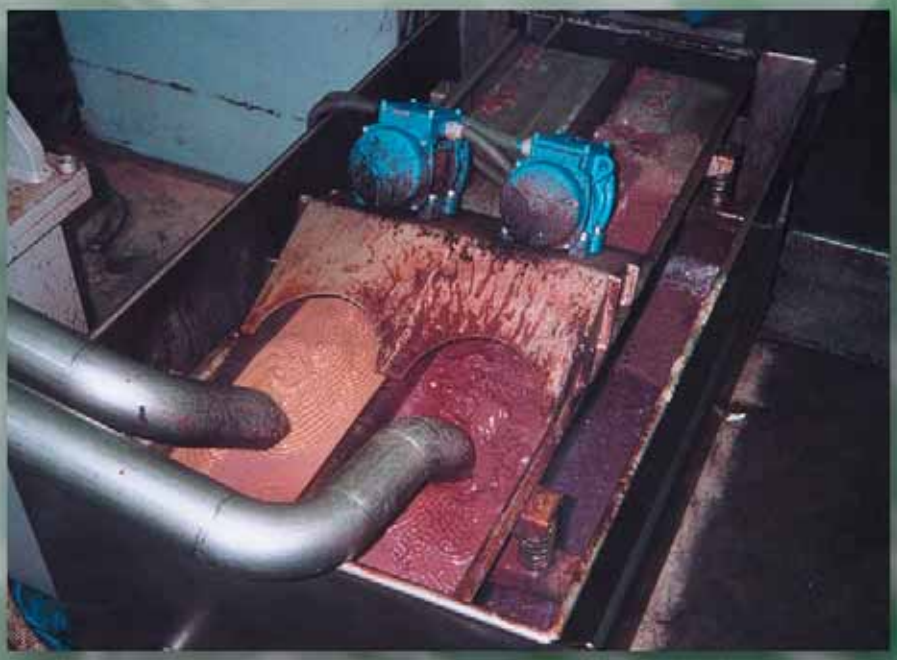
MINOS Project

Process development for an integrated olive oil mill waste management recovering natural antioxidants and producing organic fertilizer



Manual

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TERRA NOVA Ltd.

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The materialization of the Project began on October 2001 and completed on March 2004.

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This Manual was conducted by the scientific team of TERRA NOVA Ltd.

1. Introduction

Olive oil producing sector is one of the most important hellenic agricultural activities. Greece is the third olive oil producing country globally, while the hellenic olive oil is estimated to be of superior quality compared to the other olive oil producing countries.

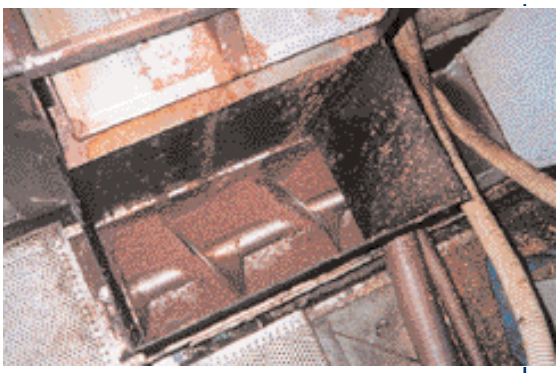
The olive oil producing sector is consisted at national level of approximately 2.700 olive oil mills. The geographical distribution of the olive oil mills is dependent on the geographical distribution of the olive trees populations. More specifically, most of the hellenic olive oil mills are located in Peloponnisos and Crete.

2. Current environmental management status

Olive oil mill wastewater (katsigaros

The main environmental parameter which is connected to the olive oil mills operation is the produced wastewater (katsigaros). This specific wastewater is produced by olive oil mills which use three-phase decanters. Most of the hellenic mills use this production technique. The solid residue produced by the specific oil producing technique is not managed as solid waste. It is a valuable by-product which is the raw material used by seed oil mills.

The main environmental impact derived by the operation of the olive oil mills during the oil producing period (October to March) is related to the management (treatment, final disposal) of the produced wastewater (katsigaros). Katsigaros is characterized by considerably high concentrations of organic load, suspended solids and oil residues. The parameter which is mainly responsible for the severe environmental impacts derived by the katsigaros final disposal into natural receivers is phenols. Phenols existing in katsigaros at significantly high concentrations act biotoxically.



Olive oil mill solid residue

Evaporation lagoons

Today the main katsigaros management practice followed by the majority of olive oil mills is its storage in evaporation lagoons, while on the other hand there are several cases where due to the lack of the appropriate infrastructure katsigaros is disposed of to nearby water streams or natural aquatic receivers in general. Of course it must be pointed out that during the last years mainly due to the increase of the local communities opposition the second of the aforementioned management practices tends to be eliminated.

Nevertheless the evaporation lagoons practice does not comprise the optimum solution for the management of katsigaros regarding the protection of the natural environment. The main problems resulting from the application of the specific practice are the following ones:

- the alteration of the groundwater quality characteristics due to katsigaros infiltration, in the cases that the surface of the lagoon bottom is not lined with non-permeable materials
- the annoyance in a significant area round the evaporation lagoons due to the discharge of strongly unpleasant odors
- the aesthetic reduction of the surrounding area.

Among the above mentioned problems, the last two are of great importance in areas where a significant tourist activity is developed.

Of course at this point it must be mentioned that the main reason for the implementation of the aforementioned practices was the absence of methods for the management of katsigaros which could simultaneously guarantee:

- The effective treatment of the specific wastewater, and
- The viability of the investment or at least its low cost (capital and operational) in order to avoid the surcharge of the olive oil production cost and consequently not to diminish the competitive presence of the product in the national and international market.

More specifically as it was mentioned above, the biotoxic properties of phenols, which are in significantly high concentrations in the produced wastewater (katsigaros), constitute a significant inhibitor of the biological processes which take place in the conventional wastewater treatment methods. This is the main reason why the common methods for the biological treatment of wastewater do not present the desired performance when applied for the treatment of katsigaros.

On the other hand during the last twenty years several other treatment methods have been developed and tested. These methods either demand a significantly high capital cost for purchasing the required equipment, a cost which cannot be afforded by the majority of the small size hellenic olive oil mills, or demand a high operational and maintenance cost, a fact that combined with the production of by-products of low or medium commercial value renders the operation of these systems non-viable.

3. MINOS target

MINOS target was the development of an innovative process for the rational management of the wastewater (katsigaros) which is derived from olive oil mills during the oil production period, in order to provide an effective solution to the so far hard to solve problem of the final disposal of the specific waste. It has been determined that the critical parameter for the development of the process would be the viability of the management system. This would be ensured through the recovery of the katsigaros polyphenols content. These substances own a high market value due to their multiple application potentials in the production of medicines, cosmetics and food supplements.

4. MINOS results

During the period between October 2001 and March 2004, that the implementation of the MINOS Project took place, the following actions materialized:

- Various alternative scenarios for the management of katsigaros were designed, tested and evaluated. These scenarios aimed at the effective and integrated treatment of the specific wastewater and simultaneously at the recovery of the wastewater polyphenols content.
- The optimum management scenario was selected according to technoeconomic and environmental criteria.
- Based on the selected scenario a test plant was designed and constructed at pilot scale.
- The pilot plant operated during two successive oil producing periods. During this period continuous improvements of the pilot plant took place in order to achieve its optimum performance.

The main steps of the developed technology are the following ones:

- Successive wastewater filtration stages
- Capture of the polyphenols by adsorbance resin
- Treatment of the resin outflow in a nanofiltration/ reverse osmosis system
- Recovery of the polyphenols captured in the resin media by using organic solvent
- Delivery of the polyphenols mixture through thermal recovery of the organic solvent
- Chromatographic separation of the polyphenols
- Composting of the sludge produced by the filtration stages and the olive leaves which are rejected as solid waste from the mills.

Olive oil mill wastewater

Wastewater filtration

Sludge composting

Capture of polyphenols by resin

Thermal recovery of organic solvent & delivery of polyphenols mixture

The application of the developed technology leads to the production of:

✔Clean water suitable for:

- Final disposal in a natural aquatic receiver
- Underground disposal
- Irrigation purposes
- Utilisation in the plant that will operate the developed technology in order to cover its various needs concerning water consumption

- Polyphenols (e.g. hydroxytyrosol) suitable, in terms of chemical form and purity, to be used as raw material in various applications:

- production of medicines
- production of cosmetics
- production of food supplements etc.

✔Natural fertilizer (compost).

5. Investment feasibility

The core of the developed technology is the recovery of the katsigaros polyphenols content. This was the main stage based on which the total of the specific wastewater treatment technology was developed. The main reason for this choice was the need to ensure that an investment for the materialization of the specific technology at full (industrial) scale would be feasible. This choice derived by the fact that polyphenols due to their strong antioxidant properties can be used in a variety of pharmaceutical applications and therefore they own a significant commercial value.

More specifically, the materialization of the developed technology demands the purchase and installation of specialized equipment and employment of specialized scientific personnel. These reasons render the installation of the specific technology in each individual olive oil mill non-viable due to the fact that the majority of these enterprises are small scale businesses.

Based on the aforementioned and in order to achieve the viability of the application of the developed technology, it is recommended the installation of central units in various geographical areas, which will cover the needs of the olive oil mills located in these areas. By this way the wastewater produced by each olive oil mill will be treated in the central units and thus the required capital and operational cost will be significantly lower compared to the option where the specific technology would be installed in each individual mill.

Concerning the financial data of such a central unit, it must be noted that the capital cost for a treatment capacity of 50 m^3 katsigaros per day is approximately 1.100.000 € while the operational cost per month is estimated to be 36.500 €. Having in mind that the katsigaros mean polyphenols concentration is ranging between 2,5-4 g/l and the market price for selling the final extract is estimated to be 0,41-1 €/g, it is concluded that based on the most moderate calculations the total depreciation of the central units equipment can be achieved within the first year of operation.

Based on the aforementioned it is concluded that the application of the developed technology at full scale comprises a considerably profitable investment, which will provide a feasible solution to the so far unsolved problem of the katsigaros management while on the other hand it will initiate a significant development perspective which will lead:

- to the development of state-of-the-art technology
- to the creation of new employment opportunities
- to the support of employment in the region
- to the development of significant commercial relations with companies located in other countries.

6. Polyphenols properties

The extract which is produced from the katsigaros management technology that was developed during the MINOS Project, contains the total of the bioactive constituents of the olive oil mill wastewater.

Specifically, the extract contains the total amount of the olive drupe polyphenols which during oil production are discarded into the wastewater. Additionally it contains a high percentage (20%) of a lactone derivative of tetrahydropyranyl acetic acid which is a rearranged part of the oleuropein molecule. Among the contained polyphenols, the most important constituents are hydroxytyrosol (~60%) and tyrosol (~20%). It is noteworthy that the olive oil contains only 2% of the total polyphenols that are contained in the olive drupe, while the rest 98% is transferred into the produced wastewater, from which it can be reclaimed through the MINOS technology.

The above constituents, either isolated or as a mixture, after several studies it has been proved that they posses a significantly high antioxidant activity. The special interest of this activity is based on the fact that those specific constituents are cell permeable and thus they can protect DNA from oxidative damage. It is known that there are many natural antioxidant compounds but very few of them posses that interesting property.

Additionally, it has been proved that the olive polyphenols enhance the strength of LDL (Low-Density Lipoproteins) against oxidation. This fact is very important because the LDL oxidation is generally thought to be responsible for the creation of atheromatic plaques and the development of coronary disease.

Olive polyphenols are also highly active in:
* inhibition of B_4 leukotriens activity
* inhibition of ACE (Angiotensin Converting Enzyme)
* antioxidative protection of leukocytes and liver cells after oxidative stress induction
* inhibition of platelets aggregation.

Their potent antioxidant activity and their ability to scavenge free radicals give them a potential utilization in breast and colon cancer protection.

Of high importance, also, is the protection of skin cells from solar radiation which is responsible for the production of harmful free radicals. Tocopherols and carotenoids, as well as other common ingredients of sunblock creams, are far less active than hydroxy-tyrosol.

Finally olive polyphenols posses antibacterial and antiviral properties and could be used to protect human or animal health and also as antimicrobial additives in food conservation.

7. Compost Use

Compost use in agriculture

The agricultural sector is potentially the major consumer of compost. More specifically, compost can be used:

- to enrich soil with organic matter and increase soil fertilization
- to improve soil aeration
- as biocide
- to decrease soil erosion
- to decrease soil need for chemical fertilization and peat
- to increase water holding and irrigation capacity of the soil
- to increase the soil capacity for nutrient absorbency and assimilation.

Compost use in landscaping

Landscaping, and generally the sector of exterior design is a field where compost can be successfully applied. Basic prerequisite for the acceptance of this product from the landscaping sector is the performance of high quality standards. Quality standards include: the absolute absence of toxic heavy metals, the appropriate particle size, the neutral level of pH and finally the moisture level (<50%). More specifically compost can be used for:

- the production of humus, improving the soil quality and benefiting the plant growth
- the maintenance and the aesthetic improvement of the landscape

- the landscaping of outdoors athletic areas, such as golf and football courts. Moreover it can be used in parks, safety islands, recreation grounds etc
- the restoration of sanitary landfills. Using compost as covering material in a daily basis, odors and methane filtration can be achieved, while when used as final covering material it improves the soil structure and reduces soil erosion.

Compost use in forestry

Compost can also be successfully used in forestry. Its most common uses are:

- in nursery gardens where seedlings are cultivated for reforestation programs or commercial use
- reduction of soil erosion, maintenance of soil fertility and replacement of the material which was removed by the plants roots system.

Summarizing all the above mentioned potential uses of compost, independently of its specific applications, we end up to the following list of compost uses:

- It replenishes the organic nutritional substances of the soil, sustains soil health and suspends soil desiccation and erosion.
- It improves and stabilizes soil pH.
- It improves the water holding capacity of soil.
- It emboldens soil worms activity and soil fauna in general, improving in this way soil aeration and soil enrichment with nutrients, decreasing at the same time the demand for chemical insecticides and fungicides.
- It improves soil structure, porosity and density. This characteristic increases soil aeration and soil water and nutrient holding capacity. As a result, heavy soils become lighter and easier to process, while the light soils increase their absorbency.
- It stores and releases gradually nutrients that are beneficial to plant growth producing healthy and rich harvest, decreasing at the same time the demand for chemical fertilization.
- It improves the plants roothold system.

- It favors the growth of microorganisms populations within the soil, and especially bacteria and fungus.
- It amplifies bacteria activity within the soil in order to suspend soil diseases.
- It improves the performance and the growing rate of seeds.
- It preserves the health of plants, animals and humans through-out the food-chain.
- It promotes sustainable practices, through the gradual abatement of chemical fertilizers and prevents the potential pollution of surface water and groundwater.