SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Alternative technologies and policies for olive mill waste management in MED countries

Presented by:

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SWIM and Horizon 2020 SM

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OMW – Current situation

More 30 million tons of solid–liquid waste (pomace and alpeorujo) and 15 million tons of olive mill wastewater (OMW) are produced each year by a large number of small olive mills scattered throughout the Mediterranean countries

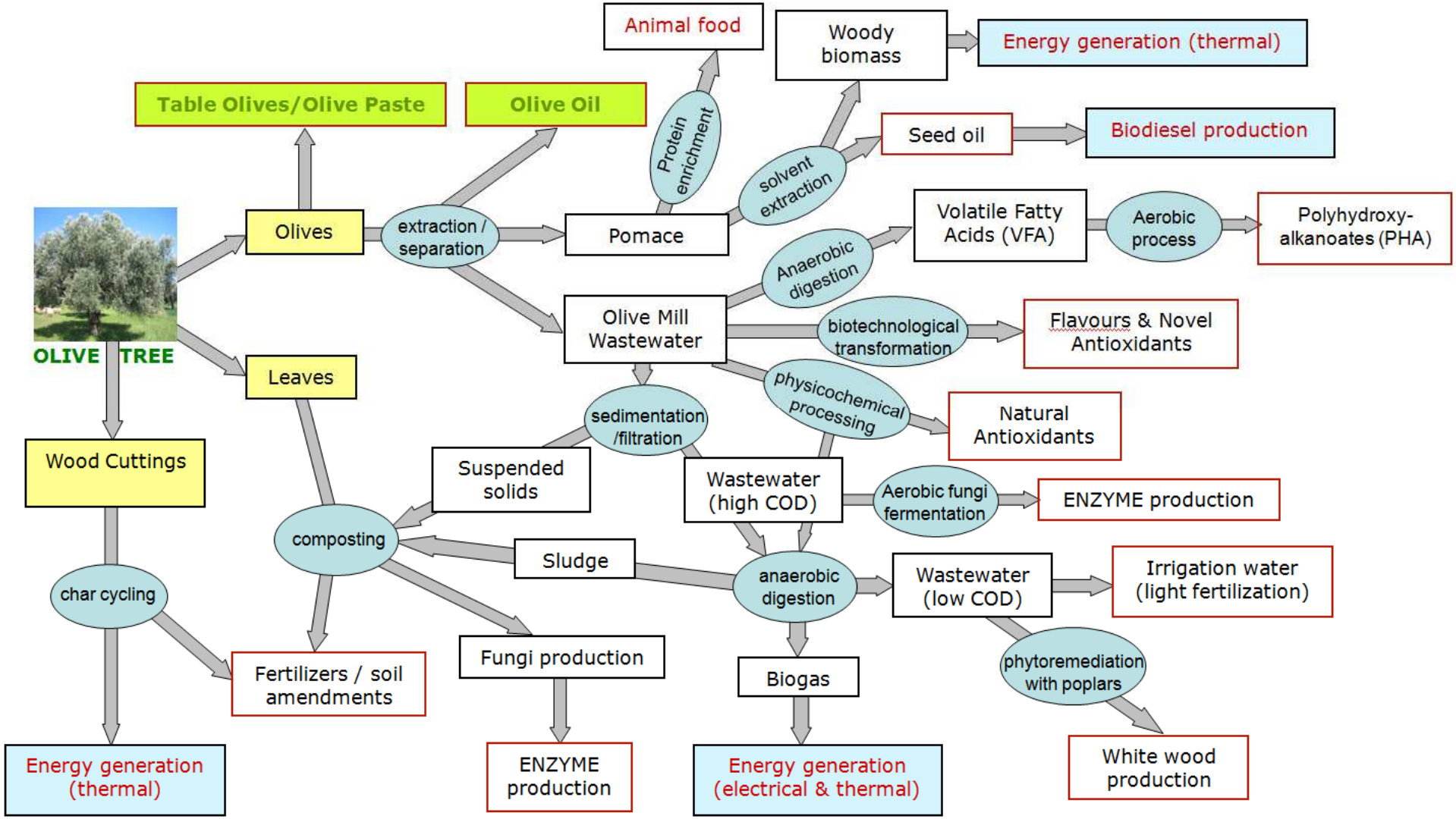
Although OMW is a natural product, it can pollute water bodies and the environment because of its composition:

- High BOD (up to 50 g/l) and COD (up to 100 g/l)
- Low pH (≤ 5)
- High EC (7-11 dS/m) and ion content (mostly K)
- High phenolic content
- Smell and color
- Toxic properties for living organisms

Due to pollution load it is not allowed to be descarded untreated op without control to the environment, especially in water bodies.

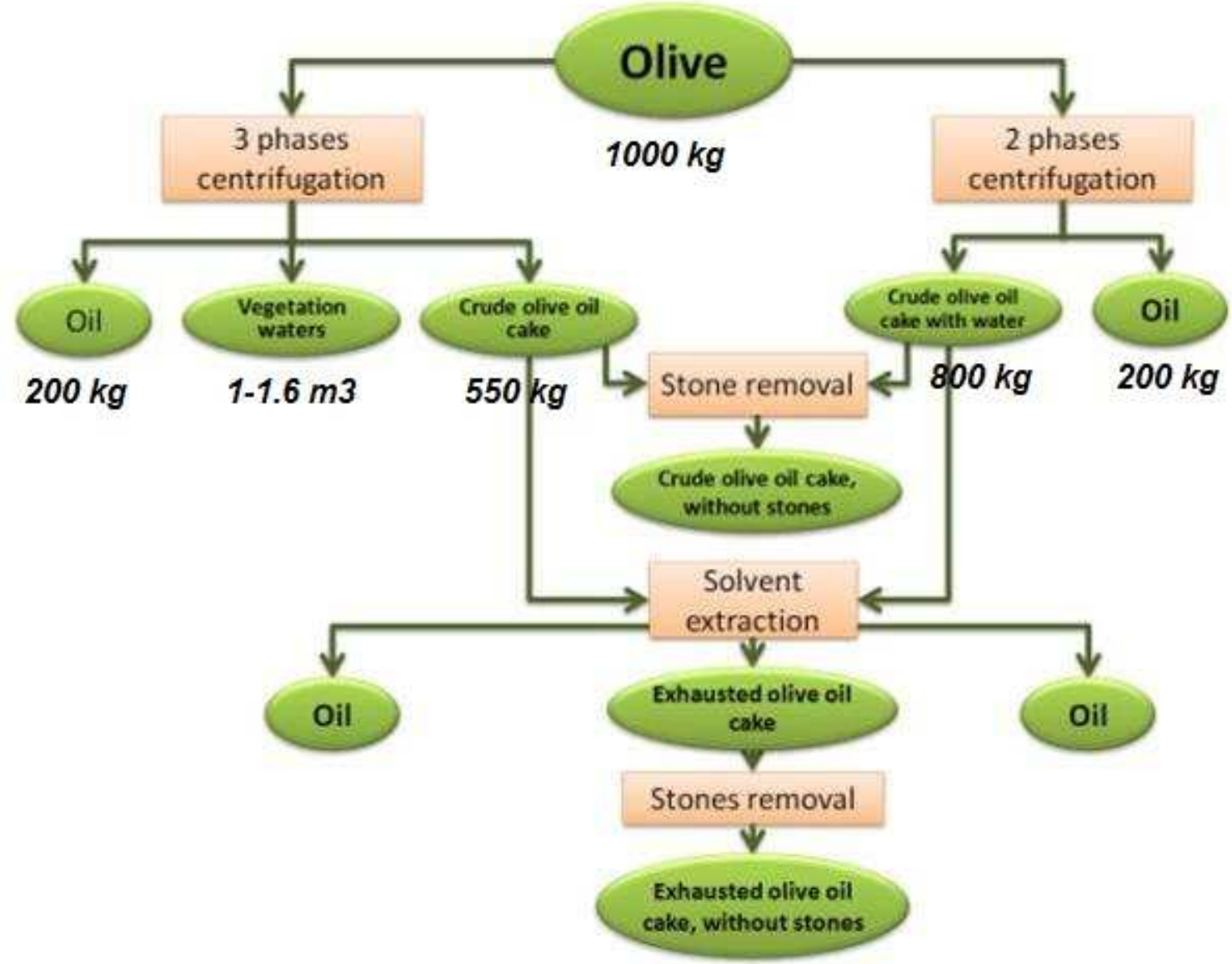
Pollution problems from OMW disposal

Olive by-products



Federici F., Fava F., Kalogerakis N. and D. Mantzavinos, "Valorisation of agro-industrial by-products, effluents and waste: concept, opportunities and the case of olive mill wastewaters", *J Chem Technol Biotechnol*, 84, 895-900 (2009).

Olive oil extraction systems



OMW treatments in MED countries

OMW possesses a double nature. It is a strong pollutant and at the same time a possible source of valuable components, such as polyphenols, flavonoids, anthocyanins, inorganic trace elements, etc., that could be isolated (removed) and economically exploited.

A large number of treatments/technologies (physical, chemical, biological) have been tested in many countries, which could be classified in the following categories:

- Detoxification processes (aerobic and anaerobic, physico-chemical)
- Processes for production of various products (fertilizers, compost, antioxidants, biopolymers, animal feed)
- Integrated processes aiming at energy recovery (biogas, electricity)
- Combined processes.

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OMW treatments in MED countries

Detoxification Processes

Aim at "cleaning" the waste so as to allow its safe, subsequent disposal at water or soil reservoirs. The most important are biological and physicochemical processes.

a. Biological processes. Use microorganisms to break down the chemicals present in OMWW. They are divided into aerobic and anaerobic processes according to the type of the micro-flora used.

b. Physicochemical Processes.

Neutralization, Precipitation/Flocculation. Involve the use of additional chemicals in order to destabilize the suspended and colloidal matter of OMW and form an insoluble solid that can be removed easily from the waste.

Oxidation processes. Several oxidizing agents have been tested for OMW treatment like hydrogen peroxide, ozone, chlorine, chlorinated derivatives in combination with ultraviolet radiation (Advanced Oxidation Processes)

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OMW treatments in MED countries

c. Thermal Processes

Use manmade heat source or a natural source of thermal energy (air, sun). Most important are evaporation, lagooning (natural evaporation) and pyrolysis. The main drawback of these processes is related to the post treatment and disposal of the produced emission.

d. Membrane Processes

Membranes are effective for separation of oil-water mixtures without adding solvents. With ultrafiltration, only a small amount of retentate (waste) is produced (permeate is 90–95% of the volume of the feed) and very high removal of lipids is achieved. Main problems: the high capital costs, the need of qualified personnel, not affordable for small oil mills.

OMW treatments in MED countries

Processes aiming at the production of various products

OMW may be regarded as an inexpensive source of inorganic and organic compounds to be recovered because of their potential economic interest or their ability to be transformed into products for use in agriculture, biotechnology, and the pharmaceutics industry as well as in the food industry.

a. Production of Fertilizers (Recycling of the Waste at Land)

Biofertilization or Bioremediation. OMWW should not be directly applied on soil and crops because of its phytotoxic properties. Treating OMW with an enriched aerobic microbial population of this kind results in a non-phytotoxic thick liquid that could be characterized as an organic soil-conditioner biofertilizer

Composting. Refers to the process of controlled aerobic biological degradation of organic substratess (wastes, residues, ect). In the case of OMW composting, OMW quantities are added to the solid substrate during the thermophilic stage to replace the water evaporated.

OMW treatments in MED countries

b. Recovery of Antioxidants

OMW contains water-soluble compounds with potential antioxidant properties, like polyphenols, flavonoids, anthocyanins, tannins, oleanolic acid, and maslinic acid. The processes of extraction of antioxidants of high added value from OMW are patented.

c. Production of Biopolymers

The production of biopolymers from OMW is a very interesting alternative, studied during the last years due to the high added value and excellent properties of these substances. The two main categories of these substancesare: exopolysaccharides and polyhydroxyalkanoates.

d. Production of Animal Feed

Olive cakes or solid residues of various OMW processes could be used in animal feeding, as they are rich in oil, carbohydrates, and proteins. Problems arise from OMWW's high concentration of potassium and phenolic compounds which are anti-digestive factors

OMW management technologies in action in EU

LIFE program: OLEICO+ Raise awareness among the olive industry operators about the careless disposal of the olive waste. Provide information on technological/financial opportunities, in order to adopt eco-friendly technologies for the recovery and recycling of these wastes.

Technology selection criteria

Key criterion: The technology must be in use for at least one year at an olive mill, it should be "licensed" and visited while in operation by one of the partners.

Less than 15 technologies were indentified.

Technologies from Italy, Spain, Portugal and Greece, including soil application, that were evaluated and their main characteristics are presented.

Composting in windrows

Country: *SPAIN, Area: Guadalcazar, Córdoba*
Company: *Aceites Coto Bajo EXP Agric. S.A.*
Amount: *25.000 m³ two-phase OMW per year.*
INPUT: *40% two-phase OMW+ 40% chicken manure + 20% leaves*
PRODUCTS: *Organic compost*

Technical problems:
1) Non-homogeneity of raw materials.
2) Bad odours during start up period.

FINAL PRODUCT: 30.000 ton/year
Land use: 2 X15.000 m² (dimensions 5mX100mX2,5m)

Investment cost:
300,000 € civil engineering works
300,000 € turn over equipment

Operating cost:
6 h/week X 15 €/h
Production cost: 0.05-0.06 €/kg-compost (expected to be reduced to 0.03 €/kg)

Composting in a U-lane

Country: SPAIN Area: El Molar - Cazoria (Jaén)
Company: Geacom (UBEDA-ES).
Amount: 9.000 tons two-phase OMW per year
INPUTS: 40% two-phase OMW + 20% sheep manure (0.04 €/kg) + 40% leaves
PRODUCT: Organic compost (C/N < 12, N-P-K: 1.2-0.4-1.6, pH:9.6)
Investment cost: 300.000 € (50% financed by Andalusia)

There is a problem with the wide distribution of compost.

Operating cost: 2 h/day for the control of the process plus 3-4 h/week for maintenance.
Personnel cost: 6,800 €/year while the maintenance cost is 4,500 €/year.
The indirect revenue is estimated 200-250 €/ha/year savings in chemical fertilizers.

Electro-coagulation

Country: SPAIN. Area: Jaén, Company: CYCLUS ID

Process steps: Homogenaization, Filtration (0.3 mm)

Electro-coagulation, Floatation & pH control

Drying of solids

INPUT: 2-phase OMW (after centrifugation)

OUTPUT: Treated effluents with COD (~1500 mg/L) acceptable by local WWTPs

Amount: 2 m3/h → 4.000 m3/year,

Investment Cost: 100,000 €

Area required: 25 m2 inside the olive mill housing with a capacity of treating 2.0 m3/h OMW.

Skilled workforce of 2 h/day and 1 person for 1 h/day is required for managing WW physicochemical parameters

Operational cost: between 1.5-1.8 €/m3.

Aerobic biological trickling filter + constructed wetland

Country: **GREECE,** Area: Amphilochia, Company: D. Vagenas (U. Ioannina/U. Western Greece).)

INPUTS: OMW+ pomace + leaves

Bioreactor: Continuous recirculation with a residence time of 24h. → Sedimentation → Constructed wetlands

PRODUCT: compost (sludge + leaves + pomace)

Investment cost:
30,000 € equipment + land cost for CW + 5-10,000 € composting unit (OMW treated: 30 m^3/day)

Operating cost: 0.1 € / m^3 (electricity)

Manpower: 2h / day
Land use: Composting: 10m X 4 m
Bioreactor: 3,5m X 1,8 m, CW: 2.000 m^2

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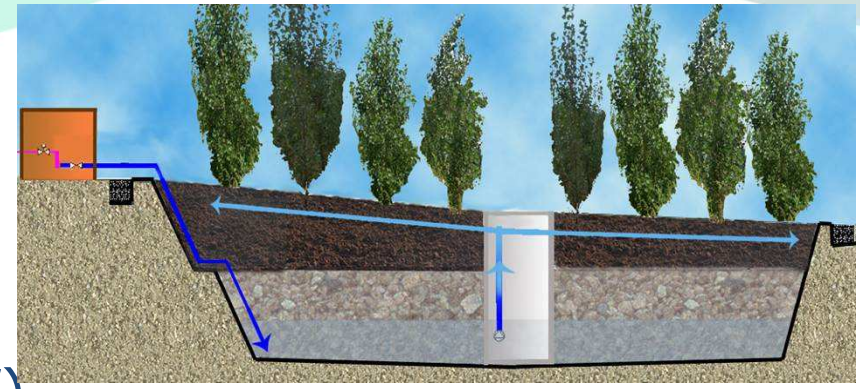
Evaporation – Hydrolysis–Oxidation : E.H.O.®

Country: **GREECE,** Area: Sparti (Laconia)
Company: ENVITEC A.E.
INPUT: *OMW*
PRODUCTS:
1) Irrigation water (80-85% OMW)
2) Bio-fuel 4.000 kcal/kg (in powder form 10 ton from100 m3 OMW)

Investment cost:
100-150 € / m^3 (i.e., for 1000 m3 OMW → 100-150.000 €)
Operating cost:
3-5 € / m^3 (electricity– 31 kWh/m3)
Manpower: One person per shift.
Expected income: 40 €/ton bio-fuel
Land requirements: very small (<100 m^2)
Problems:
Cost & need of specialized personnel.

Phytoremediation

Country: ITALY, Area: Terni, Company: ISRIM S.C.a r.l.



Amount: 50-10.000 m^3 OMW/year

INPUT: OMW

PRODUCT: Wood

Land use: 1,5 – 2 m^2/m^3

(i.e. 1500-2000 m^2 / 1000m^3 OMW)

Investment cost: 100-110 € / m^3
(i.e., 1000 m^3 OMW/year → 100.000 €)

Operating expenses:
0.2 € / m^3 /year (electricity for the pump)
Manpower: Not needed.
Expected income: 0.1 € / m^3 /year (from wood sales)
Problems:
Initial investment cost
Land requirements (30% more than a 1 m deep evaporation pond)

Anaerobic digestion in a WWTP

Country: PORTUGAL, Area: Abrantes

Company: LNEG – INETI
(Renewable Energy dept)
Investment cost: *300.000 €*

Operating cost: 14.000 €/year

INPUTS: *5 ton/day OMW+ 46 ton/day activated sludge + 1,5 ton/day OM-solids + 2,2 ton/day municipal organic waste*

PRODUCTS: *300 m^3/day biogas + Irrigation water + compost (1.6 m^3/day)*
Expected Income: *26,000 € (0.2 € / kWh x 357 kWh/d x 365 d)*

The process has eco-friendly features since it produces three by-products: water suitable for irrigation, sludge for agricultural soil enrichment and energy for WWTP running.

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Bio-fuel pellets Biocombus

Country: PORTUGAL, Area: Murca

Company: Universidade de Trás-os-Montes

Investment cost: 8.88 €/ton

Operating cost: 26.48 €/ton

INPUT: 20.000 tons pomace + 3.000 tons cork sawdust.

PRODUCT: *13.500* ton/year pellets/briquettes (20,6 MJ/kg)

Expected income: 140 €/ton (sales of pellets/briquettes)

Area required for the installation: 0.07 m^2/t wet bagasse.

The technology is eco-friendly since the whole input material coming in the plant is completely transformed in pellet.

The technology has been patented (UTAD-EP 1849756 A1) by the University of Traseos-Montes e Alto Duro of Portugal.

CIP-Eco-innovation: Filtration with sawdust & phytoremediation

Country: Greece, Area: Crete

Company: Technical University of Crete, MESOGIAKI S.A.)

Investment cost (for 1500 to 2.000 m^3/year OMW):

Extraction of polyphenols: 250.000 € (equipment)

Phytoremediation with poplars: 100.000 €

Composting unit: 50.000 € (equipment & concrete)

INPUTS: OMW

Sequential filtration of OMW through a series of filters consisting of

- Natural materials (peat, sawdust) Chemicals (resins)

COD reduction by 75-80%.

Phytoremediation: "Light OMW" taken to poplars field

Extraction of polyphenols (from ion exchange resins)

Composting of sawdust & leaves

Products: wood, polyphenols, compost

OMW application on the soil

Research has shown that soils can be used as a natural system for OMW treatment since organic compounds are fast decomposed and soils have high buffering capacity

Advantages:

- Low cost
- Increase of soil fertility (mostly K)
- Fast decomposition of the organic part
- No pollution of surface or ground water
- Increase of yield (corn, grapevines)

Phytotoxicity:

- Only in annual crops if planted before or right after the application
- Reduction of germination percentage
- Negative effects are not observed if crops are planted about 2 months after the application
- For olive trees, only in young trees when high doses were applied

(Bonari et al., 1993; Garcia-Ortiz et al., 1999; Di Giovacchino et al., 2002)

OMW application on olive orchards

The controlled soil application of OMW is practiced in many olive growing countries. Many studies have been carried out the last 20 years with controlled raw OMW application on olive orchards at volumes from 8-20 m^3 per year. All studies confirmed that there are no harmfoul effects on the soil, plant and the water aquifer.

Must remove solids before doing anything else.
Use filters (series), self cleaning

eco Olive Cleaner

Filtration unit (self cleaning)
to remove suspended solids by 99%.

+ **Subsequent passing of OMW through sawdust filter (particles <0.2 mm)**

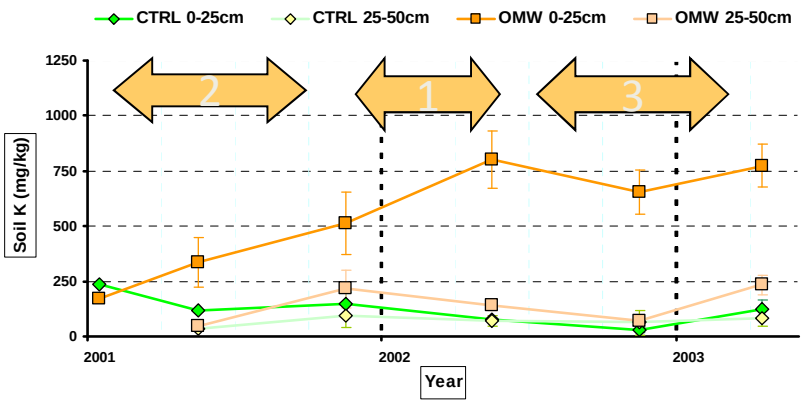
OR

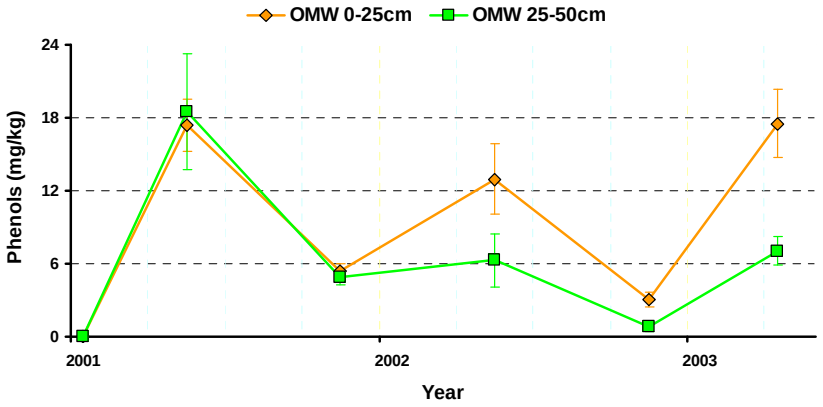
Industrial filtration system

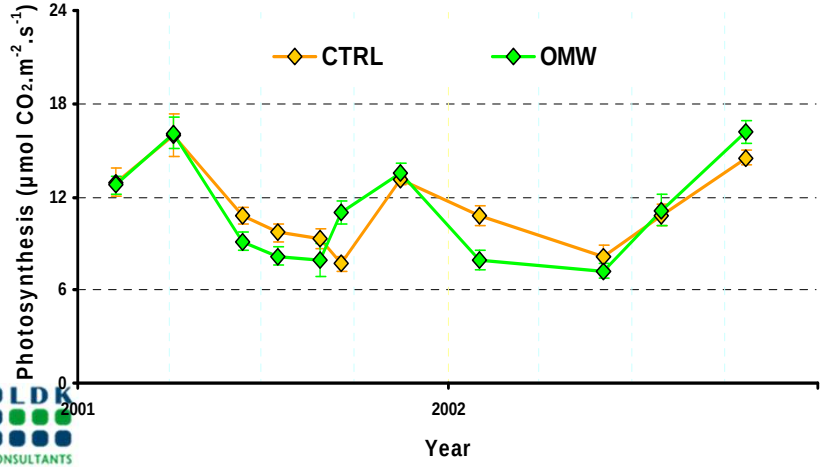
Or use of Coagulation and Sedimentation: cost of chemicals

OMW application on olive orchards

- Did not affect most of the soil parameters (pH, EC, P, N, Na)
- Increases K concentration in the soil, Eliminates weed development
- Did not affect plant performance, yield and oil quality
- Did not pollute the aquifer







Treatment	Yield (kg/tree)	Oil content (%)	K (%)
CTRL	**32.2**	**17.4**	**3.0**
OMW	**33.9**	**16.6**	**3.1**
	NS	NS	NS

Applicability and cost of the method

Area of olive orchards required for 1.500 m^3 OMW: 4 -6 ha

Easily available around an olive mill, in Greece.

Constrain: sloping and hilly area

Cost: reasonable, compared with sophisticated methods

Annual cost of the method:

10.550 €

Annual production of OMW :

1.500 m^3

Cost per lt of produced OMW:

0,007 €

Application requirement:

Detailed study for each case to determine the application dose according to soil and climatic conditions of the area

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Publications - Implementation

Most olive oil producing countries in the Med region suffer from soil degradation and thus application of OMW as agricultural amendment may be considered as a suitable approach to solve disposal problems and in parallel restore soil fertility

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Application of olive mill wastewater to a Cretan olive orchard: Effects on soil properties, plant performance and the environment

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ABSTRACT

The application of fresh olive mill wastewater (OMW) to the soil surface of an olive (*Olea europaea*, L.) orchard was studied as a low cost alternative method for the disposal of this waste. OMW were applied to a Cretan orchard with 20-year-old trees (cv. 'Kalamata') during winter time for 3 consecutive years, at a maximum annual rate of 420 m^3 ha^{-1}. The effects on soil properties and composition (pH, EC, N, P, K, organic matter and phenolic content), yield, photosynthesis and nutritional status of the trees were studied. In a separate experiment, the possibility for groundwater pollution was studied in large lysimeters (60 m^3 of soil volume). The most important effects on soil composition included a significant increase on availability of K, which enhanced soil fertility, and an increase of phenolic compounds in the OMW-treated soil. However, phenols decomposed rapidly and no accumulation trend was observed after subsequent applications. No other negative effects on soil properties and plant behavior were observed throughout the experimental period, while the composition of drainage water at a soil depth of 2 m was not altered by the application of OMW. Based on the dosage used, the cost for adopting the method was estimated to less than €0.007 kg^{-1} of processed olive fruit.

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RECYCLING OF VEGETABLE WATER & OLIVE POMACE ON AGRICULTURAL LAND
(CFC/IOOC/04)

ACHIEVEMENTS OF PROJECT CFC /IOOC/04
"*RECYCLING OF VEGETABLE WATER AND OLIVE POMACE ON AGRICULTURAL LAND*"
GOOD PRACTICE IN VEGETABLE WATER AND COMPOST
SPREADING ON AGRICULTURAL LAND: CASE OF OLIVE GROWING

Project Executing Agency CFC/IOOC/04
Agro-pôle Olivier ENA Meknès

Project CFC/IOOC/04 on the "*Recycling of vegetable water and olive pomace on agricultural land*" was set up by the Common Fund for Commodities (CFC) and the International Olive Council (IOC) for the benefit of four South and East Mediterranean olive growing countries: Algeria, Morocco, Tunisia and Syria.

The broad aim of the project was to transfer technology on the application of vegetable water (VW) and olive pomace on agricultural land and to highlight the advantages of these practices in raising crop yields and improving soil fertility as a feature of sustainable, environmentally friendly olive growing.

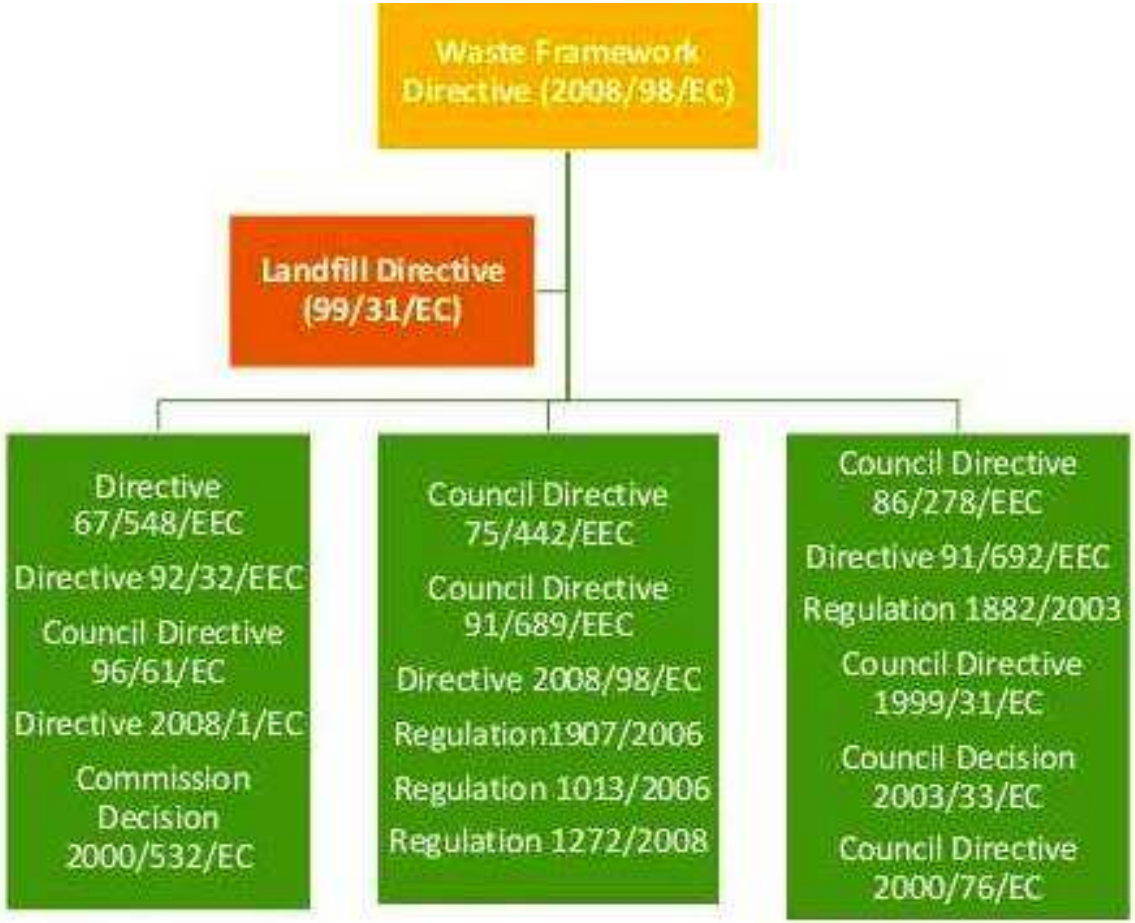
The soil application of OMW is practiced during 2014, 2015 and 2016 on 15 olive orchards in two Cooperatives (Peza and Mirabello) under specific licence from Regional Authority of Crete

Legislative aspects

EU Directive (2008)

The Waste Framework Directive (2008/98/EC) includes rules on hazardous waste and waste oils and requires Member States to recycle at least half of their household and general waste by 2020. According to the hierarchy, waste should be dealt with first by prevention, then re-use, recycling, recovery and finally, disposal.

During recovery, waste is either converted into usable forms or is incinerated so that energy is recovered.



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Legislative aspects

Italian Directive (L.574,1996 • Italian Directive n.166, 2005:

80 m^3/ha for 3-phase and 50 m^3/ha for classical 2-phase alperujo per year. Time limit on storing - not allowed in soil with herbaceous crops and in frost, snow and water-saturated soils

Portugese Directive (L No. 626/2000**):**

OMW is permitted to be disposed on soil at a maximum amount of 80 m^3 ha per year

Spanish legislation (Decree 4/2011):

Only the Regional Government of Andalusia has enacted the above law about the use of OMW as fertilizer. The volume of OMW not exceeds the amount of 50 m^3/ha/year.

Greek legislation (KYA 127402/1487/Φ15/7-12-2016):

Allow the controlled application, after a pre-tratment, of OMW to olive orchards and other crops at a maximum quantity 80 - 200 m^3/ha, depending on climatic and soil conditions.

Cyprus legislation (Ordinance No. 254/2003/1-11-204)

Define the type (2-phase or 3-phase centrifuge) and amounts of OMW allowed to be deposited in evaporation ponds or applied on the soil.

Olive Mill Structure in Greece

Typical characteristics:

Family owned, small enterprises (more than 2,000).

They cannot afford sophisticated OMW treatment facilities.

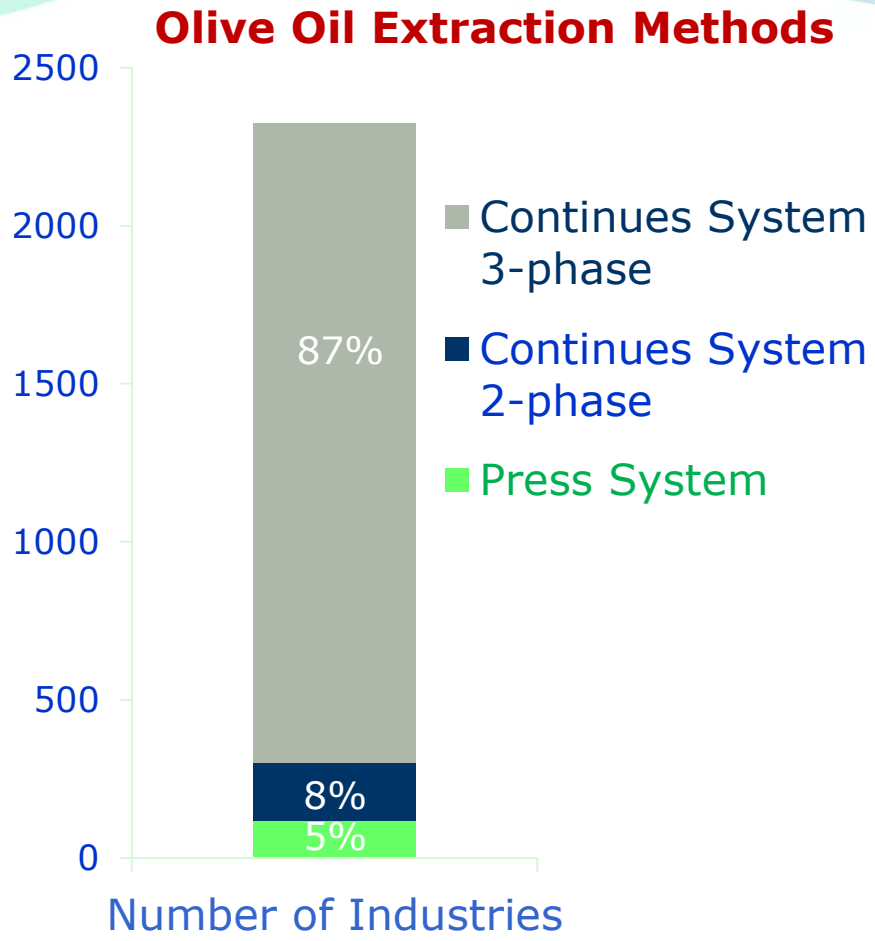
Average proccessing capacities

Classical (press): 0.4-2.0 ton/h

Centrifugal: 2.0-8.0 ton/h

There is no political will to enforce existing Environmental Legislation

Nearby houses and hotel owners dissatisfied with prevailing odors and the current state of the rivers.



OMW – current situation in Greece

- For large olive mills sophisticated combinations work successfully because they can affort the cost (construction and/or operation).
- For small family-based mills the cost is quite high, not affordable

The present situation in this case is:

- Storage in open evaporation ponds, or
- Direct disposal into the rivers or the sea causing serious environmental problems

Advantages:

- Low or without cost

Disadvantages:

- Pollution of surface or ground waters
- Centers for development of different insects
- Odors produced cause serious problems in villages or tourists

To reduce bad odors CaO is added.

The solid residues, after the evaporation of liquids, with the proper treatment can be used as soil amendment.

New technologies are developing…

Current situation in Greece: Composting

- Take place within the installations of medium-size olive extraction plants.
- INPUT: Oil extraction by-products (Olive pomace, leaves, OMW
- PRODUCTS: High quality organic compost 'HUMO-OLEA'

Capacity of 700 – 2000 tones per year

Fenton de-toxification and gradual composting

Complete control of pollution
Strengthens the circular economy

Use of 2 vs. 3 phase decanters

- In Greece some years ago, 2 phase decanters were pushed in the market as the solution to the OMW problem…
- Essentially the problem was transferred from the olive mills to the pomace processing plants!
- Reduced income to olive mill owners from sales to pomace plants → Reverse to "2.5 phase"
- Woody biomass very popular these days for home heating!...

Olive mill owners still looking for a "low" cost solution…

EU may impose penalties from 2018 to the Greek Government…

Current trend:

- Reduction of the number of olive extraction plants by merging and transformation to 2phase (subsidies)
- Modernization of pomace processing plants to accept the 2phase pomace (subsidies)

Concluding remarks

There is a need for a normative, that imposes a common policy for OMW management among EU and possibly all olive producing countries in Mediterranean region

All suggestions must be in tune with latest legislation

Ministries should accept current set of BATs (Best Available Technologies)

With respect to "direct disposal" to the ground:

- Any method that reduces COD-total (homogenized sample) by 70-90% is acceptable as equivalent secondary biological treatment
- OMW does not contain human pathogens and hence, no chlorination is needed
- Reduction by filtration typically >70% hence OK for direct disposal
- Address issue of bad odours (major "non environmental" problem)

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Thank you for your attention.

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