SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Sustainable Water Integrated Management and Horizon 2020 Support Mechanism

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Olive Mills process description and environmental aspects

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Presentation Outline

- Process description
- Methods of OMW treatment
- OMWW characteristics
- OMP characteristics
- Environmental impacts of OMWW
- Environmental impacts of OMP
- Environmental risks

Process description

Olive oil production

- The extraction of olive oil consists of three steps:
- Olive **crashing**, where the fruit is broken down and the oil is exported
- **Mixing**, where the remaining paste is slowly mixed to increase the oil extraction
- Oil **separation** from the remaining wastes

i. Traditional pressing

ii. 3- phases centrifugal extraction system

iii. 2- phases centrifugal extraction system

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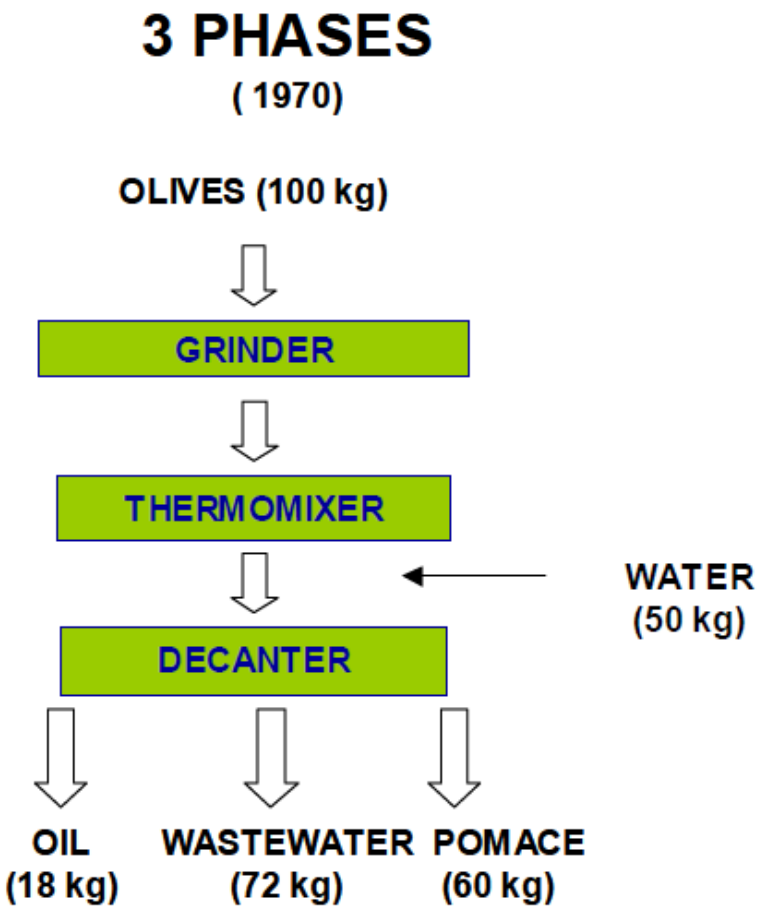
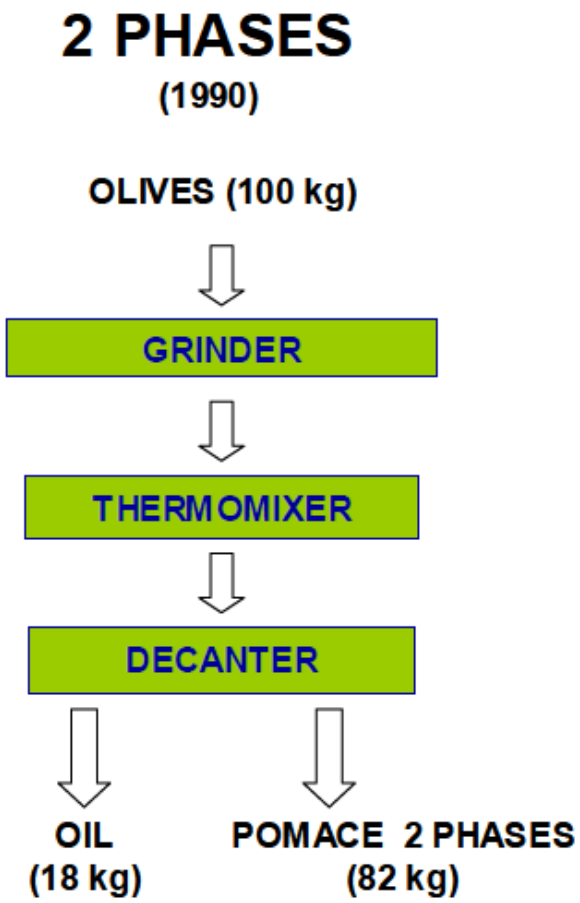
Process description

Traditional pressing	Three – phase extraction process	Two – phase extraction process
A solid fraction, “olive husk”, is obtained as a byproduct with an emulsion containing the olive oil	Predominant process in modern olive mills	‘‘Ecological’’ method, reduces the olive mill waste by 75%
The olive oil is separated from the remaining olive mill wastewater by decanting	Two streams of waste: a) wet solid cake (~30% of raw material weight) called “olive cake”	Two fractions: a) a solid called “olive wet husk” or “wet pomace”
	b) A watery liquid (50% of raw material weight) called “olive mill wastewater” (OMW)	b) A liquid (olive oil)

Process description





Use of 2 vs. 3 phase decanters- Facts from Greece

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)

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Environmental challenges

The type of olive processing determines which waste will be produced.

- On the one hand, **three-phase processing** results in OMWW as well as semi-solid OMP production.
- On the other hand, **two-phase** processing results only in the generation of OMP with comparatively high moisture content.

Both wastes contain several components that can cause adverse effects on the environment if disposed without prior adequate treatment

The management of waste from olive mills

Olive cake

- Solid fuels
- Animal feed supplement
- Return to the olive grove as mulch

Olive mill wastewater (OMW)

- Disposal of OMW in nearby aquatic receivers
- Physical and physicochemical processes
- Biological processes
- Coupled physicochemical and biological treatments

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Proper characteristics for any success treatment method

- To be technical effective
- To be integrated
- To be feasible
- To meet all Environmental limits

METHODS OF OMW TREATMENT

Physical methods

- Evaporation ponds (**lagooning**)

Biological methods

- Anaerobic digestion (biogas, compost, fertilizer, etc)
- Use of OMW for **irrigation** of olive groves
- **Co-composting** of OMW with more feedstock (compost)

Physicochemical methods

- Membranes technology combined with evaporation and wet oxidation (**EHO** method)
- Phenolic compounds removal using **ion exchange** technology (purification)

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Olive mill wastewater (OMWW)

The variations of maximum and minimum concentrations of **Olive Oil Waste Water** resulting from both methods (traditional presses and decanter centrifuge) are presented:

- color ranging from intensive violet–dark brown to black
- strong olive oil odor
- high degree of organic pollution (COD values up to 220 g/L, and in some cases reaching 400 g/L) at a COD/BOD5 ratio between 1.4 and 2.5 and sometimes reaching 5 (difficult to be degraded)
- pH between 3 and 5.9 (slightly acid)
- high content of polyphenols, up to 80 g/L; other references up to 10 g/L
- high content of solid matter (total solids up to 102.5 g/L)
- high content of oil (up to 30 g/L)

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Olive Mill Pomace (OMP)

OMP results as a semi-solid by-product from two-phase as well as three-phase processing as a dark granular material comprising the olive seed, skin and residues

It consists of **similar chemical components like OMWW** and hence is especially characterized by a low pH level, very high content of organic matter and carbon, high levels of potassium, intermediate levels of nitrogen and usually also contains phenolic and lipids compounds

In contrast to OMWW, OMP contains **low levels of phosphorus** presents a comparison of some OMP characteristics generated from two-phase and three-phase processing

A decisive difference is the higher moisture and phenols content of OMP resulting from 2-phase processing

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Olive Mill Pomace (OMP)

Parameter	Mediterranean 2-phase	Mediterranean 3-phase
Moisture%	54 – 57	45 – 50
Phenols%	2.5 – 2.7	0.35 – 0.37
Total nitrogen%	0.43 – 0.48	0.50 – 0.90
Total carbon%	25 – 29	29 – 32
C/N ratio	59 – 60	57 – 59

Environmental impacts of Olive Oil waste

Impact of OMWW disposal on the aquatic environment

Olive mill wastewater is currently the major waste product of olive oil production and is **mostly deposed into the environment**. The wastewater is either directly released into the marine environment or reaches the open sea by rivers in a diluted form.

Generally, the release of untreated OMWW in water systems causes a **prompt rise of microorganisms** that consume large amounts of available dissolved oxygen and therefore **reduce its availability for other organisms**. This may destroy the **ecological balance of an ecosystem**.

Likewise, the presence of **high phosphorus** content in OMWW can lead to the growth of algae species and hence to **eutrophication of aquatic systems**. Again, the ecological balance of groundwater and surface water can be demolished. Moreover, phosphorus provides ground for pathogens to multiply and infect waters

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Environmental impacts of Olive Oil by-products

Impacts of OMWW disposal on soil

The dispersion of untreated OMWW on soil can have adverse effects on its properties and functionalities as well as on growing plants since OMWW contains polyphenols and organic acids that are **not easily biodegradable and have phytotoxic and antimicrobial impacts**. The germination of seeds, early plant growth and the formation of leaves and fruits may hence be inhibited for different types of plants and crops. Heavy soils such as clay are prone to the accumulated salts in OMWW which may lead to the **collapse of soil structure**.

Moreover, the high levels of potassium and organic acids alter the cation exchange capacity of the soil and hence alter environmental conditions for microorganisms. As a result, **soil fertility and soil porosity can be deteriorated**. Likewise, many studies agree that OMWW **reduces hydraulic conductivity and infiltration of soils**. Also, the composition of OMWW may lead to the immobilization of nitrogen and may decrease the availability of magnesium. Finally, **OMWW may also contaminate groundwater through leaching**.

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Impacts of OMWW on air

The **disposal or storing** of OMWW may also lead to air pollution since it can undergo **fermentation** processes, resulting in methane and hydrogen sulfide formation. This is also why OMWW is often characterized by **strong odor** which suggests to construct evaporation and sedimentation ponds **not close to inhabited regions or tourist sites**

Environmental impacts of Olive Mill Pomace (OMP)

Various research studies detected that the phytotoxic and antimicrobial characteristics of untreated OMP affect nitrification in the soil and **inhibit the germination of seeds of different plant species**.

The high carbon-nitrogen ratio and low pH in the OMP **immobilize nitrogen in the soil**. Similar to OMWW, OMP also adversely affects the cation exchange capacity of soils, hence **reducing soil fertility**.

These findings suggest that the application of untreated OMP on soils evokes negative environmental implications and hence may also **reduce the agricultural productivity of affected soils**. Therefore, an effective treatment of OMP is advisable prior to releasing it into the environment.

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Discolouring of natural waters

This is one of the most visible effects of the pollution. Tannins that come from the olive skin remain in the wastewater from the olive oil mill. Although tannins are not harmful to people, animals, or plants, they dye the water coming into contact with them **dark black-brown**. This undesired effect can be clearly observed in the Mediterranean countries

Degradability of Carbon Compounds

For the degradation of the carbon compounds (BOD5), the bacteria mainly need nitrogen and phosphorus besides some trace elements. The BOD5 :N: P ratio should be 100 : 5 : 1. The optimal ratio is not always given and thus an **excess of phosphorus may occur**

Environmental risks

Threat to Aquatic Life

Wastewater has a considerable content of reduced sugar, which, if discharged directly into natural waters, would increase the number of microorganisms that would use this as a source of substrate. The effect of this is **reduction of the amount of oxygen** available for other living organisms, which may cause an **imbalance of the whole ecosystem**.

Another similar process can result from the high phosphorus content. Phosphorus encourages and accelerates the growth of algae and increases the chances of **eutrophication**, destroying the ecological balance in natural waters.

Impenetrable Film

The **lipids in the wastewater** may form an impenetrable film on the surface of rivers, their banks, and surrounding farmlands. This film **blocks out sunlight and oxygen to microorganisms** in the water, leading to **reduced plant growth** in the soils and river banks and in turn **erosion**

Soil quality

The waste contains many **acids, minerals, and organics** that could destroy the cation exchange capacity of the soil. This would lead to destruction of microorganisms, the **soil–air** and the **air– water** balance, and, therefore, a **reduction of the soil fertility**

Phytotoxicity

Phenolic compounds and organic acid can cause **phytotoxic effects on olive trees**. This is of dire importance since wastewater can come into contact with crops due to possible flooding during the winter. The phenols, organic, and inorganic compounds can hinder the natural disinfection process in rivers and creeks

Environmental risks

Odors

Anaerobic fermentation of the wastewater causes methane and other gases (hydrogen sulfide, etc.) to emanate from natural waters and pond evaporation plants. This leads to considerable **pollution by odors** even at great distances.

Other risks could be referred to in this respect, such as agricultural-specific problems arising from pesticides and other chemicals, although their effect in olive cultivation is less pronounced than other fields of agriculture. The main problem is soil erosion caused by rainwater, which results in steeper slopes and increases difficulty in ploughing.

Recognizing the environmental pressures related to olive oil production- IED

Recognizing the environmental pressures related to olive oil production

Water Consumption

Water consumption in olive-oil mills depends on the kind and condition of olives, the extraction method (pressing or centrifugation), and the engineering practices followed. Significant differences are observed during **olives washing**. This process **may consume water quantities up to 50% of the initial weight of olives**.

Large quantities of water are consumed in oil refining units. Water is used during several stages of the production process e.g. cooling and cleaning of the equipment and floors. Water consumption and wastewater production can be **reduced considerably by recycling**

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Recognizing the environmental pressures related to olive oil production

Energy Consumption

Consumption of energy is not considered a major issue with respect to olive oil production. The most common form of energy used in the sector installations is electricity. Consumption is analogous to the electric equipment used.

Emissions to air

They mainly refer to the generation of odour, mainly due to improper storage of olives and oil.

On the other hand, air emissions are generated in the oil refining stage. More specifically, air emissions derive from:

- The combustion for the production of steam
- Wastewater treatment, which usually concerns the disposal of the wastewater in lagoons in order to evaporate. This technique generates odours and VOC emissions.

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Recognizing the environmental pressures related to olive oil production

Generation of wastewater

The generation of wastewater constitutes the main environmental issues related to the production of olive oil. The wastewater present **high pollution load** (BOD, COD, suspended solids) and they also contain **natural coloring substances**, which are difficult to be removed by using conventional cleaning methods.

Wastewater is also produced mostly from the pressing process, centrifugal separation and cleaning. The wastewater produced has a **dark color and characteristic odor**.

Guidelines for the eco-production of olive oil

- Effective use of water and energy
- Minimization of air emissions, solid waste and wastewater generation
- General guidelines of good practices

Specific objectives

Aspect	Objectives
ENERGY	Reduce energetic consumption
	Performance Optimization
	Combustion processes' improvement
WASTE	Minimize waste
	Appropiate waste management: storage, identification, remove
ATMOSPHERE	Minimize chemical emissions
	Minimize noise emissions
LIQUID	Minimize spills
	Treatment improvement
SOIL	Avoid soil pollution

Optimum consumption of water

The most common measures for saving water are:

- Recycle-Reuse of cleaning water. Collection and reuse of water used in the system of equipment cleaning.
- Recycling/Reuse of water contained in the boiler for other usage within installation.
- Waterjet cleaning - Segregated collection of polluted water, and send them to a pool - Segregate clean rain water.
- Always wash fruit on a closed circuit.
- Place a water meter on the water entrance in order to register consumption.
- Control water quality of the washing circuit, in order to replace it only when necessary.
- Send sewage water to evaporation pools.
- If there are several water sources, use the poorest (quality) one for this step.

Optimum consumption of energy

Practices for Efficient Operation for energy saving (including the olive processing stages) are:

•Upgrading of automatic control systems in the stages of production and transferring of energy, personnel training, cleaning procedures, maintenance procedures, measurement of energy

• Upgrading of the mechanical equipment.

• Improving the Efficiency of Steam-boilers. The thermal energy contained in fuels should be **efficiently exploited**. **Heat recovery** from exhaust gases to be used for warming the air feed of combustion via an air to air heat exchanger.

• Reuse from **steam condensation**. The exploitation of steam condensates as feed liquid of the steam-boilers, apart from the energy saving, contributes to water saving as well

• Minimization of Thermal Losses. The **use of insulation** in equipment parts where liquids of high temperature are flowing is possible to minimize heat losses

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Energy management and transport issues

PROBLEM OR IMPACT	PROPOSAL OR GOOD PRACTICE	EXPECTED IMPROVEMENT
ELECTRIC AND ENERGETIC CONSUMPTION	**Realization of ENERGETIC EFFICIENCE AUDITS in order to detect improvements and act in the next ways:**	Consumption reduction
	Electric fares optimization.	
	Frequency inverter utilization	
	Lighting consumption reduction	
	Heat recovery from boiler smoke	
	Change to natural gas or others	
	Evaporative condensators installation	
	Boiler purgative recovery	
	Condensations recovery	
	Boilers' combustion parameters adjustment and control	
	Control of losses and leaks	
	Cogeneration installation	
	Old machinery substitution, looking for more energetically efficient machines	
	Concentrates and ground effluents preheating	
	Efficient drying	
	Installation of AUTOMATIC PROCESS CONTROL	Consumption reduction
	Mixing temperature control	Quality risks reduction
	Temperature and flow control for decanter addition water	
TRANSPORT OF POMACE	**Pomace's EFFICIENT DRYING using solar thermal energy**	Reduction of the weight to transport, and therefore less transportation related impact.
	Utilization of Pomace as BIOMASS in order to produce electricity or heat.	Transport elimination
		Electricity and heat self - production
		Reduction or elimination of electricity an fossil fuels buying.
	Utilization of Pomace as COMPOST material	Transport elimination
		Elimination of industrial fertilizers (IMPACT DETECTED ON AGRICULTURAL PHASE)
OTHER TRANSPORTS	**Creation of Buying Consortium among olive mills for gases and fossil fuels acquisition.**	Avoid small deliveries, so transport impacts are minimized.

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Minimization of air emissions

The air emissions mainly refer to odour releases. There releases may be reduced via:

- The storage of olives in appropriate areas (e.g. in silos), but not for a long period of time
- Storage of the produced olive-pomace in covered areas with adequate ventilation until their shipment to pomace-oil mills

Other measures that may be applied to reduce the air emissions related to combustion is the:

- optimization of the operating conditions,
- the regular maintenance of equipment,
- the continuous monitoring of machinery efficiency
- the substitution of diesel oil, or pomace wood by LNG

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Minimization of wastewater

A recommended system for the treatment of wastewater includes **neutralization combined with coagulation (addition of lime) and sedimentation**. The treated water may be used for irrigation of olive trees.

An alternative solution for sedimentation and digestion, without equipment for the removal of the sludge, is the use of tanks used for the clarification of sewage by **simple settling and sedimentation**, along with **anaerobic digestion of the extracted sludge**, although it has a relatively higher cost.

After the treatment mentioned above, waste still contain **high organic load**. For final disposal: irrigation of olive-plantations, condensation, **anaerobic digestion combined with biogas production** (methane production 50-60%). In this later method, the generated methane can be recovered and used for energy production.

All wastewater from oil refining may pass through an oil-separator. **Biological treatment usually follows for the reduction of BOD, suspended solids and other pollution parameters**.

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Minimization of solid waste

Olive oil production

Waste treatment to recover useful byproducts (natural coloring substances, proteins). The **pomace** should be transferred to units for the **production of pomace oil**.

Also, the frequency and volume of waste discharge from centrifuges should be **in line with the specifications** of the manufacturers of the equipment.

Storage of all waste susceptible of being dispersed by wind or water in closed and opened places.

Other proposals include:

- Registration of all waste produced and given to third parts.
- Segregation of waste by their characteristics.
- Waste giving to authorized managers, prioritizing those ones who offer recycling processes
- Storage of waste properly packed and labelled in safe places
- Avoid incineration of dangerous waste in the boiler.

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Minimization of solid waste

Oil refining

Most of the **by-products and solid wastes** produced in oil refining industries **can be used as raw materials** in several other industries. The following are recommended:

- Lecithin (by-product). It can be used in food industry, pharmaceuticals, animal food production, etc.
- Soaps. They can be utilized in soap production industry, or they can be treated with dense sulfuric acid solution. The product of this reaction is a free fatty acids (FFA) that can be used either as raw materials in other industries or as bio fuels.
- Collection of fatty compounds and usage as raw materials in soap making industries
- Spent decolorizing agents. They can be utilized in cement production or they can be used as additives from the animal food production industries
- Nickel catalyst: It can be recycled (in the hydrogenation unit) until its activity is substantially reduced. The spent catalyst can then be directed to a nickel-recovering plant.
- Bottles, papers, paperboards and other packing materials. They can also be utilized in other industries (mainly paper recycling industries).

General guidelines for good practice

One of the easier and economic ways to reduce pollution at source is the application of **good operating practices**. World wide, many companies apply such environmental policies that include personnel training, hygiene, innovative cleaning procedures, water and power consumption reduction, equipment maintenance practices and leakage detection.

It is noticed that **auditing** techniques should be applied to ensure proper application of the above.

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Practices of efficient organization

- Acceptance of an **administrative plan** by all employees. Without joint effort, adoption of environmental responsibility in the administration level, all-embracing organizing and management of the company, reduction in the source may not be successful.
- **Upgrading of mechanical equipment**. By upgrading the primary mechanical equipment, more efficient control can be achieved, production efficiency is improved and the losses in both storage/production activities are reduced.
- **Measurement and control of water and energy consumption**. The effort to reduce consumption of water or energy is always based on the evaluation of the existing situation of water and energy consumption for which appropriate consumption measurements are required. These measurements are compared with the average indexes of water and energy consumption in similar installations.

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Practices of efficient organization

- **Maintenance of the mechanical equipment**. Maintenance program should have two objectives: Preventive maintenance (according to the recommendations of the equipment manufacturer), fixing of possible equipment damages but also their prevention. The equipment of an installation should be **checked and cleaned regularly to ensure its efficient operation**. In case of a damage or a failure, it should be fixed immediately.
- **Prevention and management of leakages and fugitive escapes**. The avoidance of leakage is of primary importance for preventing pollution. Leaks and fugitive escapes can be avoided by installing appropriate equipment to prevent leaks and escapes. A leakage detection system and the implementation of preventive maintenance are considered to be helpful.

Practices of efficient organization

- **Personnel training on pollution prevention and control**. The personnel should be aware of the main issues related to the environmental performance of the installation and be educated on how to reduce the use of energy and water.
- **Assignment of responsibility for the monitoring of all pollution control systems performance**. A person responsible for the monitoring of the environmental performance of the installation should be assigned. This person will be responsible for checking the good operation of the unit and identify potential sources of unexpected pollution

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Practices of efficient organization

- Monitoring of the volume and quality of solid waste and wastewater. This data should be stored at appropriate files and be easily retrieved whenever it is necessary
- Control and maintenance of the equipment, according to the specifications of the producer of the equipment
- Detection and prevention of leakages, especially to wastewater spills, which may have significant impacts to the soil, surface and groundwater
- Tree plantation for the reduction of noise and aesthetic nuisance

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Conclusions

Short term

- Promote the use of vertical centrifuge water as land fertilizer in olive grove
- Implement environmental management systems in the oil mills (ISO 14001, EMAS, etc)
- Energy Auditing in Oil Mills
- Automatization of processes, with previous energy and mass analysis
- Promote efficient pomace drying by thermal solar energy to minimize environmental loads of transportation.

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Conclusions

Long term

Integral Management of Olive Oil.

The eco-efficient **oil mills and organic farmers** must be one when managing olive oil production:

- **Compost production** will involve many local actors: pomace (oil mill), straw (non olive oil farmers), sheep dung (livestock farmers)
- There should be a production of "green energy" for other industries based in **extra energy coming from waste** generated in the process: pruning residues, husk and other wastes.
- Some local production of biodiesel for tractor running can be planned

Co-operation

Promote corporatism of oil producers to share machinery (mainly **wastewater treatment plants**)

Local Economy: Local consumption vs. distribution of goods

Local production of goods allows consumer to have a **closer contact to oil producers** and easily **trace back** through production chain. Furthermore, money remains for local and rural economies, usually exporting nutrients in form of food at considerably low prices

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Thank you for your attention.

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