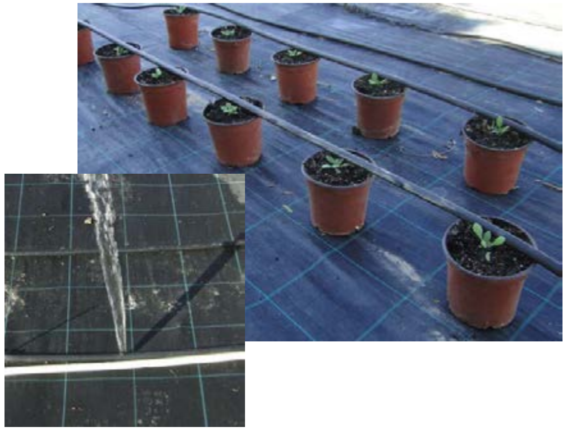


**Figure 7**. Validation of field of the Bio Pipes. Break in the pipes in the folding line.

TABLE 4. Mechanical properties of the **Bio Pipes, before and after their validation.**

| Samples | Strength at yield (MPa) | Elongation at yield (%) | Maximum Strength (MPa) | Elongation at break (%) |
|---|---|---|---|---|
| Pipe before validation | 15,0<br>0,8 | 22,0<br>1,5 | 40<br>6 | 180<br>26 |
| Pipe after validation | 17,3<br>0,8 | 22,2<br>0,8 | 62<br>8 | 190<br>15 |

## WP5. Biodegradability and Ecotoxicity evaluation

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%). |
|---|---|---|---|
| **Task 5.1 Evaluation of biodegradation of the full micro-irrigation system in laboratory scale test.**<br><br>**Task 5.2 Ecotoxicity Test**<br><br>**Contractors involved**<br><br>▪ **BAIX**<br>▪ **METAZET**<br>▪ **FORMFLEX** | Different biodegradation tests on the different proposed and developed materials for the micro-irrigation system were performed in soil and compost:<br>- Biodegradability in soil (ISO 17556)<br>- Biodegradability in compost (ISO 14855)<br>- Biodegradability under solid anaerobic conditions (ISO 15985)<br>- Disintegration in compost (ISO 16929 – EN 14045, industrial & home composting)<br>- Soil disintegration test (modified ISO | - Insufficient biodegradation in soil was established.<br>- The final compound passes the 90% biodegradation in compost, which is often most difficult to fulfil compostability.<br>- Referring to biodegradability in anaerobic conditions the new material as the PLA material has only a low biogas potential.<br>- There is not degradation in soil during one crop season.<br>- The new biomaterials do not show a | The objective was 100% successful from the industrial compostability point of view, not in soil, as already highlighted almost since the project beginning.<br><br>*REMARK: It was known since the project beginning* |

| | | | |
|---|---|---|---|
| ▪ **TNO** | 20200)<br>- Plant toxicity tests on compost residuals (OECD 208 & modifications of EN 13432)<br>- Plant toxicity tests on soil residuals (OECD 208)<br>- Earthworm, acute toxicity test on compost residuals (ASTM E 1676 & AS 4736)<br>- Aquatic invertebrate acute toxicity test with freshwater daphnids (OPPTS 850.1010)<br>- Weathering | negative influence on the germination and growth of plants.<br>- The addition of the new biomaterial does not show residuals.<br>- The biomaterial is not toxic for Daphnia.<br>- The pipes remained still intact showing a high resistance to sunlight degradation. | *that the PLA is not biodegradable in soil according ISO 17556. Many different triggered methods were tested and some good results were obtained, but without the level of success expected.* |

**CONCLUSIONS**

Figure 5, 6 and 7 and the table5 show the results obtained.

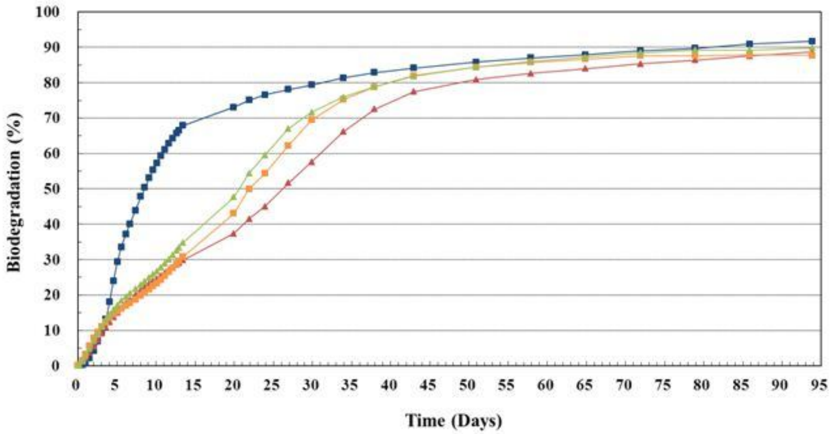



**Figure 8**. Evolution of the biodegradation of the different test materials in the biodegradability test under controlled composting conditions.

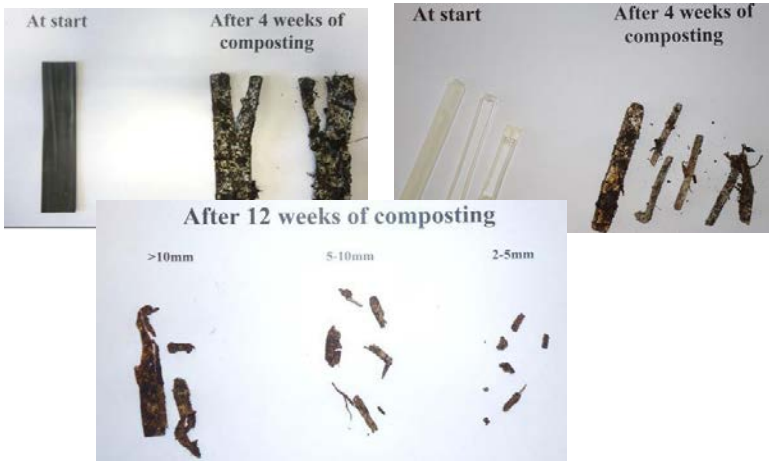



**Figure 9**. Visual comparison between the new bio-pipes at start and after 2 weeks of composting


**Figure 10**. Detailed growth after an incubation period of 8 days. Barley plant (left) and cress plant (right).

TABLE 5. Heavy metals content of the new biomaterial

| Metal | Test item | Limit values | | |
|---|---|---|---|---|
| | | Europe EN 13432 (2000) | USA ASTM D 6400-04 | Canada BNQ P 9011-911-5 |
| Zn | 2 | < 150 | < 1400 | < 463 |
| Cu | 13 | < 50 | < 750 | < 189 |
| Ni | 5 | < 25 | < 210 | < 45 |
| Cd | < 0.1 | < 0.5 | < 19.5 | < 5 |
| Pb | < 1 | < 50 | < 150 | < 125 |
| Hg | 0.1 | < 0.5 | < 8.5 | < 1 |
| Cr | < 1 | < 50 | - | < 265 |
| Mo | 0.3 | < 1 | - | < 5 |
| Se | < 0.1 | < 0.75 | < 50 | < 4 |
| As | < 1 | < 5 | < 20.5 | < 19 |
| F | < 10 | < 100 | - | - |
| Co | < 1 | - | - | < 38 |

## WP6. Industrial Scale Up and Product Validation

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%). |
|---|---|---|---|
| **Task 6.1 Scaling up of compounding process.**<br>**Task 6.2 Scaling up of pipe and drip manufacturing processes.**<br>**Task 6.3 Characterization of the obtained products**<br>**Task 6.4 Installation of the pipe and drip in the farmer's facilities.**<br>**Task 6.5 Functional test of** | WP6 was focused on achieving three objectives:<br>**Task 6.1**. Scaling up the compounding process. Adjusting the parameters at industrial level taking into account the parameters optimized at pilot plant scale.<br>**To obtain the news biodegradable products at industrial leve**l, in the following feedback system:<br>- Scaling up and optimization of pipe and | In this WP was possible:<br>To achieve that the production of the compound runs stable with low pressure and low torque, in semi-industrial equipment.<br>To obtain pipe at industrial scale up with the requirement established in task 1.1.<br>To obtain drips with the requirement established in task 1.1.<br>Related to the processability in injection | The objective was 90 % successful, due to the explanation given regarding the tailor-made mould for drips manufacturing. |

| | | | |
|---|---|---|---|
| **the final products.** | drip manufacturing processes.<br>- Characterization of the obtained products.<br>**To determine in situ that the new products satisfy the expectations** of irrigation assemblers and farmers, doing the following tasks:<br>- Installation of the pipe and drip in the farmer's facilities and end-user installers.<br>- Functional test of the biodegradable micro-irrigation products. | process, the drips were obtained in semi-automatic process due to de-moulding problems. To avoid these problems, it would be necessary to design a tailor-made mould taking into account the structural characteristics of biodegradable material developed and this issue is out of this project.<br>To achieve an acceptable weldability adjusting the pressure and temperature in this step but decreasing the extrusion speed.<br>In this WP, it has been possible to verify that the bio-pipes obtained do not suffer any significant changes after their validation on field during 6 months. | |
| **Contractors involved** | | | |
| ▪ **AIMPLAS**<br>▪ **BAIX**<br>▪ **METAZET**<br>▪ **EXTRULINE**<br>▪ **FKUR**<br>▪ **FORMFLEX**<br>▪ **TNO**<br>▪ **TOTRA**<br>▪ **UNIPI** | | | |

## WP7. Environmental, Economic and Regulatory studies

| OBJECTIVE | WORK PERFORMED | END RESULT | COMPLETION DEGREE (%). |
|---|---|---|---|
| **Task 7.1 Analysis of the material's recyclability.**<br>**Task 7.2 Life Cycle Assessment (LCA).**<br>**Task 7.3 Guide of best practices.**<br>**Task 7.4 Economic analysis.** | WP7 was focused on achieving the objectives represented by the 5 tasks:<br>- Study of the re-processability of industrial scrap.<br>- Complete Life Cycle Assessment (LCA) for the final formulations.<br>- Writing a Public Best Practice Guide | - Satisfactorily, **no effect was found caused by the addition of scrap at industrial level, for mixtures that contained up to 20% scrap**, the maximum amount usually used in the polymers processing, with the final compound formulations.<br>- The results of **this final study have not shown any significant difference for the** | The objective was 100% successful in all tasks, except for the economic study, since, taking into account the production cost and the end of life cost, the price of a |

| | | | |
|---|---|---|---|
| **Task7.5 Regulatory analysis** | - Full economic analysis with the final formulations developed, altogether a market update at the end of the project<br>- Updated regulatory analysis focused on the new product developed at EU level. | **overall impacts of the compared pipes, PE pipes**. However, there is a large uncertainty from the assumptions related to the production of 'co-polyesters', made in this study to overcome the lack of data due to confidential issues.<br>- Non-confidential information was provided on the Guide of best practices and the regulatory assessment issues. On the one hand, **basic requirements necessary to produce a bio-based, biodegradable micro-irrigation system were detailed**. On the other hand, the **most significant specifications and test methods related to HYDRUS new product were collected**, **being the ones currently applied for agricultural irrigation equipments**, in most cases made of polyethylene (PE) or poly(vinyl chloride) (PVC).<br>- **Producing biodegradable micro-irrigation pipes based on the modified commercial blend BioFlex F6510 is not yet competitive in price with the polyethylene pipes**, at the end of the project. | compostable micro-irrigation system is still approximately 2 times higher when compared to a conventional (LDPE) micro-irrigation system.<br><br>Consequently, it can be concluded that the economical objective of this WP (namely at least a 5% cost reduction from the current polyethylene pipe cost including the disposal and removal cost) was not reached. |
| **Contractors involved** | | | |
| ▪ **AIMPLAS**<br>▪ **BAIX**<br>▪ **METAZET**<br>▪ **EXTRULINE**<br>▪ **FKUR**<br>▪ **FORMFLEX**<br>▪ **OWS**<br>▪ **TNO**<br>▪ **TOTRA**<br>▪ **UNIPI** | | | |

## 1.4 Potential impact and main dissemination activities and exploitation of results

### *Dissemination Activities*

It is essential to highlight that a considerable number of dissemination activities have been completed during the development of the HYDRUS project (i.e. 16 general dissemination activities + 2 scientific publications. Moreover, 2 other scientific publications + 1 general event are planned to be carried out before the end of 2012.). The project information has been disseminated via three channels:

a) By partners within their organizations (e.g. internal newsletters, meetings, workshops, seminars, training courses, etc.)
b) By partners during external events ( e.g. fairs, conferences, networking events, etc.)
c) By partners using media across Europe (e.g. press release, Internet, specialized magazines, etc.)

The use of various channels (internal & external) and methods (mainly written & online) assured an optimal contribution of coverage, visibility and most important- setting up the scene for better market acceptance in the near future.

The activities in the Dissemination Plan covers different audiences and channels depending on the type of information to be disseminated, in order to assure the success of the project from a strategic, environmental, technologic and economic direction based on HYDRUS approach.

Dissemination tools and activities could be divided in two main groups:

a) *Industrial level*: For the SMEs, the principal objectives are to obtain results that will increase their competitiveness and market opportunities and to show these results to any potential client, in order to have a wider commercial activity and increase the company benefits. Activities such as participation in fairs, seminars, press releases…are aiming these results.
b) *Non-commercial level:* The RTD participants of the project are more focussed in non-commercial promotion and scientific aspects of the work. Only non-confidential project results are susceptible of publication or dissemination in journals, web-sites, congresses, workshops, fairs and seminars.

Furthermore, there were two scientific publications related to HYDRUS project, always taking care of the protection of the Intellectual Property Rights, without risking the possibility of applying for a patent, as it seemed to be some partners´ intention. In this way, the scientific field was also addressed in this type of events. It is also foreseen another 2 scientific publications before the end of 2012.

Therefore, it is clear that the dissemination actions for HYDRUS project is continuing after the end of the project, focused on the commercial and scientific audience, aiming the successful exploitation of the project results. Different Dissemination tools have been prepared, such as:

-Maintenance of the Online portal – Website: **http://www.hydrusfp7.eu.**

-HYDRUS Logo

-Leaflet

-General presentation of the project

-Press releases

All these resources are available at the Public part of the website and will be displayed in fairs and meetings.

### *Potential Impact and Exploitation*

The new biodegradable & bio-based product developed in the HYDRUS project may have a significant impact on the plastic and agricultural industry; providing an environmentally friendly alternatives to the current micro-irrigation systems based on conventional plastic (polyethylene). True industrial impact will require further investment, mainly aimed to optimize the actual scale-up of the drips manufacturing at scale-up level and the weldability process (manufacturing of the whole micro-irrigation system), making them suitable for a continuous fabrication stage, profitable for the SMEs involved in the production chain.

Although the project's development is aimed at specific agricultural irrigation system (according to the end-user business field and what was agreed under Annex I of the project), the compound developed (protected by an Exploitaiton Agreement under signature process among the whole consortium) plus the industrial procedure fro manufacturing pipes and drips will be able to be applied to other type of pipes (such as in gardening, animals farming and reforestation sectors) and even in other applications where concern about the environment is increasing (such as catering, packaging, surgery, hygiene, fishing, etc. sectors), provided that the specific requirements of each final product can be fulfilled/adjusted from the starting characteristics of the new material developed.

All the abovementioned sectors could be additional business for the SMEs involved in the value chain (compounder, pipe/drip manufacturers, end-users/distributors). The owners of the different results defined in the final version of the Exploitation Agreement will take into account these new niche market sectors.

Therefore, the protection plan of the project results is already initiated with the official signature of the final version of the HYDRUS Exploitation Agreement. In the Final meeting, a duration of 10 years after ending of Project was agreed. Moreover, in order to have official registration of the Foreground developed in HYDRUS, relevant documentation, accompanied by this Exploitation Agreement, will be registered under notary no later than 3 months after the Official signature of the document in order to have evidence against competitors in the event of development, commercialization and patenting of the same or a similar technology which may arise a conflict of commercial interests.

Finally, it is important to highlight that one of the SMEs and 2 RTDs coming form HYDRUS consortium have taken part in a new ECO_Innovation proposal (submitted on 06/09/2012) to optimize and industrialize what has been researched within HYDRUS (but respecting the IPR protected by the current Exploitation Agreement, using the rejected compounds not successfully industrialized within HYDRUS project, for new drips and pipes). Specifically the SME has become the coordinator of such new proposal (currently under evaluation process).

## 1.5 Website and contact details

The updated HYDRUS website domain, **http://www.hydrusfp7.eu.** was established at the end of the project under the Project Officer requirement of having an URL friendly, accessible, with its own domain, and with additional improvements, such as a content more structured and accessible to all users, without installing any additional technology, a redesign of the website, and an improved SEO (Search Engine Optimization).

Deliverable 17 "Project website" (updated final version) gives an overview of the main functionalities and structure of the website. The main structural difference is based on the intended audience: the public at large (industry stakeholders, academia, EU and national officials, etc.) and the beneficiaries involved in the project, the consortium.

*Contact details:*
AIMPLAS (Coordinator)
Tlf. +34 96 136 60 40
Fax +34 96 136 60 41
proyectos@aimplas.es

## 2. Use and dissemination of foreground

This document presents the plan for using and dissemination of the foreground for HYDRUS project. The plan focuses on both Dissemination and Exploitation activities.
The Dissemination plan (section 2.1., A. PUBLIC) includes a description of what is understood by dissemination in this context, the objectives of dissemination and the structure (activities and tools/materials).
The Exploitation strategy and activities (section 2.1, B. CONFIDENTIAL) gives an overview on how partners have agreed to carry out the exploitation of the project results, according to the Consortium Agreement signed by all partners and the subsequent Exploitation commitment agreed among all industrial partners (SMEs).

## SECTION A. Dissemination Measures. *PUBLIC*

In this context dissemination should be understood as a collection of activities and tasks promulgated at various levels and targeting various stakeholders, aiming wide diffusion of the research results generated by the project consortium.

The aims of this section are to describe the target audience, key dissemination tools used during the project lifetime and their execution timeframe.

### *2.1.1. Scope of the Dissemination – Main lines considered*

The activities in the Dissemination Plan covers different audiences and channels depending on the type of information to be disseminated, in order to assure the success of the project from a strategic, environmental, technologic and economic direction based on HYDRUS approach.

Dissemination tools and activities could be divided in two main groups:

c) *Industrial level*: For the SMEs, the principal objectives are to obtain results that will increase their competitiveness and market opportunities and to show these results to any potential client, in order to have a wider commercial activity and increase the company benefits. Activities such as participation in fairs, seminars, press releases…are aiming these results.
d) *Non-commercial level:* The RTD participants of the project are more focussed in non-commercial promotion and scientific aspects of the work. Only non-confidential project results are susceptible of publication or dissemination in journals, web-sites, congresses, workshops, fairs and seminars.

The dissemination actions for HYDRUS project will continue after the end of the project, mainly focused on the commercial audience, aiming the successful exploitation of the project results.

### *2.1.2. Structure of the plan – dissemination tools and activities*

#### *I. Dissemination tools*

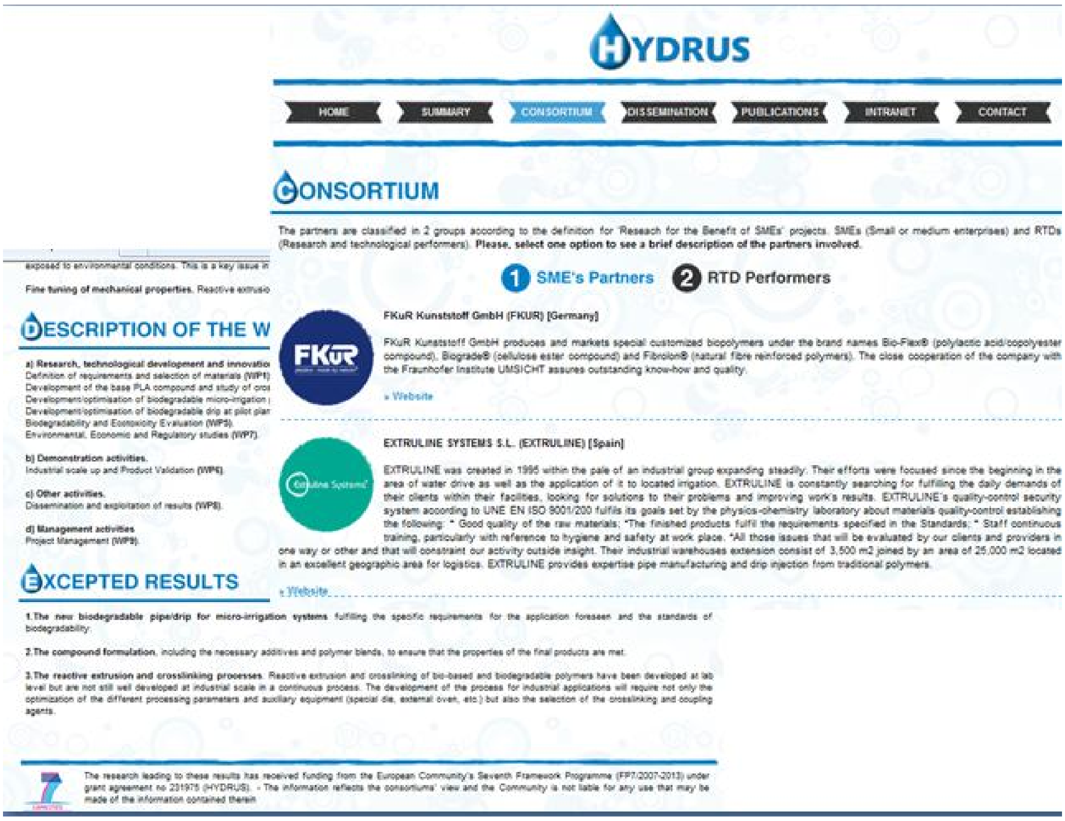
Several dissemination tools were designed and used during the HYDRUS project lifetime. The main aim of such actions was to raise awareness about project's objectives & main innovations, to develop an identity for the project.

*a. Online portal – Website*

The HYDRUS website **http://www.hydrusfp7.eu.** See some screenshots from the public part represented in figure 11.

It is an important tool for the project's development and dissemination purposes. Since the beginning of the project, a website was designed and several functionalities have been added following the needs of the partners in the consortium. The online portal is structured in two parts: an *internal part or intranet* accessible only to and by the partners in the consortium, and an *online or public section* accessible to any stakeholder interested in project's developments and achievements.

The web site´s main aim is to create a communication gateway in two senses: outside the consortium with a marketing and publicity purpose, and inside the project consortium members with an active internal communication and optimal management purpose.


HYDRUS
HOME
SUMMARY
CONSORTIUM
DISSEMINATION
PUBLICATIONS
INTRANET
CONTACT
CONSORTIUM
The partners are classified in 2 groups according to the definition for 'Reseach for the Benefit of SMEs' projects. SMEs (Small or medium enterprises) and RTDs (Research and technological performers). Please, select one option to see a brief description of the partners involved.
1 SME's Partners
2 RTD Performers
FKuR Kunststoff GmbH (FKUR) [Germany]
FKuR Kunststoff GmbH produces and markets special customized biopolymers under the brand names Bio-Flex® (polylactic acid/copolyester compound), Biograde® (cellulose ester compound) and Fibrolon® (natural fibre reinforced polymers). The close cooperation of the company with the Fraunhofer Institute UMSICHT assures outstanding know-how and quality.
» Website
EXTRULINE SYSTEMS S.L. (EXTRULINE) [Spain]
EXTRULINE was created in 1995 within the pale of an industrial group expanding steadily. Their efforts were focused since the beginning in the area of water drive as well as the application of it to located irrigation. EXTRULINE is constantly searching for fulfilling the daily demands of their clients within their facilities, looking for solutions to their problems and improving work's results. EXTRULINE's quality-control security system according to UNE EN ISO 9001/200 fulfils its goals set by the physics-chemistry laboratory about materials quality-control establishing the following: * Good quality of the raw materials; *The finished products fulfil the requirements specified in the Standards; * Staff continuous training, particularly with reference to hygiene and safety at work place. *All those issues that will be evaluated by our clients and providers in one way or other and that will constraint our activity outside insight. Their industrial warehouses extension consist of 3,500 m2 joined by an area of 25,000 m2 located in an excellent geographic area for logistics. EXTRULINE provides expertise pipe manufacturing and drip injection from traditional polymers.
» Website
DESCRIPTION OF THE W
a) Research, technological development and innovatio
Definition of requirements and selection of materials (WP1)
Biodegradability and Ecotoxicity Evaluation (WP5).
Environmental, Economic and Regulatory studies (WP7).
b) Demonstration activities.
Industrial scale up and Product Validation (WP6).
c) Other activities.
Dissemination and exploitation of results (WP8).
d) Management activities.
Project Management (WP9).
EXCEPTED RESULTS
1.The new biodegradable pipe/drip for micro-irrigation systems fulfilling the specific requirements for the application foreseen and the standards of biodegradability.
2.The compound formulation, including the necessary additives and polymer blends, to ensure that the properties of the final products are met.
3.The reactive extrusion and crosslinking processes. Reactive extrusion and crosslinking of bio-based and biodegradable polymers have been developed at lab level but are not still well developed at industrial scale in a continuous process. The development of the process for industrial applications will require not only the optimization of the different processing parameters and auxiliary equipment (special die, external oven, etc.) but also the selection of the crosslinking and coupling agents.
The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 231975 (HYDRUS). - The information reflects the consortiums' view and the Community is not liable for any use that may be made of the information contained therein

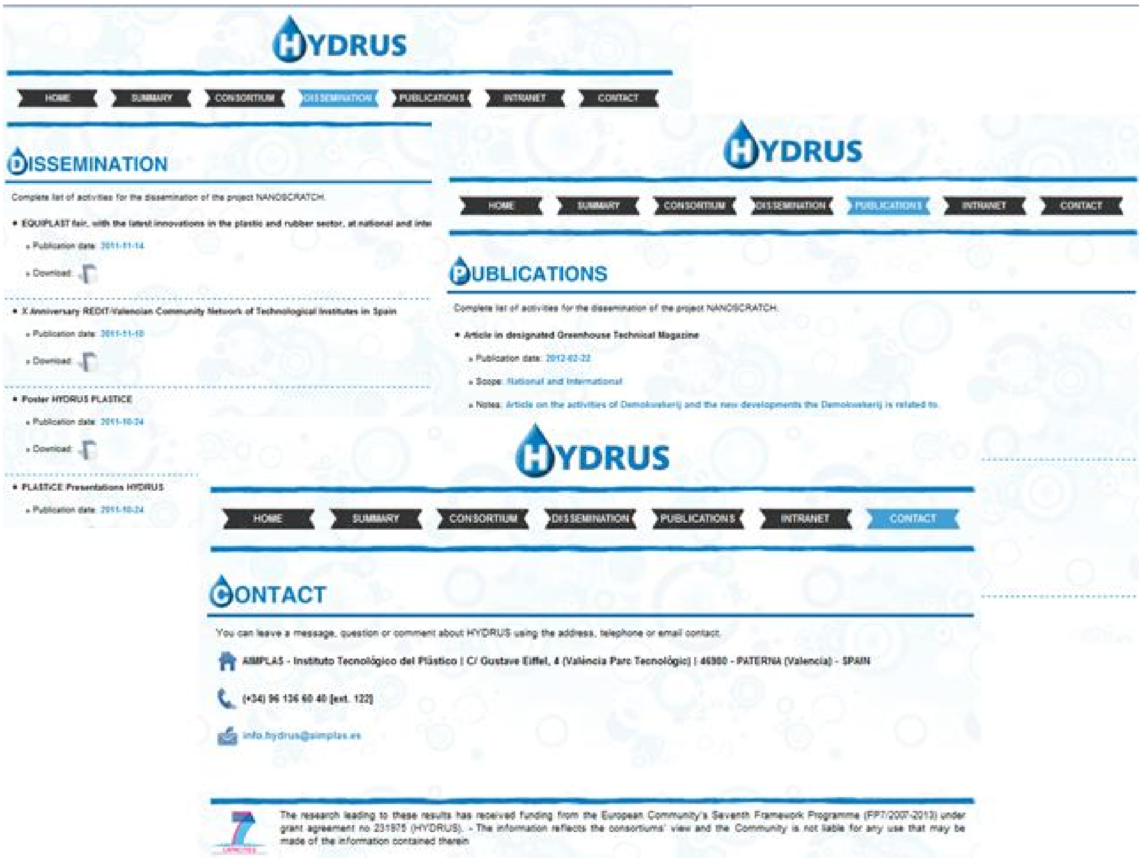



***Figure 11.*** **Different views of the Public area in the HYDRUS web site**

*b. Project identity – HYDRUS Logo*

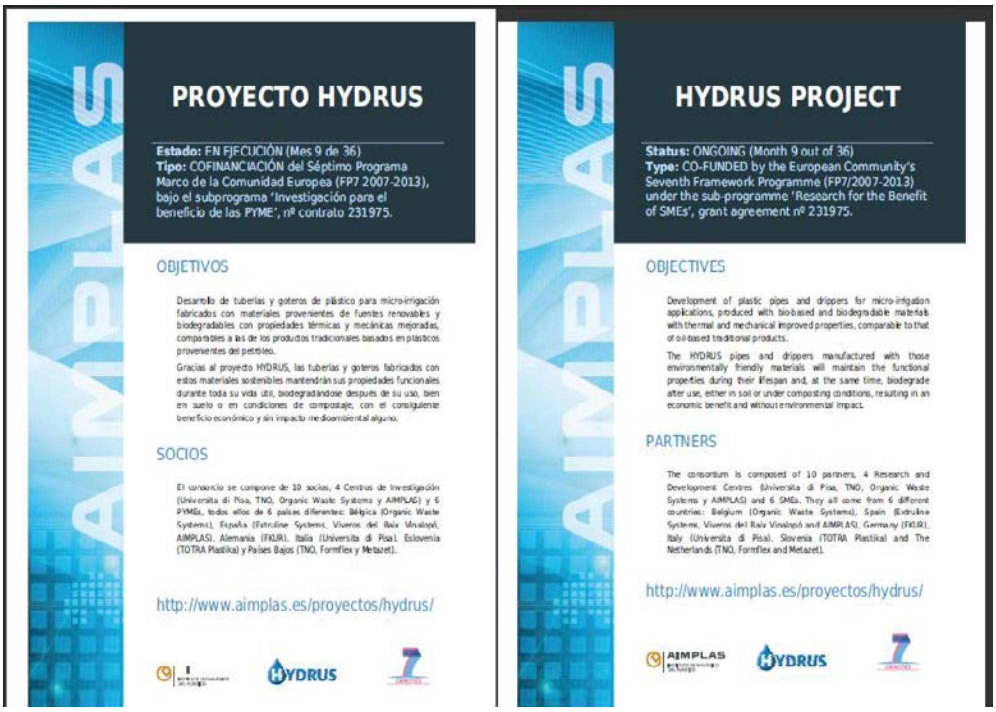
The project's corporate identity allows HYDRUS to project an instantly recognisable visual image. The Project's logo is extracted from the project's name. The use of logo, represented in figure 12, has been coherent in all publications and dissemination materials within the project. Also, the logo has been used by all partners in the written communications – templates, press releases, several project documents (minutes, agendas, official emails,...).

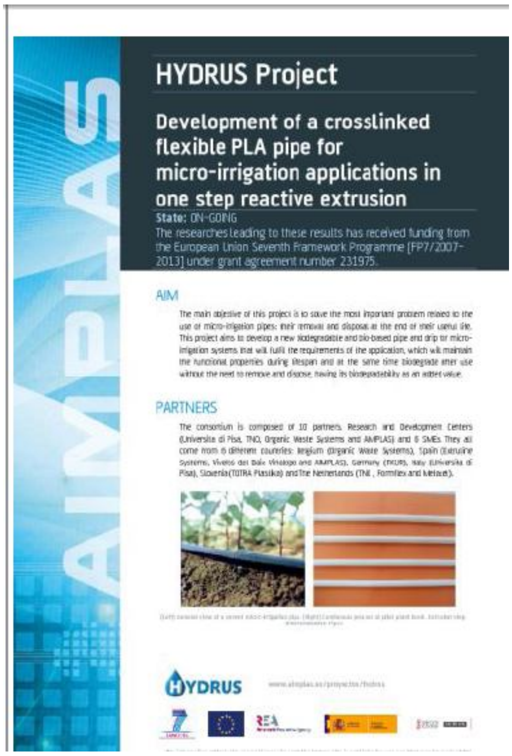
It is imperative for the project definition and identification purposes that no variations in terms of tones or fonts are to be used. Additionally, the use of logo by any other external party and for any purposes needs careful examination by the project's consortium.

***Figure 12.*** **Project logo**

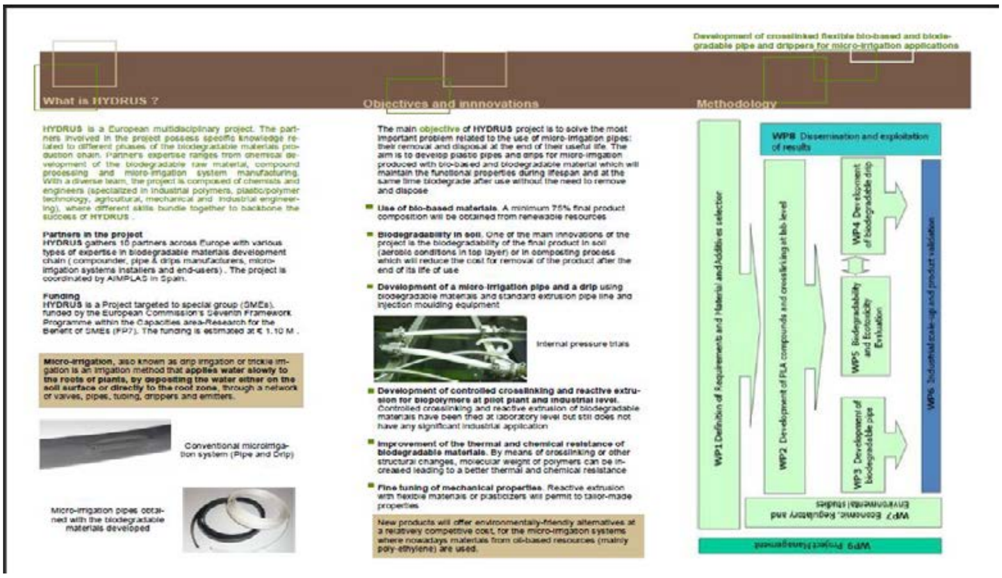
*c. Leaflet*

The project's leaflet, presented in figure 13, has been an essential dissemination tool because of its extended use – online or paper based (A4 format). Within the project, an initial leaflet was designed with the following objectives: 1) introduction of the project's consortium, 2) expected objectives and innovations during the project. The leaflet has been used during the various external and internal events where partners participated. The leaflet was updated with new pictures of the latest results, according t the project progress.




AIMPLAS
HYDRUS Project
Development of a crosslinked flexible PLA pipe for micro-irrigation applications in one step reactive extrusion
State: ON-GOING
The researches leading to these results has received funding from the European Union Seventh Framework Programme [FP7/2007-2013] under grant agreement number 231975.
AIM
PARTNERS
HYDRUS


Partners
Coordinator:
AIMPLAS
Compounder:
FKuR
Manufacturers:
Extruline Systems
Totra plastika
Final Users:
FormFlex
With technical support of:
IPCF
TNO
OWS
Organic Waste Systems
For additional information contact :
Project Coordinator: Raquel Giner Borrull
Technical Coordinator: Chelo Escrig Roldan
AIMPLAS
International Projects Department
Telephone: + 34 96 136 60 40
E-mail: proyectos@aimplas.es
http://www.aimplas.es/proyectos/hydrus/
HYDRUS Partners meeting, 19th-20th of January 2010 at TIRRENIA, Pisa, Italy
REA
HYDRUS
Development of Crosslinked Flexible Bio-Based and Biodegradable Pipe and Drippers for Micro-Irrigation Applications



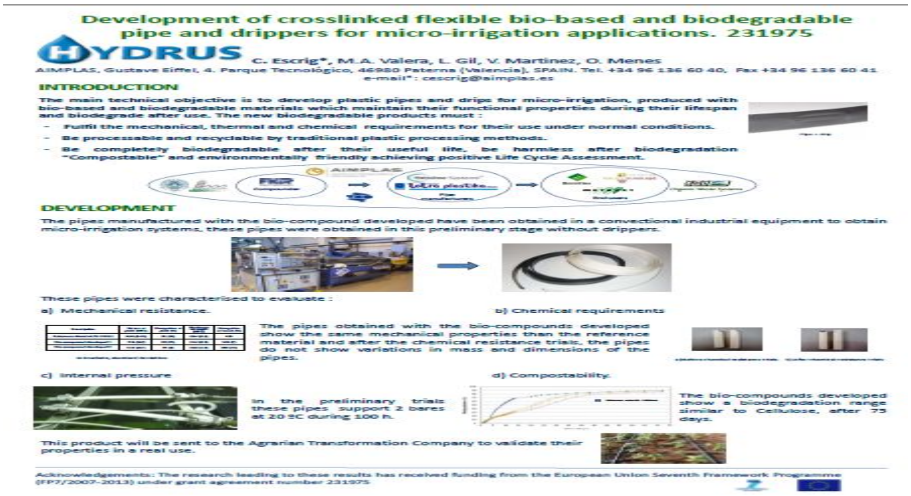



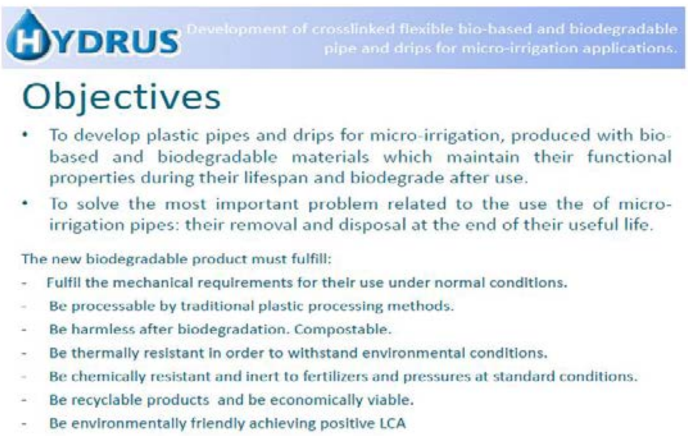

*Figure 13.* **Leaflets for the dissemination of HYDRUS.**

*d. Presentation of the project*

Since the beginning of HYDRUS activities, the content for a general presentation was drafted and used by partners in the project, according to their convenience by adapting the non-confidential content to their specific dissemination interests. The aim of such type of presentations was to introduce the external audience to the project. In general the usual common contents were: its beneficiaries, funding scheme, objectives, innovations, applications and potential access for further information. The general & non-confidential presentation was used as the main tool during international events, having therefore access to a high exposure and visibility. Figure 14 shows an example of several slides used in the general presentations of the project.


AIMPLAS
INSTITUTO TECNOLÓGICO DEL PLÁSTICO
PROYECTOS INTERNACIONALES
HYDRUS: Desarrollo de tuberias para microirrigación biodegradables mediante compuestos en base PLA. (2009 – 2012).
FKuR
Compounder
Extruline Systems
Lotra plastika
Fabricantes de tubería
FormFlex
baix vinalopó
METAZET
Usuarios finales
AIMPLAS
Organic Waste Systems
HYDRUS


HYDRUS
Development of crosslinked flexible bio-based and biodegradable pipe and drips for micro-irrigation applications.
General information about the project
Full Title: Development of crosslinked flexible bio-based and biodegradable pipe and drips for micro-irrigation applications.
Acronym: HYDRUS
Funding scheme: Research for the benefit of specific groups (SMEs)-Capacities.
FP7-SME-2008-1-231975- HYDRUS
Call Identifier: FP7 / 2007 – 2013, under grand agreement nº 231975
Number of Partners: 10
Funding:
Duration /actual month: 36 / 28


HYDRUS
Development of crosslinked flexible bio-based and biodegradable pipe and drips for micro-irrigation applications.
Objectives
To develop plastic pipes and drips for micro-irrigation, produced with bio-based and biodegradable materials which maintain their functional properties during their lifespan and biodegrade after use.
To solve the most important problem related to the use the of micro-irrigation pipes: their removal and disposal at the end of their useful life.
The new biodegradable product must fulfill:
- Fulfil the mechanical requirements for their use under normal conditions.
- Be processable by traditional plastic processing methods.
- Be harmless after biodegradation. Compostable.
- Be thermally resistant in order to withstand environmental conditions.
- Be chemically resistant and inert to fertilizers and pressures at standard conditions.
- Be recyclable products and be economically viable.
- Be environmentally friendly achieving positive LCA

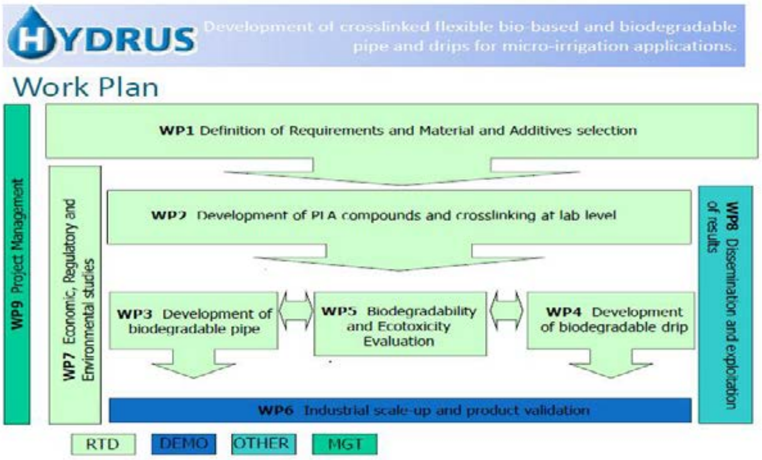



***Figure 14.*** **Slides used in the general presentation for the dissemination of HYDRUS.**

*(a) e. Press release*

As a very early stage activity, a press release with general content of the project was prepared and published in several mass media, as indicated in the dissemination activities table (Table 1 of this section 2).
It is worth noting that, due to the appealing research topic for the media, several press releases (general content) were published even during the negotiation stage, as also can be seen in Table 1 of this section 2.
The press releases were published both in hard and electronic media (newspapers/magazines, websites).

AIMPLAS NEWS

## Project HYDRUS: Biodegradable plastic pipes and drippers to preserve the environment

The project HYDRUS(X), funded by the European Commission inside the VII Framework Programme (FP7), officially began on July 1, 2009.

The aim of HYDRUS, coordinated by AIMPLAS, is to develop biodegradable plastic pipes and drippers for micro-irrigation systems in order to solve the collection and elimination of these kinds of pipes at the end of their shelf life, especially in season crops.

For this reason, it will be done a research on the development of plastic micro-irrigation pipes and drippers manufactured with materials coming from renewable and biodegradable sources with improved thermal and mechanical properties, comparable to the ones of traditional petroleum-based plastics.

In this first year of the project, the stages 1 and 2 have been successfully completed, and the development stages 3, 4 and 5 have been started. And, of course, we must not forget the stages 8, and 9 of spread, and management of the project, respectively, obtaining the following results:

- Definition of the requirements and features the micro-irrigation systems (pipes and drippers) must fulfil, by means of the description of the systems used nowadays. Such requirements involve physical-mechanical, thermal, processability, and biodegradability-compostability properties.

- Selection of the biodegradable commercial materials, and the additives to develop the new composite which will allow us to obtain the biodegradable micro-irrigation systems, taking into account the results obtained in a previous description of the materials already existing in the market.

- Development of new biodegradable composites at laboratory level adapting the commercial biodegradable materials' properties to the required properties by means of reactive extrusion.

- Control of the cross-linking system in pilot plant in a two-step process where, in the first step it is made the composite up of the biodegradable matrix and the different additives, and in the second one the pipe is obtained and the additives are activated, getting by means of reactive extrusion the new biodegradable pipe.

At this point of the project, it has been obtained a pipe for micro-irrigation, from a biodegradable thermal composite with a composition higher than 75 % coming from renewable sources, which offers the required thermal and chemical resistance. In the next years of the project development it is expected to reach the mechanical and biodegradability requirements, as well as to check their processability in industrial installations. In the same way, field tests will be carried out, which will allow to approve the functionality of the pipes during their whole shelf life.

Project HYDRUS(X): Funded by the European Commission inside the VII Framework Programme (FP7), and made up of a consortium composed by 10 partners, 4 Research Centres (Universita di Pisa, TNO, Organic Waste Systems y AIMPLAS), and 6 SMEs, all of them from 6 different countries: Belgium (Organic Waste Systems), Spain (Extruline Systems, Viveros del Baix Vinalopó, AIMPLAS), Germany (FKUR), Italy (Universita di Pisa), Slovenia (TOTRA Plastika), and the Netherlands TNO, Formflex y Metazet). A company from the Valencian Community takes part in the consortium: Viveros del Baix Vinalopó, S.L.

Project website:
proyectos.aimplas.es/hydrus

25 / OCTUBRE / 2010

Responsabilidad Social Empresarial en el Sector del Plástico
Guía de Buenas Prácticas

Extruline Systems®

**PROYECTO:** *Development of crosslinked flexible bio-based and biodegradable pipe and drippers for micro-irrigation applications (HYDRUS)*

**A.- OBJETIVOS DEL PROYECTO**

HYDRUS es un proyecto de Investigación para PYMES dentro del VII Programa Marco, compuesto por 10 socios de Italia, España, Alemania, Bélgica, Holanda y Eslovenia. Cuatro de los miembros del Consorcio son Centros de Investigación y los otros 6 son PYMES (2 son españolas).

El proyecto HYDRUS se presentó a la convocatoria FP7-SME-2008-1 con vencimiento el 11/04/2008. El pasado 30 de junio de 2008 se recibió el resultado de la evaluación de de la propuesta HYDRUS (Evaluation Summary Report). La puntuación obtenida ha sido de 13.5 puntos (de 15 posibles), por lo que el proyecto ha pasado todos los umbrales, tanto parciales: **4,5** en "Excelencia tecnológica y/o científica" (umbral 3), **4.5** en "Calidad y eficiencia del plan de trabajo y la gestión" (umbral 3) y **4.5** en el criterio "Impacto potencial basado en la consecución, diseminación y uso de los resultados del proyecto" (umbral 4), como global (umbral 11), obteniendo los mencionados 13.5 puntos.

El **objetivo principal del proyecto** es desarrollar **tuberías plásticas y sistema de goteo para micro-irrigación fabricados con materiales biodegradables** provenientes de fuentes naturales y renovables (mínimo 75% de composición). Las tuberías y goteros fabricados, mantendrán sus propiedades funcionales a lo largo de su vida útil, y al mismo tiempo se biodegradarán después de su uso, sin necesidad de desmontar la instalación, siendo este último uno de los mayores inconvenientes de los sistemas de micro-irrigación actuales debido al elevado coste de desinstalación.

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**Las nuevas tuberías** tienen que cumplir los requisitos que se exponen a continuación:

- posibilidad de elaborarse por métodos tradicionales de tratamiento de plásticos.
- ser completamente biodegradables e inofensivos después su biodegradación.
- ser termoestables.
- resistentes mecánicamente y químicamente.
- inertes a abonos y
- tener las propiedades mecánicas necesarias.

**Los goteros** tienen que reunir todos estos requisitos y además,

- tienen que tener estabilidad dimensional y
- deben poder fabricarse en máquinas tradicionales de moldeo por inyección.

El material base será un polímero proveniente de fuentes renovables. Para asegurar el correcto procesado del material, se deberá:

- Desarrollar mezclas de polímero mejoradas con aditivos
- Mejorar el proceso de reacción y compatibilización
- Mejorar el proceso de extrusión reactiva
- Probar la fabricación de las nuevas tuberías y goteros en planta piloto y a nivel industrial
- Medir las propiedades de las piezas fabricadas y comprobar que cumplen especificaciones.
- Instalar los sistemas de micro-irrigación en campo
- Verificar la biodegradabilidad y los efectos sobre las propiedades de las piezas fabricadas

Un objetivo primordial del proyecto es asegurar que **el coste de los sistemas de micro-irrigación biodegradables obtenidos tengan un coste competitivo.** Las primeras

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estimaciones indican que, tendiendo en cuenta los costes de desmantelamiento de la instalación, el coste final sea de al menos un 5% menor que el de los sistemas tradicionales. Este coste dependerá fundamentalmente del coste de los materiales utilizados (actualmente el coste de materiales provenientes de fuentes renovables es superior a los provenientes del petróleo, aunque con una clara tendencia a la baja) y de la optimización de los procesos productivos.

**B.- Situación Actual, necesidad o problemática que resuelve**

Actualmente, los sistemas de micro irrigación (ver figura 1) están muy extendidos en toda España, en particular en lugares con escasez de agua como la cuenca Mediterránea. Los sistemas de micro-irrigación permiten por una parte optimizar el uso de agua al localizar el riego allí donde es más efectivo, es decir cerca de la planta a regar y, si además, se utilizan también para dosificar los fertilizantes, contribuyen a reducir el impacto ambiental producido por la fertilización tradicional por pulverización o rociado.

Figura 1. Vista general de un sistema de micro-irrigación y detalle de una tubería.

Una vez tendida la red de tuberías y goteros, tiene una vida útil que puede depender bien de las propiedades propias de las tuberías y goteros, bien de la duración del cultivo, que puede ser de temporada, siendo necesario retirar la instalación una vez terminada la vida útil. El desmantelamiento de la instalación de micro-irrigación





es elevado, por lo que en muchos casos, se opta por triturar in situ las tuberías y goteros que permanecen en el campo con los consiguientes efectos negativos a medio-largo plazo que esto conlleva. Esto es especialmente peligroso en el caso de sistemas de fertirrigación, ya que las tuberías y goteros que han estado en contacto con fertilizantes y plaguicidas, no están totalmente libres de ellos, por lo que estos pasan al suelo, reduciendo su calidad. En este caso, además, aunque se retiren las tuberías y goteros, no pueden ser reciclados debido precisamente a estos contaminantes. En otras ocasiones, dicho coste de desmontaje supone directamente una barrera para su utilización, al no poder ser afrontado por el agricultor.

Por lo tanto, el disponer de sistemas de micro-irrigación biodegradables competitivos en coste, como los que se desarrollan en HYDRUS, que proporcionen las prestaciones suficientes (resistencia mecánica, resistencia a rayos UV, etc.) para asegurar una correcta fertirrigación de la cosecha y que posteriormente puedan ser dejados en el campo para que se biodegraden por la simple acción del tiempo y el entorno, supondría una solución para dos problemas:

1. Reducirá barreras para la utilización de sistemas de micro-irrigación frente a otros sistemas de riego
2. Supondrá un ahorro de coste para el agricultor que no tendrá que desmantelar la instalación tras su vida útil
3. Reducirá el impacto ambiental de la utilización de los sistemas de micro-irrigación

**C.- Dificultades de Desarrollo**

Actualmente los materiales biodegradables están experimentando un gran desarrollo debido al gran interés por asegurar la sostenibilidad y el respeto al medioambiente en todos los ámbitos de la sociedad actual. Sin embargo, las aplicaciones para las que son utilizados no imponen unas condiciones como las que exige la aplicación de sistemas de micro-irrigación: alta resistencia mecánica y térmica (Tª de funcionamiento hasta 60º). Los plásticos tradicionales basados en PLA, PHA, Poliésteres, almidones, no proporcionan unas propiedades suficientes para emplearlos en esta aplicación.





Por tanto, los aspectos claves para conseguir los objetivos de HYDRUS son:

1) **Optimizar las mezclas** de polímeros biodegradables con los aditivos adecuados para asegurar el correcto post-procesado (extrusión de tubería e inyección de goteros) para conseguir las propiedades objetivo. Es necesario desarrollar y optimizar métodos para mejorar la compatibilización y
2) **Demostrar las buenas propiedades mecánicas, químicas y térmicas** de los productos desarrollados durante toda su vida útil.
3) **Desarrollar/adaptar los procesos de transformación** de estos materiales novedosos a escala planta piloto primero e industrial después, asegurándose que es posible procesar los nuevos materiales sin realizar inversiones en nueva maquinaria
4) **Garantizar la biodegradabilidad** de los productos en el tiempo esperado y con las propiedades esperadas

Además, resultará imprescindible conseguir que los costes de los nuevos productos sean competitivos respecto a soluciones tradicionales.

La tarea es compleja y requiere de la integración de los conocimientos y capacidades que se han reunido en el proyecto HYDRUS, compuesto por empresas, centros tecnológicos y universidades punteras en todos los ámbitos de la cadena de valor relacionada con los sistemas de micro-irrigación biodegradables, desde la formulación hasta la instalación, pasando por la fabricación.

**D) Estado de la Tecnología en España**

En España, los sectores en que se está aplicando los plásticos biodegradables son básicamente envase y embalaje. Otros sectores de aplicación clara son el juguete, automoción, tarjetas de crédito, carcasas de equipos de comunicaciones e informáticos, entre otros.

No se conoce ninguna empresa que esté empleando este tipo de materiales para la fabricación de tuberías y goteros para sistemas de micro-irrigación. Tecnológicamente, las máquinas para procesar estos materiales son las mismas utilizadas tradi-





cionalmente. Las posibles modificaciones se definirán como resultado de las actividades llevadas a cabo en el proyecto HYDRUS.

No se dispone de datos concretos para España del volumen de mercado de los plásticos degradables. En 2007, el mercado mundial de bioplásticos, suponía alrededor del 0.3 % del total del mercado mundial; el potencial de mercado en Europa se estima que alcance los 5 millones de toneladas para el año 2020 (Fuente: European Bioplastics, junio 2008). La capacidad de producción mundial de bioplásticos se estima que se multiplicará por 4 de aquí al año 2011 (Fuente: European Bioplastics, junio 2008). Respecto a Europa, según datos de junio de 2008 (Fuente: European Bioplastics), el crecimiento anual de los bioplásticos supera el 20 %. En 2007, el total de aplicaciones de los bioplásticos en el mercado europeo supuso entre 75000 y 100000 toneladas, frente a los 48 millones de toneladas del total del mercado de plásticos en Europa.Según fuentes de DEGRADABLE PLASTICS, Freedonia Group, September 2006, en el caso de USA, el crecimiento de la demanda de plásticos biodegradables 2000-2005 fue del 16 %, esperándose un crecimiento del 19,5% para el periodo 2005-2010.

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Desarrollo de Tuberías y Goteros Biodegradables para su aplicación en Sistemas de Micro-Irrigación

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Agradecimientos

Referencias

***Figure 15*. Example of several press releases published for the dissemination of HYDRUS.**

*f. TV coverage*

As mentioned before, since even before the beginning of the project, HYDRUS topic rwas of high impact in the media (both general public and plastic sector), several TV channels contact the coordinator to know more about its progress and main results. Its appealing final product with clear environmental benefits was the key to attract their attention.


***Figure 16.*** **Example of FORMFLEX´s video on their business activities to let the consortium understand better their specific work in The Netherlands for the dissemination of HYDRUS**

### *II. Dissemination activities*

It is essential to highlight that several dissemination activities were activated and completed during the development of HYDRUS The project information was disseminated via three channels:

d) By partners within their organizations (e.g. internal newsletters, meetings, workshops, seminars, training courses, etc.)
e) By partners during external events ( e.g. fairs, conferences, networking events, etc.)
f) By partners using media across Europe (e.g. press release, Internet, specialized magazines, etc.)

The use of various channels (internal & external) and methods (mainly written & online) assured an optimal contribution of coverage, visibility and most important- setting up the scene for better market acceptance in the near future.

Table 1 of this section 2 summarises the dissemination activities (publications, conferences, workshops, web, press releases, brochures, etc) held by project partners during the whole HYDRUS project duration, *including as well the promotion made during the negotiation process.*

Furthermore, there were two scientific publications related to HYDRUS (Table 2 of this section 2).

***Table 1*. List of dissemination activities carried out by HYDRUS partners**

| TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NO. | Title | Main author | Title of the periodical or the series | Number, date or frequency | Publisher | Place of publication | Year of publication | Relevant pages |
| 1 | "Increase of the properties of Biodegradable Thermoplastic materials by reactive Extrusion maintaining their biodegradability" | M.C. Escrig, V. Martinez, M.A. Valera and L. Gil | N.A. | N.A. | 11th European symposium on Polymer Blends | Donostia-San Sebastian (Spain) | March 2012 | N.A<br>Only showed an abstract and a presentation. |
| 2 | "Development of new PLA-based biodegradable compounds for micro-irrigation applications" | Simona Bronco & Francesca Signori | N.A. | N.A. | TOP 2012 Times of Polymers and Composites | Ischia (Italy) | June 2012 | N.A<br>Only showed an abstract and a presentation |
| 3 | *FORESEEN scientific article. UNIPI-AIMPLAS* | Simona Bronco, Francesca Signori, M.C. Escrig, V. Martinez, | TBD | TBD | TBD | TBD | TBD-month 2012 | TBD |
| 4 | TBD | TBD | TBD | TBD | 7th European Bioplastics Conference | Berlin (Germany) | November 2012 | TBD |

| TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NO. | Type of activities[3] | Main leader | Title | Date/Period | Place | Type of audience[4] | Size of audience | Countries addressed |
| 1 | Press release on line | AIMPLAS | Diario Crítico | February 2009 | web | General public | Unknown | International |
| 2 | Press release on line | AIMPLAS | Europa Press | February 2009 | web | General public | Unknown | International |
| 3 | Press release on line | AIMPLAS | El Boletín | February 2009 | web | General public | Unknown | International |
| 4 | Press release on line | AIMPLAS | Interempresas | February 2009 | web | General public | Unknown | International |
| 5 | Press release on line | AIMPLAS | Mundoplast | March 2009 | web | Plastic sector | Unknown | International |
| 6 | Technical Article | AIMPLAS | Agriculture Magazine | March 2009 | Magazine | Plastic sector | 8000 copies | National |
| 7 | Technical Article | AIMPLAS | Plásticos Modernos (Technical Magazine) | April 2009 | Magazine | Plastic sector | 4000 copies | International |
| 8 | Technical Article | AIMPLAS | Plásticos y Caucho (Magazine) | April 2009 | Magazine | Plastic sector | 6000 copies | National |
| 9 | Project website | AIMPLAS | HYDRUS website www.aimplas.es/proyectos/hydrus/ | July 2009 | web | General public | *Unknown* | *International* |
| 10 | Press release | AIMPLAS | AIMPLAS INFO nº 31 (Available on-line www.aimplas.es) | November 2009 | Magazine | Plastic sector | 2000 copies | Spanish |
| 11 | Technical Article | AIMPLAS | Plásticos Modernos Technical Magazine ("Desarrollo de Tuberías y Goteros Biodegradables para su aplicación en Sistemas de Micro-Irrigación") | November 2009 | Magazine | Plastic sector | 4000 copies | International |
| 12 | Press release on-line | EXTRULINE | ASEMUPLAST (Association of plastic entrerprises in Murcia)("Guía de Buenas Prácticas") | January 2010 | Don ConsultoresS.L.; www.donconsultores.es | Plastic sector | Unknown | International |

[3] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

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|---|---|---|---|---|---|---|---|---|
| 13 | Video | FORMFLEX | FORMFLEX´s video on their business activities to let the consortium understand better their specific work in The Netherlands | January 2010 | Video | Agricultural sector | Unknown | International |
| 14 | Brochure | AIMPLAS | Brochure Spanish-English given out at SMAGUA Fair (Zaragoza, Spain). | March 2010 | SMAGUA Fair (Zaragoza, Spain). Fair addressed to the agricultural sector. | Agricultural sector | DATA: 1725 booths | 41%, Spain; the rest mainly from EU) |
| 15 | Press Release | AIMPLAS | AVEP ("Biodegradable plastic pipes and drippers to preserve the environment") | October 2010 | Press | Plastic sector | 500 copies | Regional |
| 16 | Press Release | AIMPLAS | AIMPLAS INFO nº35 ("Tuberías y goteros de plástico biodegradable para preservar el medio ambiente") | October 2012 | Press (also available on line at www.aimplas.es) | Plastic sector | 1800 copies | National |
| 17 | Brochure/press release on-line | AIMPLAS | K Fair ("Development of a crosslinked fexible PLA pipe for micro-irrigation applications in one step reactive extrusion") | November 2010 | K Fair 2010 official website(Düsseldorf,Germany) | Plastic sector | Unknown | International |
| 18 | Project general presentation | AIMPLAS | IV International Seminar on Biopolymers and sustainable Composites. www.polimerosbiodegradables.com | 07/08-03-2011 | Sorolla Palace Hotel (Valencia,Spain) | Plastic & Biodegradable sector | Unknown | International |
| 19 | Project general presentation | AIMPLAS | Informal FP7 Working Group-Network Enterprise Europe | 5/6-05-2011 | IMPIVA,Valencia,Spain | Research sector | Unknown | International |
| 20 | Project general presentation | AIMPLAS | "Ultimos desarrollos en materials biodegradables".QUIMICOVA. | 29,32 Sep and 1st Oct 2011 | QUIMACOVA-QUIMICA FUSION, Valencia,Spain | Biodegradable sector | Unknown | Spain |
| 21 | Leaflet | AIMPLAS | PLASTICE Leaflet | 24/25-10-2011 | PLASTICE, Italy | Plastic sector | Unknown | International |
| 22 | Project general presentation | AIMPLAS | PLASTICE presentations | 24/25-10-2011 | PLASTICE, Italy | Plastic sector | Unknown | International |
| 23 | Poster | AIMPLAS | Poster HYDRUS PLASTICE | 24/25-10-2011 | PLASTICE, Italy | Plastic sector | Unknown | International |
| 24 | Press Release | AIMPLAS | AIMPLAS INFO nº 40 (Available on-line www.aimplas.es) | Oct/Dec 2011 | web | Plastic sector | 1800 copies | National |
| 25 | Samples of the project and project summary | AIMPLAS | Pictures X Anniversary REDIT-Valencian Community Network of Technological Institutes in Spain | 10-11-2011 | Valencia,Spain | Research sector | Unknown | National |

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|---|---|---|---|---|---|---|---|---|
| 26 | Leaflets and samples of the project | AIMPLAS | Pictures EQUIPLAST fair, with the latest innovations in the plastic and rubber sector, at national and international level. | 14/18-11-2011 | EQUIPLAST,Barcelona,Spain | Plastic sector | Unknown | International |
| 27 | Technical article | UNIPI | New-Biodegradable chemical formulations for micro-irrigation applications | Janu/Feb 2012 | Magazine La Chimica & L´Industria, Italy | Biodegradable sector | Unknown | National |
| 28 | Article in designated Greenhouse Technical Magazine | METAZET | Article on the activities of Demokwekerij and the new developments the Demokwekerij is related to. | Feb 2012 | GlastuinbouwTechniek Magazine, Netherlands | Agricultural sector | Unknown | National |
| 29 | Abstract and technical project presentation | AIMPLAS | “Increase of the properties of Biodegradable Thermoplastic materials by reactive Extrusion maintaining their biodegradability” | 28-03-2012 | 11th European Symposium on Polymer Blends in Donostia - San Sebastian, Spain | Plastic sector | Unknown | International |
| 30 | Project general presentation | AIMPLAS | “Últimos desarrollos en el campo de los materiales biodegradables termoplásticos” www.forotecnologicoyempresarial.com | 12-04-2012 | Foro Tecnológico Empresarial BIOPLASTICOS 2012, Zaragoza, Spain | Biodegradable sector | Unknown | National |
| 31 | Leaflets and samples of the project | AIMPLAS | Pictures exhibitor HYDRUS | 08/12-05-2012 | PLAST2012, Milán, Italy | Plastic sector | Unknown | International |
| 32 | Project general presentation | OWS | Testing and Certification of Biodegradable and Compostable Polymers | 10/11-05-2012 | PLAST2012, Milán, Italy | Plastic sector | Unknown | International |
| 33 | Project general presentation | OWS | ´EXPERIENCES ON 15 YEARS OF COMPOSTABILITY CERTIFICATION ' | 27-31/05/2012 | BiPoCo 2012 Conference, Siofok, Hungary | Biodegradable sector | Unknown | International |
| 34 | Abstract and technical project presentation | UNIPI | “Development of new PLA-based biodegradable compounds for micro-irrigation applications” www.topconference.it | June 2012 | TOP 2012 meeting, Ischia, Italy | Biodegradable sector | Unknown | International |
| 35 | Project general presentation with final results. | AIMPLAS | Project general presentation with final results. | 18-19/09/2012 | Forum Plastipolis 2012 (Lyon, France) | Plastic sector | Unknown | International |
| 36 | Project prototypes + leaflets. | AIMPLAS | Project prototypes + leaflets. | 6-8/11/2012 | Agricultural film 2012. Madrid, Spain | Plastic sector | Unknown | International |

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|---|---|---|---|---|---|---|---|---|
| 37 | Abstract and technical project presentation | AIMPLAS & OWS | Project general presentation with final results, previous submission of an abstract. Possibly, Project prototypes + leaflets. | 6-7/11/2012 | 7th European Bioplastics,Berlin,Germany | Biodegradable sector | Unknown | International |