LIFE Project Number

LIFE07 ENV/GR/000280

Final Report

Covering the project activities from 1/1/2009 to 31/12/2012

Reporting Date

31/12/2013

Strategies to improve and protect soil quality from the disposal of olive oil mills' wastes in the Mediterranean region
PROSODOL

Data Project

Project location	GREECE
Project start date:	01/01/2009
Project end date:	31/12/2012
Total budget	1.628.911 €
EC contribution:	802.936 €
(%) of eligible costs	50%

Data Beneficiary

Name Beneficiary	Soil Science Institute of Athens-ELGO DEMETER
Contact person	Dr Maria Doula
Postal address	Sof. Venizelou str., 1, GR , 14123, Likovrisi
Telephone	+30 210 2832031
Fax:	+30 210 2842129
E-mail	mdoula@otenet.gr; m.doula@bpi.gr
Project Website	http:/www.prosodol.gr

1. List of Content

2. EXECUTIVE SUMMARY

2.1. Aims of the project

The olive oil extraction industry represents an important activity in the Mediterranean area. Among European countries, but also worldwide, Spain and Italy are the two leaders in olive oil production, whereas Greece holds the third place. But production carries a significant environmental problem; the extraction process generates a dark effluent characterized by high organic carbon content, particularly polyphenols which are highly polluting.
Disposal of olive solid and liquid wastes from olive oil mills is already a major environmental issue in several olive growing countries in the world. Spreading the solid waste on farmlands and storing the wastewater in anaerobic ponds causes enormous pollution to the land and air. Inappropriate disposal of olive husk and olive mill wastewater create environmental problems such as odor and ammonia released into the atmosphere and leaching of inorganic and organic substances to the soil as well as leaching of these pollutants into the ground water.
The olive mill wastes (OMW) have been, and continue to be, disposed onto farmlands, thus causing the inhibition of numerous microorganisms, a reduction in seed germination and the alteration of several soil characteristics such as porosity and humus concentration. The introduction of olive solid and liquid waste into soil tends to increase the average diameter of the soil aggregates, bulk density and slows down hydraulic conductivity. Polyphenols are well known to affect nitrification in the soil and have deleterious effect on soil microbial activity. The high C:N ratio and low pH are also known to immobilize nitrogen in the soil.
The olive husk and wastewater produced from oil extraction processes contain macromolecules such as polysaccharides, lipids, proteins and a number of monocyclic and polymeric aromatic molecules generally known as phenolic compounds. The levels of phenols in wastewater and olive husk can vary from 1 to 8 g/l and from 2.9 to 3.7mg/g, respectively. The wastewater is also characterized by dark color due to chromophoric lignin-related materials with different degrees of polymerisation and a sharp characteristic odour. Olive husk is also characterized by its phytotoxicity, hydrophobicity, salinity, low pH and polyphenols. The presence of phenols as well as short and long chain fatty acids is considered to be responsible for the phytotoxicity and antimicrobial nature of these wastes.

PROSODOL project aimed to study the effect of OMW disposal on soil and to address negative effects by introducing and demonstrating innovative methodologies for soil quality protection and improvement as well as, by developing a strategy for continuous soil monitoring that will ensure sustainable soil use.

In specific, the objectives of PROSODOL were:

1. Development and dissemination of innovative, environment friendly, low cost technologies for the protection of soil and water pollution from olive oil mills' wastes.
2. Establishment of an info-library/knowledge-base system to assess environmental impacts from olive oil mills' wastes to Mediterranean region.
3. Facilitate the implementation of Soil Thematic Strategy in areas close to olive oil mills.
4. Design, implementation and support a monitoring system for the assessment of the soil and water quality affected directly or indirectly from oil mills' activities in relation to factors, pressures and responses.
5. Identification of potential safest uses in the agricultural sector of olive oil mills' wastes and its possible contribution to agricultural production.

2.2. Main outcomes

All foresaw activities were implemented at two demonstration-pilot areas; one in Greece and one in Italy. The Greek demonstration area is located in the Municipality of Rethymnon (former Municipality of Nikiforos Fokas), in Crete. The selected pilot municipality is one of the many municipalities in Greece, but also in Mediterranean, facing the same problem of the uncontrolled disposal of untreated olive mills wastes. Five olive oil mills are in function in the selected pilot area for more than 10 years, whereas there are also two more mills that have stopped their activities before almost 10 years. Some of the active mills use evaporation ponds, while other dispose their wastes directly on soil, in rivers and streams. During the past years no detailed study had been carried out in the region but also in the neighbouring municipalities to evaluate the quality of soil and water resources and the way that mills' activities affect the surrounding environment. The second implementation site of the project was set up in Liguria Region, Italy where young olive trees were grown under controlled conditions and with the addition of specific amounts of OMWs during experimentations aiming to the identification of the optimum conditions for OMW use at olive trees orchards.

As regards the potential threats for soil quality due to the uncontrolled disposal of OMW, it was deduced that risk for soils in OMW disposal and neighbouring areas is high since a number of soil parameters exceeded normal, high or toxic thresholds. It was also revealed that there are some soil properties that protect soils from degradation; clayey soils have very strong adsorption capacity and may remove big percentages of phenols and other contaminants after one application of OMW. However, this capacity is substantially reduced after additional applications increasing thus contaminant concentration in infiltrating leachates and thus risk for deeper soil horizons overloading and groundwater contamination, as well. Consequently, higher risk is anticipated if disposal of OMW takes place on soils poor in clay and $CaCO_3$ and with low pH, on soils close to the sea or other water resources and if groundwater table is shallow.

The obtained results highlighted the need for establishing soil quality standards for some soil parameters in order to declare soils affected by induced human pollution like disposal of OMW. There is strong indication that the long-term application of OMW has the potential to induce soil or groundwater contamination. Therefore, long-term use of OMW requires monitoring to assess any risk of environmental pollution. PROSODOL proposes a set of eight soil parameters that can be used as soil indicators specific for OMW disposal area, i.e. organic matter, electrical conductivity, total nitrogen, total polyphenols, available phosphorous, exchangeable potassium, available iron and pH (mainly for acid soils).

In order to assess the risk for water bodies at areas close to OMW disposal ponds, a carefully designed water monitoring strategy was implemented in the project area and water samples were collected every 2 months for all the four years of the project from surface streams, springs, water supply pipes, old wells, existing water abstraction wells and from piezometers installed in 5 drillholes (1 of these was used as control) in the wider affected area. Results revealed that the risk for groundwater is highly depended on the soil type, the presence of limestones and the depth of groundwater table. Moreover, the presence of clays in soils reduces substantially the toxic load during infiltration.

It is anticipated that any impacts in the OMW disposal areas will affect mainly recipients at local scale. In case though of more intense activities, larger affected areas and different soil qualities (e.g. sandy soil) risk for humans and ecosystems will be much higher. It is therefore proposed that due to scattering of olive oil production units in the Med region, simple and cost effective measures should be considered including neutralization and/or dilution of OMW prior to disposal in ponds or on agricultural soils as well as, construction of impermeable evaporation ponds; in the latter case geo-membranes or alternatively clayey soils may be considered as a cheaper option.

Having performed thorough studies on soil quality and its dependence on OMW disposal in the framework of PROSODOL project and considering the specific climatic conditions of the Mediterranean countries, it is recommended that a monitoring tool fully suited to OMW disposal areas should include: (1) an optimized set of soil quality indicators; (2) threshold values for soil quality indicators; (3) a system that enhances decision making regarding the most appropriate location for OMW disposal according to certain criteria (4) a system that enhances decision making regarding the suitability of soil for OMW disposal/application (i.e. a land application system) to ensure safe disposal/use/application of OMW on soil in the Mediterranean region; (5) guidelines for periodical soil quality monitoring; (6) software application tools for soil monitoring that will facilitate adoption of the monitoring system by authorities and individuals; (7) guidelines for periodical water bodies monitoring; and (8) a code of good practices for soil management.

One of the main project's objectives was to develop and implement cost effective soil remedial actions that will remediate or, at least, protect soils from further degradation. It should be, however, highlighted that the development and implementation of soil remedial actions, appropriate and specific for OMW disposal areas, have been never implemented and demonstrated before and thus, the selection among available soil remedial methodologies was not existed as an option and, most significant, there was no possibility to compare the obtained results with results obtained from other already implemented and demonstrated methods. Therefore, all potentially applicable soil remedial methods were recorded and evaluated. It was, however, clear that a soil remediation and protection plan suitable for OMW disposal areas, should include methodologies for polyphenols reduction and retention or immobilization of inorganic constituents. Therefore, for the reduction of polyphenols concentration in soil, in situ-bioremediation was selected since it targets to the biodegradation of organic pollutants in soil by taking full advantages of the natural biodegradation process of organic molecules by soil microorganisms. For the reduction of inorganic soil constituents, the use of natural zeolite, clinoptilolite, as soil additive was considered the most suitable for this case because of the already well-known properties of natural zeolites to attract, retain and slowly release many inorganic cations, such as K^+, Na^+, Fe^{3+}, Cu^{2+} and others. Moreover, the method is of very low cost and very easy to be implemented, even by no qualified personnel.

The two methodologies applied at a pilot disposal area and the results obtained were very much satisfactory, indicating that these methods could efficiently be used for soil improvement and protection from the disposal of OMW.

Field pilot composting was implemented during the PROSODOL project using as raw materials solid OMW (i.e. sludge from inside the evaporation ponds), straw, caw manure, fresh and dry leaves, and different ratios of zeolite dust (0.00-0.80mm). After the evaluation of the results and the chemical analysis of the composts the most appropriate composition was selected and proposed.

PROSODOL focused also on the development and demonstration of low-cost OMW pre-treatment techniques with the use of various reactive agents. These reagents were used to remove solids, add alkalinity, remove some of the toxic load and degrade organic contaminants so that the main treatment that follows becomes easier or disposal to land as fertilizer is feasible. Various materials were used in lab scale in pre-treatment experiments to investigate sorption of organic contaminants, increase pH, initiate precipitation of metals in stable forms and/or remove solids from OMW. Most of these materials are low cost, by-products of other processes and are abundant in Mediterranean countries. For the pre-treatment of OMW the materials used include magnesite by-products, natural zeolite, limestone, two different types of soils, goat manure (GOM), zero-valent iron (ZVI) and activated carbon (AC). GOM and ZVI show promising results in terms of phenol removal and pH increase.

The investigation of the potential impacts of OMWs used for olive trees irrigation/fertilization on soil quality and the potential contribution to yield increase were studied at a pilot orchard for two years. For this, field trials were performed in Albenga, Italy, during which controlled distribution of OMWW and husk took place in a pilot olive orchard. A pilot scale experimentation site of around 1.500 m^2 for the controlled use of OMWW for tree land fertilization was set up and almost 200 two-years-old olive tree plants belonging to 3 different varieties (Taggiasca, Pignola, Leccino) were transplanted. OMWW and husk were distributed and the impacts on soil quality, on leachates quality and on yield were recorded and evaluated.

Finally, a fast and easy methodology was developed for the measurement of wastes' COD and BOD_5 at mill level.

For the integration of PROSODOL activities, an extensive analysis of European Union legislative framework on the subject of olive oil waste management was performed, including the relevant regulations of waste, water and soil. The analysis integrated the relevant legislative framework of the partner countries, i.e. Italy, Spain and Greece as well as of Portugal and Cyprus, as well.
In specific, the study includes (a) an analysis of the olive oil industry and the relevant environmental issues; (b) waste management and the relevant EU and national legislation on waste, water and soil; (c) legislative recommendations for olive oil waste management, both statutory and volunteer; (d) legislative recommendations as well as technical specifications and proposed strategies to monitor, protect and improve soil quality at olive oil mills' disposal areas.

For the promotion of soil protective and remedial actions at OMW disposal areas, PROSODOL proposes a set of recommendations to be included in the national/European legislative frameworks. The recommendation are those derived after evaluation of the project's outcomes and mainly from the soil monitoring actions performed at olive mills waste disposal areas, and their fulfilment is considered necessary for soil quality protection. It is believed that their incorporation as Member States' obligations in the legislative framework of the EC or/and of the Med Member States will ensure future effective monitoring of the legal and illegal disposal areas, which in turn will facilitate the sustainable management of these areas.

Moreover, PROSODOL proposes a set of technical standards which could be utilized either as Best Available Techniques for Soil Monitoring and Soil Quality Improvement or as Annexes in future Directives and legislative acts, which will assist national local/regional/governmental authorities to implement strategies to monitor, protect and improve soil quality at olive oil mills' waste disposal areas.

2.3. Key deliverables

Significant deliverables were developed during the PROSODOL project, which are divided into two categories:
Category A: Scientific studies and evaluated results of all activities
Category B: Simplified texts/Guides/manuals for stakeholders/policy makers which were printed and distributed.

Category A

General studies-Web applications

- Report for preliminary study of the pilot municipality
- Web-site of the project
- Info-library (web accessible)
- GIS Interactive maps of pilot municipality
- Monitoring System tool and the respective report (v 1.0)
- INSPIRE Conformity
- Risk Assessment
- Methodology and results of the electric tomography and magnetic susceptibility measurements
- Surface Interpolation as well as information on the construction and use of the monitoring tool's interpolation surfaces
- List of validated innovative methods for olive oil wastes analysis
- Layman's Report
- After LIFE communication plan

Soil monitoring

- Set of soil chemical, biochemical and microbiological parameters to detect contamination by olive oil mills' wastes
- Environmental risk assessment of the pilot municipality-Soil
- Soil monitoring system

Water monitoring

- Environmental risk assessment of the pilot municipality - Water bodies
- Monitoring system for water bodies

Soil remediation

- Description of a suitable low cost remediation technique for contaminated soil due to OMW wastes disposal
- Financial and Technical evaluation of the demonstration action (i.e. soil bioremediation)
- A Guide for the application of bioremediation at larger scale
- Report of best application method of porous materials at olive oil mills' disposal areas
- A Guide for the use of porous materials as soil additives at larger scale
- Benefits of soil remedial/protective techniques

Wastes exploitation and pre-treatment

- Guidelines for safe use of OOM wastes for crop production
- Report on the design and operation of a prototype waste pre-treatment system
- A Guide for the application of the waste pre-treatment system in the pilot area
- Benefits of waste pre-treatment procedure in pilot scale
- Guidelines for composting procedure at a small practical scale
- Integrated studies regarding the demonstration actions
- Financial and Technical evaluation of the demonstration actions
- Integrated Strategy of actions, measures and means suitable for Mediterranean countries

Category B

- "Good practices for the agronomic use of olive mill wastes" (in English, in Greek, in Italian and in Spanish)
- "Strategies to improve and protect soil quality from the disposal of Olive Oil Mill Wastes in the Mediterranean region: Results and Achievements of a 4-year demonstration project – What to consider; What to do" (in English)
- "Integrated Strategy of actions, measures and means suitable for Mediterranean countries" (in English, in Greek, in Italian and in Spanish)
- Proceedings of the final Symposium entitled "Olive oil mill wastes and Environmental protection" 16-18 October 2012, Chania, Greece.

3. INTRODUCTION

This is the Final Report of the 4-years LIFE07 ENV/GR/000280 project "Strategies to improve and protect soil quality from the disposal of Olive Oil Mills Wastes in the Mediterranean"-PROSODOL and includes detailed information regarding all performed activities, results and achievements.

Five beneficiaries and three countries were involved in this project, which aimed to develop and demonstrate soil protection and monitoring methodologies, low cost wastes pretreatment methodologies, and to evaluate the reuse of Olive Mill Wastes in trees irrigation and fertilization. Several other deliverables were produced through the activities of the project, which were integrated in a proposed set of actions and measures suitable for the Mediterranean region.

The five beneficiaries provide in this report all data studied, developed and implemented at the two demonstrated areas, as well as all the dissemination material produced and distributed during the project.

An evaluation of the methodologies developed and implemented relative to the initial project objectives is provided that can assist the assessment of the project contribution to the OMW management problem.

Specific proposals for the effective and quick adoption of the PROSODOL results and recommendation are developed and discussed.

The beneficiaries acknowledge the LIFE support for the fulfillment of this project.

4. ADMINISTRATIVE PART

4.1. Description of the management system

4.1.1.Description of the working method

PROSODOL was divided into 20 actions, as shown in Diagram 1.

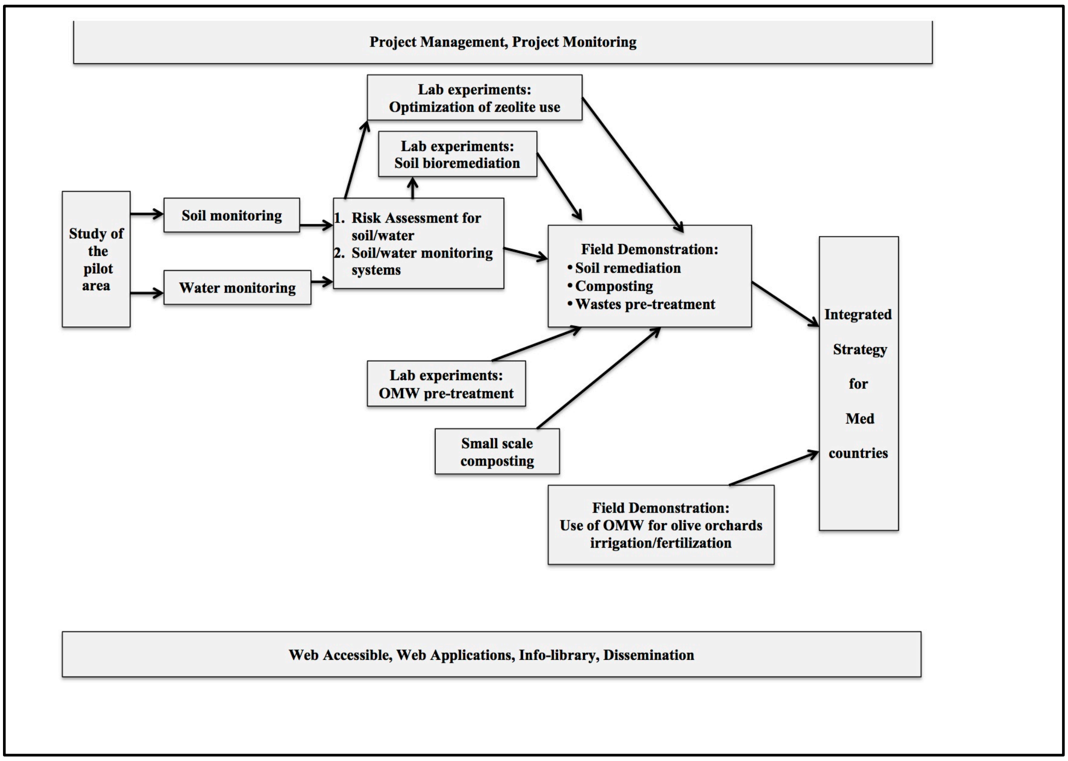


Diagram 1. Schematic presentation of PROSODOL working method.

In specific, the project included 2 management/monitoring actions, 1 action for collecting data of the pilot Municipality, 5 actions for the establishment of the web info-library, 2 soil/water monitoring actions, 3 lab/pilot actions during which all the demonstration activities were tested and optimized, 2 demonstration actions in Greece and in Italy, 1 action for the integration of all previous activities in a policy recommendation and 4 dissemination actions.

4.1.2. Beneficiaries and Project Manager

All the foreseen activities were carried out by five Beneficiaries:

1. SSIA (coordinating beneficiary) was responsible for the project management and monitoring as well as for performing all soil monitoring activities, developing/conforming/optimizing in lab/pilot scale the use of porous materials for soil improvement/remediation and the composting, implementing and demonstrating two soil remedial techniques at field scale, disseminating PROSODOL in Greece/Mediterranean and feeding the web inventory with data regarding soil and the effect of OMW.
2. TUC was responsible to collect representative data of the project area, to design and implement water monitoring activities, to develop, optimize and demonstrate an OMW pre-treatment methodology to be applied in small olive mills, to feed the web inventory with data regarding water and the adverse effects of OMW disposal and to develop the after-LIFE communication plan.
3. CEBAS was responsible to develop/optimize the bioremediation technique and give instructions on how the technique can be implemented at the pilot area, to disseminate

PROSODOL in Spain/Mediterranean and to feed the web inventory with data regarding OMW (i.e. properties, management, treatment).

4. CERSAA was responsible to develop an easy-low cost methodology for BOD/COD measurement, to study the effects of using OM wastewaters and OM husk for irrigation and fertilization, respectively of olive trees orchards, to develop a guide for the safe use of OMW in irrigation/fertilization, to disseminate PROSODOL in Italy/Mediterranean, to feed the web inventory with data regarding OMW and to organize and upload the data sent by the other beneficiaries.
5. IMS was responsible for constructing and maintenance of the PROSODOL web site, for uploading the GIS maps of the two pilot areas and for developing software tools for the continuous soil monitoring (for individuals and authorities).

The management structure of PROSODOL is seen in Diagram 2.

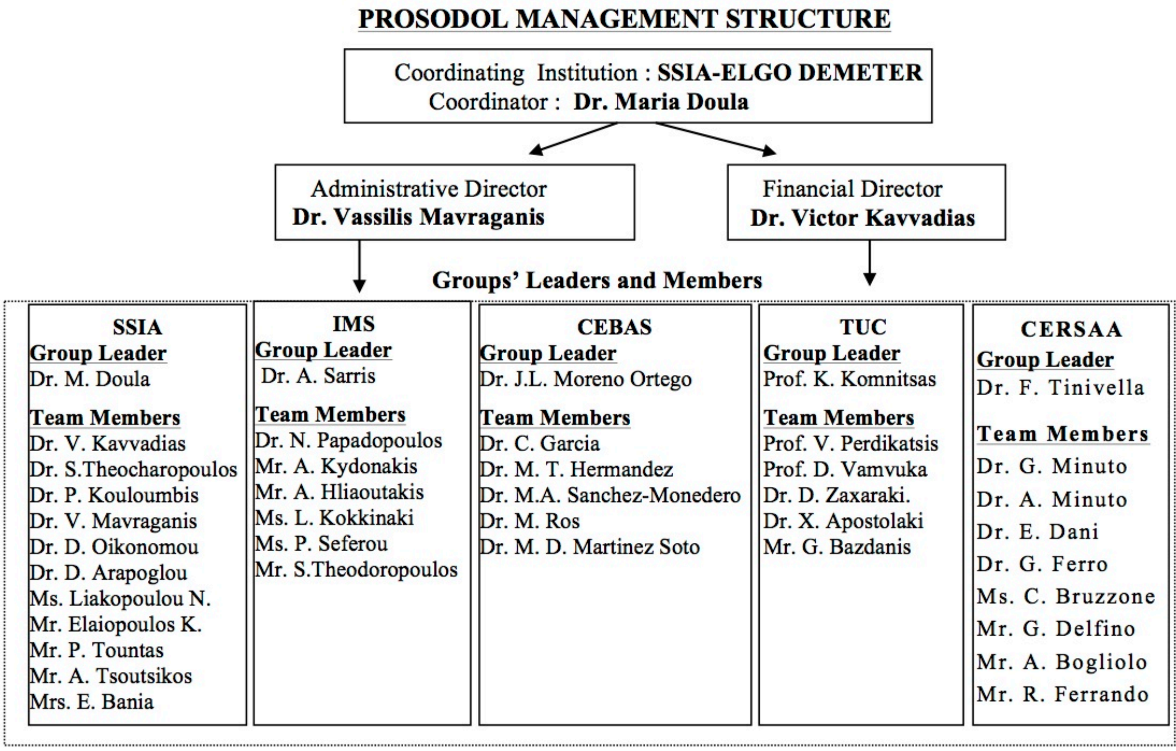


Diagram 2. Management structure of PROSODOL project

4.2. Evaluation of the management system

The management of the project was divided into five discrete stages, which were executed and evaluated during the entire life of the project ensuring that the project would be proceeded without problems and drawbacks. The assessment of the collected data was undertaken by the Coordinating Beneficiary, the coordinator herself, however always in close cooperation with the project's committees.

The five stages implemented and ensured the effective management of PROSODOL were:

1. Initiation

   The initiating processes determine the nature and scope of the project and for this the members of the Steering Committee defined them during the kick off meeting of the project. They also defined the monitoring mechanisms of the project in order to ensure the day-to-day control of the project. The committee's members discussed and decided also on procedures for project implementation, communication and cooperation, financial issues, they performed a stakeholder analysis, including users and also support personnel for the project, and they also defined the project character, including costs, tasks, deliverables and schedule.

2. Design
   After the initiation stage, the project was planned to an appropriate level of detail The main purpose was to plan time, cost and resources adequately to estimate the work needed and to effectively manage risk during project execution. This work was undertaken by the Management team of SSIA in cooperation with the Technical Committee of the project. This working group identified deliverables and created the work breakdown structure; identified the activities needed to complete those deliverables and networking the activities in their logical sequence; estimated the resource requirements for the activities; estimated time and cost for activities; developed the schedule and identified potential risks.
3. Implementation
   Implementation consisted of the processes used to complete the work defined in the project plan to accomplish the project's requirements. The implementation of the project was monitored regularly by the coordinating beneficiary, the technical and the dissemination committees and the team leader of the projects. Through six-months reports of the beneficiaries to the coordinator, any problem, difficulty or potential drawback was determined and corrective actions were taken.
4. Monitoring
   Monitoring consisted of those processes performed to observe project implementation in relation to the initial objectives so that potential problems to be identified in a timely manner and corrective action to be taken. The monitoring of the project was undertaken by SSIA in close cooperation with the Monitoring Committee of the project. The group by using the output indicators as they were defined in the Inception report of the project monitored the activities of the project in relation to the expected deliverables and outputs.
5. Closing

   The closing of the project included the formal acceptance of the produced outcomes and deliverables and it was undertaken by the coordinator and the members of the Steering Committee during the last meeting on 15 October 2012 in Crete.

The cooperation among the beneficiaries was very much satisfactory and fruitful, while meetings and communication via emails were often and effective. The coordinator and the management group of SSIA were in touch very often and meetings were held at least once a month. All-important decisions about the project were discussed in this group. All other beneficiaries followed the same procedure. Management materials were produced to assist Beneficiaries to their internal communication. The project group functioned as a dialogue group where progress, potential constraints and other relative issues were discussed.

Table 1: Meetings of the PROSODOL Committees

Meeting	Date	Location	Participants
Kick off meeting, 1st Steering Committee	23-24 February 2009	Athens, Greece	All Beneficiaries
Technical Committee	9 February 2010	Albenga, Italy	SSIA, CERSAA
Technical Committee	5 May 2009	Rethymnon, Greece	SSIA, TUC, IMS
Monitoring Committee	9 November 2009	Chania, Greece	All Beneficiaries
2nd Steering Committee	30 June 2010	Chania, Greece	All Beneficiaries
Technical Committee	1 July 2010	Chania, Greece	All Beneficiaries
Technical Committee	22 March 2011	Rethymnon, Greece	SSIA, TUC, IMS
3rd Steering Committee	17 May 2011	Chania, Greece	All Beneficiaries
Monitoring Committee	17 May 2011	Chania, Greece	All Beneficiaries
Dissemination Committee	17 May 2011	Chania, Greece	All Beneficiaries
4th Steering Committee	15 October 2012	Chania, Greece	All Beneficiaries

During the four years of the project, the beneficiaries focused on the effective project implementation and worked on project objectives. All project's objectives were fulfilled and significant results and achievements were obtained. Apart from the scientific added value of the project, it is also significant to highlight the communication of the project with the interested stakeholders, through the dissemination actions. The problem of OMW in Mediterranean is substantial and from this point of view the integrated strategy that is proposed by PROSODOL, which was derived from all its actions, can promote the sustainable management of OMW with simultaneous protection of soil and water bodies. The recommendations of PROSODOL, submitted with the most important of the deliverables, i.e. "Integrated Strategy of actions, measures and means suitable for Mediterranean countries" can by adopted by the EC and the national authorities, as it is a document that can be included in a legislative framework. Moreover, all actions demonstrated during the project (i.e. soil remediation, composting, use of OMW for irrigation/fertilization, pre-treatment of OMW at mill level) can be reproduced and implemented also in other olive oil productive countries since, apart from full description of the techniques included in the deliverables and the guides that were produced, a detailed technical-financial study was performed for all techniques and methodologies, that allows the extension of the proposed techniques from pilot to real level and also from local to national level. Benefits, requirements and restriction factors were very well described for all techniques.

The dissemination strategy was also effective and this is evidenced by public acceptance and recognition of the PROSODOL by European scientists and specifically by scientists from the Mediterranean area. Moreover, the participation of European and Mediterranean scientists in the 3-days Symposium of the project (end of 2012) was highly satisfactory. The publications of the project (for scientists and the wider society) received acceptance from the public as evidenced by web-site traffic, citation of the published scientific papers and the communication with the stakeholders.

The project has developed an After-LIFE Communication Plan that foresees the continuous dissemination and promotion of project's results. Moreover, the web site of the project will remain active and will be regularly updated by the beneficiaries. The most important issue that may affect the continuation of the PROSODOL results is the adoption of the proposed legislative recommendations. Apart from the national policy makers, who were informed by the beneficiaries, it is recommended that the EC would undertake an active role for the incorporation of the legislative recommendations into the EU legislative framework. This is very important in order to ensure sustainable disposal of OMW wastes.

5. TECHNICAL PART

5.1. Task by task-description

5.1.1. Action 2: Info-library establishment: Soil

The action aimed to feed the web-site of the project and to provide data for the following actions (e.g., soil monitoring action, pilot scale actions, integrated approach of measures and actions to be taken in the Mediterranean region, dissemination actions) during the entire duration of the project. Except for results presentation, the web-site was/is used as an info-library and for this reason information/data relative to the theme " Olive oil production in Mediterranean region" was collected.

SSIA was the responsible beneficiary of this action and collected data and information from national and other Mediterranean countries' sources; journal papers, technical reports, conference presentations in order to feed the info-library with data regarding soil types; olive oil mills' activities, places of activities, volume and type of wastes, disposal type, soil pollution extent, actions have been taken to reduce environmental impacts; methods of soil chemical analyses; soil monitoring systems, strategies developed and applied; soil remedial/protective methods that have been applied or can be potentially applied, results, benefits, required equipment and cost; composting technology, equipment and cost, economical data; national environmental legislative framework; information for organized events (seminars, conferences) in Greece but also in other European countries. The collected data was in English and in Greek. The English informative material was sent to CERSAA for organizing and uploading on the web site, while the Greek was uploaded on the web site by SSIA.

The following fields, which are seen as web pages were covered:

Soil: Quality standards

Soil: Soil sampling

Soil: Analytical Methods

Soil : Remediation

Soil : Legislation

SSIA contributed also in the creation of many other pages of the website, as mentioned.

<u>Evaluation</u>

Data collected and uploaded on the web site of the project were informative and attracted the interest of the visitors as it was recorded by the total visits of the site during the 4 years of the project.

5.1.2. Action 3: Info-library establishment: Water

In the line of Action 3, TUC collected data and information from books, journal papers, technical reports, conference presentations and other reliable sources. These data include among others: general information about surface- and groundwater and various environmental concerns associated with water; issues regarding water quality; analytical methods used to define the physical and chemical characteristics of water samples i.e. instrumental methods of analysis used in the laboratory or in field; water sampling programs and parameters to be considered (such as sample types, number and volume); legislation and common guidelines regarding drinking water quality (links to European Directives, Canadian thresholds etc are provided); assessment of risk for humans due to OMW application; inventory for OMW treatment technologies. TUC also significantly contributed to the collection of data to feed other website tabs such as news, conferences, links etc. Data have been collected in English (and also translated in Greek) and uploaded on the website of the project. These data were also useful for other actions such as pilot scale tests, integrated measures to be taken in the Mediterranean region and dissemination activities.

The following fields, which are seen as web pages were covered:

Water: Quality standards

Water: Water sampling

Water: Analytical methods
Water: Risk assessment
Water: Treatment-remediation
Water: Legislation

Evaluation
Data collected and uploaded on the web site of the project were informative and attracted the interest of the visitors as it was recorded by the total visits of the site during the 4 years of the project

5.1.3. Action 4: Info-library establishment: Waste

CEBAS has completed the info-library on the Web page of the PROSODOL project with information about olive mill wastes (OMW) management. CEBAS collected data regarding olive mill waste management in Spain from scientific papers, technical documents and Internet and sent to CERSAA according to the proposal plan. Collection of information was continuous and fell within the time schedule. After that, CEBAS collaborated to write the text of the different section and subsections of the info-library and upload in the Web Page of the Project. The English text of this part and another parts of the Info-Library were translated to Spanish in order to complete the Web Page in this language.
Inside this topic, CEBAS have described different points:

- Kinds of OMW;
- The OMW characteristics;
- Problems and environmental risk derived of these wastes;
- Method of treatment or valorization of OMW, and;
- Legislation

CEBAS contributed also in the creation of many other pages of the website.

Evaluation
Data collected and uploaded on the web site of the project were informative and attracted the interest of the visitors as it was recorded by the total visits of the site during the 4 years of the project. Moreover, the info-library contains a lot of different data, but still on the subject of the "Olive Oil production" in accordance with the targets set in the initial proposal, so, a reader can find a wide range of subjects.

5.1.4. Action 5: Info-library establishment: Data organizing

CERSAA has collected data for the establishment of the info-library. Scientific publications about OMW use/characteristics/management as well as legislative documents about different issues regarding soil, water, waste and waste management were mainly collected.
CERSAA collected data files sent by responsible beneficiaries of Actions 2,3,4 and 6 for the entire project duration and categorized and organized them by theme. Specifically CERSAA organized data according to the 3 different axes, which were previously identified: soil, water and waste management. Data sent mainly regard legislation about preservation and use of resources belonging to the compartments above mentioned and papers obtained by international reviews which deal with environmental issues about main outputs of research activities regarding soil and water bodies preservation, waste treatment, characteristics and use/disposal/treatment of OOMW, techniques for environmental monitoring, etc.
Other subjects considered for the set up of the info library were the following: olive oil mills' activities, places of activities, volume and type of wastes, disposal type, pollution extent of soil and water bodies, existing studies of regional pollution, actions have been taken to reduce environmental impacts; methods of soil/olive oil wastes chemical analyses; monitoring techniques to assess potential risks of olive oil mills' wastes, principally aimed at evaluating and quantifying the presence of vegetal oils, the level of BOD and COD; methods for OMWs treatment applied so far, or investigated and applied in pilot scale, benefits, composting technology, equipment and cost,

economical data; presentations from workshops and meetings; information of organized events (seminars, conferences) in Italy but also in other European countries.

On the whole the following contents of the info library were set up:

- Olive oil production in the Mediterranean area:
  - Overview
  - pages regarding: statistics about olive and olive oil production, surfaces, olive mills, extraction technologies,…
- Environment & olive oil production:
  - Overview
  - pages regarding: wastes produced by the olive processing, main properties of wastes, issues related to waste disposal, hazards related to waste disposal in the environment, relevant legislation
- Waste management:
  - Overview
  - pages regarding: waste treatment methods and technologies, relevant legislation
- Soil:
  - Overview
  - pages regarding: quality standards, soil sampling techniques, analytical methods used to define soil properties, remediation processes, relevant legislation
- Water:
  - Overview:
  - pages regarding: quality standards, water sampling techniques, analytical methods used to define water properties, risk assessment, remediation processes, relevant legislation
- Innovation

Evaluation

Data collected and uploaded on the web site of the project were informative and attracted the interest of the visitors as it was recorded by the total visits of the site during the 4 years of the project.

5.1.5. Action 6: Info-library establishment: Web site

The team of IMS-FORTH was the responsible beneficiary for Action 6. Under the specific action, the team of IMS-FORTH undertook the design and construction of the official Web site of the project (implemented in 4 languages: in English, in Greek, in Italian and in Spanish), which was enriched by various WEB_GIS applications. The site contributed to the dissemination of the results of the project, the establishment of a network among (and not only) the participating countries, the sharing of the information regarding olive oil disposal sites and the communication between the public and the participants. All the results of the project have been made available to the general public (Figure 1 of Annex 1).

Main outputs

To achieve the particular goals of the action, a number of info-libraries (Figure 2 of Annex 1) and available potential tools have been created and demonstrated. Info-libraries, in the form of databases or geo-databases (cartographic GIS layers), included results of the chemical analyses and magnetic susceptibility measurements carried out during a monitoring phase of pilot OMW sites (Figure 3 of Annex 1), geo-hydrological and other environmental maps and information regarding the topic of the project and related events (Figure 4 of Annex 1).

A specific tool was constructed for the incorporation of the results of the chemical analysis of the water and soil samples to the database of the Web Site of PROSODOL. The data contained various chemical variables for the several location areas, which were sampled. The variables were measured in different periods, while for soil samples, different depths were also considered. Upon the completion of the inventories of the chemical variables, the diagrammatic representation (on the fly) of the time variability of the chemical parameters has been achieved providing the user with the ability to interactively choose which variables he wants to examine and depending on this a small window where one can see the corresponding diagrams opens.

Upon the completion of the chemical parameters in the inventory, it was possible to proceed with the **multivariate statistical processing** of the data. In addition to the chemical parameters, magnetic susceptibility was measured in two frequencies using Bartington's 2B magnetic susceptibility sensor and measuring high, low and frequency dependent susceptibility in an effort to see the correlation of the magnetic properties of the soils with any heavy metals, iron content, a.o. as this is recently used for monitoring pollutants of the air and soils and thus one could also use this option for soil monitoring. Even though this action was not foreseen in the proposal, the beneficiaries considered that such an innovative approach should be conformed also to the OMW disposal areas, since it provides an option for rapid and accurate soil monitoring that can be included in any soil monitoring system. The multivariate statistics included Pearson's coefficients, Principal component analysis, a.o. (Figure 5 of Annex 1).

The Web site was also enhanced through the employment of **WEB_GIS applications** indicating the environmental maps, the sampling locations, the results of the chemical analysis, a.o., helping the visualization of them and making the site more attractive to the external visitors of the site. In order to achieve the specific goals, a number of maps were collected from various agencies and they were digitized according to their content. The result of the digitization process was imported to the GIS platform (ArcGIS 9.2.) – two main projects for each one of the regions under study (Greece and Italy). Apart from the sampling areas, three more thematic group layers were integrated to the GIS project: modern characteristics, land use elements and geomorphologic features. A total of 13 GIS services have been published and are shown as layers on top of the Google maps API (Figure 6 of Annex 1).

More specifically, modern characteristics included first level local administration units (OTA), villages and the road network comprising of main roads and dust roads. All the above were digitized from topographic maps of 1:5.000 scale produced by the Hellenic Military Geographical Service. Land use elements comprised of layers holding information in respect to the NATURA 2000 ecological network of protected areas, CORINE land cover as well as artificial vegetation, erosion, land region, soil depth, forestry capability codes and land use codes digitized from maps produced by the Greek Ministry of Agriculture. Geomorphologic features consisted of the Digital Elevation Model (DEM) and the Hillshade Model, created after processing elevation contours of 20m interval digitized from topographic maps of 1:5.000 scale, produced by the Hellenic Military Geographical Service, as well as rivers and mountains also digitized from the same maps. In addition to the group layers individual layers were also included to the GIS interface. Geological formations and faults were digitized from geological maps of 1:50.000 scale produced by the Institute of Geology and Mineral Exploration and thematic layers concerning hydrolithology, springs and hydrosprings, vectorized after hydrological maps of 1:100.000 scale could also be analysed. Moreover, the GIS project included cartographic data from Liguria region in Italy. Sample regions, urban areas, land use features and forestry types of the specific area, projected into ***Gauss-Boaga Roma 40 coordinate system,*** were collected by the Centro di Sperimentazione ed Assistenza Agricola and were subsequently integrated to the GIS application.

To insure compatibility all GIS services had to be published using WGS 1984 web Mercator projection. The maps were synthesized in two different GIS projects through the use of cashing and Google Maps API. Customization of each project was carried out for the labelling of the different layers as a function of the scale, the transparency degree of each layer, the hierarchical sequence of layers and the symbolism and colors that were used for the better visualization of the data.

All the cartographic layers were checked (and passed successfully) for **conformity to INSPIRE Directive**, based on a specific application (IMS/FORTH INSPIRE Geoportal) that was developed by the IMS-FORTH team (Figure 7 of Annex 1). The INSPIRE Geoportal provides the means to search for spatial data sets and spatial data services, and subject to access restrictions, view and download spatial data sets from the EU Member States within the framework of the INSPIRE Directive. In order to achieve this, the spatial data information of PROSODOL map document layers was added manually to the appropriate INSPIRE geo-database tables in order to fill in the information of the corresponding INSPIRE Maps layers. Map documents were created and saved based on the INSPIRE geo-database. With the assistance of the ArcGIS for INSPIRE Extension, the PROSODOL map documents were published not only as REST services but also as INSPRE View Services, having the service capabilities document freely available to the public (INSPIRE Conformity). Finally, the INSPIRE Metadata for each of these services were created with the assistance of the INSPIRE Metadata Editor of the IMS/FORTH INSPIRE Geoportal. The Metadata for each service of the IMS/FORTH INSPIRE Geoportal has been validated with the online Metadata Validator of the European Commission, as a proof of the conformance of the Metadata with the INSPIRE Directive. It has to be mentioned that the IMS/FORTH INSPIRE Geoportal is accessible from the PROSODOL's website. All interactive and thematic GIS maps are active and available to the public and in each one of them specific guidelines for their usage are provided in the corresponding Web page.

A number of tools have been also developed. These consisted of **tools for internal use**, e.g. the incorporation of the results of the chemical analysis to the database of the Web site, or external tools that can help in the monitoring of the chemical of geophysical parameters related to the OMW. The particular monitoring tools can enhance the control of targeted areas as well as, others with similar activities, by monitoring several basic chemical parameters, which will reflect the wastes' disposal activity of the areas. A user, even a public or a private service, needs to monitor measurement results of targeted areas in order to evaluate the degree of risk in the vicinity of the waste disposal areas.

The monitoring tools include:

1) **A handy Monitoring System Tool** to monitor measurement results of targeted areas in order to evaluate the degree of risk in the vicinity of the waste disposal areas,
2) **A Surface Analysis Tool** to be used for mapping the possible surface diffusion of the chemical parameters in the vicinity of the waste disposal areas,
3) **Time Lapsed Electrical Resistivity Tomography measurements (TL-ERT)** for monitoring the changes of the physical characteristics of the subsoil over time and identify the deeper diffusion of the contaminants,
4) **A GIS based tool for the Risk Assessment of the Sitting of OMW Disposal Areas.**

All of these techniques were demonstrated in the Web site of PROSODOL and the first one was made freely available to the wider public for installation. The other techniques were given with explicit clarifications and directions of how an external user can materialize them, but due to the very specialized character of them (from the side of instrumentation and software) it was not possible to provide them in the form of a "handy" downloadable tool. Explanations for the use of each monitoring tool were given in detail and were described in the Web site (as well as in this Final Report).

The design process of the **Monitoring System Application Tool** consisted of three basic principles:

1. Need to specify the most important chemical parameters for evaluating the degree of risk of the waste disposal areas
2. Need to specify the limits and range of risk zones (range of values), such as the red and the orange risk zones.

3. Design an interface that satisfies specific user needs, such as inserting, editing, searching functionalities of waste disposal areas measurements, as well as graphically presenting the risk assessment results (Figure 8 of Annex 1).

The whole application was designed and implemented with the Microsoft Visual Studio (2010) software, enhanced with the capability of monitoring one or even more measurements on different waste disposal areas, capable of use for a larger scale services, than private use only (backing up and restoring measurements data via XML). A sum of eleven chemical parameters were finally selected. The limits and the values range of the risk zones (red – high risk, orange – moderate risk) were based on specific international references and were defined in cooperation with SSIA. A user in order to evaluate the degree of risk in the vicinity of a waste disposal area needs to insert values to some or all of the above chemical parameters, and evaluate graphically afterwards the results upon a XY point diagram, where the red and orange risk zones are also presented.

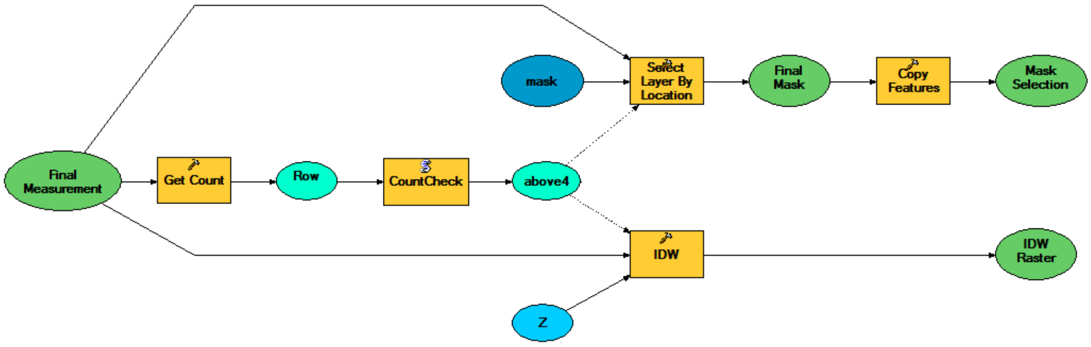
There are two ways which the user may view graphically the inserted measurements (Figure 9 of Annex 1). The first one is provided by the system by clicking on the Graph button in the main screen, and then choose the desired Chemical parameter (ex. Graph -> Electrical Conductivity submenu, Graph -> Total Phenols submenu), and the system will visualize in a tab the selected chemical parameter values of all the stored measurements. The second way is through modification of the search functionality and search results may be visualized in a graph if the user selects the preferred chemical parameter and click the Visualize Results button. The Monitoring system tool application has an extra functionality of exporting measurements in Excel File format.
The application has been implemented in four languages, English, Greek, Italian and Spanish and it is available for download (and subsequent installation) from the Web site of PROSODOL.

The Surface Analysis Tool was also developed as a tool for monitoring the surface distribution of chemical parameters. The creation of surfaces that indicate the distribution of different chemical parameters in targeted disposal areas well as, others with similar activities, in order to obtain an idea of the possible diffusion of the chemical parameters and the degree of risk in the vicinity of the waste disposal areas is the goal of this process. We need to map those variables (chemical parameters) with respect to the depth (and date) and study the temporal variations of their spatial distribution and the diffusion of them in the subsurface. The Inverse Distance Weighted (IDW) interpolation method has been found (among other similar methods) to produce the most satisfying results, and that is the method we used for the interpolation process. IDW calculates cell values by averaging the values of sampling points in the vicinity of each cell based on distance.

$$z_j = k_j \sum_{i=1}^{n} \frac{1}{d_{ij}^{\alpha}} z_i$$

The entire interpolation process results were implemented into a Map API such as Google API, or Google Earth API, and flash maps techniques (Flash Builder software), so that a user can view the interpolated surface area images simultaneously above a topographic/satellite map provided by those APIs. After consideration of the time based functionality, which a user can view the chemical parameters diffusion in a subsurface over time, testing and using several of the above techniques, Google Earth API was the most appropriate to use, which handles this possibility by integrating time tagged images via EXtensible Markup Language (XML), a language designed to transport and store information data. ArcGIS Desktop was employed for creating the interpolated surface maps using the ArcGIS ModelBuilder Tool. ModelBuilder is an application in which you create, edit, and manage models. The way to build a model is by building and connecting processes. A process is simply a tool plus its variables. A variable is either a data variable that references our data (layers, shape files of measurements information), or a value variable, which is anything else, such as numbers and text strings. Variables are connected to tool parameters. The ArcToolbox provides all the necessary tools that our model needs.

Several tools (processes) were needed to be performed in order to achieve the expected result. The first step for the whole interpolation process is to define the date and depth of a measurement for the interpolated output map file. So, the first tool that has to take place is a Selection tool, which selects the date, depth and the variable (chemical parameter) from the input measurements shape file. The next step is where the interpolation process takes place. The interpolation of a surface, ie. the diffusion of a chemical parameter in an area, has no meaning above a distance from the measurement points. For this reason we need a Mask in order to determine the interpolated area bounds. Since the interpolated surfaces can only be interpolated for more than 4 known values (points), we need to check the Final measurements number with the Get Count tool, and only if the result is above 4 measurements for a targeted area, then the interpolation takes place with the IDW tool, providing the corresponding chemical parameter and area limits, and simultaneously selecting the corresponding mask areas (polygons), intersecting measurement (point) locations. Knowing the minimum and maximum variable limits, the red value shows a high risk area of the certain chemical parameter while the blue one a low risk.



The final layer, the interpolated, masked, symbol applied layer, were saved in order to provide it as an input to the **Layer to KML** tool, which constructs our final KML file, an XML format file suitable for the Google Earth API application. Depending on the date and depth of the measurements, in every loop, a set of 28 KML files are constructed by the Model. At the end those files need to be merged by parameter, denoting for each file the date/depth inside the merged KML file. In the next final section we are going to describe the Google Earth API application (web based) implementation and usage, depending on those KML derived files. The Google Earth API it is a JavaScript API which let us embed Google Earth, a 3D digital globe, into PROSODOL Web site. Using the API we can load KML files, allowing us to build a 3D map application. The reason we use this API is because of the time plug-in, where time information contained to the derived KML files (as a feature) of the Model previously described, can be introduced to the plug-in and attached as a map view. The implementation of the map application is quite straightforward; no need to get in details at this point, and it was handled with JavaScript over PHP pages of the PROSODOL web site. By selecting the user-defined measurement (chemical parameter in fact), measurement's depth, and submitting the information to the application, the corresponding interpolated surface map is loaded. The 3D map application was designed in such a way, where the end user can easily and effectively use, and retrieve the surface interpolated information needed (Figure 10 of Annex 1).

Time Lapsed Electrical Resistivity Tomography measurements (TL-ERT) have been also explored as a Tool for monitoring the changes of the physical characteristics of the subsoil over time and identify the deeper diffusion of the contaminants. The OMW are usually disposed in evaporation ponds which are rarely of proper size and wastewaters often overflow affecting neighboring systems (soil, surface and groundwater) and other professional activities of the residents (agriculture, livestock farming). The base of the ponds is permeable and thus, the probability for groundwater and deep soil contamination is high. Consequently long-term disposal of waste, without necessary monitoring and protective measures, may cause changes in the physicochemical parameters of the surrounding ecosystems, with the risk of future non-tissue degradation of the environment. Moreover, older waste sites often lack reliable geological or artificial barriers and depositional information, to minimize the possibilities of further environmental damages. The problem of environmental degradation and waste management are of major concern of earth scientists and the local authorities.

Geophysical methodologies in terms of Electrical Resistivity Tomography (ERT) can be used for monitoring the changes of the physical characteristics of the subsoil over time and identify the diffusion of the contaminants. An ERT monitoring experiment was conducted for the first time in an OMW disposal site located in the pilot area of the project in Crete and it was proved that this technique is also suitable for OMW disposal areas. The purpose was to validate the resolvable capabilities of the method in capturing the spatial-temporal pollution caused by the low conductivity material of phenolic compounds. The ERT monitoring experiment focused on the pilot area where two evaporation ponds, a larger one at the west and a smaller at the east, were existed. The ERT field data were gathered from flat area of almost $70m^2$ at the east of the larger pond. One of the drill holes that were opened for the purposes of Action 9 by TUC, which was located close to the larger evaporation pond, was used for the validation/demonstration. A plastic piezometer was installed inside the borehole that reached the depth of 16 meters from the ground surface. A custom made multi-clone cable was manufactured which could drive simultaneously up to 48 outputs. The cable was attached on the outer surface of the plastic piezometer gradually during its installation in the borehole. The cable outputs were placed on the plastic tube every 0.4m, the lead leaf covered each outputs by surrounding the tube. Totally 36 electrodes were placed inside the borehole starting from the depth of 2m and the reaching the bottom of the borehole ((Figure 11 of Annex 1).

The ERT monitoring measurements were made in terms of surface-to-borehole mode. A dipole-dipole and gradient array configurations were employed to capture the surface, borehole and surface-to-borehole apparent resistivity measurements (Figure 12 of Annex 1). The gradient data were measured in a forward and reverse mode to evaluate and assess the noise level of the measurements. The time lapse resistivity data from totally 5 monitoring phases were collected from January 2011 until April of the same year. Each phase of the ERT monitoring data were processed individually with a standard inversion algorithm that could account for the surface-to-borehole field-measuring mode. Similar parameters were used in the inversion of the data where the program converged to a resistivity model after 5-7 iterations and RMS less than 4%. In general, the reconstructed models of all the phases and the two vertical directions showed comparable results. A thin surface high resistivity layer (~20cm/backfill material) is overlain a more conductive layer (clay and marl) and a deeper resistance layer (clay with sand). The image inside the borehole shows generally a conductive material. In order to have a better insight regarding the time-lapse variation of the subsurface resistivity, difference images were extracted between the first phase (reference phase) and the remaining ones. The most promising area that could be attributed to the movement of OMW is registered as a significant decrease (~30%) in resistivity values in the second and third phase.

In order to proceed with the quantification of the ERT results, the work went a step forward. The aim was to find correlation functions between the resistivity values extracted by the ERT monitoring and the synchronization of the ERT monitoring experiments with the soil filed samples would enhance the validity of the extracted correlation functions. The average resistivity extracted by the ERT sections was plotted against the measurements of the chemical analyses regarding pH, Zn, COD, Mn, Phenols and K. A linear trend line was adjusted in each graph correlating in this way the resistivity with the variation of the different chemical elements. It was, thus, clear that the resistivity exhibits positive linear correlation with COD and Mn, while pH and Zn are inversely proportional to resistivity. On the contrary phenols and K do not show any significant correlation with the resistivity.

Geophysical methods in terms of Electrical Resistivity Tomography can be applied in OMW sites to survey larger areas with respect to the point information retrieved by soil/water sampling and subsequent chemical analyses. The obtained results signify that the bulk resistivity reconstructed by ERT monitoring experiments show a correlation with specific chemical elements, which could be further used to monitor OMW disposal areas by this innovative and rapid method. . In this sense ERT could be used as a modern alternative tool in the original stage of monitoring and mapping the environmental pollution in OMW areas providing solutions to address such environmental problems, by projecting the variation of specific chemical elements through the measurement of subsurface resistivity.

Finally, a GIS based tool for the Risk Assessment of the Sitting of OMW Disposal Areas has been developed. The geological, hydrological and land use features in the vicinity of all OMW disposal sites of one of the three main areas of interest (prefecture of Rethymno, Crete, Greece) formed the spatial background information provided by the PROSODOL project to be used for evaluating the local risk imposed by the location of the particular facilities. In order to assess the appropriateness of the location of these facilities, two of the most used approaches to solve multicriteria problems, such as risk assessment analysis and suitability modelling, the Weighted Sum Model (WSM) and the Analytic Hierarchy Process (AHP) methods were applied in the wider area of the municipality of Nikiforos Fokas in Crete, covering actually the prefecture of Rethymno. GIS has been extensively used in applications related to environmental risk assessment. A web based map application tool was also implemented for evaluating the location suitability of the olive oil production facilities and further the waste disposal areas depending on several anthropogenic (residential areas, road network), environmental (slope, archaeological sites, lake and rivers area, Natura areas, landuse-Corine) and geological (hydrolithology, geology, faults) criteria-factors. Different scenarios were tested by weighting accordingly all these features giving evaluation suitability maps for the above risk assessment modelling techniques (Figure 13 of Annex 1).

Several studies have been focused on solving multicriteria problems that focus on risk assessment analysis and suitability modelling, such as the suitability assessment model for construction of Municipal Solid Waste (MSW) landfills by using multicriteria evaluation techniques such as the AHP method, enhanced with fuzzy factor standardization, or the risk assessment model for archaeological sites in Crete, by applying fuzzy logic and neural networks or by using multivariate statistical analysis by defining different weighting schemes. In multi-criteria problems such as suitability or risk assessment modeling, one must define the problem, break the model into sub-models, and identify the appropriate input data. Since the input criteria data (which are actually in most cases raster layers) will be in different numbering systems with different ranges, to combine them in a single analysis, each cell for each criterion must be reclassified into a common preference scale such as 1 to 10, with 10 being the most favorable. An assigned preference on the common scale indicates the relative confidence that we have in the influence of a criterion compared to another. The preference values are on a relative scale.

The preference or suitability values not only should be assigned relative to each other within the respective criterion layer but should have the same meaning between other criteria layers. On the other hand each of the criteria in risk assessment analysis may not be equal in importance. Depending on the technique used, like the Weighted Sum Model or the Analytic Hierarchy Process method, various weighting schemes are introduced and different suitability location areas are exposed in the final web map application. ArcGIS Desktop was selected for creating the risk assessment maps using the ArcGIS ModelBuilder Tool.

Thirteen criteria were gathered and selected for the area of interest. Three of them compose the anthropocentric main factor, seven of them compose the environmental factor and the rest compose the geological main factor in the underlying model. So, there are three main groups of criteria, and thirteen extended sub-criteria to take into account. The final process that need to be done for estimating the risk of OMW disposal areas in respect with the three main criteria, anthropogenic, environmental and geological (or thirteen sub-criteria), takes place in the tool (coded in Python), the red square shown at the figure above, where two different approaches for the multi-criteria analysis may take place, the Weighted Sum Model (WSM) or the Analytic Hierarchy Process (AHP) method.

A user may define the desire percentage of importance for each factor or sub-criteria, while the above approaches give the user the ability to decide the analysis process. According to the method the user chooses, different risk assessment result maps may be emerged.

Seven scenarios were created both for the WSM and AHP method in order to determine the risk assessment for the OMW disposal areas in terms of the various components of the anthropogenic, environmental, and geological criteria and moreover to fill the bulk of the diversity of the importance of these various criteria. Specific maps were created for each one of the scenarios (Figure 14 of Annex 1).

- *Scenario 1* – For the WSM this scenario is based only on the anthropogenic aspect of the risk assessment analysis. The importance is given only on anthropogenic sub-criteria (100%) while the rest are not taken into account (0%). As for the AHP the anthropogenic criteria are more important (biggest priority) than the environmental and geological criteria, while the environmental criteria are also more important than the geological ones.
- *Scenario 2* – For the WSM only on the environmental aspect of the risk assessment analysis is taken into account. The importance is given only on environmental sub-criteria (100%) while the rest are not taken into account (0%). As for the AHP the anthropogenic criteria are more important (biggest priority) than the environmental and geological criteria, while the geological criteria are more important than the environmental ones.
- *Scenario 3* – For the WSM this scenario is based only on the geological aspect of the risk assessment analysis. The importance is given only on geological sub-criteria (100%) while the rest are not taken into account (0%). As for the AHP the environmental criteria are more important (biggest priority) than the anthropogenic and geological criteria, while the anthropogenic criteria are more important than the geological ones.
- *Scenario 4* – For the WSM the importance is given in all factors and sub-criteria (100%) which actually are normalized to have an equal weight of importance. As for the AHP the environmental criteria are more important (biggest priority) than the anthropogenic and geological criteria, while the anthropogenic criteria are less important than the geological ones this time.
- *Scenario 5* – For the WSM this scenario has given an advance in importance on the anthropogenic aspect of the risk assessment analysis (50%) while the rest are sharing the rest percentage (25% and 25%). As for the AHP the geological criteria are more important (biggest priority) than the anthropogenic and geological criteria, while the anthropogenic criteria are more important than the environmental ones.
- *Scenario 6* – For the WSM this scenario has given an advance in importance on the environmental aspect of the risk assessment analysis (50%) while the rest are sharing the rest percentage (25%/25%). As for the AHP the geological criteria are more important (biggest priority) than the anthropogenic and geological criteria, while the anthropogenic criteria are less important than the environmental ones this time.
- *Scenario 7* – For the WSM the importance is given in all three main factors (100%) which actually are normalized to have an equal weight of importance, but this time giving an importance in residential area criterion a 70%, and a 30% for the road network criteria. In the environmental aspect of the criteria, full importance is given to slope, aquifers and coastline, while medium importance on the rest environmental sub-criteria. For the geological aspect of the analysis only the hydrolithology sub-criterion was given an importance of 80% having the rest sub-criteria sharing the remainder percentage. As for the AHP the environmental criteria are more important (biggest priority) than the geological, the geological criteria are more important than the anthropogenic, while the anthropogenic criteria are more important than the environmental ones, giving in such a way a balanced importance to all main factors.

Below, in Table 2, the suitability of the known OMW disposal areas locations (locations with suitability value < 5), according to the seven mentioned scenarios for each of the two decision-making approaches, is shown.

Table 2. Suitability of the known OMW disposal areas locations (locations with suitability value<5), according to the seven mentioned scenarios.

	Scenario1	Scenario2	Scenario3	Scenario4	Scenario5	Scenario6	Scenario7
WSM	**21%**	**100%**	**100%**	**92%**	**71%**	**98%**	**73%**
AHP	**22%**	**97%**	**95%**	**97%**	**85%**	**87%**	**73%**

Using the Google Maps API we can load KML files, allowing us to build a 3D map application (Figure 15 of Annex 1). The implementation of the map application was handled with JavaScript over PHP pages of the PROSODOL web site. By selecting the user-defined method (WSM or AHP), the modeling scenario, and submitting the information to the application, the corresponding risk assessment map is loaded.

This tool, although not foreseen in the proposal, is considered as highly significant and can provide authorities, i.e. local and national, with a powerful decision making tool that would enhance the definition of the areas that could be appropriate for OMW disposal, however according to the criteria set and the priorities of each territory. This tool should be used in combination with the soil monitoring system developed during Action 8 and specifically, as the initially stage of potential disposal areas' evaluation and selection.

<u>Evaluation</u>

With respect to the planned output, Action 6 has been completed complied with the expected results and deliverables of the project as mentioned in the initial proposal. Among the deliverables the following were included:

- The Web site of the project
- Inventory for the Greek Pilot area consisting of a rich geodatabase of the various environmental maps of the pilot area and the results of the measurements of the chemical analyses on the soil and water samples.
- Inventory of the Italian pilot area with the corresponding geodatabases
- WEB_GIS module for interactive construction of thematic maps in areas where olive oil mills are located
- A number of Info-libraries regarding the results of the chemical analyses and all the rest of the data that were collected during the implementation of the project.
- Announcements in International and National Conferences and relevant publications in scientific journals
- Provision of external tools that can help in the monitoring of the chemical of geophysical parameters related to the OMW.

IMS delivered all the above applications as web applications, which are freely available from the WEB site of the program:

a) all the created several web-based tools,

  - Interactive maps (http://www.prosodol.gr/?q=node/357)
  - Monitoring System tool (http://www.prosodol.gr/?q=node/3455)
  - INSPIRE Conformity (http://www.prosodol.gr/?q=node/3479)
  - Risk Assessment (http://www.prosodol.gr/?q=node/4170)

b) the Monitoring tool report v 1.0 (http://www.prosodol.gr/downloads/Monitoring%20System%20Tool%20Report%20v1.0%5BEN%5D.pdf)

c) a report on the methodology and results of the electric tomography and magnetic susceptibility measurements with clear explanations on their relevance for project implementation (http://www.prosodol.gr/downloads/ERT_Monitoring_Report.pdf),
d) Surface Interpolation (http://www.prosodol.gr/?q=node/3445) as well as information on the construction and use of the monitoring tool's interpolation surfaces (http://www.prosodol.gr/downloads/Surface%20Interpolation%20Report%20v1.0.pdf).

5.1.6. Action 7: Data collection, preliminary study of the area

This Action is one of the three (Actions 7-9), which aimed to collect representative data of the project area in Crete and to develop monitoring systems for soil/water quality.

Main outputs

The preliminary study of the project area (today Municipality of Rethymno, former Municipality of Nikiforos Fokas) was completed between January and March 2009. Collection and evaluation of all available data regarding population and local activities of the target area, number, characteristics and activities of the olive oil mills, hydro-, geomorphological and local meteorological data, initial assessment of environmental impacts caused by the disposal of OMW and identification of neighbouring systems, were carried out. Static maps were collected and uploaded on the website (http://www.prosodol.gr/?q=node/13).

An integrated water sampling strategy, suitable for the entire Mediterranean region has been completed in the line of Action 9, to allow reliable assessment of impacts and define appropriate actions to improve and protect soil and water quality from the disposal of OMW. Full assessment of soil, surface and groundwater risk was completed by the end of the project.

A risk analysis was carried out by using the "source of pollution-pollutant pathway-target (pollution receptor)" principle. Geostatistics was used for the assessment of risk while 3D maps allow the visualization of the range of selected parameters determined in soils and waters in the wider affected area.

Evaluation

Action 7 has been successfully completed during the first three months of the project, by collecting and evaluating all available data/information in the project area. The data collected have been used in other Actions of the project such as development of monitoring systems for soil and water quality and assessment of environmental impacts due to OMW uncontrolled disposal.

All the aforementioned results and outputs were included in one final report and one deliverable of the action:

1. "Report for the preliminary study of the pilot municipality in Crete" including also a preliminary assessment of risk at study area.
2. Deliverable "Risk map of the pilot municipality in Crete".

5.1.7. Action 8: Design and implementation of a monitoring system for soil quality at pilot municipality

In order to fulfil the aims of the action, SSIA developed a well-designed soil monitoring study. All the performed activities aimed to deliver:

- A risk assessment of the pilot area (former Municipality of Nikiforos Fokas, Rethymnon, Crete) regarding soil quality and generalization of the assessment to cover also other disposal areas in Med area.
- A statistical processing and evaluation of the soil chemical analyses in order to identify a set of appropriate soil indicators, specific for OMW disposal areas
- A soil monitoring system that can be used by local/regional/national authorities and by individuals (e.g. mill owners).

A carefully designed - based on the land characteristics of the area - monitoring system was implemented at the pilot Municipality, to monitor the quality of soil at olive mills' wastes disposal areas. The monitoring system foresaw the collection of soil samples at various depths from a) disposal ponds/lagoons b) close and around to disposal ponds and mostly from the down slope side of the ponds c) downstream of the disposal ponds where extensive leaching due to surface and subsurface water movement is likely to occur. Soil samples were collected periodically (every two months), categorized relative to soil classification method and analysed for: electrical conductivity, pH, water saturation, total salts, texture, $CaCO_3$, active $CaCO_3$, organic matter, nitrogen, available phosphorous, cation exchange capacity, exchangeable K, exchangeable Ca, exchangeable Mg, exchangeable Na, water soluble Na, available Fe, available Mn, available Cu, available Zn, total polyphenols, available Boron, water soluble anions: Cl^-. NH_4^+, SO_4^{2-}, PO_4^{3-}, NO_3^-, total heavy metals (Cd, Pb, Ni, Cr, Mo), microbial activity and pathogens content.

Six soil sampling campaigns took place until the action completion:

- 1st sampling between 5-7 May 2009
- 2nd sampling between 6-9 July 2009,
- 3rd sampling between 28 September-2 October 2009
- 4th sampling between 14 and 18 December.
- 5th sampling between 1-5 March 2010, and
- 6th sampling between 17-21 May 2010.

For this, five sites representing different disposal cases were studied. The soil data over the six sampling campaigns from the monitoring sites were presented:

- control soils (CS) namely representative soil of the area located in a distance from the waste disposal ponds;
- pond soils of all active sites (PS). All evaporation ponds were constructed by using native soil and simple engineering, while no impermeable membranes or other protective media were used. The ponds are in operation for more than 11 years
- active sites with surface disposal of OMW (ACTDS). Three active sites were monitored which are in operation for more than 11 years : ACTDS-1; ACTDS-2; ACTDS-3.

  ACTS-1 is a typical disposal site located in a field with almost 10% slope; pond dimensions are 50m×10m×10 m. ACTS-2 represents a different case; the pond (21m×8m×1.70m) was constructed by using native soil material excavated from the top of an adjacent hill. ACTDS-3 is a large field (1 ha) with almost 5% slope and contains two evaporation ponds with dimensions 32m×4.20m×1.70m and of 30m x 44m x 1.75 m, respectively. Direct disposal of OMW on soil takes place at ACTDS-3 every 2–3 days between May and September each year
- pond soils in inactive sites (INACTS). Two inactive sites were monitored: INACTS-4; INACTS-5 which, have been used for the disposal of OMW for 20 years but for the last 8 years are inactive. The dimensions of the inactive ponds at INACTS-4 site are 24m x17m x1.75 m. and at INACTS-5 site are 28m x 6m x 1.30m
- river site **(**RS) located at the downstream of the active site with surface disposal of OMW. Soil samples along the river banks were collected and analyzed in order to assess potential of water pollution and nutrient losses pollution, from soils of the upper hill slopes, through runoff or downward leaching.

Olive Mills Wastes (OMW) were collected from the three mills of the area (three-phase) and analyzed for pH; electrical conductivity; total organic carbon; BOD; COD; total Kjeldahl N; NH_4^+; total phenols; Mg; Ca; total P; total K; Na; Cl^-; NO_3^-; SO_4^{2-}; PO_4^{3-}; Cu; Fe; Zn; Mn; Ni; Cr; Mo.
During the six sampling campaigns, 505 soil samples and 5 wastes samples (one from each disposal area) were collected, while 16,120 analyses were conducted.

One more sampling campaign was performed in June 2011 in areas close and far from the pilot Municipality in order to (1) confirm the evaluation results as far as the risk potential of the OMW disposal areas, and (2) identify potential Ni and Cr pollution of soils due to OMW uncontrolled disposal, issue that arose during the main soil campaign.
Moreover, eleven drillings were performed (six from SSIA and 5 by TUC) in order to assess the possibility of pollutants transfer to deeper soil horizons as well as, which of the soil parameters are most likely to be affected in higher depth. Piezometers were installed by TUC in 5 drillholes to monitor pore water quality.

Apart from the soil monitoring implemented at the pilot area and in order to assess the effect of uncontrolled disposal of OMW on soil and the risk for ground water contamination, more soil types were studied in laboratory. For this, eight different soil types, representative of Med area, were amended with raw OMW and changes in leachates properties were recorded.

Main outputs

Regarding the potential risk of the OMW disposal areas, it was concluded that the long-term application of OMW on soil or in evaporation ponds has the potential to induce soil or groundwater contamination while the risk for soils at OMW disposal and neighboring areas is considered high since a number of soil parameters exceed normal, high or toxic thresholds. Considering the obtained results and after statistical evaluation, the following main soil properties are considered to be mainly affected by the disposal activity and should be continuously monitored: electrical conductivity, pH, organic matter, total polyphenols, total nitrogen, available phosphorous, exchangeable potassium and magnesium, available boron, available iron and available copper. However, not all of these soil parameters are appropriate to be used as soil indicators. Thus, after studying and statistically evaluating the results of the chemical analyses, it was concluded that among these parameters, eight are appropriate to be used as soil indicators. These are: electrical conductivity, organic matter, total polyphenols, total nitrogen, available phosphorous, exchangeable potassium, available iron and pH.

Considering the results from the drillings, it was concluded that the risk for ground soil degradation/contamination as well as for contamination transportation due to uncontrolled disposal of OMW is high especially for soils poor in clay and when the substrate characteristics enhance wastes downward movement (e.g. soft fragmented limestone). Although the obtained results are specific for the disposal areas of the PROSODOL project, yet, they are indicative and descriptive of the degradation/contamination risk that may be caused due to wastes disposal. It should be highlighted that for deeper soil horizons the soil parameters that were found to be mainly affected were electrical conductivity; total inorganic salts; polyphenols; available Fe; exchangeable Mg; and available B. If the substrate enhances downward movement, then organic matter, total nitrogen and available Zn are very likely to move to higher depths. On the contrary to the results of the surface soil, for deeper soil layers the exchangeable K, the available Cu and Mn, and the available P were measured in low concentrations for all areas under study.

Finally, the experimentations performed regarding the effect of soil texture on the extent of degradation due to OMW disposal, it was revealed that soil texture is a significant factor that may inhibit or enhance soil degradation. Thus, it was found that the pH of soil leachates is generally decreased after the addition of the wastes while the impact of wastes on leachates' pH is substantial for soils with high sand content (i.e. Loamy Sandy and Sandy). As regards the electrical conductivity, the wastes disposal cause increase in the EC of the leachates produced by all soil types. The capability to retain polyphenols and K is reduced following the order from fine textured soils to coarse textured soils. Despite that, it was observed that all soil types retained phenols and leached only a small part of the initially added amount. Regarding the leaching of Mg and Ca it was found that is higher for soils reach in Mg and Ca, while the extracting tendency of Ca and Mg does not seem to be affected by soil texture, except maybe for the case of sandy soils. All soil types released big part of the Cl^- concentration added with the OMW while, simultaneously retained almost the 1/4 of the added Cl^- amount. Phosphates concentration is also significantly affected by the addition of wastes. Soils with high sand content released lower concentrations of the anions. As regards sulfate ions, it was found that all soil types released almost the entire added amount after waste addition. Ni was found in extracts in relative high concentrations although the added Ni amount (with the OMW) was negligible due to the dissolution of soil Ni caused from the acid OMW. Other metals, such as Fe, Mn, Cu and Zn were also measured in all extracts, but their concentrations were negligible.

Regarding metals and by integrating the collected data, there is an elevated risk due to the OMW acidity, which may cause the dissolution of naturally occurring metals. The risk becomes higher due to the overloading of soils with Fe, Cu, Zn and Mn added to soils as OMW constituents. As far as Ni, Cr and Mo are concerned; if their background concentrations are high then there is a substantial risk of dilution and thus polluting deeper horizons and groundwater. The risk is considered higher for soils with low carbonate content, low pH and poor in clay. <u>An additional risk for Ni, Cr and Mo pollution should be anticipated in case of old mills equipment, since these recalcitrant metals could be produced from the corrosion of inferior quality steel equipment, which is used for olive processing.</u>

Considering all the above, SSIA developed a soil monitoring system, which, briefly includes the followings:

- An optimized set of soil quality indicators
- Threshold values for soil quality indicators
- A GIS based tool for the Risk Assessment of the Sitting of OMW Disposal Areas
- A system that enhances decision making regarding the suitability of soil for OMW disposal/application (i.e. a land application system) to ensure safe disposal/use/application of OMW on soil in the Mediterranean region (in cooperation with IMS)
- Guidelines for periodical soil quality monitoring
- Software application tools for soil monitoring that will facilitate adoption of the monitoring system by authorities and individuals (developed by IMS and incorporated in the "Soil Monitoring System")
- A code of good practices for soil management.

Set of soil indicators for OMW disposal areas

After statistical evaluation of the collected data and considering that an indicator should be characterized by four features, i.e. relevance; understandability; reliability; and accessibility of data, the following soil parameters were proposed as indicators for monitoring soil quality in areas of OMW disposal:

- Electrical Conductivity
- Organic Matter
- Total Nitrogen
- Total Polyphenols
- Available Phosphorous
- Exchangeable Potassium
- Available Iron, and
- Soil pH (mainly for acidic soil types)

All these soil parameters are characterized by the four basic features: relevance, reliability, understandability, and accessibility of data.

Threshold values for soil quality indicators

It is known that when a set of indicators is proposed, this list should be accompanied by thresholds level for each one of the indicators in order to assist evaluation of collected data and of the chemical analyses results. The thresholds could be identified based on EU directives, on national laws, but also on the international literature. The peculiarity of the indicators proposed for the case of OMW disposal is that they mainly correspond to soil properties associated with fertility and not to pollutants in the classical sense, such as heavy metals and therefore are not included in national laws or EU directives. Nevertheless, international literature can provide general limits as these properties have been extensively studied for many years. Given the complexities of setting limits and the uniqueness of each targeted area/region, the scientific teams of PROSODOL proposed that it might be more efficient to develop guidelines that can help in setting up limits under certain land and environment conditions. However, thresholds for each one of the proposed soil indicators were given in the respective deliverable "Soil monitoring tool".

A GIS based tool for the Risk Assessment of the Sitting of OMW Disposal Areas

This tool uses multi-criteria analysis in order to assist the decision making regarding the most appropriate areas to be used as OMW disposal areas. Thus, it facilitates local authorities and communities to identify to most appropriate areas considering local priorities and percularities, local conditions, environment quality and national laws. More details are provided in Action 6 (paragraph 5.1.5.)

Application of Olive Mills Wastes on soils - A Land Application System

If land distribution is planned (e.g. disposal, irrigation) the organic load and the toxic substances (e.g. polyphenols) of treated or untreated wastes should not be the only issues of concern. Specific care should be taken also for inorganic constituents and especially for K, Cl^-, NO_3^-, SO_4^{2-}, P, Mg, Fe, Zn and others, since the very high amounts disposed on soil change its quality properties drastically, while the concentrations of the inorganic soil constituents (especially K, P, Fe, Cu, SO_4^{-2}) and the electrical conductivity remain high even many years after the last disposal. Therefore, for the safe disposal or use of OMW, soil and land data have to be considered in combination with bioclimatic conditions and management practices in order to develop a system for assessing land suitability. A Geographical Information System is necessary to define the application of OMW to agricultural or other type of lands because of the importance of spatial accuracy in the application. Also, it is necessary to include information on land, soil and OMW properties, processes and composition; climate variability; land use and management; and possible environmental risks. For the fulfilment of these requirements, a **land suitability system for spatially manipulating soil and land data** that has been designed and developed by SSIA for other Greek areas in the past and it was adapted to the peculiarities of OMW disposal, was proposed and included in the monitoring system. The proposed system present the following specifications:

a) is adapted to Greek and generally speaking to Mediterranean bioclimatic conditions,
b) is general and can be used throughout Mediterranean where OMW is produced,
c) incorporates soil behavior and functions,
d) incorporates all or most of the principles of other countries
e) considers the properties and pollution charges of the OMW
f) considers soil physical and chemical properties
g) it is based on velocity of water movement, soil map interpretation and on the combination of limiting factors and downwards water movement.

The system allocates soil map units to Suitability Orders (S for suitable and N for unsuitable) and Suitability Classes according to the degree of their limitations (S1 for slight, S2 for moderate and S3 for severe limitations; N1 for currently not suitable and N2 for permanently not suitable for waste application. The system also allows the <u>Estimation of the maximum permitted OMW amount to be distributed, the Estimation of annual permitted application of OMW; provides guidelines for the determination of OMW application timing; provides details on performing accurate periodical monitoring of soil quality after applications of OMW; includes a software application tool (with two versions-see Action 6 in paragraph 5.1.5.) which has been developed by IMS, highlights the need</u>

for periodical water bodies monitoring and includes a Code entitled "Good Practices for the agronomic use of olive oil mills wastes" (the code was developed by using also the results of all other actions of the project).

Evaluation

In general, the progress and fulfilment of the action was very satisfactory, the obtained results and tools were significant and, as far as we know, never studied in such details before. All the results were exploited to develop an effective soil monitoring system that could allow the decision making process as far as the selection of areas that can accept OMW disposal is concerned; the controlled and safe use of wastes and finally the effective monitoring of soil quality by the land owners themselves, or at a higher level by the local/national authorities, since the system provides the appropriate guidelines and the software for a periodical and effective monitoring of such disposal areas. Consequently, the initial foreseen expected results were satisfied.

All the aforementioned results and outputs were included in the three deliverables of the action:

1. Set of soil chemical, biochemical and microbiological parameters to detect contamination by olive oil mills' wastes
2. Environmental risk assessment of the pilot municipality-Soil
3. Soil monitoring system

5.1.8. Action 9: Design and implementation of a monitoring system for water bodies quality at pilot municipality

In the line of Action 9, a carefully designed monitoring system has been implemented in the project area to monitor the quality of all existing water bodies including surface streams and groundwater.

After 22 sampling campaigns in total, carried out bi-monthly between May 2009 and December 2012, water samples have been collected from surface streams, springs, water supply pipes and old wells. Water samples have been also collected from piezometers installed in 5 drillholes (1 of these is used as control) in the wider affected area. Drilling and installation of piezometers took place in the first week of November 2010. Monitoring of pore water quality was carried out every two months in the period February 2011 and December 2012 (12 sampling campaigns in total). Representative water samples have been also collected from four existing water abstraction wells.

The parameters measured in situ include pH, electrical conductivity and dissolved oxygen; other parameters measured in the laboratory include COD, phenols, tannic acid, bicarbonate and total hardness, TOC, NO_3^-, SO_4^{2-}, PO_4^{3-}, NH_3-N and elements such as Ni, Cr, Mn, Cl, K, Fe, Cu and Zn.

Main outputs

Results collected within the period May 2009 - December 2012 indicate good water quality in general. It is seen that water samples are characterized by neutral to relatively alkaline pH varying between 6.5 to 8.9. Relatively high concentration of phenols (up to 5 mg/L) are seen seasonally only in one well and two springs, in a short distance from the main OMW disposal lagoon in the area. Also, in water collected from these sampling points, Ni and Cr concentrations exceed the threshold values of 0.07 and 0.05 mg/L, respectively, for drinking water. The high values measured in water samples for Ni and Cr may be attributed to the high concentration of the metals in OMW (0.5 mg/L Ni and 0.15 mg/L Cr) as well as to the contamination from other agricultural activities in the area. Leaching of Ni and Cr from soils does not seem probable under the prevailing conditions in the area. COD values are zero in all water samples. Concentration of parameters such as NO_3^-, SO_4^{2-}, PO_4^{3-}, Cl, K, Fe, Cu, NH_3-N and Zn are lower than drinking water standards,

Monitoring of pore water quality shows high concentration of phenols, K, Cr and TOC (up to 3.4, 230, 1.2 and 58 mg/L, respectively) seasonally only in piezometers installed in drillholes which are located within a distance of around 50 m from the main disposal lagoon. These high values are due to the fact that OMW is released, mainly in spring each year from the evaporation lagoon and affects nearby soils.

No contamination is detected in water samples collected from existing water abstraction wells in the study area (pH~8, electrical conductivity ~505 μS/cm, DO ~8 mg/L, phenols not detected, tannic acid<0.1 mg/L, COD=0 mg/L, total hardness ~200 mg/L $CaCO_3$, Cl<21 mg/L, NO_3^-<16 mg/L, SO_4^{2-}<13 mg/L, Cu<0.08 mg/L, NH_3-N=0 mg/L, Zn=0 mg/L, Fe=0 mg/L). The only contaminant that exceeds drinking water standards is Mn (0.2-0.7 mg/L); contamination though cannot be attributed to OMW since Mn is one of the most common elements in earth's crust and is characterized by high mobility.

It is mentioned that the fluctuations shown in the concentration of various parameters is due to the specific period required so that contaminants present in OMW disposed in evaporation ponds every November-December, migrate and affect water resources. Transport time and distance depends on the volume of the OMW disposed of every year, potential overflows, direct disposal on land, weather conditions prevailing in the area as well as on the geology and hydrogeology of the disposal and surrounding areas.

It should be underlined that the inferior steel quality equipment used in olive mills in the area over the period 1970–2000 has definitely impacted soil quality due to accumulation of Cr and Ni present in OMW, from slightly corroded steel parts. This issue is discussed in detail in the paper "K. Komnitsas, D. Zaharaki, M. Doula, V. Kavvadias, Origin of recalcitrant heavy metals present in olive mill wastewater evaporation ponds and nearby agricultural soils. *Environmental Forensics* 12 (2011) 1-8".

Geostatistics was used for the assessment of risk and the results are briefly discussed below. Water risk assessment is based on the data collected from soil and water sampling campaigns carried out in the study area.

Risk for soils in OMW disposal and neighbouring areas is rather high since a number of parameters (eg. phenols, available P, Ni and others) exceed thresholds; hot spots are shown in the upper soil layers (0–25 cm) in ponds. The risk is assessed as low to average if the entire study area is considered; however if OMW uncontrolled disposal takes place on sandy soils, in soils with limited clay content or on areas close to the sea or where groundwater table is shallow significant adverse effects and higher risk are anticipated.

Risk for groundwater is low due to the soil type in the study area, the presence of limestones/schists in low depth, the presence of clays in soils which reduces substantially the toxic load during infiltration and the depth of groundwater table which normally exceeds 50 m. Therefore the migration of phenols and other recalcitrant contaminants from surface to deeper soil horizons and especially groundwater is rather difficult.

Risk for humans is also low; higher risk is anticipated if humans drink water from public wells where high concentration of phenols has been determined in specific periods (average concentration though is rather low).

It is anticipated though that any impacts foreseen in the study area will affect mainly recipients at local scale. In case of more intense activities, larger affected areas and different soil types (e.g. sandy soil), risk for humans and ecosystems will be higher. It is therefore proposed that due to scattering of olive mills in the Mediterranean region, simple and cost effective measures should be considered including pre-treatment, neutralization and/or dilution of OMW prior to disposal in ponds or on agricultural soils as well as construction of impermeable evaporation ponds; in the latter case geo-membranes or alternatively clayey soils may be considered as a cheaper option.

Evaluation

Action 9 was successfully implemented and a carefully designed monitoring system has been developed in the study area. Water samples have been collected from surface streams, springs, water supply pipes, old wells and piezometers installed in 5 drillholes in the wider affected area. Representative water samples have been also collected from four existing water abstraction wells.

All water samples have been analyzed to identify potential contamination sources, concentration of the most important contaminants, transport mechanisms and the fate of contaminants in aquatic media. Water risk assessment was also carried out based on the data collected from soil and water sampling.

All the aforementioned results and outputs were included in two deliverables of the action:

1. "Monitoring system for water bodies".
2. "Environmental risk assessment of the pilot municipality-water bodies".

5.1.9. Action 10: Controlled use of liquid/solid wastes in tree-land fertilization

The action began on 1 October 2009 and was successfully completed during the foreseen period (1/10/2009-30/9/2011). The main objective was to evaluate the potential effects of wastes application on tree-land fertilization, the development of useful guide for the safe use of mills' wastes in tree lands (olive trees) and the development of rapid methods of wastes analyses, which can be used in field.

A pilot scale experimentation site of around 1.500 m^2 for the controlled use of OMWW for tree land fertilization was set up at CeRSAA's premises (Fig. 1 of Annex 2). The layout of the pilot area is shown in Fig. 2 of Annex 2. Around 200 two-years-old olive tree plants belonging to 3 different local varieties (Taggiasca, Pignola, Leccino) were transplanted. Two different kind of OMWW (deriving from a discontinuous and a continuous extraction system) were distributed.

A drainage system was set up before plant transplanting, digging trenches of about 1 m depth and then positioning 10 cm diameter drainage tubes covered by a polyethylene tissue. 10 meters tubes were placed so to be connected at two opposite sites of the wells (5 totally in correspondence of plots 2,3,4,5,6 - refer to Fig. 2 of Annex 2), which have been used to collect leachate for subsequent analysis. In order to carry out the distribution of OMWW in the pilot area an hanging (50 cm above ground surface) dripline system was set up using Netafim Uniram pressure compensated tubes (normally used in the agricultural sector for the distribution of water or the application of liquid fumigants).

Distribution of OMWs (OMWW and husks) was carried out in 2010 and 2011 according to what is indicated in Table 1 of Annex 2. Olive husks were distributed only in 2011. The control treatment is represented by water. Amount distributed in the pilot area were chosen in consideration of the following: (1) the soil texture, (2) the young age of plants, (3) the purpose to avoid severe interference with plant correct growth and/or heavy phytotoxic effect which could have significantly compromised the trials foreseen.

Before distribution, an extensive survey of OMWW was carried out during olive season 2009-2010 at the 2 different olive mills: 1) Terre del Barone located in Borghetto S.S. municipality (Savona province, Liguria Region, Italy) which uses a three phases extraction method; 2) Maffei located in Orco Feglino (Savona province, Liguria Region, Italy) which uses a traditional discontinuous extraction method based on millstone and pressing columns.

COD and BOD_5 expressed as mg O_2/ml and total oily matter expressed as g/l were monitored during a 4 months period between November 2009 and February 2010 in samples collected from continuous and discontinuous extraction systems. On the whole 170 analysis were carried out regarding 34 samples collected. A survey about OMWW distributed, leachates collected in the wells and soil sampled in the different plots and two different depths was carried out between the beginning of 2010 and July 2011. An overview of the analysis carried put is presented in Table 2 and Table 3 of Annex 2.

Main outputs

-Monitoring of COD and BOD content

COD and BOD5 are a very good global waste indicator and for this reason the CERSAA team focused on developing rapid methods for their determination even in olive mill level.

For this, lab trials were carried out in order to define a technique, which could give a simple and rapid quantification of such parameters. Results found permit to obtain a mathematical correlation, which could express a pollution index of the analyzed waste. Polluting load can be directly measured and monitored during the extraction process of olive oil regarding BOD_5 and COD parameters.

-Effect on soil properties - effect on leachates collected in the wells
Based on the survey carried out within the pilot area, indications about trends of main parameters of soil samples monitored were drafted. It has to be kept in mind that the registered values refers to an amount of OMWW distributed which is maximum 1,5 times the amount foreseen by the Italian law. Moreover effects on leachates collected in the wells were also registered and evaluated.

Thus, it was found that:

- pH: no acidification of soil at both depths (20 and 50 cm) was registered after OMWW ditribution.

  Comments: 1. the starting pH value of the soil was 8.3
  2.according to literature much higher amounts of OMWW (hundreds of m^3/ha) can cause relevant effects on soil properties only in the very upper layer of the soil (15 cm).

- Polyphenols: the concentration of total polyphenols showed a decreasing trend at both depths reaching almost a null concentration in the last survey. Averagely higher concentrations were measured in the upper layer of the soil treated with OMWW coming from the continuous extraction system (Terre del Barone).

  Comments: although several studies have reported significant increase in the content of phenolic compounds in soils immediately or some months after OMW application, their concentration can be lowered through the oxidation and the polymerization of OMWW in healthy soils.

- COD and BOD_5: both values are constant at 20 cm depth and they tend to decrease at 50 cm depth.

  Comments: it is likely that despite high or very high values of COD and BOD_5 characterizing fresh OMWW they will decrease in concentration during time once distributed on the soil. Such behaviour is observed even in the leachates collected in the wells (see below).

- Total oily matters: they remain constant

  Comment: a waterproofing of soil is unlikely to happen

- Exchangeable K, Mg and Ca: they all increased during time especially with regard to the starting supply of the soil.

  Comment: final concentrations of all exchangeable cations are in the range of a good-high soil, but the trend is increasing during time and a build-up of such elements with particular regards to Mg is likely to happen.

- Sulphates: values tend to be high in all samplings carried out but a general decrease is registered during time with the exception of the plot treated with high dose of OMWW deriving from the discontinuous extraction technique.

  Comment: even though sulphate value is high in the control plot too (treated with water), a certain correlation between the kind of waste and sulphate concentration trend in the soil can be reasonably set.

- Ammonium: values are constant during time at both depths sampled.

- Nitrates: they were decreased significantly during time at both depths sampled and in the control plot too.

Comment: even in consideration of the values registered for leachates collected in the wells (see below), source of variation of nitrates is likely to be related to exogenous factors such as volumes of rainfall and variations in the depth of groundwater.

– Tensioactives: they are not detectable in almost all cases.

– Phosphates: phosphate content is 0 in the soil sampled in the control plot, while it shows constant values in the samples collected at 50 cm depth and increasing values during time in samples collected at 20 cm depth.

Comment: phosphate build-up in the soil is likely to happen as a consequence of OMWW spread.

– Phosphorous that can be assimilated: high values are constant and at both depths sampled

Comment: Phosphorous that can be assimilated in the soil was high but it has to be considered that an extended spread of OMWW on the soil can lead to P build-up in the soil in consideration of the starting high concentration of such element in wastes.

No particular effects were observed in the plot were olive husks were distributed with regards to samples collected in 2011.

-Effect on leachates collected in the wells

The availability of leachates is subjected mainly to rainfall volumes, which determine the fill in of the wells. Based on the analysis carried out the data collected the following hints can be given:

- pH, polyphenols, P, phosphates, K, BOD_5 and ammonium are all parameters characterized by a low variability (at least during the sampling period).
- Nitrates are strongly affected by the presence of a more superficial groundwater in plots/treatments 5 and 6 (similarly to what happened for soil samples). From a general point of view their concentration tends to decrease during time after OMWW soil spread.
- Electrical Conductivity: compared to control plot where water was distributed, it is not significantly affected by OMWW distribution.
- Sulphates: the concentration of sulphates was high in the control well varying around 195 mg/l averagely. A quite linear increase (from 150 till 380 mg/l) was observed in the wells correspondent to plots treated with OMWW derived from continuous extraction process. More variable concentrations (around 270 mg/l averagely) were observed relevant to plots treated with OMWW derived from discontinuous extraction process.
- COD: too variable values were observed regarding this parameter therefore it is not possible to draw clear conclusions.

-General recommendations for the agronomic use of OMWs

According to the data collected during the activities carried out in the pilot area and the literature available, indications about the safe use of OMWs were drafted. Some indications regarding the limitations to be observed during distribution on the soil and the benefits achievable from a rationalized use of OMWs are also given. The recommendations were included in the deliverables of different PROSODOL actions:

- “Guidelines for safe use of OOM wastes for crop production”
- “Good practices for the agronomic use of olive mill wastes”
- “Strategies to improve and protect soil quality from the disposal of Olive Oil Mill Wastes in the Mediterranean region: Results and Achievements of a 4-year demonstration project – What to consider; What to do”
- “Integrated Strategy of actions, measures and means suitable for Mediterranean countries”.

-Technical and economical evaluation of irrigation systems in olive orchards

Field trials carried out in Italy and abroad have demonstrated the advantages deriving from using OMWW for irrigation in terms of olive and oil production. The increase in olive production can

reach 100% in comparison to non-irrigated orchards, but the extent of the increase depends on soil and climate conditions, olive tree variety, plant lay out and cultivation practices.
Normally irrigation increases yields in areas where drought periods last for more than 2 months, ETP (potential evapotranspiration) is higher than 1.100 mm per year and rainfall lower than 700 mm.
Considering the above mentioned advantages deriving from the irrigation of olive orchards, the possibility to use waste waters coming from the agricultural sector - and specifically from the olive sector - for irrigation can represent an opportunity to increase water supply and to save high quality waters for drinking purposes.
CERSAA delivered also a plan for the set up of irrigation system in pre-planting in an olive orchard. Details and specs are indicated regarding the equipment, tools and instruments used for the set up of the dual-purpose irrigation system at Cersaa's premises. Such indications can be used for the set up of similar plants in other Mediterranean areas.

Evaluation

The correspondence between indicators/expected results and results achieved is highly satisfactory.
Trials carried out at the pilot area set up at Cersaa's premises allowed to draw some guidelines for the safe disposal of OMWW in an olive orchard considering the opportunity to adopt a dual purposes irrigation system. Considering that advantages are normally observed when olive orchards are irrigated, the possibility to use waste waters coming from the agricultural sector - and specifically from the olive sector - can represent an opportunity to increase water supply and to save high quality waters for drinking purposes. Moreover practical indications regarding all components and tools for the set up of the water/OMWW distribution system were given in order to allow eventually interested olive growers to set up a similar system according to their needs and the cultivated surface. In consideration of the trials performed, the results obtained and the legislative framework that regulates the distribution of OMWW on the soil in Italy, Cersaa actively participated in the development of legislative recommendations that finally merged in a publication. Such publication will be used as guide for policy makers to set up a fruitful discussion about possible amendments to actual legislation in order to optimize the entire oil production process and introduce specifications regarding waste disposal.

All the aforementioned results and outputs were included in the two deliverables of the action:

1. "List of validated innovative methods for olive oil wastes analysis"
2. "Guidelines for safe use of OMWW wastes for crop production"

5.1.10. Action 11: Laboratory experiments : Bioremediation

The action began on 1/10/2009 and was completed according to the timetable on 30/6/2010. The main objective was to perform microcosm experiments in order to establish the effectiveness of landfarming for bioremediating soils contaminated with olive oil mills´ wastes and to optimize this bioremediation technique in order to be implemented at the pilot area of the project.

Bioremediation of soil contaminated with olive oil mill wastes by landfarming is a very competitive and low cost technology. A background study and characterization of polluted areas are necessary before landfarming implementation in pilot plots. Thus, CEBAS evaluated all available data regarding soil quality parameters and waste production details collected and sent by SSIA. During the 1st Monitoring Committee meeting, the Beneficiaries selected two polluted areas with priority for the bioremediation in base to the risk of pollution distribution and their high polyphenol content. The selected sampling points belong to the: (a) NF4 disposal area (large disposal area with two evaporation ponds where apart of disposal in ponds, the owner disposes wastes on the surface soil, and (b) to the inactive, for more than 6 years, NF6 area. A total of 5 samples were collected from these two areas: one sample and one control from NF4; one waste sample from the mill that dispose wastes at NF4 area; one sample and one control from the inactive NF6 area. Samples were air-dried and mailed to Spanish working team.

The treatments that were assayed are: i) No treatment (natural attenuation); ii) Aeration; iii) Aeration plus nutrient addition; iv) Aeration plus microorganisms and enzyme inoculation; v) Aeration plus compost addition. In the treatment iv), we decide to amend the soil with a dose (200 mg C kg^{-1} soil) of the humic extract of a compost obtained in Spain using a two phase olive mill waste (TPOMW) as raw material. We also decide to add that compost to soil samples at an equivalent dose of 300 t ha^{-1} in order to assay the above mentioned treatment v). The soil parameters that were measured, apart from polyphenol concentration, were: pH, electrical conductivity, enzyme activities, assay of phytotoxicity effect (germination seed experiment) and ecotoxicity, measured by the effect observed on luminescent bacteria, will be carried out.

In an additional experiment, the porous material (zeolite) of Action 12, which was being implemented by SSIA, was used as soil additives in order to study if their presence enhances the biodegradation process. In this second experiment, the treatment applied to the selected soils (4.18, 4.19, 6.1 and 6.2) were four: i) No treatment (natural attenuation); ii) Aeration; iii) Aeration plus zeolite addition; and, iv) zeolite addition.

In January 2010, CEBAS received the soil and olive mill wastewater (OMWW) samples for lab bioremediation experiment from SSIA. Soil samples NF 4.19 and 6.1 (contaminated soils from both areas) and NF 4.18 and 6.2 (control soils from the respective areas) were homogenized by 2-mm sieving and analyzed in order to determine the concentration both of polyphenols and some chemical elements. A very interesting result is the Ni concentrations of the soils; in all cases, they were higher than the limit values proposed both by the EU in the 3rd draft of the Working Document on Sludge (European Commission, 2000) or in the Directive about the use of sewage sludge in agricultural soil (86/278/CEE) and the Spanish Ministry of Environment (Royal Decree 1310/1990) and could come from the steel of metallic machinery used in the olive oil production.
The experimental design has foreseen the preparation of 60 plastic containers with 250 g of soil and the application of the above mentioned treatments in triplicate to the 4.19- and 6.1-polluted soils (Figures 1-8 of the respective Annex 3). The nomenclature for each treatment is shown in Table 1 of Annex 3. After a pre-incubation soil sample during 2 weeks, a fresh OMWW was added to soil. The dose of OMW added was equivalent to 500 m^3 ha^{-1} that represents 10 times the maximum dose that Italian legislation permits for the use of this kind of wastes in soil irrigation. Soil samples were collected from the different microcosms for the different analysis programmed, at 15 days before the fresh soil spiking with fresh OMWW (T0) and 3 days after then (T1). Moreover, soil samples were collected at the following time periods after T1 sampling time: i) after 15 days (T2); ii) after one month (T3); and iii) after two month (T4).
In the second experiment performed to assay the effect of zeolite on the bioremediation of soil contaminated with OMWW the dose of zeolite was 30% weight basis.

In order to achieve the Action's objectives and develop and deliver a suitable bioremediation technique for the project's disposal area, CEBAS fulfilled a series of actions and studies:

- Separation, identification and quantification of polyphenolic compounds using an HPLC device with a reversed phase column.
- Germination tests to assay phytotoxicity by testing seed germination (barley and rye-grass) and by calculating the germination index (GI)
- Ecotoxicity tests
- Soil enzymatic activities (hydrolase activity)
- Dehydrogenase activity
- Microbial biomass carbon

<u>Main outputs</u>

Results collected were evaluated and the following conclusions were obtained which were in detail explained in the deliverables of the Action:

- Phytotoxic or eco-toxicological effects were not observed prior and after of soil spiking with fresh OMWW.

- After 3 days of OMWW addition a decrease of soil pH and an increase of soil electric conductivity (EC) were detected; but then, the buffer capacity of soil stabilized the values of these two parameters inside the range of values which were measured prior, at the beginning of incubation experiment.
- From all assayed treatments, only TAN treatment with addition of N and P, applied in order to increase the activity of soil microorganisms, was probed not suitable to perform a bioremediation of soil polluted with OMWW at the pilot area.
- The treatment with aeration was demonstrate the most useful to optimize the soil bioremediation at the pilot area.
- The addition of the zeolite did not produce a higher positive effect on soil bioremediation than that produced by submitting the soil to periodically aeration.

The feasibility studies identified the optimum conditions for the implementation of the bioremediation at the pilot area and a set of instruction on how to implement the technology was delivered. As mentioned, the scenario ii) (aeration) was identified as the optimum one, since the nutrients and moisture content of the soil under remediation were adequate to provide microorganisms the appropriate conditions for their activity.

Thus, the proposed remedial scenario for the specific pilot area foresaw:

"*In the beginning of the field-works, the area should be homogenized with the use of field machines (e.g. tilling machines, excavators, mechanical shovel) until 25cm depth, while large and medium stones it would be better to be removed. One subplot should be used as control area, while after area configuration, soil samples should be collected at time zero (T0) and every 15 days throughout the bioremediation treatment (6 months). The area should be tilled every 15 days to ensure aeration while special care should be taken to maintain soil moisture at sufficient level for the enhancement of microorganisms activity*".

The proposed scenario was applied by SSIA in the framework of Action 14 between 5th November 2010 and 14th May 2011 in an area of 30m x 25m (i.e. 750m^2), where untreated OMWs from a 3-phase mill were uncontrolled disposed on soil surface for more than 15 years.

Evaluation

The progress and the results of the action were very much satisfactory and were implemented at the pilot area of the project successfully. Thus, after the completion of bioremediation pilot implementation, results indicated that the method could be effective in reducing soil polyphenols, total nitrogen, available iron and available boron. Soil analyses revealed that the *total polyphenols* content was significantly reduced during the bioremediation implementation at the pilot field of Action 14. The initial very high value was reduced by 72.6% while the final polyphenols concentration was very low, lower than the control sample of the area.

Moreover, CEBAS produced significant deliverables, which contain useful information and data regarding the development and implementation of bioremediation at OMW disposal areas, considering and analysing all factors and parameters that should be taken into consideration when this method is going to be implemented. Additionally, CEBAS performed a technical and financial study, which will further assist policy makers, stakeholders and scientists to develop and implement bioremediation. It has to be highlighted that bioremediation is a well-known and successfully applied technology for the remediation of soil contaminated by organic pollutants, however it has never been applied for the remediation of contaminated soil due to OMW disposal. From this point of view, PROSODOL provides another significant and innovative aspect on the problem of soil degradation and potential remediation. All CEBAS deliverables were used for the development of the deliverables of Action 14 and of the deliverables of Category B (mentioned in Executive Summary).

The deliverables produced in the framework of this Action 11 are:

- "A guide for the application of bioremediation at large scale"

- "Description of a suitable low cost remediation technique for contaminated soil due to OOM wastes disposal"
- "Financial and Technical evaluation of demonstration action".

5.1.11. Action 12: Laboratory experiments: use of porous materials

The Action began on 1st October 2009 and was successfully completed on 30th June 2010, according to the project timetable. The aim was to optimize the technique of using porous materials as soil additives in order to protect and further improve soil quality at OMW disposal areas.

Main outputs

The central idea of the experiments was to work with samples collected from the pilot area in Crete to define the way of porous materials application and the improvement that can be achieved by their use. Samples had been collected by degraded and non-degraded areas and were of different texture.

Action 12 was strongly dependent on Action 8 of the project (i.e. design and implementation of a monitoring system for soil quality at pilot municipality) since the soil samples used for the experiments were fully analyzed and characterized during Action 8. Evaluation of environmental status and quality of the surrounding area, carried out during Action 8, was also considered for the experiments development and for the evaluation of the obtained results. Report of Action 7 (i.e. data collection, preliminary study of the areas) was also considered in order to simulate environmental conditions.

In order to achieve the objectives of the Action, different minerals proportions were added to different soil samples that were collected from the targeted area during Action 8. The experiment was divided into two parts:

1. batch experiments to define the optimum soil to porous material ratio and the concentrations of the leached elements, and
2. columns experiments; columns of 2m high were filled with soil samples that were collected from the pilot area to simulate field conditions, considering rain water flow through the soil (samples were placed in the columns according to the depth from where they were collected) and the leached elements were measured after periodical wastes and water additions.

Moreover, pot experiments were also carried out at the beginning of Action 12 using soil samples collected from a heavy degraded area, however it was considered that the results couldn't be accurate, representative and efficient, and large soil quantities would be needed to perform the experiments. For this reason, it was decided to perform small-scale experiments with small soil quantities, to define the optimum ratio, and then to carry out larger scale experiments (column experiment) to ensure results obtained from the small scale experiments.

-Batch Experiments

For the batch experiments, 18 samples from the pilot Municipality were selected. The design of the batch experiments procedure includes two different categories of experimentations:

1. The first category includes experiments, which were conducted with ***degraded*** soil samples (10 soil samples were selected) in order to identify the composition of the leachates after water addition and the effect of the presence of porous materials as soil additives. One of the samples was collected from inside the evaporation pond NF1. Samples were prepared by mixing soil samples and different percentage of zeolite (0, 2, 5, 7, 10, 20 and 30%). Apart from clinoptilolite, bentonite and a ferrous-clinoptilolite system were also tested as additives. After the addition of deionized water, the leachates were measured for K, Ca, Mg, Na, Mn, Fe, Cu, Zn, Ni, polyphenols, NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-}. For three of the ten soil samples the procedure of water addition was repeated two more times.
2. The aim of the second experimental part was to define the effect of OMW disposal on ***non-degraded*** soil samples of different texture. For this purpose eight soil samples of different texture (C-clay, L-loamy, S-sandy, CL-clay loam, SC-silty clay, SL-sandy loam, LS-loamy

sandy and SCL-sandy clay loam) collected from areas that do not accept wastes disposal, were selected for the experiments. A specific amount of OMW was added to the samples followed by washing with deionized water, to simulate the waste disposal and the subsequent leaching due to rainfall. Mixtures were prepared by mixing soil samples and different percentage of zeolite (0, 5, 10, 20 and 30%). According to the plan, 20,0ml of OMW, after 1:10 dilution with deionized water, were added to samples. The so prepared mixtures were shaken for 24 hours at room temperature and then centrifuged. After the centrifugation, water was added to the remaining solids to simulate the leaching after wastes disposal. The procedure of waste-water addition was repeated one more time. K, Ca, Mg, Na, Mn, Fe, Cu, Zn, Ni, polyphenols, NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-} were measured for all the collected leachates.

-Columns experiments

Four columns of 2m high were filled with soil samples collected from the pilot area. Two types of samples were used: (1) sample from inside an inactive pond (NF6.1) and its control (NF6.1bl); and (2) sample from an active disposal area that accepts surface disposal (NF4.19) and its control (NF4.19bl). Zeolite was added at a percentage of 5% at the 0-25cm layer of the samples NF6.1 and NF4.19. Experiments were repeated for NF6.1. and NF4.19 without the addition of zeolite as well as for the control samples NF6.1bl and NF4.19bl. Experimental design foresaw the addition of water at NF6.1 sample (with or without zeolite) since no further wastes disposal is expected for an inactive area, while for the NF4.19 the experiment foresaw the alternately addition of water and wastes. Olive Oil Wastes were added to columns after 1:10 dilution with water. The amount of water and/or wastes added was calculated considering the average monthly precipitation (57.7mm) of the pilot area.

Each month of the year corresponded to a week in the laboratory and almost 1l of water and/or wastes was added each week in three doses of 333 ml every two days. Leachates were collected from the column bottom and analyzed for pH, EC, K, Na, Ca, Mg, Cu, Mn, Fe, Zn, Ni, NO_3^-, SO_4^{2-}, Cl^-, PO_4^{3-} and polyphenols.

The results of the Action were used for the development of the zeolite-application guide. The results and the guidelines were applied and followed in November 2010 during the application of zeolite as soil additive (Action 14). As it is explained in the respective deliverables, as far as the quality of the soil leachates is concerned, the addition of 5% clinoptilolite at soils receiving OMW affected positively the composition of the leachates by reducing :

- ✓ the Electrical Conductivity between 10% and 50%
- ✓ potassium almost to 50%
- ✓ calcium between 5% and 20%
- ✓ magnesium between 10% and 20%
- ✓ nitrates between 20% and 40%
- ✓ chlorides between 60% and 80%
- ✓ sulfates between 16% and 40%.

Moreover, the presence of zeolite stabilized the pH values of the leachates at almost constant value (around 8.00), buffering the pH changes caused by the addition of the acid OMW on soil. Regarding the soil properties, columns experiments revealed that the quality of soils accepted OMW by surface disposal were increased.

However, it was observed that despite the high nutrient retention capacity of the clinoptilolite, sodium leaching was increased almost 2-2.5 times compared to control soil when clinoptilolite was used as soil additive. Therefore, sodium should be considered as a ***restrictive parameter*** for the use of zeolite as soil amendment to improve soil quality. *Thus, it was proposed that, in order to avoid excess sodium leaching, clinoptilolite percentage should not exceed 10%, with 5% being the optimum value.* Moreover, periodical irrigation of the application field should be carried out, to assist sodium leaching, avoiding so soil salinization incidents.

Evaluation

The progress and fulfilment of the action was very satisfactory, and according to the timetable. The use of clinoptilolite as soil additive to improve and remediate degraded/contaminated soils is a very well-known technique that has been applied in many countries worldwide, however, never at OMW disposal areas. This is considered as highly innovative and as it was recorded from the obtained lab experiments, clinoptilolite is capable to protect soils form the uncontrolled disposal of OMW. It should be also highlighted that zeolite was applied on soils during the demonstration Action 14 under extreme conditions, i.e. continuous disposal of OMW and it was proved that even if the disposal of OMW is continued, soils that are amended with clinoptilolite are more protected and the zeolite keeps in its active framework the excess amounts of many inorganic nutrients while at the same time improves soil aeration and enhances organic matter and polyphenols biodegradation. The technique is strongly recommended for OMW disposal areas and for this reason it is included in the guide "Good Practices for the agronomic use of olive oil mills wastes".

All the aforementioned results and outputs were included in the two deliverables of the action:
1. "Report of best application method of porous materials at olive oil mills' disposal areas"
2. "Deliverable: A guide for the use of porous materials as soil additives at larger scale"

5.1.12. Action 13: Pre-treatment of OMW

In the frame of Action 13 a feasible and integrated low cost OMW pre-treatment methodology using various reactive agents has been developed in order to be applied in small olive mills that are mainly family businesses and widely dispersed in the Mediterranean region. The pre-treatment methodology was optimized in large laboratory scale prior to the implementation in field. Field tests were carried out in the line of Action 14 in the period November 2011-April 2012.

Several pre-treatment options have been developed in large laboratory scale (reactor, laboratory column, funnel, steel corrosion and cultivation tests). The objectives of these tests include:

- Removal of oils, paste and total solids (TS) contained in OMW
- Increase of pH and precipitation of contaminants
- Decrease of COD and phenols concentration
- Sorption of organic contaminants on various reactive materials
- Decolourization of OMW
- Improvement of the quality of the leachates infiltrating towards deeper soil horizons and groundwater
- Use of the pre-treated OMW for irrigation

Raw OMW that was used in laboratory and field tests was obtained from a three phase olive mill operating at Agios Konstantinos village, Rethymno prefecture, Crete, with an average annual production of 2000 m^3 OMW. Various materials, including goat manure, zero valent iron, iron fillings, saw dust, $Ca(OH)_2$, industrial lime, $FeSO_4.7H_2O$, magnesite by-products, natural zeolite, limestone and activated carbon were used in OMW pre-treatment experiments. Most of these materials are low cost, by-products of other industrial processes and are abundant in Crete and other parts of Greece.

Main outputs

Based on the experimental results a flow sheet for OMW pre-treatment (three different options) has been proposed and also the effects of pre-treated OMW on spinach and beetroot growth have been studied.

Centrifugation and saw dust addition (2 g/L of OMW) are considered as important initial stages since they contribute to the removal of most oil and solids and improve solid/liquid (S/L) separation and the efficiency of the following stages, reducing thus consumption of reagents. Parameters such as pH, phenols concentration, BOD and COD removal are not affected by centrifugation, as anticipated, but 20% TS removal is obtained within 5 min. The recovered oil (around 3% w/w of the feed) can be further treated and potentially used for the production of other products such as lubricants, preservatives and cosmetics.

Addition of 7 g/L $FeSO_4.7H_2O$ in the following stage of the *first pre-treatment option* results in coagulation and cumulative removal of TS up to 35% w/w. As shown in the following stage, addition of 10 g/L $Ca(OH)_2$ provides alkalinity in the system (pH increases from 4.7 to almost 8) and also results in significant removal of phenols and COD (up to 65% and 30%, respectively). Finally, addition of iron fillings (10 g/L) and 10% v/v H_2O_2 (30% w/w) results in an additional 60% phenols removal. Iron fillings can be easily recovered and re-used for several times until exhaustion.

The *second pre-treatment option* involving liming with 10 g/L $Ca(OH)_2$ and addition of 30 g/L $Ca(ClO)_2$ results in 98% phenols removal and decolourization of OMW. TS and BOD are also substantially removed.

In the *third pre-treatment option*, OMW was filtered through a 20 cm goat manure substrate after a retention period of 8 days and the quality of the final liquid is substantially improved (pH~6.5, phenols and COD removal by 90% and 25%, respectively). These results indicate that goat manure, which is available in large quantities in Cretan agricultural areas, may be considered as potential substrate in evaporation ponds that is able to reduce the volume and improve the quality of the generated leachates and thus minimize the risk for soil and groundwater contamination.

All three pre-treatment options resulted in the production of OMW with rather similar quality. The precipitates (sludge) collected after each treatment stage may be used for the production of compost, after mixing with other agricultural wastes such as straw, tree branches and olive leaves, provided that phytotoxicity tests are carried out prior to its use as soil amendment.

In order to assess the quality of the pre-treated OMW as well as study its effect on plant growth, laboratory tests were carried out using spinach and beetroot; these tests were not included in the original proposal and were carried out at no additional cost. The results have shown that low OMW application rates ($4L/m^2$) have rather limited effect on spinach and beetroot growth, at least for the cultivation period considered (6 months); when higher OMW application rates are considered (10 or 20 L/m^2) plant growth is more adversely affected, especially for beetroot.

Optimized OMW pre-treatment was thereafter implemented in the field with slight modifications. Centrifugation of OMW, which enables fast oil and paste precipitation, was not implemented in the pilot area due to the lack of equipment (a centrifuge of this size is quite expensive). The OMW pre-treatment stages in the field are described in detail in the following section 5.1.13.

Evaluation

Action 13 was successfully implemented according to the activities foreseen. Pre-treatment of OMW is very important in order to increase pH, remove organic and inorganic load and substantially improve OMW quality so that further treatment/reuse becomes easier, as well as to limit the impacts for soils, waters and ecosystems when OMW are disposed of in properly designed lagoons or on agricultural soils. OMW pre-treatment options may be considered at mill scale using cheap and readily available materials almost at no cost (apart from transport cost), such as saw dust, lime, iron fillings and goat manure.

All the aforementioned results and outputs were included in two deliverables of the action:

1. “Report on the design and operation of a prototype waste pre-treatment system”.
2. “Guide for the application of the waste pre-treatment system in the pilot area”. The deliverable contains also the deliverable of Action 14 “Benefits of waste-pre-treatment procedure in pilot scale” as explained in paragraph 5.1.13.

5.1.13. Action 14: Pilot-scale application and evaluation of the soil protective/remedial technology

The pilot scale application began on 1 July 2010 and it was completed on 30 November 2012.

The aim of the action was to demonstrate at field level all the techniques developed in lab scale, i.e. soil remediation (based on results of actions 11 and 12), pre-treatment of OMW (based on action 13); and finally composting (based on already scientific experience and on the results of the wastes chemical analyses). One more action that it was proposed and accepted by the EC, which, however, was not foreseen in the initial proposal, was the application of pre-treated wastes for lettuce cultivation and evaluation of effects on the production and on soil. The last action was proposed since it was considered as highly important to study and propose an integrated strategy, i.e. pre-treatment of wastes in field and subsequent use of treated wastes on soil or for crop cultivation. Results of Action 8 and 9 were also considered when developing and implementing all demonstration actions.

Main outputs

-Soil protection/remediation

Before applying the remedial techniques, SSIA in cooperation with the other beneficiaries defined the objectives of the remedial strategy (based on literature and soil properties of the pilot areas), which were:

1. Reduction and stabilization of soil total organic matter below 5%
2. Reduction of soil total polyphenols at concentrations equal to background levels of the area, i.e. 57 mg/kg
3. Reduction of soil electrical conductivity and stabilization under threshold of salinity, i.e. <4mS/cm
4. Reduction stabilization of soil total nitrogen below 3,0mg/g, i.e. 0,3%
5. Reduction of exchangeable K and Mg below 1,2cmol/kg and 2,2cmol/kg, respectively, or immobilization on reactive media (e.g. zeolite)
6. Reduction of available Fe and Cu below 50mg/kg and 3,0mg/kg, respectively, or immobilization on reactive media (e.g. zeolite)
7. Reduction of available P (Olsen P) below 28mg/kg or immobilization through precipitation
8. Reduction of available B below 1.5mg/kg.

In-situ bioremediation

The method applied was the bioremediation and in specific **biopiling**, but with some changes in order to be conformed to the local conditions and the specific characteristics of the area under treatment. The Spanish beneficiary provided the exact technique design after lab experiments (feasibility study-Action 11). Thus, feasibility studies identified the optimum conditions for the implementation of the bioremediation at the pilot area and a set of instruction on how to implement the technology was delivered. In particular periodical aeration and moisture control were identified as the optimum scenario, since the nutrients and moisture content of the soil under remediation were adequate to provide microorganisms the appropriate conditions for their activity.

Thus, the proposed remedial scenario foresaw:

"*In the beginning of the field-works, the area should be homogenized with the use of field machines (e.g. tilling machines, excavators, mechanical shovel) until 25cm depth, while large and medium stones it would be better to be removed. One subplot should be used as control area, while after area configuration, soil samples should be collected at time zero (T0) and every 15 days throughout the bioremediation treatment (6 months). The area should be tilled every 15 days to ensure aeration while special care should be taken to maintain soil moisture at sufficient level for the enhancement of microorganisms activity*".

Bioremediation was applied between 5th November 2010 and 14th May 2011 in an area of 30m x 25m (i.e. 750m$^{2)}$, where untreated OMWs from a 3-phase mill were uncontrolled disposed on soil surface for more than 10 years. Considering that soil was treated until depth of 25cm, the total treated soil volume was 187.5m^3.

The two following steps, namely implementation and effectiveness monitoring were carried out simultaneously since after each treatment (i.e. tillage-soil aeration) soil samples were collected and analysed to record bioremediation progress.

During the implementation, the soil of the area was homogenized with the use of an excavator until 25cm depth, while large and medium stones were removed (Photos are included in Annex 4). A small area at the upper part of the field was used as control area since no wastes are disposed there. After area configuration, soil samples were collected (one control and one mixed sample from the main experimental area).

According to the instructions, the area was tilled every 15 days until 25cm soil depth and this was carried out by using a small tilling machine. Thus, mixed soil samples were collected from the area on 5/11/2010 (first day of implementation); 23/11/2010; 27/12/2010; 18/1/2011; 12/2/2011; 14/3/2011; 15/4/2011 and on 14/5/2011. The samples were transferred to the lab and analyzed for texture, saturation percentage (%SP), electrical conductivity, total salts, pH, organic matter, calcium carbonate, total nitrogen, water soluble Na, exchangeable Na, exchangeable K, exchangeable Ca, exchangeable Mg, available P (Olsen), available-DTPA Fe, available-DTPA Cu, available-DTPA Mn, available-DTPA Zn, available B, total polyphenols, NH_4^+, NO_3^-, Cl^-, PO_4^{3-}, SO_4^{2-}, ESP and SAR. In May 2011 it was confirmed that soil quality, as far as the polyphenols content, was significantly improved. Thus, it was decided that the pilot phase was successfully accomplished.

After the completion of bioremediation implementation, results indicated that the method could be effective in reducing soil polyphenols, total nitrogen, available iron and available boron, although the latter was not exceeded the threshold value before the remediation. Soil analyses revealed that the *total polyphenols* content was significantly reduced during the bioremediation implementation. The initial very high value was reduced by 72.6% while the final polyphenols concentration was very low, lower than the control sample of the area.

There was a gradual decrease of *total N* throughout the sampling period. The soil bioremediation procedures seem to enhance N mineralization. The initial N content was significant high, considering the threshold of 3.0mg/g above which, a soil is characterized as very rich in nitrogen and also the mean value of the control samples of the pilot area, which is 2.3mg/g. The final N values are considered satisfactory and the soil could be characterized as containing the sufficient amount of total nitrogen. *Available iron*, although very much reduced, however the final value was not lower than the threshold of 50mg/kg. However, this result is accepted and the method is considered as effective in reducing available Fe.

On the contrary, the method was not effective in reducing at acceptable values the soil organic matter, exchangeable potassium and magnesium, available cooper and phosphorous. In specific, in-situ bioremediation seems to have no effect on available Cu concentration and on the exchangeable Mg, while the reduction in the concentration of exchangeable K and available P, although substantial, yet the values of these two parameters are still very high compared to the accepted thresholds.

The cost of the bioremediation (feasibility studies+field application+10 years monitoring of soil quality) was calculated equal to 46.08€/m^3 of treated soil. Complete assessment of the cost effectiveness in relation to environmental problem is included in the deliverables of the action, entitled: (1) Benefits of soil remedial/protective technique and (2) Financial and Technical evaluation of the demonstration actions.

<u>Clinoptilolite as soil additive</u>

The use of clinoptilolite as soil additive was applied between 5th November 2010 and 10th July 2012 in an area of 8.5m x 12m (i.e. 102m^2), where untreated OMWs from a 3-phase mill were uncontrolled disposed on soil surface for more than 10 years. Considering that soil was treated until depth of 25cm, the total treated soil volume was 25.5m^3. *It should be highlighted that the area* *continued to accept surface disposal of wastes during the entire demonstration phase, meaning that the results can be implemented not only at inactive but also at active disposal areas.*

The methodology included three stages:

1. Complete physicochemical characterization of the area of interest (during action 8)
2. Area configuration and application of zeolite on soil
3. Effectiveness monitoring

After having identified the threats to soil quality and the parameters that are mostly affected by the disposal of OMWs (stage 1), application of zeolite on soil at two ratios and two-grain sizes was carried out on 5 November 2010. For this, the area was configured in order zeolite to be added as soil amendment and it was divided into four sub-areas (Annex 5).
Clinoptilolite was added as dust with particles diameter <0.8mm, and of larger size (particles diameter of 0.8mm-2.5mm) in order to test the effectiveness of these two forma and also the easy of applicability. After clinoptilolite application, the area was tilled until 25cm depth with a small tilling machine.
For monitoring methodology effectiveness, soil samples were collected and analyzed every 2 months. In specific, soil samples were collected and analyzed on 18/1/2011; 23/3/2011; 17/5/2011; 28/8/2011; 8/11/2011; 24/1/2012; 29/5/2012 and 11/7/2012.

Considering the obtained soil data and the soil stress due to wastes disposal which was continued during the treatment, in general, we may conclude that the results of this type of soil remediation are very much satisfactory and the method succeeded to protect to a great extent the quality of soil since most of the remediation targets were met.

Although the final values of soil organic matter are higher than the target value, thus, the use of clinoptilolite as soil additive stabilized and maintained soil organic matter (OM) values at constant values (between 5.6 and 7.1% which are very close to target values). This is owed to the improvement of soil aeration and thus to the enhancement of soil microorganism activity to biodegrade soil organic matter. The effect of zeolite on total nitrogen content is similar to that on organic matter content and due to the same reasons, however, the final values of total nitrogen are considered unacceptable related to the target value.

Exchangeable K and available metal Fe were significantly increased in soil. The increase is owed to the retention of these elements from clinoptilolite. However, the increase is not attributed to the increase of these elements in soil particles but in zeolite framework. Consequently, this increase **does not lead** to extent K and Fe leaching but to slow release from zeolite to soil solution contributing thus to the improvement of soil quality and to the prevention of nearby systems overloading (this was also confirmed during lab experiments of action 12, during which decreased leaching of inorganics was detected due to the addition of clinoptilolite). On the contrary, and same as during bioremediation, no effect on available Cu was recorded. Regarding soil electrical conductivity, its values were decreased due to the retention of ions within zeolite framework; the EC of soil was lower than the target value of 4mS/cm. Thus, despite the increase in exchangeable K and available metals contents in soil, these amounts do not increase soil electrical conductivity because ions are held in/on the zeolite framework.
Total polyphenols were reduced, however not at such extent to satisfy the target value.

Available phosphorous was decreased as far as its higher concentration is concerned; however the final values are unacceptable. Exchangeable Mg was also significantly decreased and stabilized at lower values than the initial ones but it concentrations remain almost double than the target value. No significant effect was recorded regarding the content of available B in soil, which remained higher than the target value after the treatment.

No significant difference was obtained from the different ratios and different grain sizes of clinoptilolite, thus it is proposed that the use **of up to 5% zeolite** on soil could result in substantial improvement and protection of soil quality, as far as the above mentioned parameters. This is in

agreement with the results of action 12. After application, it is possible that periodical irrigation, in order to avoid excess sodium leaching would be necessary. Soil quality should be monitored annually. Especially, after the zeolite applications, soil samples should be analyzed for SAR and ESP every two months and for the first six months period after application.
In case that values of SAR and ESP exceeded the upper limits ($13cmol/kg^{1/2}$ for SAR and 15% of ESP) the area should be periodically irrigated.
The cost that could be generated by clinoptilolite addition in soil was estimated equal to 27.37€/m^3 of treated soil (initial risk assessment + field configuration and application + 10 years monitoring of soil quality are included).

Proposed methodology for OMW disposal areas: Combination of the bioremediation and zeolite addition

Having studied the effects on soil and the degradation caused from the uncontrolled disposal of OMW it became clear for the scientists of PROSODOL that the soil degradation is consisted of two parts that request different treatments methodologies. Thus, a soil remediation and protection plan suitable for OMW disposal areas, should include methodologies for (1) polyphenols reduction and (2) retention or immobilization of inorganic constituents.
For the reduction of polyphenols concentration in soil, in situ-bioremediation is considered appropriate since it targets to the biodegradation of organic pollutants in soil by taking full advantages of the natural biodegradation process of organic molecules by soil microorganisms.
For the reduction of inorganic soil constituents, the use of natural zeolite, clinoptilolite, as soil additive is considered the most suitable for this case because of the already well-known properties of natural zeolites to attract, retain and slowly release many inorganic cations, such as K^+, Na^+, Fe^{3+}, and others. Moreover, the method is of very low cost and very easy to be implemented, even by no qualified personnel.
Considering the results obtained related to the final quality parameters of treated soils, it is recommended that **a combination of the methods would be more effective**.

The combination includes two stages:

1st stage
Implementation of bioremediation. The treatment is anticipated to reduce significantly the polyphenols content, to reduce and stabilize total nitrogen content as well as to reduce available iron and boron.

2nd stage
Addition of clinoptilolite at the bioremediated area. The treatment is anticipated to stabilize and reduce soil organic matter, reduce the electrical conductivity and stabilize exchangeable potassium and iron because of the zeolite property to keep them on/in its 3D framework.
An overall reduction of available phosphorous and boron is anticipated due to both the remedial actions.
In case of the implementation of the 2-methods combination the cost would be almost 60.81€/m^3 of treated soil.

-Pre-treatment of OMW at field scale

Based on the results of Action 13, in the mid of November 2011 all the necessary equipment and accessories for the implementation of pre-treatment methodology was transferred to the field (Photo 1 of Annex 6). A stainless steel tank of operating capacity of 0.5 m^3 was designed by TUC, constructed and placed on a metallic base; the tank has two valves on the side and one at the bottom for the collection of liquid pre-treated OMW and precipitates, respectively. A stirrer and a motor have been fixed on the top of the tank to mix OMW with various additives. Two pumps were used for the transfer of raw OMW in the tank as well as transfer of pre-treated OMW in vessels and then disposal to the bioremediation area.

A view of the area and the pre-treatment unit used in the field is shown in Photo 2 of Annex 6.

Pre-treatment involved addition of saw dust and lime in the main 0.5 m^3 steel tank and filtration as a separate stage through a goat manure substrate in plastic vessels of 0.25 m^3 after a retention period of 8 days. A total period of ten days is required in order to produce each batch of 0.5 m^3 of pre-treated OMW. The pre-treatment stages are described in detail in the following lines.

- **Stage 1**: OMW was transferred into the pre-treatment steel tank (0.5 m^3) and left for almost one day to allow for partial separation of oil and paste which are then collected from the surface and removed. The sludge (around 10% w/w) precipitated at the bottom and collected at the end of the treatment after decanting or pumping the supernatant solution. It is known that the presence of oils and suspended solids at the surface of OMW when disposed in ponds hinders biodegradation, since it reduces the effect of the solar energy and prevents oxygen diffusion.
- **Stage 2**: Saw dust (2 kg/m^3) was added at the surface of OMW; after almost two hours most oil phases were adsorbed on the saw dust and the mixture of saw dust and oils was removed from the surface. Some precipitates formed (mixture of saw dust and paste) were collected at the final stage.
- **Stage 3**: Lime (10 kg/m^3) was added in OMW and mixed for 10 min to provide alkalinity in the system (pH increased from 4.6 to around 8.6) and partially remove phenols and COD (estimated removal 35-65% and 15-30%, respectively). OMW was then left for almost one day to enable S/L separation.
- **Stage 4**: After one day the pre-treated OMW was decanted using pumps and the precipitates formed (solids and/or other constituents) were collected from the bottom.
- **Stage 5**: OMW was transferred to plastic vessels of 0.25 m^3 capacity and after retention for 8 days and filtration through a layer (~20 cm) of goat manure the final pre-treated OMW was produced.

Solutions were collected periodically and analyzed for pH, EC, phenols, BOD, COD, TS and inorganic elements content. The pre-treatment implemented in the field, using low cost materials, resulted in good quality OMW, similar to the one attained in large scale laboratory experiments. The pre-treated OMW was used as fertilizer in bioremediation tests as well as for lettuce cultivation (tests carried out by SSIA).

An indicative cost analysis (including construction, installation, operation and implementation cost) for the proposed OMW pre-treatment methodology is shown in Table 1 of Annex 6. Two different cost analyses are shown; one for the treatment of 2.5 m^3 of OMW as implemented in the study area in the line of PROSODOL project, which is not representative due to the small volume treated, and the other for the treatment of 2,000 m^3 of OMW, which is usually the annual volume produced by a typical olive oil mill in Greece.

For a typical olive oil mill in Greece which produces annually about 2,000 m^3 of OMW a total cost of 24,165 € is estimated; the cost for the purchase of equipment reaches 6,565 €, for transport/installation 200 €, for the purchase of consumables i.e. saw dust, lime and goat manure, 5,400 € and for personnel 12,000 €.

Thus, the cost of treatment for the first year is estimated at 12.1 €/m^3. This cost will be reduced in the following years since the same equipment will be used; so a deduction of 6,765 € (for the purchase of equipment and for transport/installation) and an increase of 500 € (for maintenance) is foreseen. Thus the total annual cost is estimated at 17,900 € or 8.95 €/m^3 OMW. Part of this cost will be compensated through the use of the water and the compost produced for irrigation and fertilization, respectively. However, it should be also taken into consideration that cost for purchase of materials/reagents will be further reduced when bigger quantities are purchased, in the case of operation of a central treatment unit.

However, it is important to mention that for the production of pre-treated OMW of even better quality centrifugation in the field should be considered. The cost of an industrial centrifuge is estimated at 45,000 €. The purchase of a centrifuge is considered more appropriate though when a central/regional unit is planned for the treatment of OMW produced from more than one mill, actually from 4-5 mills in a specific area. A complete technical and financial assessment of the methodology as well as of other methods for OMW treatment are included in the deliverable: "Financial and Technical evaluation of the demonstration actions".

-Use of pre-treated wastes for lettuce cultivation

For the integration of the pilot waste pre-treatment activity, SSIA proposed the use of pre-treated wastes for lettuce cultivation, which was accepted by the EC. The treated wastes were added to the soil of the bioremediation area at two rates: $80m^3$/ha and $200m^3$/ha annually, however the total amount of wastes were added in two doses, between January and April 2012. The experiments were contacted on soil with and without the addition of 5% clinoptilolite. Soil samples were collected and analyzed periodically. Apart from soil chemical analyses to assess soil quality, small **lettuce** plants were planted in May 2012 in these plots in order to identify potential phytotoxicity, as well. The area had been already configured (in October 2011) and divided into 18 sub-plots (the scheme and photos are included in Annex 7). The results of this implementation action are considered very significant since they could be combined with the results of Action 11 regarding the effectiveness of the application of simple wastes treatment methodologies and could define the terms and conditions for soil disposal of these treated wastes as well as the potential phytotoxicity.

-Composting

The main purpose of the pilot composting activities was to demonstrate mainly to olive mills' owners how to exploit the sludge of the OMW. In many cases the OMWs after their production in the mill, they are disposed on evaporation ponds where they left in order the liquid part to evaporate. After the completion of the evaporation, the remaining solid part (sludge) is removed and disposed on land without any precautions or limitation. The demonstration focused on how the mills' owners could produce valuable products (compost) from the evaporation ponds' sludge.

Before the demonstration of the composting procedure, SSIA was experimented on the use of clinoptilolite as constituent of the feedstock. For this, and in order to identify the optimum zeolite percentage that should be added to the feedstock, six small pilot composts were prepared with different zeolite ratio. After the completion of this stage, real scale compost was produced and demonstrated among mills' owners.
A cement floor of $54m^2$ was constructed with slope of 3-4% and with a tank at one edge (from cement) where leachates were concentrated and further used for compost wetting. The composts were covered in order to be protected by rain and wind with a Top-Tex textile, however the construction of a shed could also be proposed for permanent facilities (Annex 8).

Composting started in November 2011 by preparing 6 small composts using OM sludge from the evaporation ponds, straw, caw manure, fresh and dry leaves, and different ratios of zeolite dust (0.00-0.80mm).

After the evaluation of the results and the chemical analysis of the composts, the most appropriate composition was selected and proposed.
The composting process was conducted over 120 days. The composting phase was considered finished when the temperature was stable, close to the external value, and re-heating did not occur. The temperature was recorded weekly at three depths: 1/3, 2/3 and 3/3 from the top of the composts. In general, composts temperature followed a normal pattern during the composting process. There was an initial increase in temperature to 63 – 66^{o}C followed by a gradual drop to 18 – 21^{o}C.
The moisture content was determined by gravimetrical method and was maintained at the same level by manual irrigation throughout the composting period.

The composts' pH ranged between 7.95 and 8.31 and was considered appropriate for most agricultural purposes, as reported also by other researchers.
In all cases, electric conductivity was lower than 10dS/m, threshold established as indicator of possible phytotoxic/phyto–inhibitory effects on plants or in soil. All composts have high content of

Total Organic Carbon (TOC), in average 24.9%.
The values of total nitrogen are within the range of that found for compost made from plant residues and similar to that reported for composts made from manure and agricultural residues.
The C:N ratio is within the range of composts produced by the solid part of OMWs and is considered satisfactory.
The total K is also within the range of values reported in the literature for experimentally–produced composts and also similar to those of OMW. This indicates that K was not lost through leaching during the composting process.
All the six composts showed similar pattern of changes in concentrations of phenols during the process. There was a gradual reduction in the level of phenols from start to finish of the composting process. The phenol levels dropped from 3.54 mg/g on day 1 (in average) to 1.24 mg/g on day 120 (in average).
The low polyphenol contents in the composts agree with values found by other researchers, who showed that the polyphenol content decreases during composting. In all cases, the polyphenol contents were lower than 4%: the limit, which has been, established where there is a shift between net N mineralization and immobilization during decomposition.
As regards the metals concentration (i.e. Fe, Cu, Mn, Cu and Ni), the final values in the six composts are acceptable.
The improvement of composts' quality characteristics due to the addition of clinoptilolite can be seen in the higher values of TOC, N, K, P, NH_4, Ca, Mg of some mixtures, relative to the control compost. Moreover, four composts had lower polyphenols content. This is significant, considering the ability of clinoptilolite to act as slow-release fertilizer when added to soil. However, sodium content is considered again as the ***restrictive factor*** for the use of composts in agriculture. For this, and considering also the cost for zeolite purchase (which however is not so high; 140€/ton), the addition of 10% (max) of clinoptilolite to the composted materials is recommended.

Evaluation

The progress and fulfilment of the action were very satisfactory. Action 14 was the overall and integrated action during which all lab experiments were implemented in a pilot area in order to demonstrate their applicability and their appropriateness for the specific problem of OMW disposal. The obtained results are at level "ready to be applied" while specific guidelines and proposals were developed for the authorities and the individuals (e.g. mills' owners).

All the aforementioned results and outputs were included in the four deliverables of the action:

1. "Benefits of soil remedial/protective technique"
2. "Benefits of waste pre-treatment procedure in pilot scale"
   It is mentioned that the deliverables "Guide for the application of the waste pre-treatment system in the pilot area" (Action 13) and "Benefits of waste pre-treatment procedure in pilot scale" (Action 14), have been merged in one deliverable.
3. "Guidelines for composting procedure as a small practical scale"
4. "Financial and Technical evaluation of the demonstration actions"

5.1.14. Action 15: Integrated approach of actions, measures and means suitable for the Mediterranean region

The action was successfully completed within the foreseen time period (i.e. 1/1/2012-30/6/2012). One of the objectives of this Action was the implementation of an Analysis of national and European legislative frameworks for Olive Oil Waste and Soil Protection. The results of this analysis were included in a report, which was carried out by a subcontractor in cooperation with CEBAS scientific team and also with the cooperation of the other project Beneficiaries. The principal points discussed in this report are:

- *Olive oil industry and the environment*

- *EU and national legislation on waste, water and soil*
- *Legislative recommendations for olive oil waste management*
  - Particularities of olive industry:
    - Olive mills are family businesses and small-scale enterprises.
    - Seasonal production of wastes and their variable character of the residue.
    - The quantity of wastewater generated in olive oil processing, in many cases is extremely small in comparison to other commercial industrial operations
  - Statutory legislation proposal for olive oil waste management
    - Untreated waste/wastewater disposal into the environment should be strictly banned
    - Irrespectively if is dangerous or not, the waste/wastewater should be treated before any disposal to land/surface waters
    - As olive oil waste is potentially hazardous the legislation should provide statutory limits, especially on phenols,
    - The legislative act should clearly specify that the waste should be analysed Standard sampling and analytical procedures, harmonised at EU level, could be introduced.
    - There should be a categorization of production industries according to their production capacity and/or waste generation in order to draw specific measures for waste management
    - In case evaporation ponds are used, the minimum requirement should be the use of protective layers (engineered evaporation ponds).
    - As landspreading is a common and low-cost practice, specific regulations should be developed.
    - In case of landspreading and under the condition that the olive oil waste/wastewater fulfills the requirements of the existing legislation, the OMW could be considered fertilizer and thus, annual dose estimation should follow the general rules of soil fertilization considering soil properties and purpose of use.
    - On the reuse of treated wastewater for irrigation of agricultural lands, application guidelines should be developed in order to provide a common level of environmental and public health protection
    - If olive oil waste (OOW) is considered as waste national law should allow it to be treated as municipal waste when produced by smaller olive mills
    - The EC Commission should provide technical specifications on the conditions for using olive oil waste (OOW) as a by-product regardless of their economic value and regardless of the possible need of a drying phase and/or not removal
    - National laws should be brought in line with this new concept of by-product namely the part that still provides for the economic value of by-products as a requirement (as in the case of the Italian law)
    - The regulations should take onto account (a) the use of the land (b) the soil type and (c) the period of reuse.
    - OMWs are usually discharged in small stream catchments. For this fact, there is a need for including small streams into monitoring and assessment schemes as small streams contribute to the pollution load of the river basin.
    - EQSs should be set in a EU Directive in the same way that is done for water bodies, at least as minimum requirements per soil type. The threshold for pollutants (as phenols) concentrations in soil could be set in such values as to reflect existing soil maximum background concentrations in natural undisturbed soils.
    - ELVs should be provided in national legislation as in the case of Italy and Spain but as the local conditions should be taken into account regional regulations should be also adopted as in the case of Greece
    - More favorable national laws should be introduced for obtaining permits for facilities producing energy from biomass

- Volunteer legislation proposals
  - Support of technology change to 2-phase process for minimization of waste/wastewater. When utilizing the 2-phase system the fresh water consumption is reduced and also the wastewater streams are eliminated
  - Introduce laws that expressly facilitate initiatives for municipalities to build installations in the scope of their local public services, also based on regional agreements with olive mills and with other parties that would significantly contribute to providing biomass for energy production and other uses
  - National law should expressly provide that, in the absence of adequate private initiative, municipalities are able to build such facilities and operate them within the scope of their local public services
  - The Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the, Food, Drink and Milk Industries, Chapter on Olive Oil industry should be amended including the recent advances on waste management in the sector. In the same way, National BREFs on olive oil production should be prepared in the interested countries, covering all industrial units (IPPC and non-IPPC)
  - Promotion of the establishment of collective/cetralised treatment systems

- *Soil protection from the risk of olive mill waste water disposal*
  - Statutory legislation proposals
    - Recording Olive Oil Mills Waste disposal areas
    - Characterization of disposal areas-Risk assessment
    - Evaluation of risk level
    - Defining the conditions of OMW soil disposal
    - Adoption of soil quality indicators
    - Monitoring soil indicators-Evaluation of the results
  - Technical recommendations and guidelines
    - Measures for continuous monitoring of OMW disposal areas
    - Soil remedial technologies appropriate for OMW disposal areas

Evaluation

The report delivered is considered very significant; since it integrates all PROSODOL activities and finally satisfies the main objective of the LIFE call namely “ENVIRONMENT POLICY AND GOVERNANCE”.
The analysis clearly indicates the need for certain provisions in the EU legislation in order to valorise this waste as by-product and in the same time to protect the EU soils from adverse pollution.
The legislative and policy recommendations were based on the particularities of olive oil industry in the Mediterranean area. The proposed approach is to start from an objective reconstruction of the legal framework on waste management and accommodate it to the particularities of the olive oil waste.

All the aforementioned are included in the deliverable of the action:

“Integrated Strategy of actions, measures and means suitable for Mediterranean countries”

The deliverable was translated in Spanish (by CEBAS), Italian (by CERSAA) and Greek (by SSIA), produced in 30 reprints in each language and presented/distributed to national policy makers.

5.1.15 Action 19: Project Monitoring by SSIA

The objective of the action was to measure and document the effectiveness of the project actions as compared to initial situation, objectives, expected results and environmental impacts.

In general, no problems were encountered during the implementation of this Action and all Beneficiaries made efforts in order to: (a) make all appropriate preliminary works prior the beginning of each action, (b) begin and implement actions according to project's timetable, (c) efficiently communicate with the coordinator and the other Beneficiaries and organize/synchronize their actions, (d) propagate PROSODOL and (e) submit all foreseen progress reports to coordinator according to timetable.

Activities were undertaken to measure and document the effectiveness of the project as well as to monitor its progress and success. All these issues were discussed during the meetings of the project's committees as presented in Table 1 and the beneficiaries were agreed on project' strategy.

Table 3 includes the milestone of the project.

Table 3. Milestones of the project

Name of the Milestone	Action	Status	Fulfilled on
Monitoring system for the assessment of soil quality at disposal areas of olive oil mills' wastes	8	Fulfilled	31/12/2011
Monitoring system for the assessment of water bodies quality at disposal areas of olive oil mills' wastes	9	Fulfilled	31/12/2012
Technical evaluation and synthesis of soil protective/remedial techniques with waste pre-treatment and composting procedures to be applied at the selected pilot area.	11-13	Fulfilled	30/9/2010
Guidelines for the safe/controlled use of liquid/solid olive oil wastes in crop production	10	Fulfilled	30/6/2011
Technical and financial evaluation of the results obtained from pilot scale trials in Greece and Italy	10,14	Fulfilled	30/11/2012
Extension of the results from local to national scale and development of an integrated strategy of measures, actions and means suitable for Mediterranean countries	15	Fulfilled	30/6/2012

5.2. Evaluation

The methodology applied during the project's actions was that described in the proposal. Since the processes and techniques proposed to be implemented were well-know, but not applied in the specific problem of OMW disposal areas, the scientists of all beneficiaries had to conduct lab/small scale experiments in order to adjust the processes and conform them to the specific circumstances. Thus, the implementation of all actions resulted in an integrated scenario which includes soil protection/remedial techniques, small scale waste pre-treatment methodology suitable to be applied at mill level, use of OMW in trees irrigation/fertilization, composting, and most importantly the project resulted in specific measures and means that should be taken by olive oil productive countries to ensure sustainable OMW management and environmental monitoring. These measures are presented in four languages (English, Greek, Italian and Spanish) and are at a level "ready to be applied" and "ready to be incorporated in national/European legislative frameworks".

Finally, all techniques proposed have been technically and economically evaluated and are of low cost. An extension of higher cost, however, was performed in order to develop an evaluated proposal, not for individual mill owners, but for a group of owners for the establishment of a large OMW management plant.
The obtained results against the project's objectives are presented in the following Table 4.

Table 4. Obtained results against project's objectives

Task	Foreseen in the revised proposal	Achieved	Evaluation
Actions 2-6	Info-library	YES	The info-library was developed with the contribution of all five beneficiaries. It contains data regarding the issue of OMW production and management as well as many other useful information on the issue and also general environmental issues.
	Web site of the project	YES	A well-designed, attractive web site was developed. The visitors from all around the world were much many than the anticipated during the proposal preparation. The number of visits (more than 50,000 visits and more than 38,000 people) registered to the Web site of PROSODOL since the beginning of the project surpassed our original expectations.
	Pilot areas' inventories	YES	Two inventories were developed, one for the pilot area in Greece and the other for the pilot area in Italy. Both contain useful information and maps. Furthermore all the results of the chemical analyses were filled in the inventory of the pilot area and this allowed for the multivariate statistical processing of them. In addition to the chemical parameters, magnetic parameters of the soil samples were included as these could be related to heavy metals and since they are recently used for monitoring pollutants of the air and soils (state of the art).
	Monitoring tools	YES	The monitoring tools included 1) A handy Monitoring System Tool to monitor measurement results of targeted areas in order to evaluate the degree of risk in the vicinity of the waste disposal areas, 2) A Surface Analysis Tool to be used for mapping the possible surface diffusion of the chemical parameters in the vicinity of the waste disposal areas (even if this was not explicitly stated in the original proposal it became as a consequence of the spatial distribution of the measurements that were carried out bringing added values to the results of the project), 3) Time Lapsed Electrical Resistivity Tomography measurements (TL-ERT) for monitoring the changes of the physical characteristics of the subsoil over time and identify the deeper diffusion of the contaminants (even if this action was not explicitly stated in the original proposal, it is a state of the art component that proved to be efficient for monitoring purposes and suggesting an alternatively way of monitoring of OMW without the need of chemical analyses and thus of extreme importance to the local authorities, 4) A GIS based tool for the Risk Assessment of the Sitting of OMW Disposal Areas.
	INSPIRE Geoportal	YES	This action even if it was not foreseen originally in the proposal, it is a requirement for all the European funded projects. All the cartographic layers were checked (and passed successfully) for conformity to INSPIRE Directive, based on a specific application (IMS/FORTH INSPIRE Geoportal) that was developed by the IMS-FORTH team. The INSPIRE Geoportal provides the means to search for spatial data sets and spatial data services, and subject to access restrictions, view and download spatial data sets from the EU Member States within the framework of the INSPIRE Directive.
Action 7	Collection and evaluation of all available data/ information in the study area	YES	A preliminary study of the project area was completed according to plan. Data regarding population and local activities of the target area, number, characteristics and activities of the olive mills, hydro-, geomorphological and local meteorological data and initial assessment of environmental impacts caused by the disposal of OMW have been collected.
	Risk analysis using the "source of pollution-pollutant pathway-target" principle	YES	Full assessment of soil, surface and groundwater risk was completed by the end of the project based on the results of soil and water sampling campaigns. Risk maps for soil and water were prepared for selected parameters using geostatistics.
Action 8	Risk assessment of soils that accept OMW disposal	YES	A well-designed soil sampling campaign was developed and implemented. Factors and conditions that affect soil quality were determined while the effect of uncontrolled OMW disposal was in details identified, also in relation to different soil types.
	Identification of	YES	A very useful set of soil indicators, specific for OMW disposal areas was

	soil indicators		developed after very careful evaluation of the results obtained from the soil sampling campaigns. These indicators were in the following incorporated in the Soil Monitoring System as well as in all proposed measures proposed by the project.
	Development of a Soil monitoring System	YES	The Soil Monitoring System was successfully developed and it includes two parts: (1) assess soil quality, identify the terms for OMW disposal (where, how, when, how much) and continuous monitoring during disposal and (2) software tools that can provide continuous soil monitoring by local authorities and individuals. The additional soil sampling campaign aiming to collect soil samples from different areas, away from the pilot Municipality, validated the results of action 8 and provided explanation for the very high Ni and Cr soil concentrations.
Action 9	Evaluation of the quality of the existing water bodies	YES	Water samples have been collected between May 2009 and December 2012 from surface streams, springs, water supply pipes, old wells, piezometers installed in 5 drillholes in the wider affected area and four existing water abstraction wells.
	Development of a water monitoring system	YES	A carefully designed monitoring system has been implemented in the study area. Water samples collected have been analyzed to identify potential contamination sources, concentration of the most important contaminants, transport mechanisms and the fate of contaminants in aquatic media.
	Estimation of a quantitative risk for water contamination	YES	Risk assessment for soils, waters and humans due to the uncontrolled disposal of OMW in the study area was carried out. Water risk assessment was based on the data collected from soil and water sampling campaigns.
Action 10	Specification of terms and conditions for OMW use in fertilization and irrigation of olive trees orchards	YES	The results of this action were very significant since they contribute to the sustainable use of OMW for olive trees irrigation and fertilization. CERSAA extensively studied the use of OMWs in this sector and concluded that OMWs could contribute to efficient nutrients/water recycling, the reduction of costs generated from chemical fertilization while at the same time, the benefits in yield and production were comparable to those of the traditional practices.
	Evaluation of OMW effect on soil and production quality	YES	CERSAA studied the effects on soil quality caused from the <u>controlled</u> use of OMW in irrigation/fertilization of olive orchards and concluded that the distribution of OMW under specific rules, cause no significant adverse effects on soil quality. Thus, specific recommendation were delivered and intergraded into the project's deliverables.
	Development of rapid methods for COD/BOD measurement in mills	YES	Based on the quick methods for the determination of BOD_5 and COD of OMWW it is possible, already at olive mill level, to determine values in a simplified manner. In this way olive mill owner is aware of the polluting load (at least of the 2 parameters used as indicators) ad can easily compare values with the reference ones considered in the relevant legislation.
Action 11	Specification of terms and conditions for the implementation of soil bioremediation at the pilot area of the project	YES	The lab experiments conducted during this action proved that bioremediation is an effective technique also for the remediation of soils polluted with OMWs. CEBAS delivered specific guidelines for individuals and local authorities which provide all appropriate data to evaluate, develop, implement and monitor soil bioremediation at OMW disposal areas.
Action 12	Use of different porous materials as soil additives to develop an appropriate methodology for OMW disposal areas	YES	The lab experiments resulted in the optimum methodology for the use of porous materials at OMW disposal areas. All parameters that affect the effectiveness of the methodology as well as the restricted factors were defined. Clinoptilolite was proposed to be used as soil additive. The method was evaluated relative to the environmental impacts and the benefits that can bring.
	Identification of the optimum methodology to	YES	A detailed assessed methodology was developed and delivered. However, since the application at pilot scale could have unpredictable effects, two zeolite percentages were tested in soil as well as two particle sizes. The

	be applied at pilot scale		assessment performed afterwards concerned the easy of application, the cost and the total soil improvement and protection.
Action 13	Design and efficient operation of a prototype pre-treatment system and detailed report	YES	Large scale laboratory OMW pre-treatment experiments have been carried out to optimize the pre-treatment methodology prior to the implementation in field. Various materials were used to investigate sorption of organic contaminants, increase pH, initiate precipitation of metals in stable forms and/or remove solids from OMW.
	Guide for the application of the method in the pilot area of Action 14	YES	A feasible low cost OMW pre-treatment methodology using various reactive agents has been developed in order to be applied in small olive oil mills that are mainly family businesses and widely dispersed in the Mediterranean region. This pre-treatment option can significantly improve the quality of OMW prior to application on agricultural soil or disposal in evaporation pond.
	Demonstration of a low-cost OMW pre-treatment technique at a pilot scale	YES	Done as discussed in the following activities for Action 14.
Action 14	Implementation of soil remedial and protective actions at pilot scale	YES	Two remedial methodologies were applied at a pilot field, i.e. bioremediation and use of clinoptilolite as soil additive. Both, as it was anticipated from the lab experiments, were appropriate for the specific problem and resulted in improvement and protection of soil from the degradation caused by OMW disposal. Specific guidelines were delivered to assist interested stakeholder to implement these technologies in other Med countries.
	Implementation of OMW pre-treatment at pilot scale	YES	The pre-treatment methodology applied in the field was based on the evaluation of the results of the laboratory experiments carried out in the line of Action 13. Pre-treatment involved addition of saw dust and lime in the main 0.5 m^3 steel tank and filtration as a separate stage through a goat manure substrate in plastic vessels of 0.25 m^3 after a retention period of 8 days. A total period of ten days is required in order to produce each batch of 0.5 m^3 of pre-treated OMW.
	Implementation of composting at real scale	YES	The composting methodology of OMW is a well-known practice, however, the objective of PROSODOL was to use olive husk and to co-composting it with clinoptilolite to produce an improved product that would be characterized by the beneficial clinoptilolite's property of "slow nutrient release". This was achieved firstly by implementing a small scale composting to identify which would be the optimum zeolite percentage in the compost feedstock. Thereafter, the optimum zeolite percentage was used for a large scale composting. The compost produced has very good and acceptable physicochemical properties.
	Lettuce cultivation	YES	Pre-treated wastes were used for lettuce cultivation while at the same time effects of soil disposal was monitored. It was proved that the proposed pre-treatment methodology does not affect soil quality significantly and the lettuces produced satisfied quality and, in some extent, yield standards. Thus, the proposed technique could provide an efficient solution, mainly at field level, for the re-use of OMWs. However, it is recommended that in order to achieve higher yields and products that meet market standards, ore studies are required.
	Financial and economical evaluation of the implemented techniques. Extension of the methodologies at larger scale	YES	All techniques and methodologies that were implemented at pilot scale were evaluated regarding their financial and economical feasibility. A detailed and extensive study was performed by SSIA with the contribution of all beneficiaries. The study could very much assist the EC, policy makers and stakeholders to evaluate potential actions in order to develop sustainable OMW management scenarios. The study considers a time period of 10 years and integrates other potential solutions and actions than those implemented at pilot scale, as well.
Action 15	Development of an integrated scenario, appropriate for	YES	This is the main outcome of the project, which integrates all actions and achievements produced by the project. It is a "ready to be applied" scenario and can be intergraded into the EU and national legislative frameworks. For this reason, it is delivered in four languages (English,

	the Med countries		Greek, Spanish and Italian).
Actions 16-18	Disseminate project results effectively	YES	Extensive analysis is provided in section 5.4.
	Workshops in the three participating countries	YES	Extensive analysis is provided in section 5.4.

5.3. Analysis of long-term benefits

The results obtained during PROSODOL project can be considered highly significant since they contribute to:

1. the sustainable environment monitoring
2. the improvement and further protection of soil quality at OMW disposal areas and
3. the exploitation of OMW in the agricultural sector under specific conditions

PROSODOL proposed specific, simple to apply and cost-effective practices for OMW disposal areas (i.e. soil remediation, low cost waste pre-treatment methods, composting, use of OMW for irrigation and fertilization of olive tree orchards) which, if adopted, could result in significant environmental benefits, i.e. soil and water bodies protection, nutrients recycling, minimization of OMW amounts disposed in evaporation ponds or directly on soil and water resources saving by recycling wastewater in the agricultural sector.

Furthermore, PROSODOL also proposes a Soil Monitoring System and a Water Monitoring System. These two systems are delivered at a "ready to be applied" level and can contribute to the effective and continuous environment monitoring at OMW disposal areas. The Soil Monitoring System is accompanied by two software application tools (one for individuals and one for authorities) that will assist and enhance the continuous monitoring of OMW disposal areas. Specific terms and conditions on the selection of areas suitable for OMW disposal were developed as well as guidelines and specifications on how, when and in what quantities OMW should be applied. This, in turn, is anticipated to result in environment protection and overall improvement of OMW disposal areas.

With respect to the monitoring, PROSODOL has developed and suggested 4 different types of tools that can be adopted by the local authorities and be used in a systematic way. A handy monitoring tool based on the chemical analyses can be used also by the owners and third parties and has been freely delivered to the interested parties. The rest monitoring methods (surface analysis tool and time lapsed ERT) are more specialized and can be used by the local authorities in a local scale, while the GIS risk assessment tool can be used in regional scale. All these methods constitute state of the art and are of significant importance for the future OMW monitoring.

All the implemented actions were integrated in specific legislative proposals. Thus, it is believed that PROSODOL may contribute to the improvement and completion of national legislative networks. The deliverable entitled "Integrated Strategy of actions, measures and means suitable for Mediterranean countries" (produced in English, Greek, Italian and Spanish) evaluates all existing Mediterranean and EU legislative frameworks, highlights legislative blanknesses and proposes specific, both mandatory and optional, recommendations. Considering that no specific legislation exists in the EU regarding OMW, it is believed that the results of PROSODOL could bridge the gap and bring environmental benefits to the Member States.

PROSODOL proposes actions for individual mill owners (small family-scale plants) and groups of mills (i.e. an association) at minimum costs, affordable even for small plants. However, and this should be highlighted, the lack of specific legislation (as in Greece) or the existence of incomplete and/or inappropriate legislative frameworks (e.g. Spain, Italy) deters mill owners and their corresponding associations from adopting and implementing any recommended action like soil remediation, waste recycling, etc. Therefore, the first step after PROSODOL completion should be the adoption of specific and appropriate legislation by the EU and, next, by the Member States. An appropriate legislation framework should take into account many environmental parameters apart from simply annual OMW disposal dosages on soil and the distance from inhabited areas.

PROSODOL demonstrated solutions for soil remediation, exploitation of OMW and effective soil/water monitoring. In order to achieve long-term environmental benefits, the proposals of PROSODOL should reach mill owners and local authorities through legislation. This is an empiric general conclusion that derives from the experience of conducting many stakeholders during the four years of the project. No one is willing to undertake actions that are not imposed by the Law. And there is a very simple explanation for this: the uncontrolled disposal in evaporation ponds or in water bodies or directly on soil is of zero cost.

PROSODOL proposals could undoubtedly result in long-term cost savings thanks to the recycling of water and nutrients, profits by marketing the produced composts, regional development due to the improvement of the environment at OMW disposal areas – many of which happen to lie within the borders of highly touristic regions – and indirect money saving coming from the protection of soil and water bodies quality. All these long-term benefits can also have a social impact by influencing daily life of citizens living nearby the OMW disposal areas together with the protection of their health via protecting and monitoring soil and water quality.

Although the PROSODOL activities took place in two pilot areas in Crete and in Italy, the results that were obtained are characterized by high degree of reproducibility. For the evaluation of the results the characteristics and peculiarities of the Mediterranean areas were taken into account. Thus, all proposals, measures, means and restriction factors are applicable to any Mediterranean olive oil producing country. The results have been exhibited and explained in detail to stakeholders in Greek, Italian and Spanish. All factors that should be considered when adopting PROSODOL recommendations were discussed.

Moreover, the results were presented and discussed in the presence of many scientists and stakeholders from Mediterranean countries (also including other than Spain, Italy and Greece) during the final 3-day Symposium in Crete. This particular event was especially significant since it gave the opportunity to disseminate PROSODOL objectives and results to other Mediterranean countries. The experience gained indicates that scientists and stakeholders were satisfied by PROSODOL because several studies and research on the subject of OMW have been conducted in the last decades but in an occasional and fragmentary way while, on the other hand, PROSODOL integrates sustainable practices and proposes an integrated management, remediation and monitoring strategy.
Now, after the completion of PROSODOL, there are complete and detailed studies on the effect of OMW uncontrolled disposal on soil, the effect of controlled disposal for olive tree orchards irrigation and/or fertilization and an integrated monitoring of soil/water quality strategy.

The innovative aspects of PROSODOL:

- The scientists involved in the project demonstrated methodologies for soil remediation and protection, i.e. bioremediation and zeolite application on soil. These are practices well-known worldwide but had never been implemented for OMW disposal areas. Thus, it was proved that there are low-cost methods for soil protection suitable for any Mediterranean country. Apart from the two demonstrated methods, the beneficiaries evaluated also other available and known soil remediation methods and provided a useful guide on how to select the most appropriate one.

- The development of the monitoring systems is also of high innovation level since, up to now, nothing similar existed worldwide. In addition, various ways of monitoring that can be applied in local or regional level were suggested.

- The development of a low-cost waste pre-treatment technique is another innovative aspect of PROSODOL. Despite the fact that many treatment methods have been developed so far (the most important ones have been evaluated in the deliverable of Action 14 “Financial and Technical evaluation of the demonstration actions”), their applicability is very low mainly due to their high costs. The technique proposed by PROSODOL is of low budget and can be applied at any scale (from individual mill owners up to association level) with affordable capital and operation costs.

- The development of easy and rapid methods for the determination of OMW’s COD and BOD values is also considered an innovation. The mill owners will be able to measure COD/BOD of their wastes in situ, thus enhancing waste management and safe disposal.

EU added value

All the above results can be adopted by many European countries and especially those of the South Europe, since they constitute the main producers of olive oil and thus they face similar problems with the installation and operation of OMW.

PROSODOL developed its activities based on the principles of The Soil Thematic Strategy and followed the algorithm “recording in an national inventory-adoption of nation remedial strategy-implementation of remedial activities-prevention of further soil degradation”. Therefore, the legislative proposals of the project can be adopted by the Member States and from the EU and incorporated into their legislative frameworks.

PROSODOL results contribute to soil conservation and protection, which is a principal topic in the EU. The added value of the soil monitoring system that was developed has to be founded in it’s relevance for soil protection, where soil is considered as a system where effects of many contaminants and pressures from other soil threats come together.

PROSODOL contributes to the protection of the health of European citizens that can be impaired in different ways by soil degradation by exposure to soil contaminants by direct ingestion or indirect intake (through contaminated food or drinking water).

The establishment of a system to identify the problem allows the Member States to address soil protection and combat soil threats systematically, effectively and efficiently. Member states will be in a position to adopt more targeted and efficient measures and to plan medium- and long-term strategies. By encouraging a sustainable use of soil and taking a preventive approach, the Member States will save costs, which so far were borne by society.

The close cooperation of scientists of the three countries which face the same problem of soil contamination due to oil wastes industries, for trans-national data collection and for synthesis of remedial/protective soil methods in order to apply them in a pilot scale, contributed to an effective and efficient conformation of the common problem. The methodologies applied through this cooperation are ready to be transferred and implemented in Mediterranean countries, while through this cooperation, dissemination of the project’s results to the three major olive oil productive European countries but also to other countries, was easier and wider.

Long-term indicators

The following indicators could be monitored in a long-term basis:

1. The number of Med countries that have adopted the proposed legislative changes and incorporated them into national legislative frameworks.
2. The number of OMW disposal areas in Mediterranean region that have been registered as potentially degraded and the number of inventories established with data of such disposal areas.
3. How much degraded OMW disposal areas have been remediated in Med region
4. In how much OMW disposal areas have been implemented the soil/water monitoring systems that are proposed by PROSODOL.

5.4. Dissemination issues

Dissemination strategy includes three specific Actions (16, 17, 18) however; dissemination of project's achievements was conducted in the framework of other project's actions, as well.
The main PROSODOL dissemination strategy was constructed onto three axes (i.e. Greece. Italy and Spain), although there were also common dissemination activities.
The Greek, Spanish and Italian dissemination plans were divided into four parts of activities:

a. *Dissemination to national stakeholders*

   This foresaw the organization of four workshops (one every year) in the three countries. The target audience was producers, mill's owners, technicians operating in the extension service, policy makers, other stakeholders and general public. Moreover, project outcomes were disseminated through articles in national dedicated scientific reviews, press releases, leaflets and brochures containing the project's outline objectives, benefits, etc. The web site of the project was accessible through the web-sites of the Beneficiaries, while posters and metallic boards were erected at beneficiaries' premises and at pilot areas. Training workshops for mill owners and other stakeholders were organized in all the tree countries.

b. *Dissemination in the Mediterranean region*

   Three workshops organized in the three countries targeted mainly to scientists in order to disseminate the results obtained after the implementation of the pilot scale activities of the project and to present the suggested technologies as well as, all the measures and actions which should be taken to face the problem of soil and water contamination by the olive oil mills' wastes and simultaneously to conform with the European Soil Thematic Strategy and with the European legislative framework in general. One, final, Mediterranean three-days conference was organized in Greece (Crete) during the last quarter of the project. Scientist of the involved countries presented the results and conclusions of the project. The workshop targeted to scientists of other Med countries (European, Israel, Turkey, etc.), researchers from other consortiums relative to the same problem as well as policy makers.

c. *Dissemination to national authorities*

   This part of the dissemination strategy took place after the completion of Action 15. Beneficiaries in the three countries promoted the final report, which includes all necessary measures and actions, appropriate to be taken in Greece, Italy and in Spain but also in the Mediterranean region, to national authorities.

d. *International dissemination*

   International dissemination was performed through the web site of the project, all the contained informative data, the publications in international scientific journals and the announcements in International scientific conferences.

Evaluation of dissemination strategy

PROSODOL results were effectively disseminated to stakeholders, policy makers, agricultural associations, public authorities, environmental organizations, scientists, non-technical parties and general public in all three participation countries, but also to other Mediterranean countries. The produced material and the organized events were received the acceptance of the targeted audience and this was proved by the number of the web-site visits and also by the participants of the workshops and the training courses. No significant problems were recorded while the objectives were reached.
It should be highlighted that, PROSODOL produced significant, very useful and "ready to be applied" results. The targeted audience could be considered as ready to accept the legislative recommendation. Thus, if these results will be adopted and incorporated into the EU policy then this can ensure the AFTER-LIFE sustainability of PROSODOL. The beneficiaries believe that the

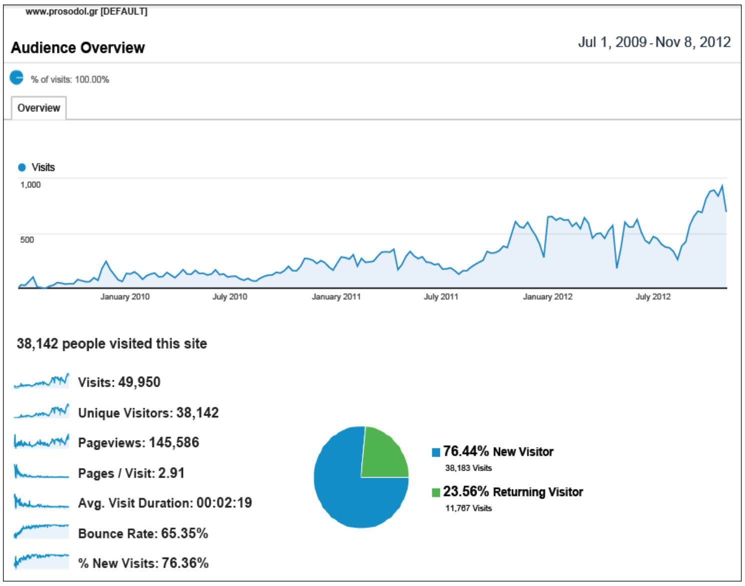
EU can adopt the results of PROSODOL as they proposed in the project's deliverables since they are assessed and conformed to the Mediterranean specific environmental problems.

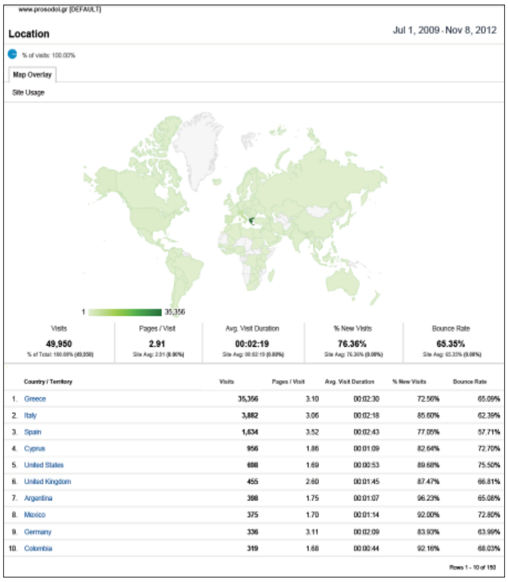
5.4.1. Dissemination: overview per activity

In this section, all dissemination activities performed during the different project's actions are presented.

5.4.1.1.Actions 2-6: Info-library and web site of the project

The info library, established by all three beneficiaries and the informative web site of the project had more than 50,000 visits (more than 38,000 people and 1040 visits/month on average) since the beginning of the project. The number of visits is very much satisfactory, if one considers the initial target number, which was 300 per month (see graph below).





5.4.1.2. Action 16: Dissemination-Spain

- CEBAS-CSIC produced a set of informative material (Annex 9) to be distributed during the workshops and also to be sent to interested stakeholders, which included (a) a 8-pages brochure in Spanish with information regarding project objectives, expected outcomes, results and Beneficiaries, (b) o notepad with PROSODOL Logo, (c) workshop programs, and (d) a pen. The informative material was printed in total at 250 copies.
- A Spanish version of the Project poster and Workshop posters (50 copies) was also prepared (Annex 10). Posters were erected at Beneficiaries' premises. Posters were also used in dissemination activities (workshops) during project lifetime.
- CEBAS-CSIC produced two books and distributed during the lifetime of the project:
    - o 70 reprints in English of the official edition of project results entitled: "Strategies to improve and protect soil quality from the disposal of Olive Oil Mill Wastes in the Mediterranean region: Results and Achievements of a 4-year demonstration project – What to consider; What to do".
    - o The deliverable "Integrated Strategy of actions, measures and means suitable for Mediterranean countries" of Action 15 (prepared by CEBAS) was translated in Spanish, printed in 30 reprints and distributed to national authorities and other stakeholders (Available on line

      http://www.prosodol.gr/sites/prosodol.gr/files/Legislative%20study_esp.pdf).

- Workshops
  - CEBAS organised the first national workshop at its premises on 11 December 2009, which principally aimed to present the objectives and the first results of the project. The workshop was entitled: "*Olive oil mill wastes: Problems and management and valorisation sustainable systems*". Several experts from scientific, technical and administrative communities were invited to present their experiences in this workshop.
  - On 19 November 2010, CEBAS organized the 2nd national workshop, which took place in CEBAS premises entitled: "Olive oil mill wastes and polluted soil". The principal aims of this workshop were to present the objectives and achievement of the project. Several experts from the scientific, technical and administrative communities were invited in order to interchange information and experiences about the environmental and agronomical use olive oil mill waste. Apart of the oral presentation to explain aspects of this Project such as the general objectives, actions implemented by CEBAS research team and results obtained during the bioremediation of soils polluted by the OMW application, other three oral presentations were showed in this meeting relative to the valorisation of OMWs.
  - In May 2011, Concepcion Garcia-Ortiz Civantos and Antonia Fernández Hernández, technicians of IFAPA institute "Venta del Llano" in Jaén, invited CEBAS to participate and organize a training and demonstration workshop which would be finally celebrated on 07/06/2012. The IFAPA institute, belonging to the Regional Government of Andalucía, is a research and training center devoted to olive oil production in this Region. Moreover this institute is in permanent and close contact with olive oil producer and farmer associations from this Region which is leader of olive oil production in the World. For this event, CEBAS prepared 100 copies of dissemination material for delivering to the audience. This material was composed of: i) a leaflet with the principal objectives of our Life Project; ii) the program of the workshop; and, iii) also informative sheets about the environment problem to be solved, the objectives, the expected results, the actions and the implementation areas. The audience of this workshop was integrated principally by farmers, olive mill owners and technicians. After the reception and presentation of the workshop, Dr. Sánchez-Monedero spoke about theoretical aspects of the elaboration of TPOMW (waste produced in the two phase olive mills). Then, Dr Moreno spoke about PROSODOL project and the principal results obtained through a laboratory experiment of soil bioremediation in order to determine the feasibility of *landfarming* treatment of a specific area of land affected by the repeated disposal of OMWW in Crete. The toxicity problem of this kind of wastes on soil microorganism and plants was noted as risk when this kind of uncontrolled OMWW disposal was used. Also, it was explained that the toxicity of this soil affected by OMWW disposal can be diminished through the use of low-cost bioremediation treatment such as land treatment or *landfarming* and composting. Several concerns, questions and comments about these topics were underlined by the audience and we can establish an interaction in order to answer and explain them. The event was closed with a practical lesson of the elaboration of TPOMW compost in the IPAFA facilities which was lectured by Concepcion Garcia-Ortiz Civantos and Antonia Fernández Hernández.
  - CEBAS has organized the Mediterranean and fourth national workshop of PROSODOL in Spain. This event was celebrated inside the CEBAS-CSIC premises on 21st March 2012, in which the other partners of the Project have participated in order to disseminate the principal results. Apart of the oral presentation to explain aspects of this Project such as the general objectives, beneficiaries and actions implemented by CEBAS, the other Beneficiaries explained the remaining Actions of the Project. The Workshop was completed with other presentations on legislative aspects, composting experiences, and valorisation systems of OMW in Spain. The audience of the workshop included mainly mills owners, representatives

of regional authorities, scientists and wider public. This event was an opportunity for interacting between PROSODOL beneficiaries and national stakeholders and several aspects of OMW management were discussed.

- Sent data Project and Legislative Study to *Dirección General de Evaluación Ambiental, Consejería de Agricultura, Agua y Medioambiente*, Regional Gobernment of Murcia, Spain.
- Publications :
  - Inglezakis, V.J., Moreno, J.L., and Doula, M. 2012. Olive oil waste management EU legislation: Current situation and policy recommendations. International Journal of Chemical and Environmental Engineering Systems (IJCEES) 3(2):65-77.
  - Moreno, J. L., Bastida, F., Sánchez-Monedero, M. A., Hernández, T. and García, C. 2013. Response of soil microbial community to a high dose of fresh olive mill wastewater. Pedosphere.
- Announcements in scientific international conferences
  - Inglezakis, V.J., Moreno, J.L., Doula, M.K. "Implications and complications arising from the EU legislation on the management of olive oil waste". Proceedings of "ATHENS 2012, International Conference on Sustainable Solid Waste Management", 28-29 June 2012, Athens, Greece.
  - Moreno, J.L., Doula, M.K., Sanchez-Moreno, M.A., Garcia, C., Kavvadias, V., Theocharopoulos, S. "Bioremediation technology implementation at an olive mill waste disposal area". Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp.112-119.
  - Moreno, J.L, Doula, M.K, Sánchez-Moreno, M.A., García, C., Kavvadias, V., Theocharopoulos, S. "Implementation of bioremediation technology to olive oil mill waste disposal area". Proceedings of the 3nd International Conference on Hazardous and Industrial Waste Management, 12-14 September, 2012, Chania-Crete, Greece.

5.4.1.3. Action 17: Dissemination-Italy

- A metallic board (70x100 cm) was prepared and installed in the pilot area at Cersaa's premises.
- CERSAA produced one informative leaflet of the project in Italian language in 500 copies to be used as an easy to tool to get a very quick overview about project objectives and activities foreseen. The leaflets were distributed during the entire duration of the project to interested stakeholders during workshops, meetings and personal communications at Cersaa's premises. (Annex 11).
- A 30 pages brochure was prepared in 500 copies in Italian language (Annex 12) that was distributed according to the same procedures as leaflets. The brochure is intended to describe more in details all project activities, partners, expected results, methodologies adopted, environmental issues related to OMWW. A specific focus is dedicated to the activities carried out in the pilot area of CERSAA.
- Project poster was prepared and uploaded on the web page of CERSAA's website dedicated to PROSODOL Total visits of CERSAA's website during 2011: 11000 ; total pages visited: 42000.
- CERSAA produced three books and distributed during the lifetime of the project:
  - A manual entitled "Good practices for the agronomic use of olive oil mills wastes- Application Guide". Reprints : 200 in Italian

(https://www.dropbox.com/home/SYMPOSIUM%202012%20CRETE_Not%20to%20be%20deleted).

- An official edition of project results entitled: "Strategies to improve and protect soil quality from the disposal of Olive Oil Mill Wastes in the Mediterranean region: Results and Achievements of a 4-year demonstration project – What to consider; What to do" .
- The deliverable "Integrated Strategy of actions, measures and means suitable for Mediterranean countries of Action 15 (prepared by CEBAS) was translated by CERSAA in Italian, printed in 30 reprints and distributed to stakeholders and national authorities/policy makers (https://www.dropbox.com/home/SYMPOSIUM%202012%20CRETE_Not%20to%20be%20deleted).

- 3 TV broadcasts were realized within the TV format "Agricultura News" designed by Cersaa and broadcasted since 2009 on regional channels.

  The reportages were broadcasted on 14/11/2009, 05/02/2011, 18/06/2011). In each episodes different issues regarding olive processing, olive oil production, olive waste disposal were addressed. In the broadcast on 18/06/2011 Dr. Marouli (former project auditor) released an interview about PROSODOL project and relevant issues taken in consideration. Average audience of episodes is around 50.000 people.

- Workshops
  - On 14/12/2009 the first workshop was organized at Cersaa's premises. Audience was mainly composed by technicians, olive mill owners, students, officials of agricultural organizations. The following issues were presented and debated: project presentation, legislative issues related to OMWW disposal in Italy according to present legislation, main phytopathological problems observed in Italian olive orchards.
  - On 25/09/2010 the second workshop was organized and hosted at the fair "Fiori, frutta qualità" annually arranged by the municipality of Celle Ligure (Savona province, Liguria) in September in order to promote the following sectors: agriculture, handicraft and tourism. Audience was mainly composed by the wide public that attended the fair interested to issues related to oliviculture. The following issues were presented and debated: project presentation, practical aspects related to olive growing, advices about olive protection from pests and pathogens.
  - On 18/03/2011 the third workshop was organized at Cersaa's premises. An innovative technique, based on vacuum evaporation, for olive mill waste waters treatment was presented by a responsible of the creator firm, the Delca s.r.l. of Turin (Italy). Thanks to the availability of a pilot scale demonstrative machine that was brought on purpose, it was possible to realize a practical demonstration of its functioning, showing its by-products (water and a concentrated residue) and stirring up further on the discussion amongst the workshop participants. Audience was mainly composed by olive mill owners, technicians, officials of Liguria Region, officials of agricultural organizations. The comprehensive presentation of project activities and main outcomes was followed by the explanation of main technical and economical characteristics of the plant for OMWW treatment based on vacuum evaporation.
  - The <u>Mediterranean workshop</u> was organized at Cersaa's premises on 06/10/2011. Representatives of each partner country took part to the workshop giving presentations about the activities carried out in each partner country and stressing main outcomes achieved. Moreover OMWW treatments techniques and disposal issues were taken in consideration as well as legislative issues regarding OMWW disposal. The latter subject was widely discussed thanks to the presence of officials of Liguria Region who illustrated

potential evolutions and amendments regarding the legislation regulating the olive sector on a regional basis according to recent.

- Training workshops
  - o Two training workshops were organized by Cersaa at Olive Mill “CATI”, Quiliano (Savona province, Italy) in order to address practical issues related to olive orchard management, olive growing, pests and disease control in olive management. First workshop was held on 19/02/2011 and it was attended by 50 people. The second workshop was held on 27/01/2011 and it was attended by 30 people.
- Announcements in scientific international conferences
  - o Tinivella, F., Minuto, A., Medini, L., Bruzzone, D., Doula, MK., Kavvadias, V. “Effects deriving from the spreading of olive mill wastewaters in an olive orchard on the chemical characteristics of the soil and on plant development. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 73-81.
- Press releases were prepared in order to advice local press about events and workshops organized. Altogether 8 press releases were published both on internet and in the weekly-issued newsletter “Flornews” regarding agricultural subjects and addressed to around 1000 recipients in Liguria Region.
- 5 articles were prepared and published in internet. Three of them were published on “Savona Economica”, an online journal weekly issued set up by the editorial staff of the Chamber of Commerce, Industry, Handicraft and Agriculture of Savona.
- Contacts were established with policy makers with specific regards to officials belonging to the central administration of Liguria Region and responsible for issues related to oliviculture (Dr. Favero Riccardo). A meeting with Dr. Favero was scheduled in order to present the publication “Integrated Strategy of actions, measures and means suitable for Mediterranean countries” and to discuss about possible actions aimed at introducing amendments to regional legislation about OMWW disposal according to the outcomes of the project.
- Others
  - o CERSAA published an article in the technical journal regarding the olive oil sector (edited by Edagricole, Bologna, Italy):
    Tinivella F., Medini L., Bruzzone D., Minuto A., Minuto G (2012). Il residuo a 105 °C rivela la nocività dei reflui liquidi. Olivo&Olio 15 (2), pag. 40-42. The audience of the journal is mainly represented by olive growers, olive mill owners, companies and firms operating in the sector of olive processing and olive oil production, technicians, academics. Monthly circulation of journal is around 5.000 copies.

    CERSAA produced also a Project Newsletter. The September 2012 project newsletter was prepared in Italian language and distributed to over 1000 recipients through e-mail. The newsleter is included in Annex 13.

5.4.1.4. Action 18: Dissemination-Greece

- A project logo was created and used in posters, metallic boards, communication forms, web site and for all dissemination actions.
- A metallic board (2m x 3m) with two printed sides, one in English and one in Greek was erected at the Greek implementation area in Crete.
- SSIA produced a set of informative material (Annex 14) to be distributed during the workshops and also to be sent to interested stakeholders, which included (a) a 16-pages brochure with information regarding project objectives, expected outcomes, results and Beneficiaries, (b) o

notepad with PROSODOL Logo, (c) workshop program, and (d) a pen. The informative material was printed in total at 900 copies.

- The project logo was printed in poster (150 copies) and distributed among all beneficiaries. An English version of project posters (150 copies) was prepared by the project coordinator and circulated among all beneficiaries (Annex 15). A Greek version of the poster (150 copies) was also prepared and was distributed among the Greek Beneficiaries. Posters were erected at Beneficiaries' premises but also at the Town Hall of Municipality of Nikiforos Fokas, at the Town Hall of Municipality of Rethymnon, and at the premises of the Union of Agricultural Cooperatives of Rethymnon, Crete. Posters were also used in dissemination activities during project lifetime (workshops, participation in conference, erected during other scientific activities in which beneficiaries' scientists participated in Greece and abroad, etc).
- 100 CDs were produced and distributed to many workshops participants, mainly scientists, stakeholders and local authorities. The CD contained
    - o project dissemination material (posters, logo, booklets)
    - o the manual entitled "Good practices for the agronomic use of olive oil mills wastes-Application Guide" in Greek and in English
    - o the official edition of project results entitled : "Strategies to improve and protect soil quality from the disposal of Olive Oil Mill Wastes in the Mediterranean region: Results and Achievements of a 4-year demonstration project – What to consider; What to do" (in English)
    - o The deliverable "Integrated Strategy of actions, measures and means suitable for Mediterranean countries" in Greek
    - o Photos from PROSODOL activities
- SSIA produced five books and distributed during the lifetime of the project:
    - o A manual entitled "Good practices for the agronomic use of olive oil mills wastes-Application Guide". Reprints : 300 in Greek

      (http://www.prosodol.gr/sites/prosodol.gr/files/DGr_6.pdf).
    - o An official edition of project results entitled: "Strategies to improve and protect soil quality from the disposal of Olive Oil Mill Wastes in the Mediterranean region: Results and Achievements of a 4-year demonstration project – What to consider; What to do" (200 reprints in English) (http://www.prosodol.gr/sites/prosodol.gr/files/DGr_8.pdf)
    - o The deliverable "Integrated Strategy of actions, measures and means suitable for Mediterranean countries" of Action 15 (prepared by CEBAS) was translated by SSIA in Greek (http://www.prosodol.gr/sites/prosodol.gr/files/DGr_9.pdf), printed in 30 reprints and distributed to stakeholders, national local policy makers and local authorities. Reprints were sent after request to EPSILON S.A., which is the authorized institution for the development of legislative proposals relative to wastes management in Greece to be incorporated in national law. Moreover, after contact with representatives of the Greek Ministry of Environment and Climate Change, a reprint of the deliverable was sent to the Directorate, which is responsible for the legislative proposals to the Government.
    - o 100 reprints of the 3-days conference's proceedings (https://www.dropbox.com/s/lyaa3tskerp8wvg/Symposium%20proceedings.pdf)
- Workshops (the presentations of the workshops can be found in the web site of PROSODOL)
    - o The first Greek workshop took place on 4 December 2009 in Athens. The title of the workshop was "Olive oil Production and Waste management in the Mediterranean-Presentation of PROSODOL project". The informative material that was distributed to the participants was a folder which contained : (a) a 16-pages brochure with information

regarding project objectives, expected outcomes, results and Beneficiaries, (b) o notepad with PROSODOL Logo, (c) workshop program, and (d) a pen. The audience of the workshop included mainly scientists, students and wider public.

- The 2nd workshop was organized on 4 April 2012 in Kalamata (one of the main olive oil productive Greek prefectures). The title of the workshop was “Olive Mills Wastes management and Environmental protection”. The workshop was organized with the support and the contribution of the Regional Authority of Peloponnese. The audience of the workshop included mainly mills owners, representatives of local authorities, scientists and wider public.
- The 3rd workshop was organized on 12 October 2012 in Amfissa (also one of the main olive oil productive Greek prefectures). The title of the workshop was “Olive Mills Wastes management and Environmental protection”. The workshop was organized with the support and the contribution of the Regional Authority of Sterea Ellada (Central Greece). The audience of the workshop included mainly mills owners, representatives of local authorities, scientists and wider public. The president of the NAGREF, Dr. Gikas, participated also and opened the event with a dedicated speech.
- The 4th workshop was organized on 21 December 2012 in Athens. The title of the workshop was “Olive Mills Wastes management and Environmental protection-LIFE PROSODOL: Four years of activities”. The audience of the workshop included mainly scientists, students, representatives of local authorities and wider public.
- The Mediterranean Greek workshop was organized on 18 May 2011 at Rethymnon, Crete. The workshop was organized with the support of the Municipality of Rethymnon, which offered a conference room at the Civilization Centre of the town; and the Union of Agricultural Associations of Rethymnon, which contributed to the catering. It is also significant that representatives of two more LIFE projects, i.e. OLEICO and INFOIL, participated in the workshop and presented the projects to the participants.
  Representatives of the Italian and the Spanish beneficiaries participated also in the workshop with presentations oriented to the management of OMW in Italy and Spain. These presentations were attracted the interest of the participants and mainly of the olive oil mills owners.

  The audience of the workshop included mainly mills owners, representatives of local authorities, scientists and wider public. Informative material was produced and distributed together with little olive oil trees, which excited the participants.

  The event was covered by three local TV channels (CRETA TV, KYDON, NEA TV) while interviews were taken by the journalist from Dr. M. Doula, Dr. S. Theocharopoulos and Mr. G. Marinakis (Mayor of Rethymnon Municipality). The event was also presented and advertised by many local newspapers and web sites.
- The 3-days Final Symposium of PROSODOL was organized on 16-18 October 2012 in Chania, Crete with the participation of many scientists from Greece, Italy, Spain, Portugal, Cyprus, Turkey, Israel, Romania and Norway. The speakers were 36 while the participants were more than 200. The morning sessions were in English and scientific and research works on the subject of the symposium were presented. The afternoon sessions were in Greek and Greek scientists as well as representatives of the industrial sector presented to local stakeholders, mill’s owners, scientists, students and local authorities the progress in science on the issue “Olive Mill Wastes” as well as the environmental impacts of the uncontrolled disposal of OMWs.

  The symposium was organized with the Cooperation with the Centre of Environmental Education of Edessa-Giannitsa (CEE). The CEE (as legal representative of the Greek Ministry of Education, arranged the live broadcasting of the afternoon sessions from the

Greek school network (the program for the live broadcasting is presented in the link : http://vod.sch.gr/video/iptv/646).

For the symposium a specific dissemination material was produced, which included a bag (one for the speakers and one, simpler for the participants), the proceedings envelope, notebook, pens, and specific cards for the meals/dinners.

A specific web page was created for the symposium through which the participants could be registered and informed regarding the event (http://www.prosodol.gr/Crete2012/)

- The 2nd workshop in Kalamata was presented in the local TV-channels during the News broadcasting as reportage. The Med workshop in Rethymno as well the 3-days Symposium in 2012 were also presented as reportages in the local Cretan TV-channels.
- Radio interview of the coordinator on 9 November 2009. The Greek national radio station *NET-105.8* invited the coordinator to describe the project in general and especially its first results. The interview was broadcasted in the morning of the 9th November 2009 in Athens and Crete. The same interview was broadcasted in other Greek cities on different dates.
- On 21th August the large scale composting was performed at the pilot area in Crete with the participation of almost 30 local mill owners.
- Publications
  During the lifetime of the project the following scientific articles were created by the scientists of the three Greek beneficiaries:
  - Kavvadias, V., Doula, M., Komnitsas, K., Liakopoulou, N. 2010. Disposal of olive oil mill wastes in evaporation ponds : Effects on soil properties. *Journal of Hazardous Materials*, 182, 144-155.
  - Komnitsas, K., Zaharaki, D., Doula, M., Kavvadias, V. 2011. Origin of recalcitrant heavy metals present in olive mill wastewater evaporation ponds and nearby agricultural soils » *Environmental Forensics,* 12 : 319-326.
  - Doula, M.K., Elaiopoulos, K., Kavvadias, V.A., Mavraganis, V. 2012. Use of Clinoptilolite to improve and protect soil quality from the disposal of Olive Oil Mills Wastes. *Journal of Hazardous Materials,* 207-208, 103-110.
  - Inglezakis, V.J., Moreno, J.L., Doula, M.K. 2012. Olive oil waste management EU legislation: Current situation and policy recommendations. International Journal of Chemical and Environmental Engineering Systems, 3(2), 65-77.
  - Doula, M.K., Kavvadias, V.A., Elaiopoulos, K. 2012. Zeolites in Soil Remediation processes. In : "Natural Zeolites", V. Inglezakis and A. Zorpas (eds). Bentham Publisher, chapter 22, pp. 519-568.
  - Kavvadias, V., Komnitsas, K., Doula, M.K**.** 2011. Long term effects of Olive Mill Wastes disposal on soil fertility and productivity. In: Satinder Kaor Brar (ed.) Hazardous Materials : Types, Risks and Control. NOVA Science Publishers, Inc. ISBN: 978-1-61324-425-8. Chapter 16.
  - Komnitsas, K., Zaharaki, D. 2012. Pre-treatment of olive mill wastewaters at laboratory and mill scale and subsequent use in agriculture: Legislative framework and proposed soil quality indicators. Resources Conservation and Recycling 69, 82-89.
- Announcements in scientific international conferences

  The Greek beneficiaries participated in national and international conference relative to the OMW management and prepared the following presentations, which are included in the conferences' proceedings:

- Doula M., Kavvadias, V. Theocharopoulos S., Kouloumbis P., Ikonomou, D., Arapoglou D. Environmental impacts relative to soil quality caused from the disposal of olive oil mills' wastes. Case study: A municipality in Crete, Greece. Proc. Int. Conf. AMIREG 2009 Towards sustainable development: Assessing the footprint of resource utilization and hazardous waste management in CD-ROM, http://heliotopos.conferences.gr/?amireg2009 (Eds. Z. Agioutantis, K. Komnitsas), Athens, Greece, 7-9 September 2009, pp. 84-89.
- Zaharaki, D., Komnitsas, K. Existing and emerging technologies for the treatment of olive oil mill wastewaters, Proc. Int. Conf. AMIREG 2009 Towards sustainable development: Assessing the footprint of resource utilization and hazardous waste management, in CD-ROM, http://heliotopos.conferences.gr/? amireg2009 (Eds. Z. Agioutantis, K. Komnitsas), Athens, Greece, 7- 9 September 2009, pp. 440-446.
- Kavvadias, V. Sarris, A., Doula, M.K, Zaharaki, D., Theocharopoulos, S., Komnitsas, K. "Soil Quality Monitoring in Olive Oil Mill Waste Disposal Sites" Proceedings of the 2nd International Conference on Hazardous and Industrial Waste Management, 5-8 October, 2010, Chania-Crete, Greece, pp. 485-487.
- Doula, M.K. Elaiopoulos, K., Kavvadias, V., Mavraganis, V. "Use of Clinoptilolite to improve and protect soil quality from the disposal of olive oil mills wastes" Proceedings of the 2nd International Conference on Hazardous and Industrial Waste Management, 5-8 October, 2010, Chania-Crete, Greece, pp 481-483.
- Arapoglou, D., Doula, M.K., Kavvadias, V., Ikonomou, D., Theocharopoulos, S., Tountas, P. "Monitoring of Phenols concentration in soil of olive oil mill waste disposal sites" Proceedings of the 2nd International Conference on Hazardous and Industrial Waste Management, 5-8 October, 2010, Chania-Crete, Greece, pp 477-479.
- Doula M.K., Kavvadias, V., Theocharopoulos, S., Elaiopoulos, K. "Use of clinoptilolite for soil improvement at olive oil mills wastes disposal areas". Proceedings of "ATHENS 2012, International Conference on Sustainable Solid Waste Management", 28-29 June 2012, Athens, Greece.
- Inglezakis, V.J., Moreno, J.L., Doula, M.K. "Implications and complications arising from the EU legislation on the management of olive oil waste". Proceedings of "ATHENS 2012, International Conference on Sustainable Solid Waste Management", 28-29 June 2012, Athens, Greece.
- Doula M.K., Theocharopoulos, S., Kavvadias, V., Lolos, P. "Disposal of olive oil mills wastes in evaporation ponds: a serious threat for soil quality". Proceedings of the 3nd International Conference on Hazardous and Industrial Waste Management, 12-14 September, 2012, Chania-Crete, Greece.
- Chliaoutakis, A., Kydonakis, A., Doula, M.K, Kavvadias,V., Sarris,A.,Theocharopoulos, S. "Proposed tool for soil monitoring for olive oil mills wastes disposal areas". Proceedings of the 3nd International Conference on Hazardous and Industrial Waste Management, 12-14 September, 2012, Chania-Crete, Greece.
- Moreno, J.L, Doula, M.K, Sánchez-Moreno, M.A., García, C., Kavvadias, V., Theocharopoulos, S. "Implementation of bioremediation technology to olive oil mill waste disposal area". Proceedings of the 3nd International Conference on Hazardous and Industrial Waste Management, 12-14 September, 2012, Chania-Crete, Greece.
- Kavvadias, V., Papadopoulou, M., Doula, M.K., Theocharopoulos, S. "Olive mill waste application on soil: effect on soil microbial activity and its relation to soil chemical properties". Proceedings of the 3nd International Conference on Hazardous and Industrial Waste Management, 12-14 September, 2012, Chania-Crete, Greece.

- Chliaoutakis, A., Kydonakis, A., Doula, M.K., Kavvadias, V., Sarris, A., Papadopoulos, N. “Geospatial tools for olive oil mills’ wastes (OOMW) disposal areas management”. Advances in Geoscoience, EARSeL, 2012, 24-15 May 2012, Mykonos island, Greece.
- Doula, M.K., Theocharopoulos, S., Kavvadias, V., Kouloumbis, P. “Proposed system for soil quality monitoring at olive mill waste disposal areas”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 170-179.
- Inglezakis, V., Doula, M.K., Theocharopoulos, S., Kavvadias, V. “Review and discussion on the costs and economic feasibility of olive mill waste treatment methods”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 202-211.
- Kavvadias, V., Doula, M.K., Theocharopoulos, S., Kouloumbis, P. “Lettuce cultivation at an olive mill waste disposal area”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 92-100.
- Moreno, J.L., Doula, M.K., Sanchez-Moreno, M.A., Garcia, C., Kavvadias, V., Theocharopoulos, S. “Bioremediation technology implementation at an olive mill waste disposal area”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp.112-119.
- Theocharopoulos, S., Doula, M.K., Kavvadias, V., Kouloumbis, P. “Indicators for monitoring soil quality at olive mill waste disposal areas”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp.101-110.
- Tinivella, F., Minuto, A., Medini, L., Bruzzone, D., Doula, MK., Kavvadias, V. “Effects of OMWW spreading on soil properties and on plant growth of an experimental olive orchard”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 73-81.
- Chliaoutakis, A., Kydonakis, A., Sarris, A., Papadopoulos, N., Doula, M.K., Kavvadias, V. “Geo-informatic web-based application for olive mill’s wastes disposal areas management”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp.158-169.
- Doula, M.K., Kavvadias, V., Theocharopoulos, S., Sarris, A., Zorpas, A. “Proposals for the olive mills’ owners and the local authorities”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 337-347.
- Kavvadias, V., Doula, M.K., Theocharopoulos, S., Kouloumbis, P. “Effects of OMW disposal on soil and on the environment-Results of PROSODOL project”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 260-266.
- Zaharaki, D., Komnitsas, K. 2012. Effects of pre-treated olive mill wastewaters on soils and plant growth, Proc. Int. Conf. Protection and Restoration of the Environment-XI (PRE-XI) in CD-ROM, http://www.pre11.org/ (Eds. K.L. Katsifarakis, N. Theodossiou, C. Christodoulatos, A. Koutsospyros, Z. Mallios), Thessaloniki, Greece, 3-6 July, 1012 pp. 605-614.
- Komnitsas, K., Zaharaki, D. 2012. “LIFE+PROSODOL Project: After LIFE communication plan”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 180-188.
- Komnitsas, K., Zaharaki, D. 2012.“Low cost pre-treatment of olive mill wastewaters: effect on spinach and beetroot growth”. Symposium on Olive Mill Wastes and Environmental Protection, 16-18 October, 2012, Chania, Crete, Greece, pp. 82-91.

- The scientific team off SSIA was submitted three articles for presentation in the 4th International Congress EUROSOIL 2012 which took place in Italy between 2 and 6 July 2012 (http://www.eurosoil2012.eu/).

- Doula, M.K., Kavvadias, V. 2011. Effect of Olive Oil Mills Wastes (OOMW) disposal on soil physical and chemical properties. An article prepared for the proceedings of the workshop “Pollution and Waste in Antiquity” which took place on 7-9 September 2010 in Glaskow, UK.

- Doula, M.K., Kavvadias, V., Kouloumbis, P., Theocharopoulos S. 2012. “Effects of Olive Mills Wastes disposal on soil.” 14th National Soil Science Conference, 1-2 November, Thessaloniki.

- Five press releases were distributed

- Two articles in NAGREFs journal: (1) an article in Greek dedicated to the workshop of PROSODOL (on 4th December, 2009) was published in the NAGREF’s magazine. The magazine of NAGREF is available on-line (http://www.nagref.gr/ main menu>publications) and also sent by mail to all NAGREF’s researchers and scientific staff (almost 500 employees of Academic status) and to selected institutions and governmental agencies, and (2) an article published in 2012 dedicated to the obtained results of PROSODOL, this article was printed and distributed during the workshops.

- Another presentation has been made by Dr. A. Sarris of IMS at the Archaeo-Telepiskopika Nea, the official Newsletter of the Laboratory of IMS-FORTH.

- SSIA produced also three articles for local press.

- The project was presented by many web newspapers and other sites.

- The Layman’s report was produced in English (https://www.dropbox.com/s/uj7k5uv4clu19mt/laymans%20report.pdf) and in Greek (https://www.dropbox.com/s/433fq9q9mkhmnb1/DGr_56.pdf), printed in 10 reprints and distributed

- Others
    - PROSODOL developed cooperation with (a) LIFE ENVIFRIENDLY (b) LIFE-INFOIL (c) LIFE OLEICO (d) Prof. C. Halvadakis, coordinator of the project “Innovative Olive oil Mill wastewater management systems” funded by the EU Regional Development Directorate-General (e) Prof. G. Zervakis, coordinator of the project “Biological treatment and exploitation of olive oil mills wastewater. Mechanisms and integrated applications” and (f) Prof. A. Vlyssidis, who has developed the FENTON Method for wastes treatment and developed and applied in real scale a method for wastes composting.
    - After specific invitation the project participated with a separate kiosk in the one of the most significant Med exhibitions “Elaiotexnia” (http://www.eleotexnia.gr/eng/). The exhibition took place between 16 and 18 April, 2010. The project and its results were presented to visitors and printed material (brochures, booklets) was also distributed. Visitors were mainly scientists, mill owners, consumers and general public.

    - An article was published in Greek in the magazine “Elaiokosmos” regarding the objectives and the activities of the project. The workshop of PROSODOL, which took place in Athens on 4th December 2009 was also extensively presented. The article was also uploaded on the web site of the magazine (http://www.compassmedia.gr/previous.html - No 13). The readers of the magazine are mainly mill owners, farmers, agronomists, environmentalists, and students.

    - The Greek magazine “ECOTEC” (http://www.ecotec.gr/index.php) specialized in environmental subjects published an interview of the coordinator regarding the effects of wastes disposal on soil properties. The interview was published in the issue of September 2010. The readers of the magazine are mainly environmentalists, agronomists, scientists in general and students.

- A presentation regarding the “Management of natural resources of Crete” was made by Dr. A. Sarris (IMS) in the course of the VESTA-GIS Hellenic Workshop/VEST-GIS & NATURE-SDIplus TRAINING WORKSHOP, which was organized at MAICH facilities in Chania on 27 April 2010. Among others, the presentation made a clear mention of the activities of the LIFE project and captured the interest of the audience. The presentation was made after invitation based on current activities of IMS in the LIFE project.
- The coordinator (Dr. Maria Doula) was invited by the Department of Archaeology of Glasgow University to present the project results in a workshop organized in Glasgow on 7 and 8 September 2010, and especially the results regarding the effect of OMW disposal on soil. The issue discussed concerned the question “how it would be possible by measuring soil parameters to identify the locations of olive mills in the antiquity”. All expenses (travel and accommodation) were undertaken by the Glasgow University.
- A BA dissertation has been written by Stefanos Chatziathanasiou from the University of Crete (Physics Department) based on the processing of measurements from ERT at the disposal area. The reference for the BA dissertation is:
  «Στέφανος Χατζηαθανασίου, "Διαχρονική παρακολούθηση της δομής του υπεδάφους σε περιοχές απόθεσης αποβλήτων από ελαιοτριβεία με την μέθοδο της γεωηλεκτρικής τομογραφίας", Τμήμα Φυσικής, Πανεπιστήμιο Κρήτης, 2011».

5.4.2. Layman's report

The Layman's report was produced according to the instructions given in the web page of LIFE, in English and in Greek ((https://www.dropbox.com/s/uj7k5uv4clu19mt/laymans%20report.pdf) and https://www.dropbox.com/s/433fq9q9mkhmnb1/DGr_56.pdf), printed in 10 reprints and distributed.

5.4.3. After-LIFE Communication plan

An after-LIFE Communication Plan has been prepared by TUC, for the maximum dissemination of project achievements (Annexes 16-19). The plan focuses on a) the development of a strategy to continue dissemination of project achievements after its end, b) raising awareness of all relevant stakeholders in issues related to OMW management and c) promoting application of the proposed technologies at least at mill scale. The plan was prepared in four languages: English, Greek, Italian and Spanish. An overview of the plan is discussed in the following paragraphs.

The main achievements of the PROSODOL which has been successfully completed between January 2009 and December 2012, implemented by three Greek, one Italian and one Spanish partners, include among others:

- Development of a low cost OMW pre-treatment technology as well as its application at pilot scale.
- Application of a bioremediation technology at pilot scale for soils contaminated by the disposal of OMW, through in situ land treatment or land farming.
- Development of a Soil Monitoring Tool to monitor basic soil parameters in areas affected by the disposal of OMW and evaluate soil risk.
- Development of a set of actions, means and strategies for monitoring and improvement of soil quality at OMW disposal areas; these activities need to be considered by national policy makers in the Mediterranean region.
- Proposal for the development of a legislative framework regarding disposal and management of OMW (in Greek, Italian and Spanish).
- Development of a guide (in English, Greek, Italian and Spanish) for the agronomic use of OMW.
- Development of a soil protective/remedial technology in OMW disposal areas using clinoptilolite as soil amendment.
- Assessment of the suitability of pre-treated OMW for lettuce cultivation.

During the entire project life various dissemination activities have been implemented such as organization of 14 workshops and one 3-day symposium and cooperation with agricultural organizations; establishment of a communication network involving many interested stakeholders; printing of leaflets/posters/brochures; development of a well designed website, www.prosodol.gr, in four languages (English, Spanish, Italian and Greek); publications in journals (6), conferences (29) and book chapters (2).

The most important activities foreseen in the after-LIFE Communication Plan include: i) maintenance of the established communication network between all interested stakeholders (agricultural associations, mill owners, local authorities, chambers of commerce and experts from research organizations and universities), ii) preparation of newsletters with the most important news and results, iii) activities which are of interest for the general public, such as interviews in local channels, articles in websites, iv) maintenance of the web-site of the project, v) publication of articles in scientific journals and presentations in workshops/conferences, vi) dissemination of project results in events such as project visits, workshops etc. organized in the line of other projects implemented by the involved beneficiaries.

An estimated draft budget of the foreseen activities is also presented in the plan. The dissemination actions that will be continued after the end of the project do not require specific funding sources and the foreseen cost will be covered by beneficiaries' own funds. The risk that could affect the efficiency of the plan as well as contingencies for their elimination, are also discussed.

6. Annexes

Annex No	Title/Content
1	Web site of the project, web applications and ERT method
2	Experimental pilot area in Italy
3	Bioremediation feasibility experiments
4	Implementation of bioremediation at the pilot OMW disposal area
5	Addition of clinoptilolite at the OMW disposal areas
6	Pilot OMW pre-treatment unit
7	Use of pre-treated OMW for lettuce cultivation
8	Composting of OMW
9	Spanish informative material
10	Posters produced by CEBAS-CSIC
11	The Italian informative leaflet
12	The Italian brochure
13	The Italian Newsletter
14	The Greek informative material
15	Project posters produced by SSIA

List of abbreviations

CEBAS : Centro de Edafologia y Biologia Aplicada del Segura (Beneficiary)
CERSAA : Centro Regionale di Sperimentazione e Assistenza Agricola (Beneficiary)
ELGO DEMETER : Hellenic Agricultural Organization DEMETER
IMS : Institute of Mediterranean Studies (Beneficiary)
NAGREF: National Agricultural Research Foundation
OMW : Olive Mills Wastes
OMWW: Olive Oil Wastewater
SSIA : Soil Science Institute of Athens (Coordinating Beneficiary)
SV : Savona Province
TUC : Technical University of Crete (Beneficiary)