

Integrated Strategy of actions, measures and means suitable for Mediterranean Countries

Analysis of national and European legislative frameworks for Oil Olive Waste and Soil Protection

April 2012

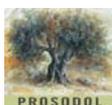
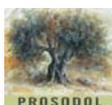


TABLE OF CONTENTS

EXECUTIVE SUMMARY	5
1 OLIVE OIL INDUSTRY AND THE ENVIRONMENT	6
1.1 THE OIL OLIVE INDUSTRY	6
1.2 WASTE GENERATED AND CURRENT PRACTICES FOR WASTE MANAGEMENT IN THE SECTOR	8
1.2.1 OLIVE MILL WASTEWATER	9
1.2.2 SOLID AND SEMI-SOLID WASTE	9
1.3 ENVIRONMENTAL EFFECTS OF OLIVE MILL WASTE	11
2 EU AND NATIONAL LEGISLATION ON WASTE, WATER AND SOIL	13
2.1 WASTE	13
2.1.1 WASTE OR NOT WASTE? THE EXCEPTIONS	16
2.1.1.1 By products	16
2.1.1.2 End-of-waste status	19
2.1.1.3 Agricultural materials	20
2.1.2 HAZARDOUS WASTE AND DANGEROUS SUBSTANCES	20
2.2 WATER	25
2.2.1 OVERVIEW	25
2.2.2 REUSE OF WASTEWATER	28
2.2.3 SETTING OF LIMIT VALUES: ELVSAND EQSS	29
2.2.3.1 Emission Limit Values	30
2.2.3.2 Environmental Quality Standards	31
2.3 SOIL	35
2.3.1 SOIL IMPROVERS AND ORGANIC WASTE FERTILIZERS	36
2.3.2 LANDSPREADING OF WASTE	37
2.3.3 SEWAGE SLUDGE	40
2.3.4 LIMIT VALUES AND QUALITY STANDARDS FOR LANDSPREADING OF SOIL ADDITIVES OTHER THAN SEWAGE SLUDGE	43
2.4 NATIONAL LEGISLATION ON OLIVE OIL WASTE OF THE PARTICIPATING COUNTRIES	47
2.4.1 ITALY	47
2.4.2 SPAIN	48
2.4.3 GREECE	50
2.4.4 PORTUGAL	51
2.4.5 CYPRUS	51
2.4.6 EMISSION LIMIT VALUES FOR DISCHARGES TO SURFACE WATER AND SEWER	53
3 LEGISLATIVE RECOMMENDATIONS FOR OLIVE OIL WASTE MANAGEMENT	54
3.1 THE PARTICULARITIES OF OLIVE OIL INDUSTRY	54
3.2 STATUTORY LEGISLATION PROPOSALS	54
3.3 VOLUNTEER LEGISLATION PROPOSALS	56
4 SOIL PROTECTION	57
4.1 INTRODUCTION	57
4.2 STATUTORY LEGISLATION PROPOSALS	60
4.2.1 RECORDING OLIVE OIL MILLS WASTE DISPOSAL AREAS	60
4.2.2 CHARACTERIZATION OF DISPOSAL AREAS-RISK ASSESSMENT	60
4.2.3 EVALUATION OF RISK LEVEL	62



4.2.4	DEFINING THE CONDITIONS OF OMW SOIL DISPOSAL	63
4.2.5	ADOPTION OF SOIL QUALITY INDICATORS	67
4.2.6	MONITORING SOIL INDICATORS-EVALUATION OF THE RESULTS	69
4.3	TECHNICAL RECOMMENDATIONS AND GUIDELINES	70
4.3.1	MEASURES FOR CONTINUOUS MONITORING OF OOMW DISPOSAL AREAS	70
4.3.2	SOIL REMEDIATION	75
5	REFERENCES	89
5.1	LITERATURE	89
5.2	EU LEGISLATION	98
5.3	NATIONAL LEGISLATION	100
6	ANNEX 1: CRITICAL LEVELS OF SOME MAIN SOIL PROPERTIES	103
6.1	REFERENCES OF ANNEX 1	105
7	ANNEX 2: SOIL INDICATORS-DETERMINATION AND EVALUATION	107
7.1	REFERENCES OF ANNEX 2	116
8	ANNEX 3: LAND SUITABILITY MAP FOR VIOTIA PREFECTURE, GREECE	119
9	ANNEX 4 DEVELOPMENT OF INTERPOLATION SURFACES FOR SOIL MONITORING	120
9.1	INTERPOLATION SURFACES	120
9.2	THE ARCGIS MODEL BUILDER	121
9.3	GOOGLE EARTH API APPLICATION	127
10	ANNEX 5. INSTRUCTIONS ON HOW TO CARRY OUT BIOREMEDIATION MONITORING	128
10.1	STATISTICAL CONSIDERATIONS	128
10.2	SOILS SAMPLING IN THE TREATMENT ZONE AND IN THE UNDERLYING UNSATURATED ZONE	128
10.3	SOIL PORE LIQUID SAMPLING IN THE UNSATURATED ZONE	129
10.4	WATER SAMPLES FROM THE SATURATED ZONE (I.E., GROUNDWATER)	129
10.5	RUNOFF WATER MONITORING	130
10.6	AIR MONITORING	130



TABLE OF FIGURES

Figure 1: A decision tree for waste versus by-product	18
Figure 2: Hazardous Waste Assessment Methodology in UK	23
Figure 3: Management of contamination	59
Figure 4: The interface of the map application for a disposal area. Yellow flags represent sampling sites inside the area of interest.	73
Figure 5: Strategy for bioremediation activities	78
Figure 6: Flow chart for determining the bioremediation potential of OMW disposal sites.	79
Figure 7: (a) clinoptilolite structure (b) Clinoptilolite in dust form.	85

TABLE OF TABLES

Table 1: Comparison of throughputs for the three-phase and two-phase olive oil processes	8
Table 2: ELVs and EQSs in EU legislation	33
Table 3: Geological and Hydrogeological conditions determining vulnerability mapping categories	39
Table 4: Maximum permissible limits for land application, EU, US and National Legislations (mg/kg dw)	40
Table 5: Annexes IA, IB and IC of Directive 86/278/EEC	41
Table 6: Proposed limit values on potentially toxic elements (PTE) in sewage sludge and in soil (mg/kg dw)	42
Table 7: Limit values for concentrations (mg/kg dm) of organic compounds in sludge	42
Table 8: Quality criteria for the final compost products	43
Table 9: Limit Values for heavy metals, organic pollutants and salmonella in fertilisers, growing media and soil improvers in Austria	44
Table 10: Ecological criteria for eco-label of soil improvers	45
Table 11: Wastewater limit values for food industries in Greece	50
Table 12: Maximum annual waste quantities allowed for two-phase centrifuge olive mills in Cyprus	51
Table 13: Maximum annual waste quantities allowed for three-phase centrifuge olive mills in Cyprus	51
Table 14: Quality of liquid waste entering the evaporation tank in Cyprus	52
Table 15: ELVs for discharges to surface waters and sewers (in parenthesis) in Italy, Greece, Spain and Portugal	53
Table 16: Risk assessment rating	62
Table 17: Criteria for land suitability for OOMW disposal	63
Table 18: The soil parameters that can be monitored with the monitoring application tool and the respective values range of the risk zones	74
Table 19: Site and soil characteristics identified as important for bioremediation application	80
Table 20: Requirements of a complete monitoring program	83
Table 21: Typical Monitoring Plan for Bioremediation implementation	83



Executive summary

The present report presents an extensive analysis of European Union legislative framework on the subject of olive oil waste management, including the relevant regulations of waste, water and soil. The analysis is integrating the relevant legislative framework of the partner countries, i.e. Italy, Spain and Greece as well as of Portugal and Cyprus.

Chapter 1 of the report presents an analysis of the olive oil industry and the relevant environmental issues. **Chapter 2** focuses on the waste management and presents the relevant EU and national legislation on waste, water and soil. **Chapter 3** summarizes the legislative recommendations for olive oil waste management. As the overall objective is the tentative harmonization of rules and laws, specific recommendations are provided and discussed, both statutory and volunteer. **Chapter 4** is focusing specifically on soil protection. Soil protection analysis includes legislative recommendations as well as technical specifications and proposed strategies to monitor, protect and improve soil quality at olive oil mills' disposal areas. The five **Annexes** are supporting the soil protection analysis.

Data from the info-library of the PROSODOL project and evaluated results from monitoring and pilot actions as well as all actions' deliverables were utilized for the development of the current report.



1 Olive oil industry and the environment

The environmental impact of olive cultivation and olive oil production is particularly important for Spain, Italy and Greece as the major producers in EU. Spain, with 2.47 million ha, has the largest area under cultivation, followed by Italy (1.16 million ha), Greece (0.81 million ha) and Portugal (0.38 million ha). France is smaller producer, with an area harvested of around 18 900 ha. Other smaller producers are Cyprus (11 600 ha), Slovenia (800 ha) and Malta (less than 100 ha)(LIFE Focus, 2010).

1.1 The oil olive industry

The European Union (EU) dominates the international olive oil market as the four major producers, Spain, Italy, Greece and Portugal grow more than 70% of the world's olives, and the EU accounts for a similar share of global olive oil production. Olive farms range from very small (<0.5 ha) to very large (>500 ha) and from traditional, low-intensity groves to intensive, highly mechanised plantations (LIFE Focus, 2010).

The processes in use are as follows (ECOIL, 2005; MORE, 2008):

- **Traditional Olive Oil Mills.** Produce oil, a dry pomace and olive water. The ground paste is placed between pressing mats and is subject to pressure, to expel the oil mix (mixture of oil and water). The mixture is then poured into a vat or holding tank. This is allowed to rest so that gravity and different densities come into play, separating the oil from the water. Because no water is typically added, waste production is minimal.
- **Continuous systems (two-phase and three-phase):**
 - a) *Three-phase olive system.* The process is based on a 3-phase decanter: 1 litre of water is added per kilo of paste; it is then added to a horizontal centrifugal machine, where the solid is separated from the oily phase. This phase or unpurified oil is then passed on to a vertical centrifugal machine, where the oil is separated from the vegetable water. The process produces oil, pomace or husk and wastewater (vegetable water) commonly denominated by the acronym OMWW. Water is added during processing and increases total waste produced. The pomace is dry and can be used to obtain pomace oil or treated as a waste. Wastewater generated has high organic load and contains high amounts of polyphenols.
 - b) *Two phase olive system.* The process based on a 2-phase decanter: Same process as above, but instead of adding water for the horizontal centrifugation, the vegetable water is recycled. The process requires little added water and produces oil and a humid pomace or two-phase olive mill waste (TPOMW). TPOMW is not considered as a disposal problem compared to the wastewater produced in a 3-phase system. TPOMW is usually dried onsite to obtain a pomace with less than 50% of water. However, drying process is costly and greenhouse gasses and fumes are produced (Niaounakis and Halvadakis 2006)

In Spain the most widely used process is the “2-phase”. In Italy both “3-phase” and traditional methods are used, while in Greece “3-phase” is more common.



The Mediterranean olive oil sector includes a large number of family businesses, which can be hardly considered as industrial plants, in terms of BATs, permitting and inspection. On the other hand, the production of olive oil can also represent an important economy sector, vital to the local or even national economy. The most significant example is the region of Andalusia, Spain, where approximately 1/3 of the total world olive oil production is concentrated. At least until 2003, there were a lot of SMEs in all countries and, with an exception of pomace oil extraction plant in Portugal, there were no mills or extraction plants falling within the scope of the Integrated Pollution Prevention and Control (IPPC) **Directive 96/61/EC** (IMPEL, 2003). According to Annex I of the IPPC Directive, the relevant to olive oil production activity is 6.4(b):

6. Other activities

6.4. (b) Treatment and processing intended for the production of food products from:
— vegetable raw materials with a finished product production capacity greater than 300 tonnes per day (average value on a quarterly basis).

It should be noted that **Directive on industrial emissions 2010/75/EU** (IED) was adopted on 24 November 2010 and it entered into force on 6 January 2011 and has to be transposed into national legislation by Member States by 7 January 2013. The IED replaces the IPPC Directive and the sectoral directives as of 7 January 2014, with the exemption of the **Large Combustion Plants (LCP) Directive 2001/80/EC**, which will be repealed with effect from 1 January 2016. The recently adopted Industrial Emissions Directive has introduced additional provisions to ensure that the operation of an installation does not lead to **deterioration in the quality of soil** (EC, 2012).

According to the Reference Document on Best Available Techniques in the Food, Drink and Milk Industries, the subsector where olive oil production belongs to is Vegetable oils and fats (paragraph 4.7.4) (IPPC BREF, 2006). Only olive oil should be considered as “product” for determining whether an olive mill falls under IPPC or not (pomace oil, for the pomace extraction plants). By products such as pomace from olive mills or cake from extraction plants should not be counted as products. According to the study of the European Union Network for the Implementation and Enforcement of Environmental Law (2003) (IMPEL, 2003):

- Olive mills are generally SMEs, in all countries but Spain. The number of mills in Italy, Greece and Portugal exceeds those in Andalusia. The percentage of large mills in those countries is 9, 1, and 11%, respectively. There is no IPPC olive oil mill in the participating countries.
- 2-phase systems have only penetrated in Spain (98% of plants in Andalusia) and Croatia. In all other countries they represent less than 5% of the plants. Press systems dominate in Portugal, while 3-phase decanters are dominant in the other countries.
- Pomace extraction plants: The number of such plants significantly smaller than the corresponding number of olive mills in all countries and it is about the same in Spain, Italy, and Greece. The percentage of “large” plants is higher, though. Still, the majority of those plants are SMEs in all countries but Portugal, where 75% of the extraction plants are characterized as large, and 1 of them falls under IPPC.



1.2 Waste generated and current practices for waste management in the sector

Wastes generated by the olive sector are solid wastes (as olive husks or crude olive cake) and olive mill wastewater (LIFE Focus, 2010). The resulting wastes depend on the production process. Until the introduction of the two-phase decaners, both the press-systems and the decanter systems resulted in solid residue called olive cake (sludge) and the vegetable water (liquid effluent). In the early 90's, the 2-phase decaners appeared which practically eliminate liquid effluent, since there is no water addition and there is only one residue resulting from the process as liquid and solid residue comes together, in the form of a sludge (IMPEL, 2003).

The throughputs of the two-phase and three-phase olive oil processes are compared in Table 1(IPPC BREF, 2006).

Table 1: Comparison of throughputs for the three-phase and two-phase olive oil processes

Data		Two-phase process		Three-phase process	
		IMPEL project data	Spanish data	IMPEL project data	Spanish data
Input	Olives (t)	1	1	1	1
	Water (m ³)	0	0	0.5	0.7-1
Output	Oil (t)	0.18	0.2	0.18	0.2
	Wastewater (m ³)	0	0	0.72	1-1.2
	Pomace (t)	0.82	0.8	0.60	0.5-0.6

The common methods used for the disposal, storage or treatment of olive solid and liquid wastes from olive oil extraction processes in different olive growing countries in the world are given below(Nair and Markham, 2008; Saadi et al., 2010):

- Uncontrolled spreading of olive husk on farm lands at rates of 100 - 200 m³/h/year
- Irrigation of tree crops with olive oil mill wastewater at the rate of 80 m³/h/year
- Controlled spreading of OMWW in **Italy** for 3-phase extraction process at the rate of 80 m³/h/year and for the classical extraction process at the rate of 50 m³/h/year
- Controlled spreading of composted or raw olive husk in **Italy**.
- The **Israel** Ministry of Environmental Protection permits land spreading of OMWW at a rate of 40-50 m³/ha/year, every alternate year in the same area and controlled spreading of olive husk produced in the 3-phase extraction process at the rate of 40 m³/h/year every alternate year in the same plot
- Irrigation of olive trees with OMWW in **Greece** at the rate of 1.5 m³/tree/year
- Uncontrolled discharge of OMWW in **Israel** into municipal wastewater treatment plants
- Storage of OMWW in open anaerobic ponds
- Storage of OMWW using floatation devices
- Storage of OMWW using open settling tanks
- Limited methods of composting olive solid waste (treatment). In Andalucía, Spain, there is a consortium of olive mills which produce compost with their semisolid wastes (TPOMW compost) which is used for organic farming. This



activity is funded and promoted by the Regional Government of Andalusia(<http://www.juntadeandalucia.es/agriculturaypesca/portal/areas-tematicas/produccion-ecologica/produccion/compostaje/index.html>)

- Biofilters for the treatment of olive liquid waste (treatment)
- Production of biogas (methane) from treatment of olive solid waste. (treatment)

1.2.1 Olive mill wastewater

Traditional olive oil processing methods are estimated to produce between 400 and 600 litres/tonne of processed olives, three-phase processes produce 800-1000 litres/ tonne of processed olives while almost no wastewater (OMWW) is produced by the two-phase process. The characteristics of OMWW are variable, depending on many factors such as method of extraction, variety and maturity of olives, region of origin, climatic conditions and associated cultivation/processing methods (LIFE Focus, 2010; Ouzounidou et al., 2010). OMWW is essentially water by 80-83%, organic compounds (mainly phenols, polyphenols and tannins) account for a further 15-18% and inorganic elements (such as potassium salts and phosphates) which make up the remaining 2% (LIFE Focus, 2010). In more detail, general, OMWW (olive mill wastewater from three-phase extraction systems) is a recalcitrant dark brown effluent, with a distinctive odour, acidic (pH=4.0-5.5) and high conductivity (6,000-16,000 $\mu\text{S}/\text{cm}$). Furthermore, OMWW present high values for most pollution parameters (Ouzounidou et al., 2010): BOD₅: 40-95 g/l, COD: 50-180 g/l, LD₅₀ toxicity for fish: 8.7% and they contain large amounts of suspended solids and high concentrations of polyaromatic compounds, e.g. simple phenols and flavonoids, or polyphenols (0.5-24 g/l). The levels of phenols in OMWW can vary from 1 to 8 g/l (Nair and Markham, 2008). Moreover, OMWW possesses considerable amounts of mineral nutrients such as potassium (K₂O: 2.4-10.8 g/l) and phosphorus (P₂O₅: 0.3-1.5 g/l), and a wide-range of micronutrients (Ouzounidou et al., 2010). The phenolic compounds are a large family of molecules sharing one common feature, at least one phenolic group, substituted in most of the cases with another functional group. The 50 phenols that have already been identified in olive mill wastewater belong to three important categories of phenolic compounds: (a) cinnamic acid derivatives, (b) benzoic acid derivatives, and (c) compounds related to tyrosol (Kappelakis et al., 2008). The toxicity of olive mill waste is mainly related to its high content of phenolic compounds, which are distributed between oil (2%), OMWW (53%) and pomace (45%) (Rodis et al., 2002).

Olive oil mills' polluting charges are significant with high levels of both BOD₅ and COD and this represents a notably large organic matter load compared to standard municipal wastewater and anaerobic digestion of the waste results in only 80 to 90 % COD removal and this treatment remains insufficient to permit OMWW effluent to be discharged back into the environment (LIFE Focus, 2010). Furthermore, an important problem is phenols, which are difficult to purify and do not respond well to conventional degradation using bacterial-based techniques (LIFE Focus, 2010).

1.2.2 Solid and semi-solid waste



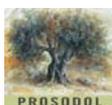
As concerns olive mill semi-solid waste from two-phase extraction systems (TPOMW), which practically integrates into one waste-stream the OMWW (though in smaller quantities) and the olive pomace of the three-phase extraction process, it presents a moisture content of about 60-65%, pH of 4.9-6.8, a high content in organic matter (60.3-98.5%) comprising relatively large amounts of lignin, cellulose and hemicellulose, lipids and carbohydrates as well as phenolics (Ouzounidou et al., 2010). TPOMW contains phenolic alcohols, phenolic acids such aselenolic acid derivatives like oleuropein, flavonoids lignin and lignanes (Stamatakis, 2010). The levels of phenols in olive husk can vary from 2.9 to 3.7 g/kg (Nair and Markham, 2008).

The stream of the milled olives in “2-phase process” is separated in a 2-phase decanter. This system enables reduced fresh water consumption and the elimination of wastewater streams. Unfortunately, TPOMW, which is produced comprises both, solids and water (OMWW) from the olives and poses again difficulties for disposal, as it is very difficult to handle, dries out very slowly and it is again very polluting (MORE, 2008). TPOMW is constituted from a mixture of olive pit/stone, olive pulp and skin, as well as, pomace olive oil plus the water added in the olive mills. The moisture content is about 35-70% depending on the olive oil production process (MORE, 2008).

The most common disposal methods in Greece, due to the lack of specific legislative framework and effective monitoring by the responsible governmental, regional and local authorities, include storage in evaporation lagoons, discharge into nearby water bodies and land application (Ouzounidou et al, 2010; Kavvadias et al., 2010). In Italy, the management of OMW is ruled by the law No 574 of 1996 and the Ministerial Degree of 6th July 2005 with the majority of the mill owners already conformed to them. The common practice is the separation of the wastewater from husk and use of wastewater for irrigation or just soil disposal while the husk is landfilled. In Spain, the wastes of the olive oil industry are mainly used for the production of heat and energy, or they are composted; however large amounts are still deposited in evaporation ponds. According to the study of the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) soil application and use for irrigation is common for liquid effluent (vegetable water) from 3-phase & press olive mills while evaporation ponds are also used. It is not uncommon to discharge in waters without treatment and/or not to comply with limits. Solid waste from 3-phase & press olive mills is generally used for pomace oil extraction. Soil conditioning and composting are used alternatively. For the 2-phase sludge, composting is the main practice in Italy, while in Spain is also used as biomass-fuel (IMPEL, 2003). Furthermore, the main comments of the study concerning Best Available Techniques and priorities for the sector are (IMPEL, 2003):

- Full treatment or disposal of waste is neither viable nor acceptable option
- Application to soil seems the preferable way for waste re-use
- Need for practical solutions for re-use of pomace from 2-phase systems

According to the study of the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) practices or methods that allow minimisation or reuse of the waste from the processing of olives at a reasonable cost, or, even better, while making a profit, are necessary in order to minimise environmental impact and to promote environmental compliance of the sector. The penetration of 2-



phase systems in other countries, in addition to Spain and Croatia, would be facilitated by the existence of proven economically viable methods for the handling and exploitation/re-use of the sludge (pomace) (IMPEL, 2003).

Finally, although the majority of the sludge produced in evaporation ponds is disposed of in landfill sites, the remainder is used either in agriculture after natural dewatering due to its high fertilising value or as a heat source because of its oil content (Hytiris et al., 2004).

1.3 Environmental effects of olive mill waste

The current waste management practices in the olive oil sector result in environmental problems as soil contamination, underground seepage, water-bodies pollution and foul odor emissions (Ouzounidou et al., 2010). Phenolic nature deserves special attention because of their influence on three of the main properties of OMWW: antibacterial effect; phytotoxic effect and dark colour (Cabrera et al., 1996). Discharging untreated or partially safe olive mill wastewater back into natural water systems can result in a rapid rise of BOD and COD and this could quickly offset the equilibrium of an entire ecosystem (LIFE Focus, 2010).

The OMWW is a complex mixture of water, sugars, nitrogenous substances, organic acids, pectins, mucilages and tannins, lipids and inorganic substances. All of them have poor biodegradability and high phytotoxicity due to the presence of a large amount of phenolic compounds, free fatty acids and inorganic salts (mainly potassium salts) (Zafra et al., 2006). Furthermore, phenols, together with alcohols, aldehydes, and organic acids, result in a very low pH threatening the environment, especially the water bodies (LIFE Focus, 2010; ECA, 2010).

OMWW, due to its composition, has potential for use as a fertiliser and in irrigation. However, phenolic compounds are both antimicrobial and phytotoxic and thus restrict the reuse of OMWW while are difficult to be removed by conventional degradation using bacterial-based techniques (LIFE Focus, 2010). While phenolics are mainly held responsible for the olive oil wastewater strong antimicrobial and phytotoxic properties, non-phenolic-related toxicity attributed to long-chain fatty acids and volatile acids was also reported (Ouzounidou et al., 2010). Moreover, olive mill wastewater has been shown to affect the physical and chemical properties of soil and its microbial community, while several studies have evidenced its phytotoxic effects and antimicrobial activity. OMWW can be toxic to anaerobic bacteria, which may inhibit conventional secondary and anaerobic treatments in municipal treatment plants (Karaouzas et al., 2011). OMWW, even highly diluted, has significant impacts on the aquatic fauna and to the ecological status of fluvial ecosystems. The phenolic content (phenols, flavonoids or polyphenols) along with long chain fatty acids produce methanogenic toxicity and therefore the option of discharging olive mill wastewater to land should be carefully considered (Paredes et al., 1986; Hamdi, 1992; D'Annibale et al., 2004; Mekki et al., 2007). Several studies showed the phytotoxicity of OMWW and suggested that its phenolic components were responsible for this effect (Casa et al., 2003; Kapellakis et al., 2008). The toxic effects of OMWW and its polyphenolic fraction to aquatic organisms, on bacteria and yeast and on seed germination are well documented



(Kapellakis et al., 2008). The phytotoxic effect on higher plants is especially severe during germination and seedling development (Casa et al., 2003). The phenols present in OMWW, except their oxidation products, can also have a direct effect on several fish species. The river fish *Gambusia affinis* and the crustacean *Daphnia magna* are severely intoxicated by phenol derivatives (40 mg/L) after 15 min exposure. This concentration can be achieved by the addition of 1 L OMWW in 100,000 L of water (Stamatakis, 2010). A research has studied the effect of 13 OMWW samples from different regions of Portugal in microorganisms including *Daphnia magna* and has concluded that polyphenols have low toxicity but low biodegradability whereas tannins exhibit high toxicity and biodegradability.

Furthermore, the very high BOD₅ and COD, which cannot be reduced in appropriate levels by anaerobic digestion poses another threat for the receivers (LIFE Focus, 2010). Further concerns are caused by the high concentrations of phosphorus in OMWW, since it is released into natural waters this can encourage and accelerate the growth of algae (LIFE Focus, 2010). Landspreading and treatment in evaporation ponds could lead in groundwater pollution problems. Recent studies have also shown that the contamination with phenolic substances can reach the groundwater. In fact, as long as OMWW remains on the evaporation pond, phenolic substances can be released and leached down to deeper horizons and laterally far from the site through the permeable subsoil levels (Shadou et al., 2009). Other studies have shown mobility of phenolic compounds even in fine textured soils and enhances the risk for groundwater contamination (Kavvadias et al., 2010).

The presence of organic matter as well as many inorganic compounds causes severe pollution when OMWW is disposed of into water bodies, but in soil it prevents erosion and can be beneficial to soil fertility (Kapellakis et al., 2008). Controlled land application of OMWW results in increase of soil organic matter and nutrient availability and thus, improves soil fertility and productivity by controlling the nutritional and biological equilibrium in the soil–plant interface. However, negative effects may appear when some factors, such as soil properties and type, moisture content, water table and crop type are either underestimated or not considered at all. It is also known that OMWW contain oil compounds that may result in increased soil hydrophobicity and decrease water retention and infiltration rate. The use of OMWW in agriculture may also affect acidity, salinity, N immobilization, microbial response, leaching of nutrients and concentration of lipids, organic acids and phenolic. These latter compounds with bactericide and phytotoxic properties may cause alterations in N cycle, changes in soil microbial activity as well as contamination of surface and groundwater (Kavvadias et al., 2010).

Other environmental problems include (LIFE Focus, 2010; Stamatakis, 2010; Kapellakis et al., 2008; Nair and Markham, 2008):

- Lipids, producing an impenetrable film on the surface of rivers, their banks and surrounding farmland which blocks out sunlight and oxygen from microorganisms in the water, leading to reduced plant growth in the river bank soils and in turn soil erosion;
- The high C:N ratio and low pH in the olive husk are known to immobilise nitrogen in the soil



- Acids, minerals and organics can adversely affect the cation exchange capacity of soils, which is a measure of soil fertility.
- Unpleasant and far reaching odours can be created by fermentation of the OMWW discharged in the natural environment, which emits methane and other pungent gases, such as hydrogen sulfide.
- Staining of natural waters. The change in color of natural waters can be attributed to the oxidation and subsequent polymerisation of tannins producing darkly colored polyphenols, which are difficult to remove from the effluent.

2 EU and National Legislation on Waste, Water and Soil

As far as handling the processing of olive residues, the reform of common agricultural policy in olive oil does not provide specific provisions for the management of olive mill wastes (MORE, 2009). Thus, each Member State (MS) should develop national legislation governing this area, which should be in line with the EU legislation.

It should be noted that the major part of legislative EU acts are in the form of Directives, allowing the MSs to adopt and impose complementary measures. A classic example is the setting of emission limit values and environmental quality standards. Consequently, each country might have its laws and regulations, which are often very different and there is a need for the drafting and introduction of international norms, which will impose single strategy in the management of olive residues (MORE, 2009). On the other hand, with some exceptions, framework national legislation of EU MSs is governed by the EU legislation and in the following the most important legislative and policy EU initiatives are presented and analysed, with focus on legislation relevant to olive mill waste.

2.1 Waste

A number of EU laws regulate waste management and the core legislative act is the **Waste Framework Directive (2008/98/EC)**, which also includes rules on hazardous waste and waste oils, which were previously covered by separate legislation. According to the WFD, waste should be dealt with first by prevention, then reuse, followed by recycling, recovery, and finally, disposal. Under the method of recovery, waste is either converted into usable forms or is incinerated so that energy is recovered (LIFE Focus, 2010). In the last option of landfill disposal the relevant rules are provided by **Landfill Directive 99/31/EC**. The relevant waste legislation is listed below.

- **Directive 67/548/EEC** on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances. The Directive is permanently updated. The seventh amendment of the directive is made by **Directive 92/32/EEC**.
- Council **Directive 75/442/EEC** on waste constitutes the legal framework for Community policy on waste management to limit its production. The directive is replaced by the **Directive 2008/98/EC**.
- Council **Directive 86/278/EEC** of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in



agriculture. The purpose of this Directive is to regulate the use of sewage sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and man, thereby encouraging the correct use of such sewage sludge. The Directive lays down limit values for concentrations of heavy metals in the soil, in sludge and for the maximum annual quantities of heavy metals, which may be introduced into the soil. The Member States must take the measures necessary to ensure that these limit values are not exceeded through the use of sludge. The Directive has been amended by the **Directive 91/692/EEC** of 23 December 1991 standardizing and rationalizing reports on the implementation of certain Directives relating to the environment further amended by **Regulation 1882/2003** and **Regulation 1882/2003**.

- Council **Directive 91/689/EEC** of 12 December 1991 on hazardous waste. The object of this Directive is to approximate the laws of the Member States on the controlled management of hazardous waste. Member States ensure that hazardous waste is recorded and identified; they also ensure that different categories of hazardous waste are not mixed and that hazardous waste is not mixed with non-hazardous waste. Any establishment or undertaking, which carries out disposal or recovery operations must obtain a permit. The permit requirement may be waived if the method of recovery is such that there is no danger to human health or the environment, or if the Member State has adopted general measures laying down conditions for various methods of recovery. Establishments or undertakings, which carry out disposal and recovery operations and producers of hazardous wastes are subject to periodic inspections. The Directive is repealed from the **Directive 2008/98/EC** on waste with effect from 12/12/2010.
- Council **Directive 96/61/EC** concerning integrated pollution prevention and control. The purpose of this Directive is to achieve integrated prevention and control of pollution arising from the activities listed in its Annex I. It lays down measures designed to prevent or, where that is not practicable, to reduce emissions in the air, water and land from the largest industrial installations, including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole. In order to be operated, all installations covered by the Directive are required to obtain a permit from the competent authorities in the EU Member States. Those permits must contain conditions based on the Best Available Techniques (BAT), as defined in Article 2 of the Directive. The Directive was originally adopted as Council Directive 96/61/EC and after several amendments codified as **Directive 2008/1/EC**.
- Council **Directive 1999/31/EC** on the landfill of waste. The aim of this Directive is, by way of stringent operational and technical requirements on the waste and landfills, to provide for measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from landfilling of waste, during the whole life-cycle of the landfill. The Directive defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land. Landfill of Waste Directive is supplemented by the Council **Decision**



2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC

- Council **Directive 2000/76/EC** on the incineration of waste. The aim of this Directive is to prevent or to limit as far as practicable negative effects on the environment, in particular pollution by emissions into air, soil, surface water and groundwater, and the resulting risks to human health, from the incineration and co-incineration of waste. This aim shall be met by means of stringent operational conditions and technical requirements and emission limit values for waste incineration and co-incineration plants.
- Commission **Decision 2000/532/EC** of 3 May 2000. The List of Wastes (formerly the European Waste Catalogue), is a catalogue of all waste types generated in the EU. The different types of waste in the List are fully defined by a six-digit code, with two digits each for chapter, sub-chapter and waste type. The List is used to categorize items and substances when they become waste, but does not itself define items and substances as waste. The List of Wastes replaced **Decision 94/3/EC** and **Decision 94/904/EC**. The List of Waste has been amended by Commission **Decision 2001/118/EU**, **Decision 2001/119/EU** and **Decision 2001/573/EU**.
- **Regulation 1907/2006** of the European Parliament and of the Council of 18 December 2006. Concerns the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending **Directive 1999/45/EC** and repealing Council **Regulation 793/93** and Commission **Regulation 1488/94** as well as Council **Directive 76/769/EEC** and Commission **Directive 91/155/EEC**, **Directive 93/67/EEC**, **Directive 93/105/EC** and **Directive 2000/21/EC**.
- **Regulation 1013/2006** of the European Parliament and of the Council of 14 June 2006 on shipments of waste. The Regulation applies to shipments of waste, both within and into or out of the European Community. It concerns the application by the Member States of a system of prior authorization for the shipment of waste for disposal or for recovery. A common, compulsory notification system and a standard consignment note for shipments of waste have been introduced according to the Regulation. Member States have obligation take the necessary steps to inspect, sample and monitor waste shipments. The aim of renewed Regulation is to reinforce, simplify and specify the existing procedures for controlling waste shipments. It will thus reduce the risk of waste shipments not being controlled. The regulation has replaced **Regulation 259/93** with effect from 12 July 2007 and is amended by the Commission Regulation No **1379/2007** of 26 November 2007 amending Annexes IA, IB, VII and VIII.
- **Regulation 1272/2008** of the European Parliament and of the Council of 16 December 2008 on classification, labeling and packaging of substances and mixtures. The regulation amends and repeals **Directive 67/548/EEC** and **Directive 1999/45/EC** and amends **Regulation 1907/2006**.
- **Directive 2008/98/EC** of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. The essential objective of all provisions relating to waste disposal must be the protection of human health and the environment against harmful effects caused by the



collection, transport, treatment, storage and tipping of waste. It introduces an approach that takes into account the whole life-cycle of products and materials and not only the waste phase. Member States shall take appropriate steps to focus on reducing the environmental impacts of waste generation and waste management, thereby strengthening the economic value of waste. Furthermore, the recovery of waste and the use of recovered materials should be encouraged in order to conserve natural resources. In order to ensure the protection of the environment, provisions have been made for a system of permits for undertakings which treat, store or tip waste on behalf of third parties, for a supervisory system for undertakings which dispose of their own waste and for those which collect the waste of others, and for a plan embracing the essential factors to be taken into consideration in respect of the various waste disposal operations. This directive strengthens the provisions relating to waste prevention and energy efficiency. The directive from 12/12/10 repeals the **Directives 75/439/EEC, 91/689/EEC and 2006/12/EC.**

The mill operator, as a producer of waste, is under certain conditions responsible for proper management of such waste until recovery or disposal. Based on the WFD rules the oil mill operator has the following options (Taccogna, 2010):

- On-site disposal, or on-site recovery, by installing a suitable system at the olive mill
- Have the waste managed by public municipal waste management services under a specific agreement
- Deliver the waste, by means of an authorized waste collector, to authorized recovery or disposal installations
- Deliver the waste, by means of an authorized waste collector, to a party authorized to handle prior blending or mixing, repackaging and storage for subsequent transfer to authorized recovery or disposal installations
- The situation would be simplified if the olive pomace waste were treated as municipal waste, at least for smaller olive mills. In this case the producer would only need to deliver it to a municipal waste service without needing to stipulate an agreement and pay only the waste management tax or fees.

According to the study of the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL), the residues from the olive processing process should not be considered as waste if there are possibilities for their reuse. Use of effluent for irrigation and use of sludge as fertiliser after composting seem to be viable options, among others (IMPEL, 2003). The exceptions are analyzed in the following paragraphs.

2.1.1 Waste or not waste? The exceptions

2.1.1.1 By products

It is true that the characterization of a waste as by-product simplifies its further use. These materials are generated from industrial processes, which are considered, by the producers at least, to be by-products rather than wastes so that they can be recycled to



land as soil improvers and fertilisers with minimum restriction (EC-DG, 2001). EC Directive 2008/98 specifies in the preamble (under point 22), the need to avoid confusion with regards to the various aspects of the concept of waste and so make a distinction between waste and by-products (Taccogna, 2010). However, confusion still exists and in some cases the courts resolve these issues. A characteristic example is “*The Spanish Manure cases*”: In the joined cases of Commission v Spain (C-416/02 and C-121/03), the court held that manure will not be waste where it is used as soil fertiliser as part of a lawful practice of spreading on clearly identified parcels (regardless of whether the parcels are within or outside the agricultural holding that generated the effluent) and if its storage is limited to the needs of those spreading operations (EC, 2007).

Pursuant to Article 5 of **Directive 2008/98/EC** of the European Parliament and of the Council on waste and repealing certain Directives of 19 November 2008, the by-product is a substance or object resulting from a production process the primary aim of which is not the production of that item. Such a substance or object can be regarded as not being waste if the following conditions are fulfilled:

- (a) further use of the substance or object is certain;
- (b) the substance or object can be used directly without any further processing other than normal industrial practice;
- (c) the substance or object is produced as an integral part of a production process; and
- (d) further use is lawful; the substance or object fulfills all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

In order to clarify doubts raised in the past, art. 5 of the directive also provides that, following a specific procedure (“*Committee procedure*”), the EC Commission can “*adopt measures to determine the criteria to be met for specific substances or objects to be regarded as a by-product and not as waste*”, i.e. acts laying down the conditions and technical criteria, also in detail, for each sector and so also oil mills and olive pomace accordingly (Taccogna, 2010). In Figure 1, Annex II of the EC document “*on the Interpretative Communication on waste and by-products*” (2007) is presented (adopted by EC, 2007).

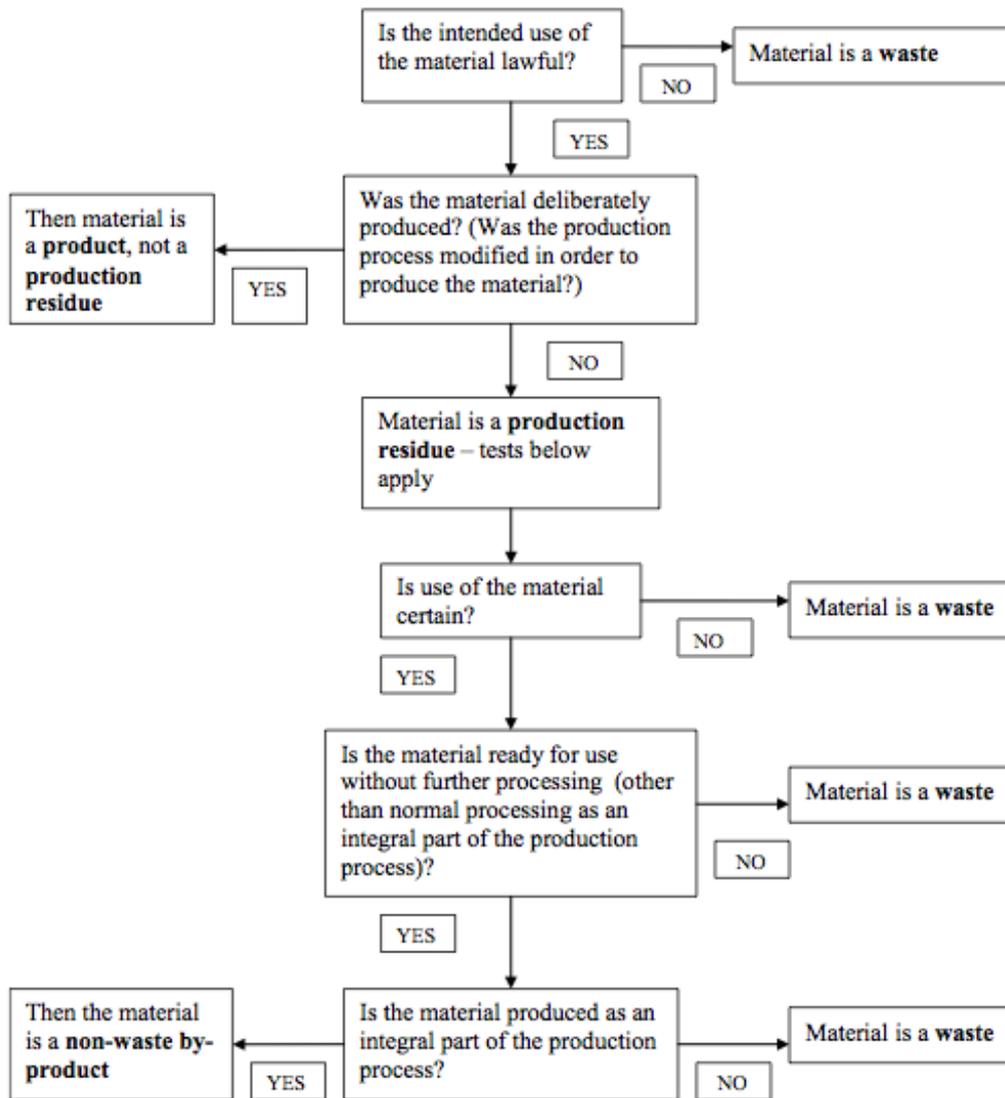


Figure 1: A decision tree for waste versus by-product

Concerning olive oil pomace and the definition above (Taccogna, 2010):

- Point (a): the conditions for using, as a by-product, pomace from the pressing process in an olive mill, without applying the rules on waste, can exist with regard to its possible uses: selling it to olive pomace refineries for chemical processing to extract olive pomace oil; spreading it as fertilizer (or mixed with backfill ground); as an additive in animal feed; for fuel (or similar), such as biomass, at energy production installations.
- Point (b): Olive pomace deriving from mechanically pressing olives in the mill, for producing olive oil, conclusively meets the second condition where a by-product can be obtained only if the substance is produced as an integral part of the process (or not as the primary aim of production).
- Point (c): it might be possible to consider that olive pomace can be used directly without needing any special processing other than normal industrial practice and so essentially in the same state as when it is pressed in the mill. Although it is



true that further drying may sometimes be needed, it can still be considered as “common industrial practice” and so it complies with the legal rules provided for by-products.

- Point (d): since olive pomace is a natural substance, and considering its properties, it might be assumed that there is no adverse impact.

By-products are exempted from REACH regulation, article 2(7)(b), unless they are imported or placed on the market themselves. A by-product consumed **by the same legal entity** does not need to be registered while the by-product placed on the **market** is regarded as a substance that **does need to** be registered.

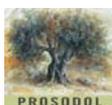
2.1.1.2 End-of-waste status

According to Article 6 (end of waste status) of the **Waste Framework Directive**, certain specified waste shall **cease to be waste** when it has undergone a **recovery operation** and complies with specific criteria to be developed in line with certain legal conditions, in particular:

- (a) the substance or object is commonly used for specific purposes;
- (b) a market or demand exists for such a substance or object;
- (c) the substance or object fulfills the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
- (d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

According Art. 3, point 15 of the WFD: “*recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations*”. These operations are:

- R1 Use principally as a fuel or other means to generate energy
- R2 Solvent reclamation/regeneration
- R3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)
- R4 Recycling/reclamation of metals and metal compounds
- R5 Recycling/reclamation of other inorganic materials
- R6 Regeneration of acids or bases
- R7 Recovery of components used for pollution abatement
- R8 Recovery of components from catalysts
- R9 Oil re-refining or other reuses of oil
- R10 Land treatment resulting in benefit to agriculture or ecological improvement
- R11 Use of waste obtained from any of the operations numbered R 1 to R 10
- R12 Exchange of waste for submission to any of the operations numbered R 1 to R 11
- R13 Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced)



Furthermore, as soon as a material **ceases to be waste**, REACH requirements apply in principle in the same way as to any other material (ECA, 2010). The stage in the processing of waste at which REACH obligations start to apply depends on when the material loses its waste status. Recovery processes often take place in several steps, and sometimes only the last step will result in a material that will no longer be classified as waste under the EU waste legislation. Additionally, there may be cases where only a fraction of the material resulting from the recovery process will be non-waste (ECA, 2010). Moreover, pursuant to Article 2(2) of REACH, waste materials, including wastes that arise during recovery processes, i.e. **remain wastes**, are not considered as substances, mixtures or articles. For the purpose of REACH, recovered substances should only be understood as substances that, after having been part of waste materials, have **ceased to be waste** according to the Waste Framework Directive. The constituents of the recovered substance may have been present as such in the waste stream or have been obtained from the waste stream through chemical modification during the recovery process (ECA, 2010).

In many occasions, under legal acts for **fertilizers**, the olive oil waste can be considered as fertilizer, as for example in Italy. A complication here is that if fertilizer it is not waste and thus might fall under REACH regulation.

2.1.1.3 Agricultural materials

Art. 2.1(f) of **Directive 2008/98** provides that waste rules are in no way applied (a priori) to “*non-hazardous agricultural or forestry material used in farming, forestry or for the production of energy from such biomass through processes or methods which do not harm the environment or endanger human health*”. One might be led to believe that olive pomace would be classified as a natural non-hazardous agricultural material and so it should fall under this rule. First of all is questionable whether this material is non-hazardous (see paragraph “*Hazardous waste and Dangerous substances*”). Secondly, as is very well analysed elsewhere, olive oil pomace it is not exempt only because it is an agricultural “derivative” from the rules on waste (Taccogna, 2010).

2.1.2 Hazardous waste and Dangerous substances

Originally, the properties which render waste as hazardous were laid down in the **Directive 91/689/EEC** and were further specified by the **Waste List Decision 2000/532/EC**. In a further step the **Hazardous Waste Directive 91/689/EEC** was repealed by the **Waste Framework Directive 2008/98/EC**. In the later, the definition of “hazardous waste” is provided as a waste which displays one or more of the hazardous properties listed in Annex III, numbered from H1 to H15):

- H 1-Explosive
- H 2-Oxidizing
- H 3-A-Highly flammable
- H 3-B-Flammable
- H 4-Irritant
- H 5-Harmful
- H 6-Toxic



- H 7 –Carcinogenic
- H 8- Corrosive
- H 9-Infectious
- H 10-Toxic for reproduction
- H 11-Mutagenic
- H 12-Waste which releases toxic or very toxic gases in contact with water, air or an acid
- H 13-Sensitizing
- H 14 –Ecotoxic
- H 15-Waste capable by any means, after disposal, of yielding another substance.

The **Waste List Decision 2000/532/EC** is a catalogue of all wastes, grouped according to generic industry, process or waste type. It differentiates between non-hazardous and hazardous by identifying hazardous waste entries with an asterisk (*) (UK Environmental Agency, 2005). Furthermore in Article 2, the wastes classified as hazardous are considered to display one or more of the properties listed in Annex III to **Directive 91/689/EEC** and, as regards H3 to H8, H10 and H11 of the said Annex, one or more of the physicochemical characteristics listed:

- flash point ≤ 55 °C
- one or more substances classified as very toxic at a total concentration $\geq 0,1$ %
- one or more substances classified as toxic at a total concentration ≥ 3 %
- one or more substances classified as harmful at a total concentration ≥ 25 %
- one or more corrosive substances classified as R35 at a total concentration ≥ 1 %
- one or more corrosive substances classified as R34 at a total concentration ≥ 5 %
- one or more irritant substances classified as R41 at a total concentration ≥ 10 %
- one or more irritant substances classified as R36, R37, R38 at a total concentration ≥ 20 %
- one or more substances known to be carcinogenic of category 1 or 2 at a total concentration $\geq 0,1$ %
- one or more substances toxic for reproduction of category 1 or 2 classified as R60, R61 at a total concentration $\geq 0,5\%$
- one or more substances toxic for reproduction of category 3 classified as R62, R63 at a total concentration ≥ 5 %
- one or more mutagenic substances of category 1 or 2 classified as R46 at a total concentration $\geq 0,1$ %
- one or more mutagenic substances of category 3 classified as R40 at a total concentration ≥ 1 %

The classification as well as the R numbers refer to **Directive 67/548/EEC** on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances and its subsequent amendments. The concentration limits refer to those laid down in **Directive 88/379/EEC** on the approximation of the laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labeling of dangerous preparations and its subsequent amendments. Furthermore, in the Annex of EWC Directive, point 6, is further clarified that if a waste is identified as hazardous by a specific or general reference to dangerous substances, the waste is hazardous only if the



concentrations of those substances are such that the waste presents one or more of the properties listed in Annex III to **Directive 91/689/EEC**. For the purpose of this Decision, “dangerous substance” means any substance that has been or will be classified as dangerous in **Directive 67/548/EEC** and its subsequent amendments.

As is evident the classification into hazardous and non hazardous waste in EU is based on the system for the classification and labeling of dangerous substances and preparations. The WFD **Directive 2008/88** indicates that the classification of waste as hazardous waste should be based on the European legislation on chemicals. Annex III of the WFD attributes the 15 hazardous properties by reference to (UK Environmental Agency, 2005):

- The Dangerous Substances **Directive 67/548/EEC**, and
- The Dangerous Preparations **Directive 1999/45/EEC**

The **Decision 2000/532/EC** links the classification of certain hazardous wastes to the concentrations of “dangerous substances” within the waste and threshold concentrations derived from these directives. It should be noted that **Regulation 1272/2008** on the classification, labelling and packaging of substances and mixtures (CLP), replaces **Directive 67/548/EEC** and **Directive 1999/45/EC**. A “substance” is “dangerous” if it is given a “risk phrase”. There are found by use Annex VI, Table 3.2 to the Classification, Labelling and Packaging of Substances **Regulation 1272/2008**(CLP). If none of the substances in the waste have “risk phrases” the waste is not hazardous. There are a number of steps involved in determining if a waste is hazardous or non-hazardous. These steps are set out in a flowchart in Figure 2, which is published for UK (adopted by UK Environmental Agency, 2005).

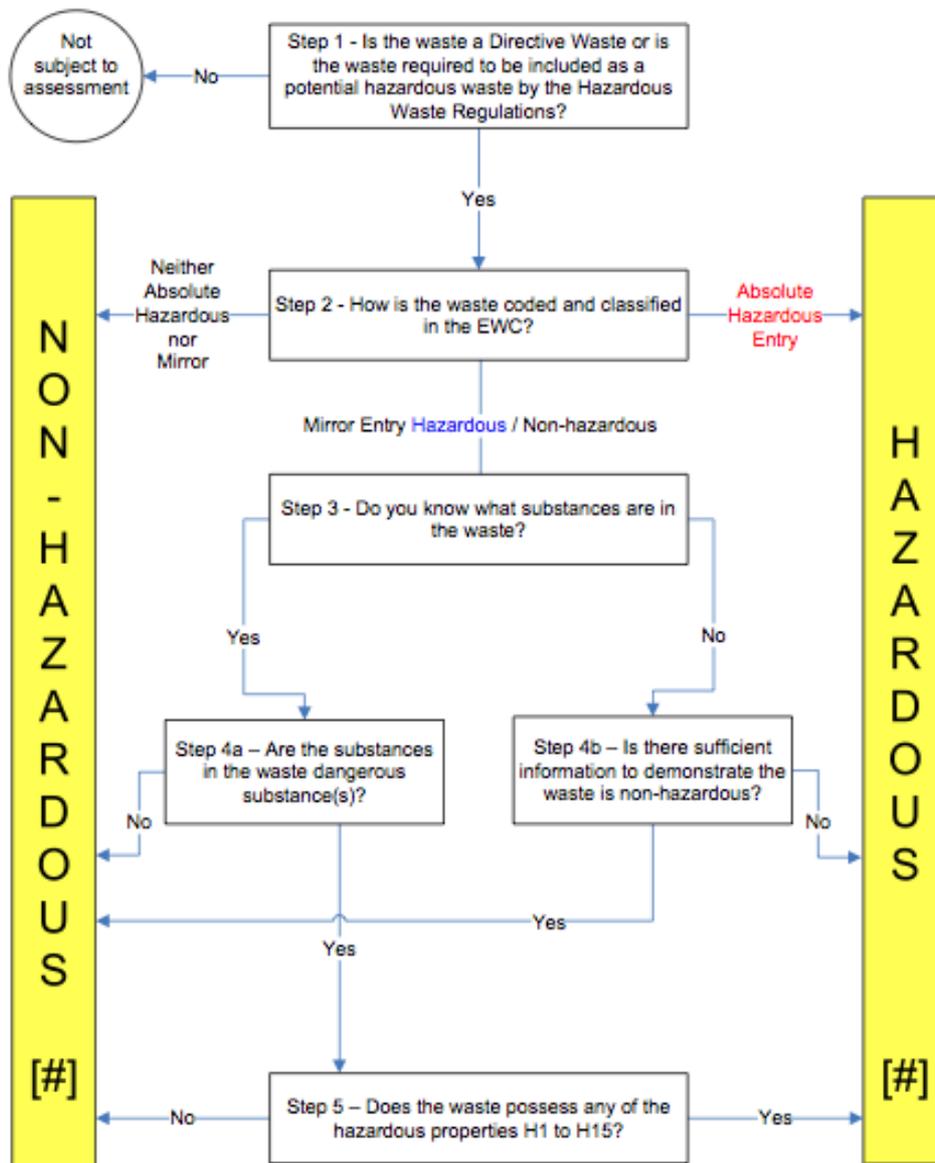


Figure 1: Hazardous Waste Assessment Methodology

Figure 2: Hazardous Waste Assessment Methodology in UK

UK legislation goes a step further and defines as (UK Environmental Agency, 2005):

- “Absolute” hazardous waste: These wastes are marked in the EWC with an asterisk (*), but the waste description next to the six-digit code does not have a specific or general reference to “dangerous substances” in the waste description. They are automatically considered hazardous. It is not needed to work out what chemicals are in the waste to find out if it is hazardous or not but one must still find out if what hazardous properties the waste has for consignment and transport purposes.
- “Mirror” hazardous waste: Some wastes can be either hazardous or not, depending on whether it contains “dangerous substances” at or above certain levels. A “substance” is “dangerous” if it is given a “risk phrase”. There are found by use Annex VI, Table 3.2 to the Classification, Labelling and Packaging



of Substances **Regulation 1272/2008**(CLP). If none of the substances in the waste have “risk phrases” the waste is not hazardous. In order for a waste identified by a “mirror entry” to be hazardous it must “display” a hazardous property.

Olive oil waste falls under category 2 “*Wastes from agricultural, horticultural, hunting, fishing and aquacultural primary production, food preparation and processing*” in the EWC **Decision 2002/532**. More specifically, the appropriate code is 02 03 “*Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee and tobacco preparation and processing; tobacco processing; conserve production*”. This kind of waste is not marked by asterisk and thus is not an “absolute” hazardous waste. In the same way, according to UK guidelines, this code does not contain any “mirror” hazardous waste (UK Environmental Agency, 2005). However, in publication for oil olive waste of the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) is stated that “*special legislative provisions are needed for the solid residue, since, in principle, could be considered hazardous waste*”(IMPEL, 2003).

Thus a further analysis is needed here as olive oil waste contains phenols, which are (potentially) dangerous substances, while several studies show that the waste is phytotoxic and hazardous for several microorganisms (for analysis see Paragraph “*Environmental Effects*”). These negative effects on the environment render this waste as (potentially) “ecotoxic”, code H14: “*waste which presents or may present immediate or delayed risks for one or more sectors of the environment*”, in the meaning of in Annex III to **Directive 91/689/EEC** and to **Directive 2008/98/EC**. Furthermore phenols are included in Annex II to **Directive 91/689/EEC** (code c39), which lists chemicals that render the waste as hazardous when it exhibits properties of Annex III while several phenols are included in the **CLP Regulation 1272/2008**. For olive pomace deriving from olive oil extraction at olive mills, it has been argued that for this waste “*it would appear appropriate to rule out the applicability in limine of regulation (EC) no. 1907/2006 concerning the registration, evaluation, authorisation and restriction of chemicals (REACH)*” (Taccogna, 2010). This exclusion is based on the provisions of art. 2.7(b), with respect to point 8 of annex V of **REACH Regulation 1907/2006**, on substances present in nature that are not chemically modified and cannot be classified as hazardous substances pursuant to **Directive 67/548**. A detailed analysis of this argument is made here for clarification purposes. The essential elements to be considered are:

- Substances must meet the definition of a “substance which occurs in nature” as defined in Article 3(39) of **REACH Regulation 1907/2006**, which means a naturally occurring substance as such, unprocessed or processed only by manual, mechanical or gravitational means, by dissolution in water, by flotation, by extraction with water, by steam distillation or by heating solely to remove water, or which is extracted from air by any means.
- Substances are not exempted if they are classified as dangerous according to **Directive 67/548/EEC**. This means that a substance is not exempted if it is either on Annex I of **Directive 67/548/EEC** or the manufacturer or importer of the substance has assessed it as meeting the criteria set out in Annex VI of **Directive 67/548/EEC**. Phenols and their derivatives are included in the Annex I of the **Directive 67/548/EEC**, with entry of 604. Thus, the argument of



exclusion of olive oil waste is failing due to the considerable existence of phenolic compounds in this waste.

- Apart from the above mentioned issues, Article 2(2) of REACH **Regulation 1907/2006** reads: “Waste as defined in Directive 2006/12/EC of the European Parliament and of the Council is not a substance preparation or article within the meaning of Article 3 of this Regulation” and thus it clearly excludes waste from the scope of the Regulation. Therefore, the REACH requirements for substances, preparations, and articles – such as registration, authorisation, and communication of information along the supply chain - do not apply to waste. REACH doesn’t have any jurisdiction **within** the waste stage, but this does not, however, mean that **substances in waste** are totally exempted from REACH. Manufacturers or importers of a substance as such, in mixtures or in articles subject to registration under REACH, are obliged to take the waste life-cycle stage of the substance into account, according to Article 3(37) (ECA, 2010).

Concluding, we can summarize the conclusions as follows

- Within its **waste life** irrespectively if it contains dangerous substances or not the waste falls under the **Waste Framework Directive** and not the **REACH Regulation**
- As it contains phenols, which as (potential) dangerous substances render this waste as (potentially) **hazardous**
- If the material in question is a **by-product** is exempted from **Waste Framework Directive** as well as **REACH Regulation**, if is consumed by the same legal entity while the by-product placed on the market is regarded as a substance that does need to be registered.
- In principle, substances **recovered** by waste fall within the scope of **REACH Regulation**
- As soon as a material **ceases to be waste** in the basis of **Waste Framework Directive** provisions, **REACH Regulation** requirements apply in principle in the same way as to any other material.
- Olive waste is a **natural material** as defined in **REACH Regulation** but as contains potentially **dangerous substances** is not absolutely excepted from the scope of the regulation

2.2 Water

2.2.1 Overview

The **Water Framework Directive 2000/60/EC** deals with water management in the broad sense and it requires Member States to take a strategic and integrated approach to the management of all water resources and river basins (LIFE Focus, 2010). The directive also addresses water quality, with the aim by 2015 of achieving an appropriate ecological and chemical status for surface waters, as well as an acceptable chemical and quantitative status for groundwater. Furthermore, the **Groundwater Directive 2006/118/EC** is a daughter directive of the Water Framework Directive, dealing with the issue of water quality (LIFE Focus, 2010). Wastewater from olive oil production falls under the **Urban Waste Water Treatment Directive 91/271/EEC**. This concerns



the collection, treatment and discharge of urban wastewater and the treatment and discharge of wastewater from certain industrial sectors, including manufacture of fruit and vegetable products, under which olive oil production would fall (LIFE Focus, 2010). Amongst other things, the Directive states that discharges of **biodegradable industrial wastewater** from certain industrial sectors that do not enter urban wastewater treatment plants before being discharged into receiving waters, should be subject to the appropriate treatment (Kapellakis et al., 2008). Thus, olive mill wastewater treated effluent should be released into the receiving waters only when it meets the relevant quality standards and the provisions required by this Directive.

In the following the summary of EU legislation on water is presented.

- Council **Directive 75/440/EEC** of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the Member States. This Directive concerns the quality requirements which surface fresh water used or intended for use in the abstraction of drinking water, hereinafter called "surface water", must meet after application of appropriate treatment. Ground water, brackish water and water intended to replenish water-bearing beds shall not be subject to this Directive. This Directive includes values for 46 parameters indicating the quality of surface water for drinking. The Directive has been amended by the Council **Directive 79/869/EEC**, further amended by Council **Directive 81/855/EEC**, Council **Regulation 807/2003/EC** and **Directive 91/692/EEC**.
- Council **Directive 76/160/EEC** of 8 December 1975 concerning the quality of bathing water. The Directive concerns the quality of bathing water, with the exception of water intended for therapeutic purposes and water used in swimming pools. The physical, chemical and microbiological parameters applicable to bathing water are indicated in the Annex, which forms an integral part of the Directive. The Directive has been amended by the **Directive 91/692/EEC**, **Regulation 1882/2003/EC** and Council **Regulation 807/2003/EC**.
- Council **Directive 76/464/EEC** of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community Member States shall take the appropriate steps to eliminate pollution of the inland surface water, territorial waters, internal coastal waters and ground water by the dangerous substances in the families and groups of substances in List I of the Annex and to reduce pollution of the said waters by the dangerous substances in the families and groups of substances in List II of the Annex. The Council **Directive 76/464/EEC** has been amended by **Directive 91/692/EEC** and **Directive 2000/60/EC** further amended by **Decision No 2455/2001/EC**. Under **Directive 76/464** on pollution caused by dangerous substances discharged into water the following "daughter" Directives set ELV's / EQS's for List I substances:
 - Council **Directive 82/176/EEC** of 22 March 1982 on limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry
 - Council **Directive 83/513/EEC** of 26 September 1983 on limit values and quality objectives for cadmium discharges
 - Council **Directive 84/156/EEC** of 8 March 1984 on limit values and quality objectives for mercury discharges by sectors other than the chlor-alkali electrolysis industry



- **Council Directive 84/491/EEC** of 9 October 1984 on limit values and quality objectives for discharges of hexachlorocyclohexane
- **Council Directive 86/280/EEC** of 12 June 1986 on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC amended by **Directive 88/347/EEC** and **Directive 90/415/EEC**.
- The above Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC have been repealed by the **Directive 2008/105/EC** of the European parliament and of the Council of 16 December 2008, on environmental quality standards in the field of water policy.
- ✓ **Council Directive 78/659/EEC** of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life. This Directive sets quality standards for two categories of water: suitable for salmonids (salmon, trout) and suitable for cyprinids (coarse fish). The Directive has been amended by the **Directive 91/692/EEC** and the Council **Regulation 807/2003/EC**.
- ✓ **Council Directive 79/923/EEC** of 30 October 1979 on the quality required of Shellfish Waters. This directive concerns the quality of shellfish waters and applies to those coastal and brackish waters designated by the Member States as needing protection or improvement in order to support shellfish (bivalve and gasteropod molluscs) life and growth and thus to contribute to the high quality of shellfish products directly edible by man. The Directive has been amended by the **Directive 91/692/EEC**.
- ✓ **Council Directive 80/68/EEC** of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances. The purpose of this Directive is to prevent the pollution of groundwater by substances belonging to the families and groups of substances in lists I or II in the Annex. The Directive has been amended by the **Directive 91/692/EEC**.
- ✓ **Council Directive 91/271/EEC** concerning urban wastewater treatment was adopted on 21 May 1991 to protect the water environment from the adverse effects of discharges of urban waste water and from certain industrial discharges. On 27 February 1998 the Commission issued **Directive 98/15/EC** amending Directive 91/271/EEC to clarify the requirements of the Directive in relation to discharges from urban waste water treatment plants to sensitive areas which are subject to eutrophication. This had the effect of amending Table 2 of Annex I.
- ✓ **Council Directive 91/676/EEC** of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. The Directive aims to protect waters in Europe by preventing nitrates from agricultural sources from polluting groundwater and surface waters by encouraging the use of good agricultural practices. The Nitrates Directive is an integral part of the Water Framework **Directive 2000/60/EC** and is one of the key instruments for protecting water against agricultural pressures.
- ✓ **Council Directive 98/83/EC** of 3 November 1998 on the quality of water intended for human consumption. This Directive has repealed **Directive 80/778/EC** (25.12.2003) and concerns the quality of water intended for human consumption.
- ✓ **Directive 2000/60/EC** of 23 October 2000 establishing a framework for Community action in the field of water policy. **Directive 2000/60/EC** the Water Framework Directive will require water to be managed on the basis of river basins. A river basin management plan will have to be drawn up for each region to ensure that good water quality is maintained. The Directive stipulates the use of both ELVs for



point sources and EQSs. New standards adopted under this Directive may well replace those set out in some of the Directives above.

✓ **Decision 2455/2001/EC** of 20 November 2001 establishing the list of priority substances in the field of water policy and amending **Directive 2000/60/EC**.

✓ **Directive 2006/118/EC** of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration. This new directive establishes a regime, which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater. The directive establishes quality criteria that takes account local characteristics and allows for further improvements to be made based on monitoring data and new scientific knowledge. The directive thus represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive (WFD) as it relates to assessments on chemical status of groundwater and the identification and reversal of significant and sustained upward trends in pollutant concentrations. Member States will have to establish the standards at the most appropriate level and take into account local or regional conditions.

✓ **Directive 2008/105/EC** of the European parliament and of the Council of 16 December 2008, on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council.

2.2.2 Reuse of wastewater

The problem of widespread practice of reuse of untreated wastewater for irrigation on agricultural lands with public health risks in many Mediterranean countries has been pointed out in the report of MED-EUWI (2007).

The relevant to wastewater reuse subject Directives are:

- The **Urban Wastewater Treatment Directive** (91/271/EEC) requires that “*treated wastewater shall be reused whenever appropriate*” under the requirement of “*minimising the adverse effect on the environment*”
- The **Water Framework Directive** (WFD) (2000/60/EC) refers, under Annex VI (v) to “*emission controls*” and under Annex VI(x) to “*efficiency and reuse measures, inter alia, promotion of water efficient technologies in industry and water saving techniques for irrigation*”, as two, non-exclusive list, supplementary measures.

The major concerns relevant to agricultural irrigation are the contamination of soil, groundwater and produce with chemical and/or biological hazardous substances. In the **Water Framework Directive**, there is no explicit limitation to use a specific type of water (MED-EUWI, 2007). The only requirement concerns the achievement of quality standards defined in other directives and for agricultural irrigation these are: the Nitrate Directive, Groundwater Directive, Drinking Water Directive (see Table 2) and the Sewage Sludge Directive (see Chapter 2.3.3).



2.2.3 Setting of limit values: ELVs and EQSs

An important component in protecting the environmental quality is the regulation of point source discharges. These are usually expressed in terms of “end of pipe” limits on certain physical parameters or on the concentrations of specific chemicals (Whitehouse, 2001). **Emission Limit Values** (ELVs) are based on Best Available Technology with respect to emissions and apply to all discharges from specific industry sector, irrespective of the dilution capacity of the receiving media and are usually expressed as legally binding minimum standards. Thus ELVs have a strong technological and economic basis and may vary for different sectors of industry. They may be expressed either as a chemical concentration in the final effluent or as a load (mass) discharged per unit of production (Whitehouse, 2001). On the other hand, **Environmental Quality Standards** (EQSs) refer to specific chemicals or parameters describing thresholds below which no adverse impact on the receiving media is predicted and which take explicit account on the characteristics of the media in question. EQSs are relevant to a particular site and set maximum concentrations of each substance that can be discharged from a particular discharge point. Thus, EQSs are ultimately based on the hazards posed by the chemical in question to aquatic life and are biologically based rather than technologically based (Whitehouse, 2001).

The relation between emission limit values and quality standards is historically a difficult one (EEB, 2005). Quality standards refer to certain physical environmental standards while emission limits refer to individual economic activities and should ensure the achievement of environmental quality standards. This so-called **combined approach** and **Water Framework Directive** specifies that: “*With regard to pollution prevention and control, Community water policy should be based on a combined approach using control of pollution at source through the setting of emission limit values and of environmental quality standards*”. Different countries have chosen different approaches: Germany has traditionally applied a technologically driven emission limit approach while the UK has preferred setting emission limit values to determine what level of pollutant discharges is acceptable (EEB, 2005).

EU wide water quality standards are to be set on the basis of an ecotoxicological approach for only a limited number of chemical substances, while most European environmental quality standards are developed on the basis of human health protection, e.g. drinking water and bathing water (EEB, 2005). It must be noted that environmental quality standards, which are directly linked to the ecosystem approach have not been developed in a satisfactory level. The most advanced ecosystem approach is represented by the **Water Framework Directive**, which describes the standards and parameters in a normative way, but leaves it up to Member States to set quantitative standards. Furthermore, at EU level a few emission standards have been established for industrial discharges into water (EEB, 2005). Finally, EU guidance for setting national, regional or local emission limit values for bigger industrial installations is provided via the IPPC Directive, based on Best Available Technologies (BAT). While EU legislation has set a sufficient number of EQSs for water, the setting of ELVs is basically under the responsibility of the Member States and only few ELVs have been defined in the relevant EU legislation (see Table 2). It is true that EU legislation could not take into



account the specific characteristics of any location and thus EQSs and ELVs set by EU legislation should be seen as **minimum requirements**.

2.2.3.1 Emission Limit Values

The term “Emission” according to the **Directive 96/61/EC** is defined as: “*the direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water or land*”. The term “Limit Value” is defined by the **Directive 96/62/EC** as: “*a level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained*”.

The Water Framework **Directive 2000/60/EC** in Article 2(40) defines the Emission limit Values: “*Emission limit values means the mass, expressed in terms of certain specific parameters, concentration and/or level of an emission, which may not be exceeded during any one or more periods of time. Emission limit values may also be laid down for certain groups, families or categories of substances, in particular for those identified under Article 16. The emission limit values for substances shall normally apply at the point where the emissions leave the installation, dilution being disregarded when determining them. With regard to indirect releases into water, the effect of a wastewater treatment plant may be taken into account when determining the emission limit values of the installations involved, provided that an equivalent level is guaranteed for protection of the environment as a whole and provided that this does not lead to higher levels of pollution in the environment*”. The definition is essentially the same to this defined in the **Directive 96/61/EC** concerning integrated pollution prevention and control: “*the mass expressed in terms of certain specific parameters, concentration and/or level of an emission, which may not be exceeded during one or more periods of time. Emission limit values may also be laid down for certain groups, families or categories of substances, in particular for those listed in Annex III. The emission limit values for substances shall normally apply at the point where the emissions leave the installation, any dilution being disregarded when determining them. With regard to indirect releases into water, the effect of a water treatment plant may be taken into account when determining the emission limit values of the installation involved, provided that an equivalent level is guaranteed for the protection of the environment as a whole and provided this does not lead to higher levels of pollution in the environment, without prejudice to Directive 76/464/EEC or the Directive implementing it*”.

ELV's set by EU legislation are of three types:

- ✓ ELV's for specific sector
- ✓ ELV's for specific environmental medium
- ✓ ELV's for both specific sector and environmental medium

According to the **IPPC Directive** definition, ELV's should take into account the protection of the environment as a whole. Furthermore, in Article 9, paragraph 4 of



IPPC Directive, it is stated that ELV's "*shall be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions*". Local environmental and geographical conditions (Article 9, paragraph 4) and the concept of the protection of the environment as a whole (Article 2, paragraph 6) are taken into account when setting EQS's and from that point of view these factors are "projected" through EQS. Thus, when setting an ELV's for a specific installation one should take into account the Best Available Technologies (BAT's) and the EQS's for the specific location. Best Available Techniques (BAT) are defined as: "*the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole*". It should be noted here that ELV's cannot be based on non-national BAT guidelines (BREF's) but on "national" BAT.

2.2.3.2 Environmental Quality Standards

Environmental quality standards are set in order to protect human and ecosystem health and prevent damage to the physical environment. The term "standard" refers here to any limit placed on the presence of a contaminant in the ambient environment and, as used in this document, refers to all standards, guidelines, objectives and criteria used by the competent authority. Standards can be either numerical values or narrative descriptions. The principal difference between ELV's and EQS's is that ELV's concern the discharges from an industrial source while EQS's concern the environmental medium without any reference to the sources of emissions.

Environmental quality standard is defined **Water Framework Directive 2000/60/EC** in Article 2(35) as: "*the concentration of a particular pollutant or group of pollutants in water, sediment or biota which should not be exceeded in order to protect human health and the environment*". According to the **IPPC Directive 96/61/EC**, environmental quality standards shall mean: "*the set of requirements which must be fulfilled at a given time by a given environment or particular part thereof, as set out in Community legislation*".

The quality objectives are substantiated at a various level (UK Environmental Agency, 2005). For example, there are "desirable levels" (long-term objectives), "maximum tolerable levels" (short term objectives) and "intervention levels" (alarm function). These different sorts of quality objectives need to be quantified with their own forms and accuracies. The effects related environmental policy is based on specific substances. In this approach the quality of the environment is translated to concentrations of individual substances. The process for setting standards also recognizes that some contaminants can move through the natural environment, persist for long periods of time, and/or accumulate in the food chain (bioaccumulation). As a general approach, standards:

- are based on the best scientific information available



- are set to protect the most sensitive receptors (e.g. sensitive sub-populations which includes children) and
- incorporate socio-economic considerations where appropriate

In Table 2 the ELVs and EQSs for the water protection set in the EU legislation are presented.

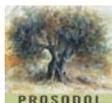


Table 2: ELVs and EQSs in EU legislation

Directive	EQS / ELV	List Of Parameters / Pollutants Involved	Activity (Source)	Environmental Media
Directive 75/440/EEC	EQS	This Directive includes values for 46 parameters.	-	Surface / Drinking Water
Directive 76/160/EEC	EQS	This Directive includes values for 19 microbiological and physicochemical parameters.	-	Bathing Water
Directive 76/464/EEC	ELV/EQS	This Directive includes lists of families and groups of substances, for which however no numerical values are provided.	-	Inland Surface Waters Territorial Waters Internal Coastal Waters Groundwater
Directive 78/659/EEC	EQS	This Directive includes values for 14 parameters.	-	Fresh Waters
Directive 79/923/EEC	EQS	This Directive includes values for 20 parameters.	-	Shellfish Waters
Directive 80/68/EEC	ELV/EQS	This Directive includes lists of families and groups of substances, for which however no numerical values are provided.	-	Groundwater
Directive 82/176/EEC	ELV/EQS	Mercury	Chlor-Alkali Electrolysis Industry	-
Directive 83/513/EEC	ELV/EQS	Cadmium	Industrial Plants	-
Directive 84/156/EEC	ELV/EQS	Mercury	Other Industrial Sectors Other Than The Chlor-Alkali Electrolysis Industry	-



Directive 84/491/EEC	ELV/EQS	Hexachlorocyclohexane	Industrial Plants	-
Directive 86/280/EEC	ELV/EQS	DDT, carbon tetrachloride and pentachlorophenol	Industrial Plants	-
Directive 88/347/EEC	ELV/EQS	Aldrin, dieldrin, endrin, isodrin, hexachlorobenzene, hexachlorobutadiene and chloroform	Industrial Plants	-
Directive 90/415/EEC	ELV/EQS	1,2-dichloroethane, trichloroethane, perchloroethane and trichlorobenzene	Industrial Plants	-
Directive 91/271/EEC	ELV	BOD, COD, TSS, total phosphorus, total nitrogen		
Directive 91/676/EEC	EQS	Nitrates	Agricultural Sources	Surface/Ground Water
Directive 98/83/EC	EQS	Microbiological parameters (2), chemical parameters (26) and indicator parameters (20)	-	Drinking Water
Directive 2000/60/EC	EQS/ELV (NO VALUES GIVEN)	Annex X provides a list of priority substances in the field of water policy but no numerical values.	-	Surface And Ground Water
Directive 2006/118/EC	EQS	Values for nitrates and active substances in pesticides, including their relevant metabolites, degradation and reaction products are provided. Furthermore, a minimum list of pollutants and their indicators for which Member States have to consider establishing threshold values is included. No numerical values are provided.	-	Ground Water
Directive 2008/105/EC	EQS	This Directive includes values for 33 parameters.	-	Inland And Other Surface Waters



2.3 Soil

Different Community policies contribute to soil protection, particularly environment (e.g. air and water) and agricultural (agri-environment and cross-compliance) policy. However, even if exploited to the full, existing policies are far from covering all soils and all soil threats identified (EC, 2006). For these reasons, the Commission adopted a **Soil Thematic Strategy** (COM(2006) 231) and a proposal for a **Soil Framework Directive** (COM(2006) 232) on 22 September 2006 with the objective to protect soils across the EU. The Communication (COM(2006) 231) sets the frame and the proposal for a framework Directive (COM(2006) 232) sets out common principles for protecting soils across the EU (EC, 2006; EC, 2006b). Within this common framework, the EU Member States will be in a position to decide how best to protect soil and how use it in a sustainable way on their own territory. The overall objective is protection and sustainable use of soil, based on the following guiding principles:

- Preventing further soil degradation and preserving its functions:
- when soil is used and its functions are exploited, action has to be taken on soil use and management patterns, and
- when soil acts as a sink/receptor of the effects of human activities or environmental phenomena, action has to be taken at source.
- Restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil.

The main aspect of the Soil Thematic Strategy was the proposal, by the European Commission, for a Soil Framework Directive. This would require Member States to systematically identify damaged soils, combat soil degradation and to identify areas where there is a risk of erosion, landslides, loss of organic matter in soils, or compaction or salinisation of soils. Member States would then adopt risk reduction and remediation plans for affected areas, within national remediation strategies (LIFE Focus, 2010).

In 2012, EC released a new communication COM(2012) 46, which provides an overview of the implementation of the Thematic Strategy for Soil Protection¹ since its adoption in September 2006 (EC, 2012). According to this report, the European Parliament adopted its first reading on the proposal for the Soil Framework Directive in November 2007 by a majority of about two thirds. At the March 2010 Environment Council, a minority of Member States blocked further progress on grounds of subsidiarity, excessive cost and administrative burden and up to date no further progress has since been made by the Council (EC, 2012). Nevertheless, some countries are already adopting aspects of the EU Soil Thematic Strategy in their national legislation (JRC, 2012).

On legislation, the Commission in 2012 will review the Environmental Impact Assessment Directive, which will provide an opportunity for better integrating soil concerns at an early stage of project planning. Finally, the recent **Directive on industrial emissions 2010/75/EU** (IED) was adopted on 24 November 2010 and replaces the IPPC Directive as of 7 January 2014. This new Directive has introduced



additional provisions to ensure that the operation of an installation does not lead to **deterioration in the quality of soil** (EC, 2012).

2.3.1 Soil improvers and organic waste fertilizers

Recycling composted sludge and biodegradable waste in agriculture is considered a way of maintaining or restoring the quality of soils, because of the fertilising or improving properties of the organic matter contained in these materials (EC, 2004). Furthermore, the use of organic waste as fertilisers instead of mineral ones does not increase the global nutrient pool within the agricultural and urban systems, which is already problematically large in much of the EU while the use of such materials can result in energy savings (EC, 2004). The application of organic waste (sludge and biowaste) on soils can pose certain environmental problems mainly related to (EC, 2004):

- an excessive and/or unbalanced supply of nutrients
- the introduction of pollutants, such as heavy metals and organic compounds
- and the spreading of human, animal or plant pathogens.

It should be noted that **bio-waste** is defined in the Green Paper On the management of bio-waste in the European Union (EC, 2008): *“biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste”*.

Organic fertilisers are potentially the most difficult sector to regulate due to the diversity of potential raw materials, many of which are waste from other processes, and which carry risks related to the spread of animal and plant diseases. Guidance on waste and recovered substances has been issued by the European Chemical Agency (ECA, 2010). The relevant discussion is made in the present study in paragraph *“By products and end-of-waste status”*. The term “soil improver” is defined in Article 1 of the **Decision 2006/799/EC**: *“The product group ‘soil improvers’ shall comprise materials to be added to the soil in situ primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity”*. In the following the relevant legislation is presented.

- **Regulation (EC) 2003/2003** of the European Parliament and of the Council of 13 October 2003 relating to fertilisers (“the Fertilisers Regulation”) aims to ensure the free circulation on the internal market of “EC fertilisers” i.e. those fertilisers that meet certain requirements for their minimum nutrient content, their safety, and their absence of adverse effect on the environment. The Fertilisers Regulation is a recast of 18 earlier Directives. The main objective is to inform farmers about the minimum nutrient content of fertilisers described in the fertiliser type designations of Annex I to the Fertiliser Regulation. The production process and the labelling requirements are also described.
- **Decision 2006/799/EC** of 3 November 2006 establishing revised ecological criteria and the related assessment and verification requirements for the award of



the Community eco-label to soil improvers (notified under document number C(2006) 5369). The environmental performance of soil improvers shall be assessed by reference to the specific ecological criteria set out in the Annex of the Decision.

- **Regulation No 834/2007** of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. The Organic Farming Regulation lays down conditions for the use of compost in organic farming.
- **Regulation (EC) 1069/2009** of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation)
- **Regulation (EU) 142/2011** of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive. In the Annex XI, “*Organic fertilisers and soil improvers*”, the Regulation sets requirements and standards for processing of the by-products before applying on land.

2.3.2 Landspreading of waste

Apart from the disposal of solid or semi-solid waste the effluent generated from the food industry is also frequently spread directly on agricultural land. A company choice between installing an effluent treatment plant on site or spreading it directly is not solely dictated by economic factors but also by the local agricultural situation (EC-DG, 2001). Several studies have demonstrated that the controlled spreading of olive mill waste into agricultural land could offer a significant solution for the disposal of such effluents, especially in areas with soils poor in organic matter (Ouzounidou et al., 2010). Olive mill waste is a natural product rich in organic compounds and it contains significant amounts of sugars, minerals and other plant growth promoting substances. This use could be sustainable provided that its phytotoxic properties and certain adverse effects on soil properties are taken into account and/or eliminated (Ouzounidou et al., 2010). Although many experiments evidenced the beneficial effect of controlled olive oil wastewater applications on soil fertility, the polluting load of this waste and its inhibition effects on seed germination sometimes led to the avoidance of their use in agriculture. Toxic effects are associated with nitrates leaching and negative impacts on microorganisms when untreated olive oil wastewater is applied at high rates (100-200 m³/ha) (Ouzounidou et al., 2010; Cabrera et al., 1996). Phytotoxicity is related to phenolic compounds and salt content while as general conclusion the possible phytotoxicity hazards are significantly lower in organic-rich soils as soil has the potential to reduce the phenolic load as reported in several studies (Casa et al., 2003; Ouzounidou et al., 2010; Cabrera et al., 1996). Recent studies have also shown that the contamination with phenolic substances can reach the groundwater through leaching (Shadou et al., 2009).



The key tenet in support of landspreading of wastes is that it recycles nutrients and organic matter to the land, which would otherwise be lost in disposal to landfill or thermal destruction (EC-DG, 2001). Potential disadvantages of landspreading include:

- Hazard to human and animal health due to pathogens
- soil contamination from potentially toxic and persistent elements or organic compounds, and associated implications including long-term effects on soil fertility
- periodical soil degradation due to salts overloading
- pollution of water (surface and groundwater)
- nuisance (odour, visual)
- damage to soil structure from spreading operations

It should be noted that landspreading is linked to soil quality as well as to underground water quality. Groundwater vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. It is usually dependent on the nature (sandy, gravelly, clay, etc.) and depth of soil/subsoil overlying an aquifer (i.e. its shallowness). The travel time, attenuation capacity of the subsoils (i.e. ability to filter contaminants) and the nature of the contaminants are also important elements in determining the vulnerability of groundwater (see Table 3, adopted from EPA, 2004).

A wide range of wastes and by-products of industrial processes is being spread on the land in agriculture, forestry and land reclamation operations. It is expected that landspreading will increase following the implementation of Community and National regulations which restrict disposal of organic-rich materials in landfills and which require treatment of organic-rich industrial effluent from different branches of the food and drink and other sectors (EC-DG, 2001). Land application serves two objectives: (a) waste disposal and (b) recycling of waste components (Ouzounidou et al., 2010).



Table 3: Geological and Hydrogeological conditions determining vulnerability mapping categories

Subsoil Thickness	Hydrogeological Requirements				
	Diffuse Recharge			Point Recharge	Unsaturated Zone
	Subsoil permeability and type				
	high permeability (sand/gravel)	moderate permeability (sandy subsoil)	low permeability (clayey subsoil, clay, peat)	(swallow holes, losing streams)	(sand & gravel aquifers only)
0-3 m	Extreme	Extreme	Extreme	Extreme (30m radius)	Extreme
3-5 m	High	High	High	N/A	High
5-10 m	High	High	Moderate	N/A	High
>10 m	High	Moderate	Low	N/A	High

Notes: (i) N/A = not applicable
(ii) Permeability classifications relate to the engineering behaviour as described by BS5930

The **Waste Framework Directive** sets out the principles of the necessary controls where waste materials are to be recycled to the land but there is a case for introducing more specific controls to ensure a high level of environmental protection (EC-DG, 2001). The **Directive 86/278/EEC** on landspreading of sewage sludge and **Directive 91/676/EEC** on protection of waters against pollution caused by nitrates from agricultural sources contain much of relevance to the landspreading of wastes. Furthermore, **Regulation 1069/2009** regards animal by-products and includes rules for landspreading of such material as soil improver. More information on soil improvers is provided in paragraph “*Soil improvers and organic waste fertilizers*”.

In the **Waste Framework Directive**, the landspreading is found as:

- Disposal operation (D1): Deposit into or on to land (e.g. landfill, etc.)
- Recovery operation (R10): Land treatment resulting in benefit to agriculture or ecological improvement

Thus, in case the landspreading results in benefit to agriculture or ecological improvement is a **recovery operation**. It should be noted that the **protection of environmental quality** should be always be ensured (EC-DG, 2001). **By products**, considered as such by the producers, are excluded from the waste regulations so that they can be recycled to land as soil improvers and fertilisers. Although this practice may be convenient for the producer is not necessarily compatible with ensuring a high level of environmental protection where these materials are used in agriculture for landspreading (EC-DG, 2001).

In developing a practical scheme for operational purposes, a banding of materials into broad groups maybe helpful. All materials would be subject to overall generic controls



and there would be further specific controls for each group according to their properties and progressively detailed information would be required according to the class of waste. The main groups and information needed might be (EC-DG, 2001):

- **Class 1:** Farm residues recycled on the farm of production e.g. manure from animals grazing in situ. Information needed: (a) Source of waste, (b) extent of treatment (e.g. storage for 3 months at ambient temperature).
- **Class 2:** Benign wastes containing negligible levels of contaminants e.g. green waste, biological sludge from food waste treatment. Information needed: (a), (b) plus (c) Basis for benefit to agriculture (e.g. content of nitrogen), (d) Content of plant nutrients and lime (nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, trace elements), organic matter, dry solids, pH value. And (e) Evidence that the waste contains only negligible concentrations of contaminants.
- **Class 3:** Wastes which may contain contaminants (pathogens, heavy metals and other potentially toxic elements, organic contaminants) e.g. dredgings from waterways, tannery waste, paper waste. Information needed: (a)-(d) plus (f) Content of contaminants (pathogens – most probable numbers; concentrations of heavy metals, other potentially toxic elements and organic contaminants) and (g) Evidence that the waste is free of contaminants other than those specified.

As regards the Class 3 wastes, the quality rules in **Directive 86/278/EEC** on sewage sludge could provide the basis for deciding on acceptability for landspreading (EC-DG, 2001). In this scheme, olive oil waste should be between Class 2 and Class 3.

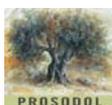
2.3.3 Sewage sludge

Water policy in the European Union is regulated by the **Water Framework Directive**, which targets the long-term progressive reduction of contaminant discharges to the aquatic environment in urban wastewater (EC-DG, 2001b). Several Directives have an influence on sludge management but the ones, which have the strongest impact on sludge management is the **Directive 91/271/EEC** on urban waste water treatment and the **Directive 86/278/EEC** on the use of sludge in agriculture (Zorpas and Inglezakis, 2011).

In the beginning of the 1980, some countries established limit values for some selected heavy metals in sewage sludge to be used for agricultural applications (Eriksson et al., 2008). In accordance with **Directive 86/278/EEC**, national legislation, which has been established in the Member States prohibits the use of sludge in agriculture if the heavy metals concentrations exceed specific limit values (Table 4). The limit values for heavy metals in sludge defined in national regulations are presented in Table 4 (Stylianou et al., 2008). In most cases, these limit values have been set significantly below the requirements of **Directive 86/278/EEC** (Zorpas and Inglezakis, 2011).

Table 4: Maximum permissible limits for land application, EU, US and National Legislations (mg/kg dw)

Metal	86/278/EEC (range)	Sweden	Netherlands	France	USA (Part 503)
-------	-----------------------	--------	-------------	--------	-------------------



Zn	2500-4000	800	300	3000	7500
Cu	1000-1750	600	75	1000	4300
Ni	300-400	50	30	200	420
Cd	20-40	2	1.25	20	85
Pb	750-1200	100	100	800	840
Cr	-	100	75	1000	3000
Hg	16-25	2.5	0.75	10	57
Mn	-	-	-	-	-

Sewage Sludge Directive prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. Treated sludge is defined as having undergone "*biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use*". However, in order to provide protection against potential health risks from residual pathogens (Zorpas and Inglezakis, 2011):

- Sludge must not be applied to soil in which fruit and vegetable crops are growing or grow
- Grazing animals must not be allowed access to grassland or forage land less than three weeks after the application of sludge

Limit values for concentrations of heavy metals in sewage sludge intended for agricultural use and in sludge-treated soils are set in Directive Annexes and are shown in Table 5 (Zorpas and Inglezakis, 2011; EC, 2011). The proposed limits for the new Greek Decision on Sewage Sludge are in parenthesis (MEECC, 2012).

Table 5: Annexes IA, IB and IC of Directive 86/278/EEC

Metal	Limit values for concentrations of heavy metals in soil (mg/kg dm)¹	Limit values for heavy metal concentrations in sludge for use in agriculture (mg/kg dm)	Limit values of heavy metals which may be added annually to agricultural land, based on a 10 year average (kg/ha/y)
Cadmium	1-3	20-40	0.15 (0.015) ²
Copper	50-140	1000-1750	12 (3)
Mercury	1-1.5	16-25	0.1 (0.01)
Nickel	30-75	300-400	3 (0.75)
Chromium	-	-	(3)
Lead	50-300	750-1200	15 (1)
Zinc	150-300	2500-4000	30 (7.5)

¹For 6<pH<7

²The proposed limits for the new Greek Decision on Sewage Sludge are in parenthesis (MEECC, 2012)

Directive 86/278/ EEC was adopted over 25 years ago and the European Commission is currently assessing whether the current Directive should be reviewed – and if so, the extent of this review (EC, 2011). The experience gained so far in the EU has shown three main weaknesses of this Directive, which are (EC-DG, 2001b; EC, 2011b):

- covers only urban sludge but does not consider other non-hazardous sludges (e.g. paper sludges or textile sludges) that may have the similar negative and positive implications as urban sludge when they are spread on land;

- regulates the spreading of sewage sludge to agricultural land only but does not provide for any measure as regards other types of land use as for example non-agricultural land (e.g. tree plantations, green areas, landscaping purposes etc) which may have potential adverse impacts on human health and on wildlife and biodiversity;
- it is not conservative enough in taking into account the effects of long term accumulation of heavy metals to the topsoil

The changes proposed included the following:

- Revision of current limit values for heavy metals;
- Introduction of limit values for organic pollutants;
- Introduction of pathogen concentration limits; and
- Introduction of a quality assurance system

Some of the proposals are presented in Table 6 and Table 7 (EC-DG, 2009). In the same tables, the proposed limits for the new Greek Decision on Sewage Sludge are presented in parenthesis (MEECC, 2012).

Table 6: Proposed limit values on potentially toxic elements (PTE) in sewage sludge and in soil (mg/kg dw)

Metal	Sludge	Soil		
		5<pH<6	6<pH<7	pH>7
Cd	10 (5)	0.5 (0.5)	1 (1)	1.5 (1.5)
Cr	1000 (500)	50 (50)	75 (75)	100 (100)
Cu	1000 (800)	30 (40)	50 (50)	100 (100)
Hg	10 (5)	0.1 (0.2)	0.5 (0.5)	1 (1)
Ni	300 (200)	30 (30)	50 (50)	70 (70)
Pb	750 (500)	70 (50)	70 (70)	100 (100)
Zn	2500 (2500)	100 (100)	150 (150)	200 (200)

Concerning organics, the following are considered of primary importance for EU as limits are to be set in the revision of **Sewage Sludge Directive** (Langenkamp et al., 2001):

- AOX, the so-called “sum of halogenated organic compounds”
- linear alkylbenzene sulphonates (LAS)
- di(2-ethylhexyl)phthalate (DEHP)
- NPE (nonylphenole and nonylphenole ethoxylates with 1 or 2 ethoxy groups)
- polynuclear aromatic hydrocarbons (PAHs)
- polychlorinated biphenyls (PCBs)
- polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs).

Table 7: Limit values for concentrations (mg/kg dm) of organic compounds in sludge

	AOX	DEHP	LAS	NP/NPE	PAH	PCB	PCDD/F ng TEq/kg dm
EU	500(500)	100	2600	50	6 ¹	0.8 ² (0.8)	100 (100)



Denmark	-	50	1300	10	3 ¹	-	-
Sweden	-	-	-	50	3 ³	0.4 ⁴	-
Lower Austria	500	-	-	-	-	0.2 ⁵	100
Germany	500	-	-	-	-	0.2 ⁵	100

¹ Sum of acenaphthene, phenanthrene, fluorine, fluoranthene, pyrene, benzo(b+j+k) fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene

² Sum of 6 congeners PCB 28, 52, 101, 138, 153, 180

³ Sum of 6 compounds

⁴ Sum of 7 congeners

⁵ Each of the six congeners PCB 28, 52, 101, 138, 153, 180.

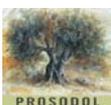
The EU working document contains limit values for concentrations of seven groups of compounds: 11 PAHs; LAS; DEHP; NPE; AOX; and 7 PCBs as well as PCDD/F i.e. chlorinated dioxins and furans. Finally, in the Water Framework Directive a list of 33 priority substances of importance for the water phase that are primarily based on monitoring data in European surface waters are established (Eriksson et al., 2008).

Finally, concerning pathogens, a moderate proposed change to the current Directive is to introduce standards for pathogens in line with the conventional treatment as given in the Commission Communication in 2003 (EC-DG, 2009). Conventional treatment means any sludge treatment capable of achieving a reduction in *Escherichia coli* to less than 5×10^5 colony forming units per gram (wet weight) of treated sludge.

2.3.4 Limit values and quality standards for landspreading of soil additives other than sewage sludge

In the 2nd Draft of the working document on Biological Treatment of Waste (Compost), the quality criteria presented in Table 8 for the final product are proposed in Annex III (EC, 2001). Compost or digestate of class 1 shall be used according to best agronomic practice without any specific restriction. Compost or digestate of class 2 shall be used in a quantity not exceeding 30 tonnes dry matter per hectare on a three-year average.

Table 8: Quality criteria for the final compost products



Parameter	Compost/digestate (*)		Stabilised biowaste (*)
	Class 1	Class 2	
Cd (mg/kg dm)	0.7	1.5	5
Cr (mg/kg dm)	100	150	600
Cu (mg/kg dm)	100	150	600
Hg (mg/kg dm)	0.5	1	5
Ni (mg/kg dm)	50	75	150
Pb (mg/kg dm)	100	150	500
Zn (mg/kg dm)	200	400	1 500
PCBs (mg/kg dm) (**)	-	-	0.4
PAHs (mg/kg dm) (**)	-	-	3
Impurities >2 mm	<0.5%	<0.5%	<3%
Gravel and stones > 5 mm	<5%	<5%	-

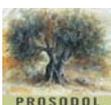
(*): Normalised to an organic matter content of 30%.

(**): Threshold values for these organic pollutants to be set in consistence with the Sewage Sludge Directive.

Table 9 presents the limit values for heavy metals, organic pollutants and salmonella in fertilisers, growing media and soil improvers are set in the Fertilizer Law (1994) and Fertilizer Ordinance (2004) in Austria.

Table 9: Limit Values for heavy metals, organic pollutants and salmonella in fertilisers, growing media and soil improvers in Austria

		Fertiliser, soil conditioner	Mineral Fertiliser >5 % P ₂ O ₅	Growing media
Lead	mg/kg dm	100	100	50
Cadmium	mg/kg dm	3	75 mg/kg P ₂ O ₅	1
Chromium	mg/kg dm	100	2500	70
Nickel	mg/kg dm	100	100	70
Mercury	mg/kg dm	1	1	0,5
Vanadium	mg/kg dm	-	4000	-



Parameter	Unit	
Polycyclic aromatic hydrocarbons (PAH)	mg kg ⁻¹ dm	6
Pesticides (Σ of ten compounds) e.g. DDT, DDE, δ - HCH	mg kg ⁻¹ fm	0,5
Polychlorinated biphenyls PCB	mg kg ⁻¹ dm	0,2
Dioxins (2-,3-7-,8-TCCD)	ng TE kg ⁻¹	20
Caesium-134 and Caesium-137	Bq g ⁻¹ product	0,5
Salmonella in 50 g F.M.	CFU/g	0

The **Decision 2006/799/EC** for the award of the Community eco-label to soil improvers, sets specific ecological criteria in the Annex of the Decision. Concerning limitation of hazardous substances, in the final product, the content of the elements as presented in Table 10 shall be lower than the values shown below, measured in terms of dry weight.

Table 10: Ecological criteria for eco-label of soil improvers

Element	mg/kg (dry weight)
Zn	300
Cu	100
Ni	50
Cd	1
Pb	100
Hg	1
Cr	100
Mo (*)	2
Se (*)	1,5
As (*)	10
F (*)	200

(*) Data relating to the presence of these elements are needed only for products containing material from industrial processes.

Furthermore the Decision specifies,

- Physical contaminants: In the final product (with mesh size 2 mm), the content of glass, metal and plastic shall be lower than 0,5 % as measured in terms of dry weight.
- Nitrogen: The concentration of nitrogen in the product shall not exceed 3 % total N (by weight) and inorganic N must not exceed 20 % total N (or organic N \geq 80 %).



- Product performance: (a) Products shall be supplied in a solid form and contain not less than 25 % dry matter by weight and not less than 20 % organic matter by dry weight (measured by loss on ignition) and (b) Products shall not adversely affect plant emergence or subsequent growth. The applicant shall provide, together with the European Eco-label application, results from a vegetative trial (germination test, phytotoxicity test, growing-on test, etc) attesting benefits of the product regarding plant development.
- Health and safety: Products shall not exceed the maximum levels of primary pathogens as follows: Salmonella: absent in 25 g, Helminth ova: absent in 1,5 g, E. coli: < 1 000 MPN/g.

According to the **Decision 2006/799/EC**, testing and sampling shall where applicable be carried out in accordance with test methods developed by Technical Committee CEN 223 “*Soil improvers and growing media*” until relevant horizontal standards elaborated under the guidance of CEN Task Force 151 ‘Horizontal’ become available. Project HORIZONTAL started in December 2002 with the aim to develop horizontal and harmonised European standards in the field of **sludge, soil, and treated biowaste** to facilitate the regulation of these major streams in the multiple decisions related to different uses and disposal governed by EU Directives. Horizontal standards were developed for sampling, biological parameters, hygienic parameters, organic parameters, inorganic parameters, mechanical properties and leaching in the fields of sludge, soil and treated biowaste (HORIZONTAL, 2012).



2.4 National legislation on olive oil waste of the participating counties

At the moment there is no European Union legislation regulating olive mill waste management, and standards are left to be set by individual countries, whereas in Italy, Portugal (Ouzounidou et al., 2010) and recently in Spain among olive-oil producing countries there is legislation for disposal/application in agricultural soil. Furthermore, the issue of whether pomace should be considered as “waste” has been addressed in Italy and Portugal and has been resolved (it is not considered as hazardous waste); no specific legislation exists in the other countries (IMPEL, 2003).

In the following paragraphs brief analysis is provided on the specific issue of olive oil waste regulations in Italy, Greece and Spain as well as in Portugal and Cyprus. The later cases have some interest as they are olive oil producers and have special provisions on this kind of waste.

2.4.1 Italy

The Legislative Decree n° **152 of 1999**, transposition of the European Directives 91/271/CEE and 91/676/CEE, regulates the waters safeguard from pollution. The article 38 of this act makes reference to the Italian **Law n°574 of 1996** with regards to agronomic use of sewage sludge and other wastes such as OMWW. With Law n°574, the agronomic use of these by-products is allowed on the ground of their composition and the characteristics of soils. Such use has to be authorised each time by the competent public authority on the ground of simple documentation but subordinate to limitations, verifications and possible sanctions in order to avoid any fraudulent activity that can pollute water tables (MORE, 2008). This law allowed the **direct application** of the **olive mill wastewater** without previous treatment (Kapellakis et al., 2008). Technical aspects according to the law 574/96 (MORE, 2008; RES-HUI, 2006):

1. maximum tolerance limit for soils: 50 m³/ha/year for olive mill waste waters (olive oil wastewater) deriving from traditional mills (discontinuous extraction systems); 80 m³/ha/year for vegetable water deriving from centrifugal extraction (continuous extraction systems);
2. possibility for the Mayor of any municipality of modifying those limits or suspending fertirrigation in case of environmental risk;
3. submission of the agronomic report to the Municipality at least 30 days before the spreading. The report has to be written by an expert technician and has to cover topics such as the characteristics of the soil, the time and means of spreading;
4. uniform spreading in order to avoid surface runoff;
5. it is forbidden to spread vegetable water on:
 - soils which are at less than three hundreds meters from the preservation areas for water collection destined to the human consumption;
 - soils which are less than two hundred meters from inhabited areas;
 - soils which are cultivated with vegetable crops;
 - soils where water tables are at less than ten meters depth;
 - soils which are frozen, covered by snow, awashed or saturated with water.



6. Waste storage in the oil mill less than 30 days (limit protracted to 3 months – D Lgs 22/1997)

With the **6 July 2005 Decree**, “*Criteria and technical rules regarding regional regulation of the agronomic use of olive mill waste waters and other mill wastes*” that makes reference to article n° 38 of Decree n° 152 of 11 May 1999, some more exclusions of lands are added (RES-HUI, 2006):

- Distance <10m from river banks
- Distance <10 m from sandy shore or lake water
- Lands with slope >15% and lacking of hydraulic and agricultural setting
- Woods
- Gardens and public areas
- Quarry

Furthermore, the same Decree prohibits the mixing of olive oil wastewater with other wastewater (e.g. animal slurry) or waste. Finally, oil mill water plus stone fragments and fibrous part of the fruit can be used in agriculture and are not subject to Fertiliser Law No 748.

According to **Law n° 574 of 1996** wet olive husks can be used as soil amendment notwithstanding to the indications given in the Italian **Law n° 748 of 1984** on fertilizers and subsequent modifications such as legislative **Decree n° 217 of 29 April 2006** “*Revision of regulations on fertilizer use*”. According to the later, **wet olive husks** can be considered as a “*simple not-composted plant amendment*” and therefore they can be applied to soil without any specific limitations if they comply with the thresholds set by the decree regarding some specific parameters, i.e. humidity, pH, organic carbon, organic nitrogen, total Cu referred to dry matter, total Zn referred to dry matter, total peat content and other heavy metals contents.

With the **D.M. 05/02/1998** and **D. Lgs n. 22/97**, by products coming from olive oil pressing are allowed to be placed in the market. The same Decree specifies that olive husks (pomace) are non-dangerous waste. The same waste can be used in the energy sector, as defined in the DPCM 08/10/2004 (MORE, 2008; RES-HUI, 2006). Finally, The disposal of wastewaters of any kind and, therefore, of OMWW too in sewage systems or in superficial water bodies (rivers, lakes etc) is regulated by the Decree 152/2006. The specific thresholds set by the Decree for all the parameters to be taken in consideration for disposal are listed in Table 3 of Annex 5 of the Decree. The ELVs are set for national level (IPPB BREF, 2006b).

2.4.2 Spain

Following the introduction of the three-phase process in the ‘70s decade large quantities of olive mill wastewater became a major surface water pollution problem. It was in 1981 that the Spanish Government adopted a legal framework to prohibit the discharge of untreated olive mill wastewater into rivers and subsidized the construction of about 1000 ponds for its storage during the milling period, aiming at the evaporation of its water during the warm Andalusian summer (Kapellakis et al., 2008). The result of these initiatives was the improvement of water quality in the nearby rivers and streams.



During the 1991–1992 a shift from the three-phase to two-phase system was implemented resulting in lower wastewater discharges. Nowadays, more than 90% of the OMs operate with the two-phase system (Kapellakis et al., 2008).

In Spain, there is a Ministerial Decree about the operations of valorisation and disposal of wastes, and the European list of Wastes. (O.M. MIMAM 304/2002, 19 February 2002, activities of valorization and disposal of wastes). Two phase olive oil mill wastes or olive oil mill wastewaters are not generally considered dangerous wastes by the Spanish legislation. Only these wastes are considered secondary products, which can be valorized in order to prevent soil or water contamination. However, olive oil mills produce other wastes are considered dangerous waste such as: motor oils, used lubricants, boilers particles, rejected chemicals, fluorescents tubes and other wastes that contain mercury, etc.

The recent **Decree 4/2011** of the Regional Government of Andalusia is issued for the use of **wastewater** produced in OMs as soil amendment in agriculture. In particular, Art. 7 specifies that:

- The volume of effluent to be applied to agricultural land in no case exceed the amount of 50 m³/ha/year.
- Applications should be designed so as not to produce surface runoff, leaching, or invasive lesions of the soil water table.
- The field application of effluent shall be subject to the following areas of exclusion:
 - located within 500 meters compared to urban areas.
 - The police zone 100 meters above the public water mastery, defined in Article 6.2.b of Regulation for Public Water, approved by Royal Decree 849/1986 of 11 April.
 - The easement area of protection of 100 meters above the Shoreline Public Domain, as defined in Article 23.1 of Law 22/1988 of 28 July, Costas.

In relation to operations in olive oil mills and treatment plant of OMW there are several aspects, which are regulated by the Spanish legislation. In general, wastewaters is sent to ponds, where is evaporated or infiltrated in soil for irrigation. However, wastewater can affect the hydraulic public network and the related Spanish law with this aspect is **Law 46/1999** of 13th of December as modification of **Law 29/1985**, of 2nd of August. It is compulsory that olive oil mill holders have a specific authorisation for every catchments of continental water over or under ground. Also an authorization of spill is required for all activities that are susceptible to cause pollution or degradation of the hydraulic public network. The request will be able to require a project of processing, hydrogeological and environmental studies or any documentation that will be considered necessary. There are some wastewater parameters that must be considered as minimum to select the best wastewater depuration treatment. Actually the spill of OMWW to hydraulic network is forbidden in Spain. The **Real Decreto 849/86** of 11th April 1986, entitled “*Reglamento del Dominio Público Hidráulico*” (Regulations of the Hydraulic Public Domain) specifies in the Anexo al título IV (4th annex) certain emission limits, which depend upon the extent and efficiency of the applied wastewater treatment. The Emission Limit Values (ELVs) are set for national level (IPPB BREF,



2006b).The legislation concerning waste water discharges into sea waters, either directly or via interior waters, is laid down by the **Real Decreto 258/1989** de 10 de marzo 1989 (Royal Decree 258/1989 of 10 March 1989). According to this decree the emission limits are fixed for each specific industrial plant.

2.4.3 Greece

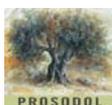
In Greece there are no specific regulations regarding the discharge of olive mill wastewater. The main principles for olive mill wastewater management are based on the **Law 1650/86** “*For the Protection of the Environment*” according to which, olive mill owners are obliged to provide an environmental impact assessment study. The updated circular letter YM/5784/23-1-1992 (No 4419/23-10-1992) refers to the problems encountered due to olive mill wastewater disposal, the need for an efficient pre-treatment and the care required in order to avoid disposal to various water resources. The present legislative status in Greece (Laws 1650/86 and 3010/2002) does not allow application of untreated olive mill wastes to soil surface.

Each Prefecture is responsible for adopting proper olive mill wastewater management practices encouraging different waste management approaches. For example, olive mill wastewater management in the Prefecture of Messinia is based on the modification of a three-phase decanter system into a two-phase, in the Prefecture of Lesvos olive mill wastewater was discharged until recently untreated onto aquatic ecosystems, while in the Prefecture of Iraklio the disposal of waste in the aquatic environment are forbidden (Kapellakis et al., 2008).

Wastewater limit values are not set in national level and have been issued for many of the prefectures in regional level (IPPC BREF, 2006b). The limits are applied for any kind of discharges, including those from food industries (IPPC BREF, 2006b; ECOIL, 2005). However, the values in Table 11, which are set by the Law 1180/1981 are considered as guidance values, specifically for the emissions for the production and treatment of oil (industrial sector: “Production and processing of vegetable/animal fats and oils”). It is noted that the final limit values for emissions to water are issued by each prefectural authority according to the location of the specific water recipient (ECOIL, 2005).

Table 11: Wastewater limit values for food industries in Greece

Pollutant	Limit value – daily maximum (kg/ton of product)	Limit value –monthly average (kg/ton of product)
BOD	4.0	2.0
COD	6.0	3.0
Suspended solids	5.0	2.0
Oils	1.0	0.5



Finally, the recent **Joint Ministerial Decision (KYA) 145116/2011** regulates the reuse of treated wastewater for several purposes, including irrigation in arable lands. The minimum requirement is the use of a biological treatment and disinfection units.

2.4.4 Portugal

After Italy, similar special permission in Portugal also allows the spreading of olive mill wastewater on land as set by **Law No. 626/2000** (Kapellakis et al., 2008). Technical aspects according to the Law 626/2000:

- maximum tolerance limit for soils: 80 m³/ha/year for vegetable water;

General Water emissions are regulated by **Decreto Lei 236/98**, of 1 of August 1998. Wastewater discharge limits are defined in its Annex XVIII. The ELVs are set for national level (IPPC BREF, 2006b).

2.4.5 Cyprus

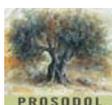
Of particular interest is the case of Cyprus as there is special legislative act for oil olive waste, and in particular the **Cyprus Ordinance No. 254/2003** of 1 November 2004 on Water Pollution Control (Waste Disposal Permit) Ordinance of 2003, Official Newspaper of the Cyprus Government No. 3649 (ECOIL, 2005; Anastasiou et al., 2011). The waste streams generated by olive mills differ according to the process used for the oil extraction; i.e. if is two-phase or three-phase centrifuge. The types and amounts of waste allowed to be deposited are shown in Table 12 and Table 13 (ECOIL, 2005; Anastasiou et al., 2011).

Table 12: Maximum annual waste quantities allowed for two-phase centrifuge olive mills in Cyprus

Waste stream generated	Maximum annual waste quantities allowed (m ³)
a. liquid waste from the washing of the olives	180
b. liquid waste (water and minimal olive oil mill wastewater) originating from the centrifuging decanters, where the separation takes place of the plant liquids of the fruit from the oil	400
c. sludge (mixture of olive dregs and olive oil mill wastewater) originating from the decanter	750
d. sludge settling at the liquid wastes evaporation tanks	-
e. leaves from the defoliation	-

Table 13: Maximum annual waste quantities allowed for three-phase centrifuge olive mills in Cyprus

Waste stream generated	Maximum annual waste quantities allowed (m ³)
a. liquid waste from the washing of the olives	1600
b. liquid waste (water and minimal olive oil mill wastewater) originating from the centrifuging decanters, where the separation takes place of the plant liquids of the	1400



fruit from the oil	
c. solid waste (olive dregs) originating from the horizontal centrifuging decanter	750
d. sludge settling at the liquid wastes evaporation tanks	-
e. leaves from the defoliation	-

Regardless the type of process they originate from (two-phase or three-phase) (ECOIL, 2005):

- liquid wastes (wastes types a and b in the Tables above) should be temporarily stored in waterproof sealed tanks. Whether or not the streams are mixed or separated depends on the method of disposal.
- sludge (olive dregs – type c in the above Tables) should be temporarily stored in a covered area with concrete base (platform). Liquids originating from leakages or run-offs from the temporary storage areas for the solid wastes or sludge should be collected and transferred to the liquid wastes tanks, via open-air waterproof pipes.

Waste stream (a), liquid waste from the washing of the olives: can be used for irrigation of cultivations (trees, forest-trees, etc) surrounding the olive mill. In cases that the waste is mixed with liquid waste originating from the centrifuging decanters (b), the liquid wastes should be transferred for final disposal in evaporation tanks. Evaporation tanks should be open, waterproof, earthen and shallow; i.e. maximum depth of 1.2 m. Liquid wastes should be transferred to the evaporation tank within closed pipes or with a tanker. The required quality of the liquid wastes to be disposed in the evaporation tank is shown in Table 14 (maximum allowance) (ECOIL, 2005; Anastasiou et al., 2011).

Table 14: Quality of liquid waste entering the evaporation tank in Cyprus

Parameter	Maximum value allowed
pH	5.0 – 7.0
Electric conductivity	10,000 μ S/cm
Suspended solids	5,000 mg/l
BOD5	10,000 mg/l
Fat	6,000 mg/l
Phenols	1,000 mg/l

Sludge produced by the decanter (c) of a two-phase mill, should be collected and transferred by a tanker to the appropriate facilities for incineration or composting. At the end of functioning period, no sludge should be present at the temporary storage area mention previously. Solid wastes (c) produced by a three-phase mill should be collected and used as animal stocking or fertiliser or sent to a seed-oil production facility for further treatment (ECOIL, 2005; Anastasiou et al., 2011). The institution exploiting the waste, should maintain a database for the quantities and the ways the waste has been disposed. In cases that the olive dregs are used as soil improver (fertiliser), the application should be at least 300 m from residential areas, with maximum disposal rate 3.5 tonnes/ hectare/ year. For both of the above cases, at the end of functioning period, no sludge or solid waste should be present at the temporary storage area mention previously. Sludge depositing at the bottom of the evaporation tanks (d), should be



collected when needed after the liquid present in the tank has been dried, and transferred for disposal to an approved public area or as soil improver (under the conditions stated above) (ECOIL, 2005; Anastasiou et al., 2011).

2.4.6 Emission Limit Values for discharges to surface water and sewer

In the following Table 15 some relevant ELVs for discharges to surface waters and sewers in Italy, Greece, Spain and Portugal are presented as set by national legislation and also found in the related literature (IPPC BREF, 2006b; IMPEL, 2003). Values for Greece are for Thessaloniki and Athens as set by **ΦΕΚ 582/Β/2-07-79** and **ΦΕΚ 82/Β/94** and may vary for other regions.

Table 15: ELVs for discharges to surface waters and sewers (in parenthesis) in Italy, Greece, Spain and Portugal

Parameter	Italy	Greece	Spain	Portugal
pH	5.5-9.5 (5.5-9.5)	6-9 (6-9.5)	5.5-9.5	6-9
BOD₅ (mg/l)	40 (250)	15-60 (250-500)	40-300	40
COD (mg/l)	160 (500)	45-180 (1000)	160-500	150
TSS (mg/l)	80 (200)	25-1000 (500-3000)	30-300	60
Oil/grease (mg/l)	20 (40)	5-40 (40-100)	20-40	15
Phenols (mg/l)	0.5 (1)	0.005-0.5 (5-10)	0.5-1	0.5
Total P (mg/l)	10 (10)	0.2-10 (10)	10-20	10
Total N (mg/l)	15 (30)	10-15 (25)	15-50	15
Free Cl (mg/l)	0.2 (0.3)	0.4-1 (5)	0.5	0.5
Nitrates (mg/l)	20 (30)	4-50 (20)	10-20	50
Nitrites (mg/l)	0.6 (0.6)	1-3 (4)	-	-



3 Legislative Recommendations for Olive Oil Waste Management

3.1 The particularities of olive oil industry

It is true that if the rules on waste management were applied strictly and in their dimensions the operators of olive mills would be burdened with extensive bureaucratic and operational obligations and would suffer a considerable financial impact as well as be exposed to a series of sanctions should they not comply with the aforementioned rules (Taccogna, 2010).

Generally speaking, olive mills are family businesses and small-scale enterprises, scattered around olive production areas, making thus individual on-site treatment options unaffordable (Paraskeva and Dimopoulos, 2006). On the top, since SME olive mills have a low benefit/cost ratio, the need to meet environmental regulations could lead many of them to closing down. For example, it is assumed that small olive mills cannot build and operate anaerobic treatment plants because of their high cost. Due to the seasonal nature (the harvest period ranges from September to February) and the variable character of the residue, anaerobic plants would not be advised, because they need a long running-in phase of several weeks or months. However, this system could be applicable to cooperatives that also work with other agricultural products whose residues can be composted in different seasons. Furthermore, the quantity of wastewater generated in olive oil processing, in many cases is extremely small in comparison to other commercial industrial operations and thus the purification costs cannot be justified from the point of view of volume and duration of individual production.

Combining the current financial crisis and the fact that most olive production units are small sized, the application of detailed regulatory waste rules would put their sustainability at risk. However, this observation, though understandable should not lead to the conclusion that the law should “bend” meet the needs of a specific sector (Taccogna, 2010). The correct approach is to start from an objective reconstruction of the legal framework on waste management and accommodate the particularities of the olive oil waste. Furthermore, even under the current waste management laws it could be possible to exempt olive pomace from being subject to the rules on waste management, albeit not a priori or in a sweeping manner (Taccogna, 2010).

The following recommendations focus on the waste legislative part while for **soil protection** the relevant recommendations are presented in detail in Chapter 4.2 “*Statutory legislation proposals*”.

3.2 Statutory legislation proposals

Following the analysis of the previous chapters we conclude on the following legislative proposals:



- 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 and specific emission limit values should be defined, especially in the case of land spreading where no statutory standards exist but only application rates in some national legislation.
- As olive oil waste is potentially hazardous the legislation should provide statutory limits, especially on phenols, under which the waste is characterized as non-hazardous. The focus should be the categorization as H14 (ecotoxic) and limits as well as tests and monitoring measures should be provided depending on the receiving media, i.e. soil and surface waters.
- The legislative act should clearly specify that the waste should be analysed for its physicochemical characteristics, as for example: vegetative trials, germination tests, phytotoxicity tests, growing-on test, etc, testing its toxicity potential regarding plant development and the environment in general. 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, i.e. waste/wastewater management facilities within the industry or establishment of collective schemes for smaller units
- 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, especially for small production units, specific regulations should be developed. For further analysis for this subject see: Chapters 2.1.1 (by products), 2.3.4 (landspreading) and 4.2.4 (soil).
- 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, pursuant to art. 5 of Directive 2008/98, 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 into account (a) the use of the land (e.g., agriculture, food products, non-food products, residential/parkland, commercial and industrial), (b) the soil type and (c) the period of reuse.
- OMWs are usually discharged in small stream catchments (<10 km²), which are not considered in the Water Framework Directive 2000/60/EC. Therefore, 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, especially when they are small

3.3 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
- It would be recommendable to 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/centralised treatment systems (see below)

Using data from a Greece basin and appropriate tools, it was found that viable solutions could be found, towards centralised and decentralised management practices. Two alternative plans were analysed (Kapellakis et al., 2006):

- a centralised plan, which refers to the collection and transfer of OMWW into central treatment plants. This is based on the collection via pipe network, treatment in central conventional plants, and reuse of all the reclaimed OMWW for irrigation purposes. Costs for central treatment plants would be very high, with uncertain probability of payback. Considering that OM are seasonally operated, mainly small-sized, and widely distributed, this poses an additional seasonal maintenance constraint for both pipes and treatment facilities.



- a decentralised plan, which is based on in situ OMWW treatment. This plan is based on the employment of natural treatment systems, such as constructed wetlands and slow rate systems, for the collection, treatment, and reuse of the produced OMWW. Compared to conventional technologies, natural treatment systems represent a cost-effective treatment method with large area requirements. All OMWW effluents produced in the vicinity of an olive mill would be collected and treated in the same plant and thus treatment would occur in several small plants, providing that plants are installed in every village with olive mills.

The centralised treatment plants scheme has been also proposed for Crete, Greece (JHACE, 2012). The benefits of such system are as follows:

- More effective control of effluents quality, as the control is implemented by specialized personnel and supervised by centralised bodies
- Simplified monitoring procedures for the same reasons as above, as long as the number of centralized units is small
- Simplification of maintenance, repair and replacement of equipment in the centralised units
- Sustainable development of the management system as the investment and operational costs are distributed among the connected olive oil production units

Finally, one major advantage of a centralised wastewater treatment system is the possibility of reuse of treated wastewater for irrigation, which is a very important initiative, especially for the Mediterranean countries where the scarcity of water is a reality and a serious problem to be addressed the following years. For the relevant EU legislation see Chapter 2.2.2 “*Reuse of wastewater*”.

4 Soil Protection

4.1 Introduction

Soil is a dynamic and living resource, which needs minimal and suitable conditions to carry out its indispensable functions for its conservation, to produce food and for supporting the environment quality (Doran and Parkin, 1996). It is characterized by different properties, which define its quality and which may vary depending on several factors such as climate, parent material, inhabiting organisms and microorganisms, human agricultural practices.

The concept of soil quality emerged in the early 1990s, and the first official definition of this term was proposed by the Soil Science Society of America Ad Hoc Committee on Soil Quality (S-581) in 1997 (Karlen et al., 1997). Soil quality was defined as “*the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation*”. For the committee proposing this definition, the term soil quality is not synonymous with soil health, and they should not be used interchangeably. Soil quality is related to soil functions, whereas soil health



presents the soil as a finite and dynamic living resource (Doran and Zeiss, 2000). Soil health is defined as “*the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health*” (Doran et al., 1996).

These two definitions may appear similar, but soil health concept directly mentions plant health, which is not the case in the definition of soil quality of Karlen et al. (1997). In a simple manner, the Natural Resources Conservation Service of the United States Department of Agriculture proposes on its website (soils.usda.gov/sqi, 2005) the following definition: “*soil quality is how well soil does what we want it to do*”. Because of the numerous possible uses of soil, the meaning of the term soil quality heavily depends on the ecosystem considered. In agricultural soils, plant and animal productivity and health would be of the greatest importance, whereas it would not be the same in urban soils. Even in a given ecosystem, e.g. cultivated soils, their multifunctionality makes it difficult to define a healthy soil without first defining the targeted goal or aim. Such goals could be plant health, atmospheric balance, avoidance of erosion, etc.

In accordance with the Thematic Strategy for Soil Protection (COM 2006, 231 final) actions and means should be oriented to ensure sustainable use of soil. Against this background, the Commission considers that “*a comprehensive EU strategy for soil protection is required. This strategy should take into account all the different functions that soils can perform, their variability and complexity and the range of different degradation processes to which they can be subject, while also considering socio-economic aspects.*

The overall objective is protection and sustainable use of soil, based on the following guiding principles:

1. *Preventing further soil degradation and preserving its functions:*
 - *when soil is used and its functions are exploited, action has to be taken on soil use and management patterns, and*
 - *when soil acts as a sink/receptor of the effects of human activities or environmental phenomena, action has to be taken at source.*
2. *Restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil”.*

Having examined different options, the Commission proposes a Framework Directive as the best means of ensuring a comprehensive approach to soil protection whilst fully respecting subsidiarity. Member States will be required to take specific measures to address soil threats, but the Directive leaves to them ample freedom on how to implement this requirement. This means that risk acceptability, the level of ambition regarding the targets to be achieved and the choice of measures to reach those targets are left to Member States. According to the Directive, the certain threats to soil such as

erosion, organic matter decline, contamination that may occur in specific risk areas must be identified.

For soil contamination a national or regional approach is recommended as being more appropriate. The proposal sets up a framework for adopting, at the appropriate geographical and administrative level, plans to address the threats where they occur. With respect to management of contamination, an approach based on the following Figure 3 is envisaged.

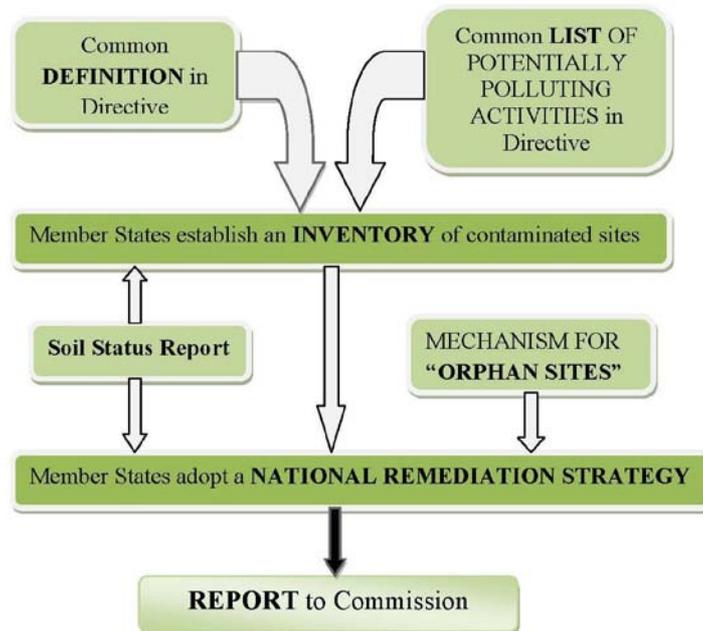


Figure 3: Management of contamination

According to the Directive, management of contamination sites must be implemented on the basis of the requirements:

- Identification and registration of contaminated sites
- Establishment a national remediation strategy
- Prevention of contamination via a requirement to limit the introduction of dangerous substances into the soil

For the fulfillment of these requirements:

- a set of recommendations appropriate to be integrated into the European and/or national legislative frameworks are proposed. The recommendation are those derived after evaluation of the PROSODOL project outcomes and mainly from the soil monitoring actions performed at olive mills waste disposal areas, and their fulfillment is considered necessary for soil quality protection. It is believed that their incorporation as MSs 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.
- 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.

4.2 Statutory legislation proposals

In all Mediterranean European countries, regardless if specific laws are existed or not, the uncontrolled disposal of olive oil mills' wastes is not permitted. Thus, prior soil disposal, the mills waste should be pre-treated according to guidelines described in the national legislative framework. If there is no legislative framework, then a minimum required measure could be the treatment of wastes with lime in order to increase pH and reduce the organic load and the total solids. The description of pre-treatment technologies are not included in the aims of this document, however, an extensive study was made within the framework of the LIFE05 ENV/GR/000245 Project entitled "*Environmental Friendly Technologies for Rural Development-ENVIFriendly*" and can be found in the work of Nikolaidis et al. (2008).

The following six measures are proposed to be included in the European legislative framework as well as in the national frameworks of Mediterranean olive oil productive Member States:

- (1) Recording Olive Oil Mills Waste disposal areas
- (2) Characterization of disposal areas-Risk assessment
- (3) Evaluation of risk level
- (4) Defining the conditions of OMW soil disposal
- (5) Adoption of soil quality indicators
- (6) Monitoring soil indicators-Evaluation of the results

As regards soil quality protection from the disposal of OMW, these measures are considered as being efficient for maintaining soil quality and sustainability.

4.2.1 Recording Olive Oil Mills Waste disposal areas

Each country should identify the OMW disposal areas in its territory and record them in a national inventory. The inventory will contain all licensed disposal areas and as many as possible non-licensed ones. Local inventories should be created as a first step under the responsibility of local or regional authorities, which afterwards will be integrated into a national inventory under the responsibility of governmental agencies. GIS mapping of the disposal areas and the establishment of a digital database is strongly recommended.

4.2.2 Characterization of disposal areas-Risk Assessment

As a second step, governmental and local authorities should proceed to complete and detailed characterization of the disposal areas and to the performance of risk assessment studies.

Recorded OMW disposal areas should be characterized considering location, hydrogeology, physiography, geomorphology, land use, soil structure, texture, water permeability, coefficient of hydraulic conductivity (saturated or unsaturated), porosity, presence and depth of impermeable soil layers. Additionally, the collected data may include, history of the site, extent and types of contaminants that may exist, hydrogeological and hydrological regime for the broader area, known/anticipated



presence and behavior of receptors, sampling of soil and groundwater: comparison with generic guideline values or quality standards, sampling of soil and groundwater: site-specific modeling of fate, transport and exposure and comparison with toxicological values, and other parameters which may be considered necessary for the complete characterization of the area. Such a characterization will permit the performance of the risk assessment study of the area and the identification of the sites which pose risk to human health and to the environment.

For a risk to exist there must be a *source* (or hazard or pressure), a *pathway* and a *receptor* (or target). This is the basis for the *Source-Pathway-Receptor (S-P-R) conceptual model* for environmental management. In addition, a conceptual model also provides information useful to the scoping of any investigation as it identifies the sites that pose the greatest risk to the environment and human beings and also identifies the S-P-R linkages that have the highest risk associated with them (Daly, 2004). Thus, the detailed information obtained through the assessment will further assist the decision on the extent of measures, which are required to manage the risk, which may involve breaking the pathway or removal of the source or monitoring of the receptor.

Indicatively, a risk assessment study could comprise:

1. Preliminary investigation (desk study, site reconnaissance and sometimes limited exploratory investigation). The goal of this preliminary stage is to assess whether potentially contaminating activities have taken place on the site, whether soil and/or water pollution is suspected, and in some cases to confirm the existence of pollution. In short, this phase focuses on hazard identification.
2. Detailed investigation. The aims at the main site investigation stage are (a) to define the extent and degree of contamination, (b) to assess the risks associated with identified hazards and receptors and (c) to determine the need for remediation in order to reduce or eliminate the risks to polluted or actual receptors.
3. Supplementary or feasibility investigations to better define the need for and type of remedial action or monitoring. The aim may be to assess the feasibility of various remediation techniques; this may include more detailed physical and chemical characterization of soils and laboratory studies on soil or groundwater treatability. Supplementary investigations may also be designed to improve understanding of the nature, extent and behavior of contaminants.

The risk assessment, however, should not be limited to toxic constituents, like the polyphenols, which may pose threat to human and animal health but to consider also the potential progressive soil degradation due to the presence in OMW of other less hazardous or non-hazardous constituents, like nutrients and other inorganic waste's constituents. This factor is often underestimated and the majority of risk assessment studies focus on the toxicity, which may be caused to soil and to humans from polyphenols. Thus, if land distribution is planned the organic load and the toxic substances (polyphenols) should not be the only issues of concern. Specific care should be taken also for inorganic constituents (e.g. K, Cl⁻, NO₃⁻, SO₄²⁻, P, Mg, Fe, Zn and



others), since the very high concentrations disposed on soil change drastically its quality properties, while their concentrations in soil as well as, the soil electrical conductivity remain high even many years after the last disposal. For this, the performance of a complete soil physicochemical analysis and identification of the organic and the inorganic soil constituents are strongly recommended. Determination of phytotoxicity potential is also recommended.

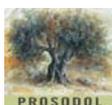
The risk for each potential pathway is considered to be a combination of the probability that a hazard will reach the target (e.g. high polyphenols concentration in soil due to OMW disposal) and the magnitude of harm if the target is exposed to the hazard (e.g. phytotoxicity). The probability that a contaminant will reach a target in sufficient concentration to cause harm may be assessed qualitatively according to the scale: **high** (certain or near certain to occur), **medium** (reasonably likely to occur), **low** (seldom likely to occur) or **negligible** (never likely to occur). The magnitude of harm is assessed as: **severe** (human fatality or irreparable damage to the ecosystem), **moderate** (e.g. human illness or injury, negative effects on ecosystem function), **mild** (minor human illness or injury, minor changes to ecosystem) or **negligible** (nuisance rather than harm to humans and the ecosystem). The qualitative level of risk associated with each pollutant pathway is then assigned by the combination of the aforementioned probability with the magnitude of harm. Thus, having identified all the crucial parameters the risk should be rated according to Table 16 (Modis et al., 2008).

Table 16: Risk assessment rating

Probability	Magnitude			
	<i>Severe</i>	<i>Moderate</i>	<i>Mild</i>	<i>Negligible</i>
<i>High</i>	High	High	Medium/Low	Near zero
<i>Medium</i>	High	Medium	Low	Near zero
<i>Low</i>	High/Medium	Medium/Low	Low	Near zero
<i>Negligible</i>	High/Medium/Low	Medium/Low	Low	Near zero

4.2.3 Evaluation of risk level

The third step is to evaluate the level of risk of the suspicious areas and exclude for further future disposal of all areas under *high risk*. For these areas a remediation plan should be developed and implemented immediately. For areas under *medium risk*, further assessment of the threat type and potential extent is strongly recommended in order to decide the conditions of waste disposal or the design and implementation of remediation actions. For these cases, decisions should be taken considering data collected during the risk assessment study is proposed. For areas under *low* or *near zero risk*, a management plan for the safe disposal of OMW should be developed and implemented under the supervision of local authorities and the responsible governmental agencies.



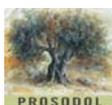
4.2.4 Defining the conditions of OMW soil disposal

It is very likely, some areas, although being of low or negligible pollution/degradation risk, to be inappropriate to accept OMW soil disposal due to their specific characteristics. In order to ensure safe disposal of OMW, soil and land data have to be considered in combination with bioclimatic conditions and management practices. The ultimate goal should be to apply or dispose OMW to land in such a way, that the soil either filters the potential toxic elements effectively, or electrochemically absorbs them or decomposes them in order that a clean solution passes through the soil body. The soil should not be overloaded with inorganic constituents and must maintain all its functions and its absorption capacity to ensure a sustainable system.

The decision of land distribution is proposed to be taken considering appropriate suitability criteria, as presented in Table 17. In this table two suitability orders are defined: (S for suitable and N for unsuitable) and five 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 (Soil Science Society of America, 1986; MAFF, Dept. of Environment, 1989; Theocharopoulos et al, 1998).

Table 17: Criteria for land suitability for OOMW disposal

Property	S1	S2	S3	N1	N2
Flooding	never	seldom	often	always	As N1
Depth to bedrock, cm	>300	>180	100-180	<100	<50
Depth to impermeable layer, cm	>200	>180	100-180	<100	<50
Coverage with water	never	never	seldom	often	always
Groundwater level, cm	>300	>180	100-180	<100	<50
Infiltration rate, cm/h	2.0-6.5	0.5-6.5	0.5<,>6.5	0.5<,>6.5	As N1
30-150cm					
Slope, %	<3	3-8	8-12	>12	>15
Stones, % (>7.5 cm)	<20	<35	>35		
Texture	All except CL, SC, SiCL, SiC, C, LS, S or with gravels	All except SiC, C, S or with gravels	All except C or with gravels	Clay (vertisols), very Sandy	As N1
Structure	granular angular-blocky	blocky or prismatic	massive platy compacted	vertic	As N1
SAR	<12	<12	>12		
pH	7.3-8.4	6.6-7.3	5.6-6.5	<5.6	As N1
EC, mmhos/cm	<4	<8	<16	16-40	>40



CEC, meq/100g	>16	8-16	<8	<8
Salt, %	<0.09	0.09-0.16	0.16-0.26	>0.41

Considering the specific properties of soils at disposal areas, local particularities and the limitations of Table 17, the following steps should be followed in order to adopt and implement safe disposal or application of OMW.

Step 1: Definition of suitable or unsuitable soils for OMW disposal

Soils with the potential to receive or soils that should be excluded from OMW disposal/distribution/application are identified based on permanent physical and/or chemical characteristics (Table 17). Moreover, prior the final decision and incomplementarity with the parameters of Table 17, the presence of toxic soil conditions should be assessed by using the standard methods for the determination of (a) nitrogen mineralization and nitrification in soils and the influence of chemicals on these processes (ISO 14238:1997); (b) the effects on earthworms (ISO 11268-1:1993); (c) the chronic toxicity in higher plants (ISO 22030:2005); and (d) soil biomass or soil respiration (ISO 14240-1:1997). The selection among these standard methods should be based on several factors, such as current soil quality condition, past, present and future use of the area, amounts of produced waste and treatment level. Olive mills' wastes should also be analyzed in terms of BOD₅, COD₅, pH, total solids, total suspended solids, total volatile solids, ash, total organic carbon, total nitrogen, total phosphorous, electrical conductivity, total sugars, fats and oils, total phenols, potassium, sodium, calcium, magnesium, total sulfur, total chlorine, iron, manganese, zinc, copper, nickel, chromium and molybdenum.

Step 2: Estimation of the maximum permitted OMW amount

The soils that are suitable for OMW application should be further studied in order to define the **maximum permitted amount** (or the maximum amount they can afford) of OMW based on their physicochemical properties and on OMW composition and considering legally applied thresholds for these properties. Provided that no regulation neither directive exist in the EC, the estimation of the annual OMW application rate is suggested to be performed taking into account the maximum permitted levels of potentially toxic elements as defined by the European Community (EC Council Directive 86/278) for sewage sludge application and the thresholds as derived from the literature, especially for the non-toxic micro- and macro-nutrients. Further analysis on soil improvers, fertilizers and landspreading is provided in Chapter 2.3.

As regards heavy metals, the EC Council Directive defines thresholds for Cd, Cu, Ni, Pb, Zn and Hg. For the case of OMW, potential risk may arise from Ni, Cr and Mo (from the steel parts of mills' equipment), which may be present in OMW (liquid and solid). However, high concentration values of these three metals (and also of the other heavy metals) are not expected in OMW and thus, heavy metals amounts that exceed the thresholds defined in the Directive are unlikely to be detected (see specific restriction below). High concentrations of the other heavy metals that are not mentioned in the Directive are also unlikely to be detected in OMW. Yet, the limit values for



concentrations of heavy metals in soil as defined in the Directive should be considered prior the estimation of the maximum permitted OMW amount.

Step 3: Estimation of annual permitted application of OMW

The annual distribution rate and timing of wastes application should be determined, regardless if wastewater or solid OMW (i.e. dry husk, wet husk, composts from all mills by-products), or wastes originated from 2-phase systems are to be distributed. The annual rate and timing of OMW application could be determined by taking into account the maximum permitted levels of potentially toxic metals as defined by the European Community (EC Council Directive 86/278) for sewage sludge application and the thresholds as derived from the literature, especially for the non-toxic macronutrients (e.g. P, K, N) and for the available forms of metals. The annual permitted application should be estimated after evaluation of the specific local environmental conditions and soil quality. Since the most of the OMW constituents are non-toxic and are considered as important nutrients (N, P, K, organic matter, Fe, etc), the application of OMW could be beneficial for soil quality and may improve fertility. However, due to the very high load of OMW in these constituents, the disposal on soil should follow restrictions and rules and the annual application should be estimated by considering:

- The concentration of the specific elements/substances in soil
- The concentration of the specific elements/substances in OMW
- The specific climatic, geomorphologic and environmental conditions of the area that may affect the behavior of these elements/substance in soil (leaching, adsorption, decomposition, etc)
- The maximum permitted amount of each of these elements/substances that can be disposed on soil without changing its quality

The distribution of OMW may increase soil content in polyphenols substantially and thus, this is a very significant limiting factor for the agronomic use of OMW. All studies performed so far have reported noticeable increase in the content of phenolic compounds in soils immediately or after some months from waste application (Kavvadias et al., 2011). However, a healthy soil is capable to reduce the concentration of phenols through natural biodegradation processes (Mechri et al. 2008; Nikolaidis et al. 2008). Several studies demonstrate that toxicity in OMW-amended soil tends to disappear just few months after application. However, if soil distribution is planned, some characteristics of polyphenols behavior in soil should be taken into consideration. Thus, one should consider that phenols do not move rapidly across the soil profile (Chartzoulakis et al., 2010), their leaching was shown to be negligible in soils rich in carbonates and clay materials, they can be adsorbed by soil organo-mineral components and thus, can be detected in high concentrations even at depth of 125 cm (Sierra et al., 2007) while residual levels of polyphenols remain significant for many years in soil in case of application of untreated wastes (Feria, 2000; Mekki et al., 2006). Apart from polyphenols, the low pH values of OMW should always be an issue of concern as well as, the impact of low acidity on many physicochemical and biological soil properties.

As regards the nutrients' content, the OMW could be considered as a nutritional material (like fertilizers) and thus, annual dose estimation should follow the general rules of soil fertilization considering soil properties and purpose of use.



In general, changes in soil quality can be assessed by measuring soil parameters and comparing them with the EQSs at different time intervals, for a specific use in a selected area-system. The maintenance of the EQSs at acceptable values ensures the normal functioning of the soil ecosystem health. The peculiarity of the effect of OMW on soil is that, apart from the toxic polyphenols, the most of the soil parameters that are substantially affected concern inorganic soil constituents, mainly corresponding 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, it may be more efficient to develop guidelines that can help set limits under certain land and environmental conditions. Thus, although a general definition of soil parameters' thresholds could be performed after searching in international literature and national or EU legislative frameworks, it should be highlighted that the definition of thresholds would be more effective and representative of each target area if they would be determined after evaluation of data collected from the areas of interest and by taking into account local characteristics and values of the soil parameters of representative control samples.

Especially for polyphenols, for which the assessment of their concentration in soil is considered difficult and with high degree of uncertainty, due to the lack of generally accepted threshold (see also recommendation in paragraph 3.2-proposal No3), it is recommended to use local and site specific threshold as guideline/normal values (Zhou, 1996; Swartjes, 1999; Sierra et al., 2001; Mekki et al., 2007; Di Serio et al., 2008; Kavvadias et al., 2010).

General, threshold values and the respective literature are included in Tables 1 and 2 of Annex 1 for the most of the soil constituents. These values are proposed to be considered and potentially adopted as EQSs by European Member States.

Step 4: Time of OMW application

In case of olive mills' wastewater or solid waste use for land spreading, the time of application has to be defined considering the annual rainfall rate, intensity and distribution throughout the year and the temperature, in relation to water balance, soil properties and processes, microbial activity and OMW decomposition. The background philosophy is to apply OMW at periods where rainfall induced leaching of the soil water is not expected.

Step 5: Soil Monitoring

The next step is the periodical monitoring of the impact of OMW application on soil, on water bodies and the environment under the specific bioclimatic conditions of the Mediterranean areas through a systematically planned sampling scheme combined with different eco-biotoxicological tests.



4.2.5 Adoption of soil quality indicators

The continuous monitoring of a pilot area within the framework of PROSODOL project revealed that not all of the measured parameters are affected by the disposal of OMW. In particular, some of the measured parameters remained almost unchanged or the changes recorded were not significant relative to the control soil samples used for comparison (e.g. exchangeable Ca), other were subject to changes but their values were depended also by the different seasons and thus are inappropriate to be used as indicators (e.g. Cl^- , NH_4^+ , SO_4^{2-} , PO_4^{3-} , NO_3^- , microbial activity). Other parameters were significantly changed due to wastes disposal but this change lasted for short time after ceasing of wastes disposal although the area were still very much degraded (e.g. N, B). Finally, there were parameters that exhibit significant changes strongly depended on OMW disposal (e.g. organic matter, exchangeable K, available Fe). From the evaluation of the obtained results it was clear that, since soil degradation at OMW disposal areas remain significant also for inactive-abandoned disposal areas, the indicators to be established should cover these two potential cases namely, active disposal areas and inactive-abandoned disposal areas.

Thus, in order to select the most suitable soil parameters, four features, i.e. relevance; understandability; reliability; and accessibility of data were considered as well as, along with the percentage of soil samples collected from all disposal areas (active and inactive for many years) that exhibit high values of the measured parameters compared to the control samples. The following soil parameters are proposed as indicators for monitoring soil quality in areas of OOMW 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 for being quality indicators (Adriaanse, 1993; OECD, 1993):

- **Relevance:**All indicators are related to the disposal of OMW and as it was observed during the soil sampling campaigns of the PROSODOL project and the analyses performed for many soil samples (affected and control) and during different seasons, their values are depended only on disposal activity.
- **Understandability:**All indicators are soil parameters that are used for many years to characterize soil systems and thus, are very much understandable, even by people who are not experts.



- Reliability: The proposed indicators are reliable as proved by many soil analyses, by periodically sampling from the same sites and by data evaluation.
- Accessibility of data: Indicators provide timely information and as it was proved by the monitoring of the disposal areas, one disposal it was enough to increase these parameters to values much higher than control samples. It is also highlighted that, during soil sampling campaigns of the PROSODOL project, unknown and non-studied sites were recognized as being disposal sites after having analyzed these parameters.

All soil laboratories worldwide perform analyses in a daily basis for the determination of the parameters proposed as soil indicators, except perhaps the determination of soil content in polyphenols. However, the fact that, for almost all soil parameters many different methods of analysis have been developed, often makes results produced between different laboratories, not comparable. For this reason, the use of methods and procedures that will ensure precise, repeatable and traceable determination of the proposed indicators are required. The adoption of standard methods and procedures will ensure precision, repeatability, comparability and traceability. Annex 2 includes recommendations in performing the determination and evaluation of the proposed indicators based on standard methods.

The Ni, Cr and Mo issue

Corrosion of steel in various media has been studied extensively. It is known that steels with higher than 12% w/w Cr content exhibit very good resistance to corrosion due to the formation of an invisible passive chromium oxide film on their surface as a result of reactions between chromium and atmospheric oxygen; when steel equipment operate in acidic or basic environments this film may be destroyed increasing thus their susceptibility to corrosion. The presence of Mo in steels stabilizes this film and increases the resistance in media containing chlorides which in increased concentrations may cause both pit and crevice corrosion. The presence of Ni increases resistance to corrosion only if the content of molybdenum exceeds 3% w/w. Corrosion rates lower than 0.02 mm/y indicate excellent resistance of steels to corrosion; 0.1 mm/y is an acceptable rate whereas rates higher than 1 mm/y are not acceptable. The corrosion rate of alloys depends mainly on the type of the alloy, the concentration of organic and inorganic components in solution, as well as the operating parameters, mainly pH, redox potential and temperature (Streicher, 1974; Garner, 1981; Hu et al., 2010).

Steel equipment involving mechanical parts are used during olive oil extraction; mills with moving steel drums mill the pretreated olives to produce the olive pulp; malaxers stir the pulp at a particular temperature, which should not exceed 30°C; two- or three-phases decanters (horizontal separators) separate the pulp into oil and pomace/water; finally oil separators polish the oil phase and remove residual water and fine lees material. Corrosion of these steel parts are likely to occur during the entire olive oil production process due to single or synergistic effects of organic and inorganic constituents. Moreover, temperature, over the range 25°C–40°C, could have a minor effect on corrosion rates.



Thus, contamination of soils with recalcitrant heavy metals is an issue that needs to be seriously considered in OMW disposal sites. Therefore, it is proposed that, in case that mills' steel equipment is composed by an alloy of inferior quality than 316, then periodical monitoring of soil contamination by Ni, Cr and Mo is required (Komnitsas et al., 2011).

Soil colour

Soil colour is constituted of the overall hue (based on primary colour), chroma (the strength of the colour) and the degree of greyness (from black to white) of the soil. When soil degradation takes place, both texture and colour change, and this change is often one of the first obvious indicators of soil degradation.

Colour changes occur in soils that accept surface disposal of OMW, while such degraded systems don't seem to recover after many years of last disposal. Munsell soil-colour charts give a full description and code for soil colors. It is necessary to standardize the moisture level of the soil for the color determination and to record soil colour both in dry and wet/moist representative soil samples. Moreover, for soil-degradation assessment it is necessary to compare colors between un-degraded and degraded conditions.

4.2.6 Monitoring soil indicators-Evaluation of the results

Due to their simplicity and easiness in analysis, soil quality indicators should be monitored once a year and preferably before OMW distribution. This requires annual soil sampling and chemical analysis in the framework of a defined monitoring strategy that land users or polluters must follow. Sampling and proceeding of soil samples to laboratory should be under the responsibility of the land owner. The results of the chemical analysis should be evaluated by an expert (e.g. agronomist) and a technical report should be submitted to the responsible authorities. The report, apart from the evaluated results of soil and wastes analysis, should also include a detailed description of the wastes distribution plan (amount, timing, equipment use). The responsible authorities for results collection and evaluation could be either local or regional, depending on the decisions ultimately taken by Member States. The evaluation of the soil quality indicators within a defined ecological zone requires (Arshad and Martin, 2002):

- Direction of change-positive or negative increase or decrease, etc
- Magnitude of change-percent change over the EQSs or baselines values of the area
- Rate of change-duration: months, years
- Extent of change-percentage of the area being monitored i.e. what percentage of the area has changed with respect to the selected indicator during a specified period.

Depending on the evaluation results, the responsible authorities may permit OMW disposal or not, while in case of continuation of OMW disposal on soil, the maximum dose should be determined considering the risk level of the area. The responsible authorities should establish a periodical monitoring strategy in order to be able to identify potential risks at any time. A specific inventory (a data base) of each disposal



site should be established and updated annually. This will facilitate the immediate identification of risky areas as well as, will provide data regarding history of the site, specific local geomorphological characteristics, amounts of waste that have been disposed each year, results of waste and soil chemical analyses and any other data that are considered useful and necessary for the effective protection of soil quality and function.

If, for any reason, observed that a disposal area is under risk of soil deterioration, then, after evaluation of risk level, changes in land distribution plans may be proposed or the authorities may require development and implementation of a remedial strategy.

4.3 Technical Recommendations and Guidelines

In the following sections technical standards are presented. These can be utilized either as Best Available Techniques for Soil Protection or as Annexes in future Directives and legislative acts. Apart from the aforementioned, statutory measures, which ensure sustainable management of OMW disposal areas, there are also other measures that can be optionally adopted in order to facilitate local and regional authorities to perform continuous control as well as, to select and apply the appropriate soil remedial technique, in case that remediation is required.

The proposed optional measures are of two kinds:

- Measures for continuous monitoring of OMW disposal areas, and
- Soil remedial technologies, appropriate for OMW disposal areas.

The adoption of these measures in combination with the statutory ones ensures the integrated control of the OMW disposal areas, but mainly the future protection and improvement of soil quality. As such, they are considered to be fully harmonized with the EC requirements for soil quality protection as these are described in the Thematic Strategy for Soil Protection.

4.3.1 Measures for continuous monitoring of OOMW disposal areas

Three measures are proposed; the two of them could be adopted by local and regional authorities (cases 4.3.1.1 and 4.3.1.2) since their development and application require the contribution of qualified personnel and scientists. The third one (case 4.3.1.3) is suitable for use by individuals (e.g. disposal areas' owners) but also by local authorities, as it is simpler and does not require specific knowledge and qualifications.

4.3.1.1. Suitability of OMW disposal-Soil maps

To facilitate the implementation of the proposed measure No 4 (i.e. defining the conditions of OOMW soil disposal-paragraph 4.2.4.), the introduction of a Geographical Information System is proposed as necessary to define the application of OMW to agricultural or other type of lands because of the importance of spatial accuracy in the application. Such an illustration will further facilitate decision making while at the same time a very useful GIS maps database will be created. For the GIS maps creation, 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. The land suitability system for spatially manipulating soil and land data that is proposed, has been designed and developed in Soil Science Institute of Athens (SSIA)-ELGO-DEMETER for other Greek areas in the past and it was adapted to the peculiarities of OMW disposal (FAO, 1976; Soil Science Society of America, 1986; MAFF, Dept. of Environment, 1989; Theocharopoulos et al., 1998;).

The system requires a complete initial soil survey at region or larger level, which should include systematic soil sampling and then mapping of the results. An example is presented in Annex 3 for Viotia prefecture, Greece for the application of sewage sludge performed at prefecture level from SSIA. Each mapping unit was categorized according to the following: polygon type (mapped, not mapped, lake, sea), drainage class, (assessed from profile morphology), texture (classes and for 3 depths i.e. 0-25 cm, 25-75 cm and 75-150 cm), gravel (classes), slope (classes), erosion (classes), calcium carbonate (classes), soil order, suborder and great group, irrigability (availability of water for irrigation), variability class and limitations, rainfall, and geology of the parent material. Also infiltration rate and the presence and depth of the impermeable layer were recorded in some mapping units. In each mapping unit, analytical data from profile samples or auger sampling for each horizon were also stored. The system considers data and criteria of Table 17 by allocating soil map units to the 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 application/disposal of OMW directly on soil has to consider location, geology, physiography, geomorphology, hydrogeology, land use, soil structure, texture, water permeability, coefficient of hydraulic conductivity (saturated or unsaturated), porosity, presence and depth of impermeable soil layers. Moreover, it is necessary to include the soil quality indicators as they proposed in paragraph 4.2.5 (i.e. soil pH, electrical conductivity, organic matter, total nitrogen, polyphenols, exchangeable potassium, available phosphorous and available iron). Total salts content, Sodium Adsorption Rate (SAR) and toxicity indicators are also recommended to be included.

OMW should also be analyzed in terms of physical and chemical parameters as defined in paragraph 4.2.4.1 (Step 1). The most efficient way to produce a single-factor soil map or a land evaluation map for OMW disposal/application is to write a macro routine or command file. This specifies the selection criteria that are required to produce the land suitability map. The mapping unit and/or sample points are then interrogated to determine if they meet those required conditions. The fundamental process in the whole system, in order to evaluate for OMW application, is the comparison or matching of land use requirements (Table 17) with the attributes of the land mapping units. The proposed system should be built up by considering the five steps as described in paragraph 4.2.4.



4.3.1.2 Monitoring soil quality-Development of maps of soil constituents distribution vs time and depth

To facilitate the implementation of the proposed statutory measure No 6 (i.e. monitoring soil indicators-evaluation of the results-paragraph 4.2.6), the development and use of maps of soil constituents' distributions vs. time and depth is proposed. Through this tool, local and regional authorities will have the opportunity to screen disposal areas rapidly, identify potential risky conditions, carry out systematic monitoring of the areas of interest and facilitate decision making on the appropriate measures to be taken at field or municipal scale. The proposed tool integrates the continuous monitoring of the OMW disposal areas into the regular activities of local/regional authorities and thus, allows the proper and continuous monitoring of such areas.

However, this indeed requires the cooperation of the owners of the disposal areas, since repeated soil samplings at various sites are necessary for maps creation and update. The proposed application tool uses interpolation surfaces that indicate the distribution of the different physical and chemical parameters in the area of interest, so the user can rapidly obtain an idea of the possible diffusion of the chemical parameters and the degree of risk in the vicinity of the waste disposal areas. This, potentially, allows also the establishment of an Operational Centre which could be located, for instance, in cooperation with the Environmental Protection Office of the Local Government (District) in the premises of a Municipality, and can undertake the continuous monitoring of areas under risk and the scientific and consulting supporting of the owners.

The design of the particular software package needs to monitor a number of private fields that are spread around and make queries based on various spatial and chemical attributes. Thus, it is proposed that, for each OMW disposal area, one initial mapping should be carried out by performing soil sampling from various sites and for at least 4 times (e.g. every two months). The sampling sites will be decided according to the generally accepted soil sampling rules and a qualified person should be present and undertake the overall control. The collected soil samples should be analyzed for the parameters, proposed as suitable indicators for OMW disposal areas (paragraph 4.2.5). The maps that will be created should be used for no more than 5-8 years. After this period, the maps should be updated by repeating the sampling procedure. In the meantime, soil quality could be assessed by using the tool of the following paragraph 4.3.3, i.e. the simpler one that does not require specific skills and can be carried out by the areas' owners annually. Figure 4 presents the interface of the map application that it is proposed to be created for the disposal areas.

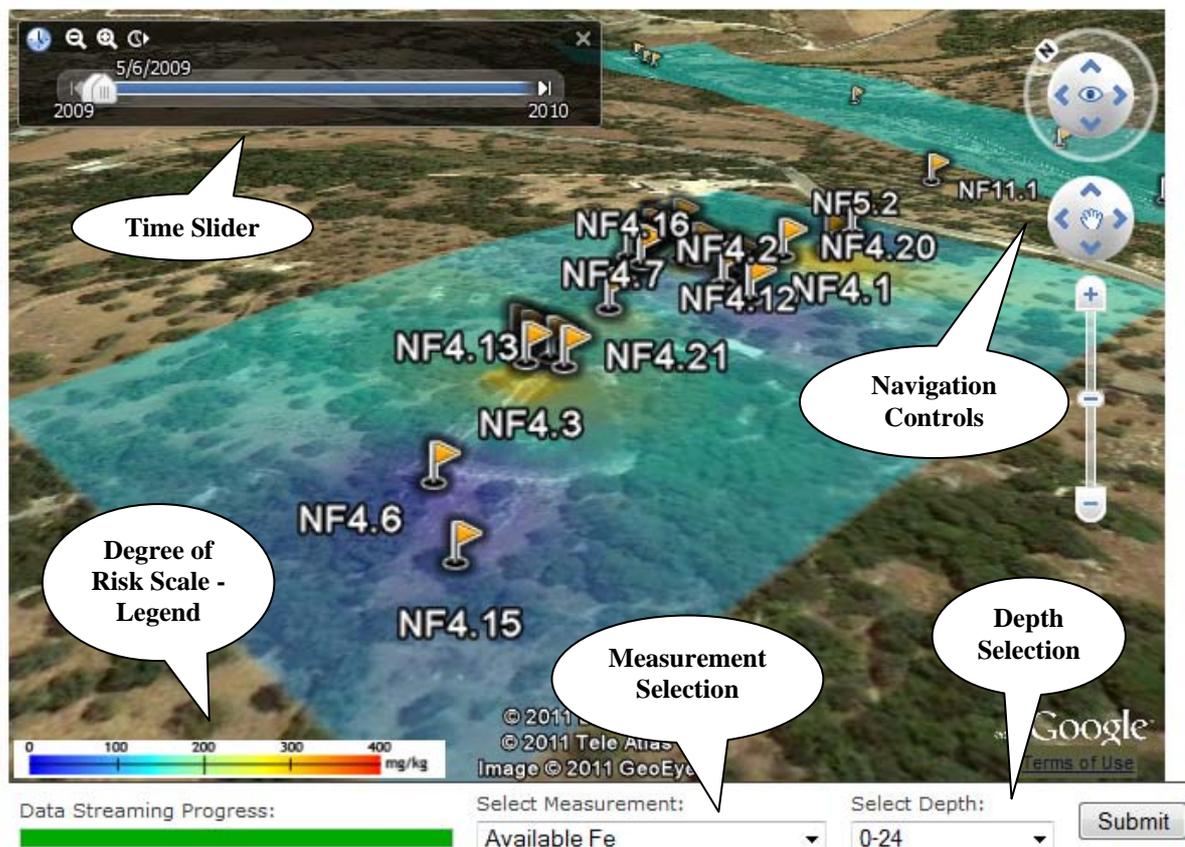


Figure 4: The interface of the map application for a disposal area. Yellow flags represent sampling sites inside the area of interest.

The creation of the interpolation surfaces requires a number of data around the vicinity of OMW disposal areas in order to identify the distribution of the different chemical parameters in the area, so that 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. Various interpolation algorithms could be used for mapping the specific parameters, however the method of the Inverse Distance Weighting (IDW), which calculates cell values by averaging the values of sampling points in the vicinity of each cell based on distance, is proposed since it causes limited secondary effects (e.g. bull's eye effect around isolated sample points, extreme trends away of the sample areas, etc). Such an application allows:

- *Measurement Selection*–The user selects the name of the chemical parameter in order to see the corresponding interpolated surface map.
- *Depth Selection*–The user can choose the depth of soil for which the user wishes to see the value of the selected chemical parameter. Then the user can submit the information provided, and the map application starts to stream the data needed and present the corresponding interpolated surface map.
- *Navigation Controls*–The user may navigate inside the map through the navigation controls, in any direction, angle, pan and zoom, giving user the freedom of any view perspective.



- *Time Slider*- An animation of the interpolated surface area map can be viewed through different time periods on the Google map.
- *Degree of Risk Scale – Legend* – When the interpolated surface map is loaded the corresponding scale of the risk degree of the selected chemical parameter is shown.

The 3D map application was designed in such a way, that the end user can easily and effectively use, and retrieve the surface interpolated information needed. Details on developing similar interpolation surfaces are given in Annex 4.

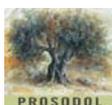
4.3.1.3. Monitoring soil quality- Software for soil monitoring by land users and polluters

A simpler version of the application tool, mainly addressed to individuals, such as mills’ owners, disposal areas owners and farmers who may use OMW for irrigation/fertilization or just land distribution is proposed as an additional optional measure, which provides interested individuals with the potential to monitor soil quality of their property periodically, identify potential risks on time and take the appropriate measures in cooperation with local responsible authorities. This tool, although not proposed as statutory measure, however it would be very useful to be included in the annual reporting obligations of the disposal areas’ owners to the local/regional authorities. Thus, the owners could submit the outputs of the tools to the local responsible authority annually, and obtain specific advice on the management of their property. The tool is a user-friendly software (available for free downloading form the website of PROSODOL project: <http://www/prosodol.gr/?q=node/3455>) and requires no specific knowledge and skills in order to be correctly applied under real conditions.

The application tool requires periodical soil sampling at pre-defined sites and the measurement of the soil quality indicators. The user enters the measurements at various time intervals and monitors the fluctuation of the values through the time. Results are indicated through predefined diagrams that have orange and red flags depending on the degree of alert that needs to signaled to the users. The user can enter more than one OMW disposal area and can also export the data into an excel format and use them for other applications. The tool permits the monitoring of eleven soil chemical parameters, i.e. the soil quality indicators plus total Ni, Cr and Mo. The limits and the values range of the risk zones (red – high risk; orange – moderate risk) are denoted in the specific columns of Table 18.

Table 18: The soil parameters that can be monitored with the monitoring application tool and the respective values range of the risk zones

Soil Parameters	Orange zone	Red zone	Limits	References
-----------------	-------------	----------	--------	------------



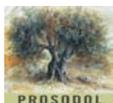
Electrical Conductivity, (mS/cm)	>2-4	>4	0.2-40	CCME, 2007; MAAF, 1988; Ilaco, 1985
Organic Matter (%)	> 5.0	>20	0.05-55	MAAF, 1988; Ilaco, 1985; Couwenberg, 2009
Total phenols, (mg/kg)	>40	>150	0.1-700	CLEA, 2005; Swartjes, 1999
Total Nitrogen (%)	> 0.3		0.02-3.00	MAAF, 1988; Ilaco, 1985
Available P-Olsen (mg/kg)	29-59	> 60 (potential high P mobility)	1-500	MAAF, 1988; Ilaco, 1985; Carrow et al., 2004; McDowell et al., 2002
Exchangeable K (cmol/kg)	>1.2-2.0	>2.0	0.1-30	MAAF, 1988; Ilaco, 1985; Marx et al., 1999
Available-Fe (mg/kg)	>20-40	>100	1-400	Mitra et al., 2009; Abreu et al., 2005
Total Cr (mg/kg)	64-200	>200	5-1000	EA, 2001; Komnitsas et al., 2010
Total Ni (mg/kg)	30-100	>100	5-500	Swartjes, 1999; Kabata-Pendias and Pendias, 1994; Linzon, 1978; Council Directive 86/278/EEC; Pollak and Favoino, 2004
Total Mo (mg/kg)	3-4	>4	1-200	Swartjes, 1999; Kabata-Pendias & Pendias, 1994; Pollak & Favoino, 2004
pH	>8.0	>8.5	4.0-9.5	CCME, 2007;

The user in order to evaluate the degree of risk in the vicinity of a waste disposal area needs to assign values to some or all of the above chemical parameters, and evaluate graphically afterwards the results upon a XY point diagram. The software and the respective manual in English, Greek, Italian and Spanish are provided free of charge included in the project website: www.prosodol.gr.

4.3.2 Soil Remediation

In accordance with the Thematic Strategy for Soil Protection (COM 2006, 231 final) actions and means should be oriented to ensure sustainable use of soil. In the light of the above, Member States should proceed to restoring actions in areas that have been identified to be under high risk of soil degradation and conform with the requirement expressed in the Strategy: “*restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil*”. In addition, areas under medium risk could be also subject to remediation, but this decision will be made by the responsible local or regional authorities considering many factors and not only the rate of the soil risk assessment.

So far, no specific technique has been developed for the remediation of OMW disposal areas. In the framework of PROSODOL project, two methods were developed and implemented in a pilot area in Crete Island, South Greece. The evaluation of the results



revealed that both of them are suitable for OMW disposal areas, if applied properly and under scientific and technical control by qualified persons. These techniques are (a) bioremediation and (b) application of the natural zeolite, namely clinoptilolite.

It should be, however, underlined that although efficient, the techniques target to different soil properties and contaminants and their application depends on the specific problem recorded at the targeted areas. Thus, bioremediation targets to organic pollutants, such as polyphenols, while the application of zeolite targets to the inorganic soil constituents. Considering these, it is very likely to apply both techniques at the same waste disposal area, however, starting from bioremediation. The successful application of the two methodologies is depended on the exact adoption of the guidelines, as proposed in the following, and the periodical monitoring of their effectiveness, as far as the soil quality is concerned.

4.3.2.1. *Bioremediation*

Bioremediation is a process in which microorganisms metabolize contaminants through oxidative or reductive processes. As such, it uses relatively low-cost and simple techniques, which generally have high public acceptance and can often be carried out on site. However, bioremediation is not always suitable for a given problem and detailed study of local soil conditions are required in order to identify if the organic contaminants could be biodegraded by soil microorganisms and if the residual contaminant levels after bioremediation implementation are acceptable (Vidali, 2001). Under favourable conditions, microorganisms can completely metabolize organic contaminants and convert them into non-toxic by-products, such as carbon dioxide and water or organic acids and methane (USEPA 1991).

Bioremediation terminology

Bioremediation uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances that are hazardous to human health and/or the environment. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site. Contaminants are transformed by living organisms through reactions that take place as a part of their metabolic processes. Bioremediation process refers to the enhancement of this natural process, either by adding microorganisms to soil, referred to as *bioaugmentation*, or by providing the appropriate conditions and/or amendments, such as supplying oxygen, moisture and nutrients, to enhance microorganisms growth in soil, referred to as *biostimulation*. Bioremediation in the presence of air or oxygen is called *aerobic bioremediation* and typically proceeds through oxidative processes to render the contaminant either partially oxidized to less toxic by-products or fully oxidized to mineral constituents, i.e. carbon dioxide and water.



At many contaminated sites there exist microorganisms that have developed the capability to naturally degrade the present contaminants. However, not all sites are enriched in suitable microbes and typically the lack of appropriate environmental conditions (such as sufficient electron acceptor levels and/or bioavailability restraints) conducive for rapid contaminants degradation. *Engineered bioremediation*, therefore, typically involves oxygen supply (or other electron acceptor), moisture, and nutrients to the contaminated soil zone so that, to stimulate contaminants degradation by the naturally existing microorganisms. In order bioremediation to be satisfactory occurred, it has to be ensured that electron acceptor, moisture and nutrient concentrations are maintained in sufficient levels and at the proper rate. This requires extensive monitoring to assure that the process is proceeding satisfactorily.

In general, the application of bioremediation technology includes three steps:

1. Feasibility studies to identify the bioremediation potential of the site of interest
2. Implementation of the bioremediation technology, and
3. Effectiveness monitoring

The flowchart outlining the decision making strategy involved in bioremediation activities is provided in Figure 5.

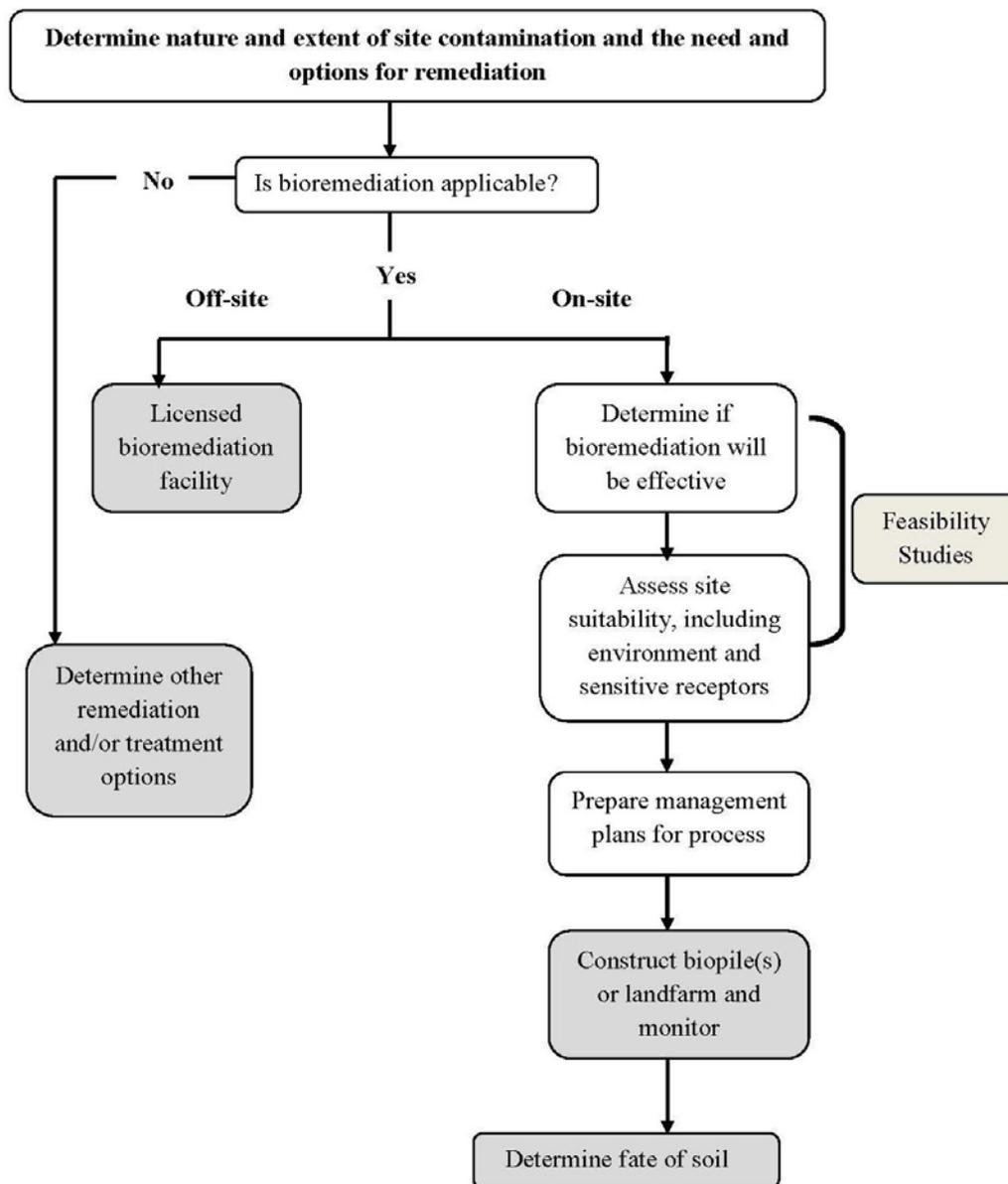


Figure 5: Strategy for bioremediation activities

Feasibility studies

Generally, bioremediation can be used in any soil type with adequate moisture content, although it is difficult to supply oxygen and nutrients into low permeability soils. It should be noted, however, that very high contaminants concentrations may be toxic to microorganisms and thus may inhibit their activity. In such cases of heavy contaminated sites, bioremediation may not be the best remediation option. Therefore, prior implementation, a feasibility investigation is needed to determine if biodegradation is a viable option for the specific site, soil type and contaminant conditions (Aggarwal et al. 1990). For the determination of the bioremediation potential of a site contaminated with organic wastes, treatability studies are required to provide specific information

regarding the potential rate and extent of bioremediation, the fate and behavior of organic pollutant in surface soil and deeper vadose zone. Treatability studies include studies in field and in laboratory. A flowchart for determining the bioremediation potential of an OMW contaminated site is presented in Figure 6.

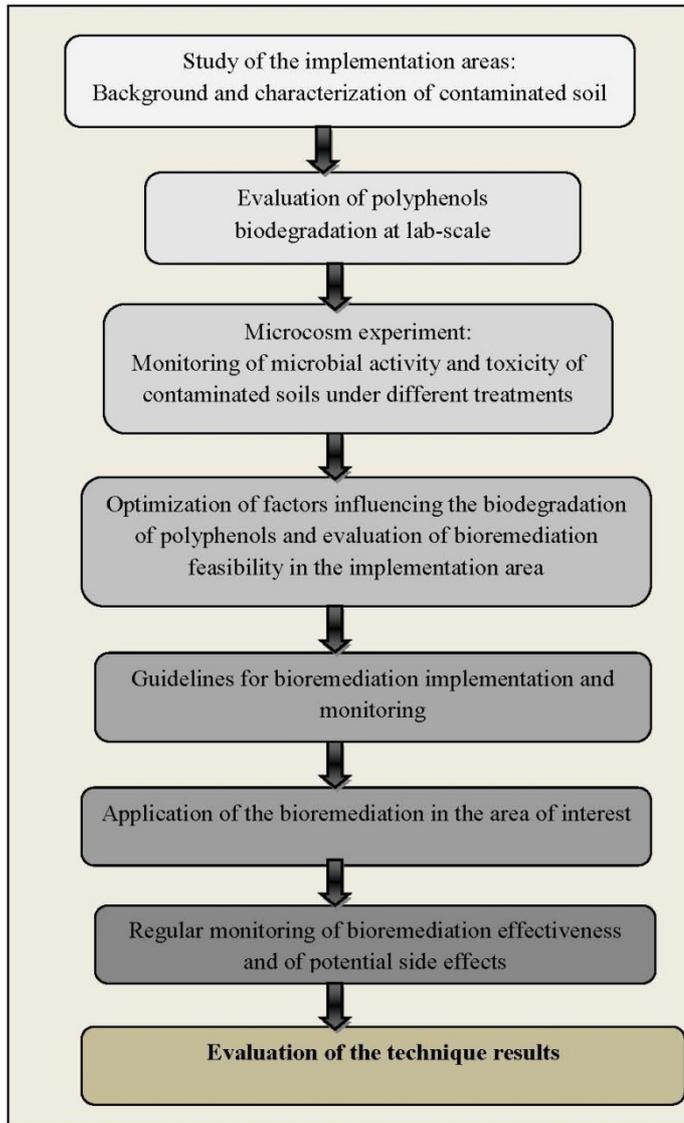


Figure 6: Flow chart for determining the bioremediation potential of OMW disposal sites.

The understanding of the specific organic pollutants characteristics and of soil properties allows the investigation of the possibility of soil and groundwater contamination as well as the possibility to apply bioremediation at a specific OMW disposal area (Sims et al., 1989). There are specific characteristics which are considered important for describing and assessing the environmental behavior and fate of organic pollutant in soil, and can be summarized as: 1) characteristics related to potential of leaching and water solubility; 2) characteristics related to potential volatilization; 3) characteristics related to potential of biodegradation; and 4) characteristics related to chemical reactivity.



An adequate site characterization, including surface soil characteristics, subsurface hydrology, and microbiological characteristics, is the basis for the rational design of a bioremediation system.

Thus, prior the implementation the following issues should be clarified:

- History and characteristics of the area (e.g. previous soil uses and amendments, frequency and amount of added OMW, present and future use, geomorphological and hydrological data).
- Complete physicochemical characterization of the disposed OMW.

The complete and detailed characterization of the site of interest and of the disposed waste is necessary to determine potential applications and limitations of the technology. Site characteristics strongly affect the success of the technique implementation and this, in turn, strongly affects the final soil clean-up. Thus, properties such as steep slopes, excessively wet conditions, soils high in sticky, plastic clays, etc. may affect the choice of the appropriate treatment or the manner in which the in-situ treatment will be conducted, or may even preclude the use of any in situ treatment method. Appropriate site modifications and management options to enhance treatment are dependent upon the existing site conditions. Site and soil characteristic that should be considered and evaluated prior the bioremediation application are listed in Table 19. Other limitations to the use of bioremediation at a specific site are usually related to: 1) time required for cleanup; 2) level of cleanup attainable; and 3) cost of cleanup using bioremediation. Moreover, microbiological characterization of the contaminated site should be conducted to ensure that the site has a viable community of microorganisms to accomplish biodegradation of the organic pollutant present at the site. Approach to estimating the kinds, size and metabolic activities of soil microbial population are very common.

The identification of all these properties is very important in order to establish, at a later stage in the laboratory, the environmental factors (water, oxygen, nutrients content, pH, and temperature) that can be critical for the microbial biodegradation of polyphenols, which are the toxic organic pollutants present in high concentrations in OMW disposal areas. This information combined with the result obtained from laboratory studies will assist the selection of the most suitable method for the bioremediation of degraded soils due to OMW disposal.

Table 19 Site and soil characteristics identified as important for bioremediation application

Characteristic	Parameter
Site location/topography and slope	
Soil type, and extent	



Soil profile properties	Boundary characteristics Depth Texture* Structure* Color Degree of mottling Bulk density Clay content and type Cation exchange capacity* Organic matter content* pH* Eh* Aeration status*
Hydraulic properties and conditions	Soil water characteristic curve Field capacity/permanent wilting point Water holding capacity* Permeability Infiltration rates Depth to impermeable layer or bedrock Depth to groundwater*, including seasonal variations Flooding frequency Run-off potential*
Geological and hydrogeological factors	Subsurface geological features Groundwater flow patterns and characteristics
Meteorological and climatological data	Wind velocity and direction Temperature Precipitation Water budget

**Factors that may be managed to enhance soil treatment.*

After the detailed site and soil characterization, laboratory studies will indicate which the more suitable soil treatment/management is, in order to increase bioaugmentation and biostimulation of soil microbial community and to monitor, under these conditions, the risk of phytotoxicity or ecotoxicity as well as, the polyphenols concentration through soil incubation. Thus, laboratory tests will:

- confirm that the polyphenols are available to microorganism and can be biodegraded
- observe that polyphenols biodegradation will be relatively fast
- determine treatment conditions that facilitate polyphenols biodegradation rate (i.e. soil aeration, water content, temperature, pH, potential addition of nutrients- especially N and P)
- identify if other factors can facilitate the process (e.g. addition of humic extract of compost or direct compost addition).

In general, the philosophy behind the strategy of laboratory studies is to determine the optimum conditions for microbial activity and if these exist in the area of interest. If



they do not exist or if they are not sufficient to provide the proper environment for polyphenols biodegradation, then they should be externally provided.

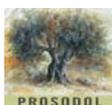
Firstly, the existence of microorganisms capable to biodegrade polyphenols should be determined. If such microorganisms do not exist, then they should be artificially added. Thereafter, the conditions (i.e. soil aeration, moisture, nutrients' concentration) that ensure the optimum microbial activity should be determined. For this purpose, the microbial activity and some soil properties under various conditions of aeration, moisture and nutrients' levels are tested in soil samples collected from the targeted area. The required determinations are:

- Separation, identification and quantification of polyphenols (mainly using HPLC)
- Water soluble polyphenols
- Microbial biomass carbon
- Water soluble carbon fraction
- Soil pH and electrical conductivity
- Phytotoxicity tests by conducting germination tests
- Exotoxicity tests
- Soil enzymatic activities by identifying Urease and Dehydrogenase activity

Soil samples should be analyzed for the above parameters before and after the application of the different conditions of aeration, moisture and nutrients' level.

Implementation

The feasibility study will result in a set of instructions that should be exactly followed. In the case of bioremediation technique there is not a common rule for the implementation since the conditions are depended on the specific site and soil characteristics. Once the instructions have been developed, the implementation should be carried out under the supervision of local authorities and of qualified personnel. The authorized agency/department/qualified person for carrying out all the necessary field works should guarantee that the operating plan includes the anticipated frequency of aeration and nutrient and water addition as identified during the feasibility studies as well as, that monitoring of implementation effectiveness is performed regularly. The overall strategy could be potentially modified based on the results of regular monitoring of the soil under treatment. The plan should also account for seasonal variations in ambient temperature and rainfall. In general, aeration, and water and nutrients applications should be more frequent in the warmer, drier months. There is also the possibility, depending on local conditions, to use specific soil covers (e.g., plastic or geofabric/textile) to protect the implementation area. In such a case, the condition of the cover must be checked periodically to ensure that it remains in place and that it is free of rips, tears, or other holes.



Monitoring bioremediation effectiveness “in-situ”

During the execution of an in-situ remedial action, the primary objectives are to prevent off-site migration of hazardous constituents via migration to ground or surface water, as well as to render the pollutant non-hazardous through degradation, detoxification, or immobilization. To assure that these objectives are being met, a monitoring program must be established. Specific objectives of a monitoring program are to:

- Assure that the hazardous or toxic constituents of contaminated soil are being degraded, detoxified, or inactivated as planned.
- Monitor degradation rates of degradable constituents.
- Assure that pollutants are not entering in waters by runoff or infiltration in unacceptable concentrations.
- Determine whether adjustments in treatment management are needed to maintain the treatment process (e.g. is soil pH within appropriate range? Does soil moisture require adjustment? etc.).

A complete monitoring program should include the media listed in Table 20(adapted from US-EPA, 1983).

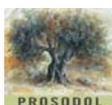
Table 20:Requirements of a complete monitoring program

Media to be monitored	Purpose
Soil in the treatment zone	Determine extent of degradation, transformation, and immobilization; pH and nutrient status; and, any other factors or substances affecting treatment execution and effectiveness.
Soil cores (unsaturated zone)	Determine slow movement of pollutants
Soil-pore liquid (unsaturated zone)	Determine highly mobile constituents
Goundwater	Determine mobile constituents
Runoff water	Determine migration offsite of soluble, suspended, or adsorbed pollutants.
Air	Determine personnel and population health hazards.

The authorized agency/department/qualified person for carrying out all the necessary field works should guarantee that the monitoring plan is described in detail and includes monitoring of soil under treatment for pollutant reduction and biodegradation conditions (e.g., CO₂, O₂, CH₄, H₂S), air monitoring for vapor emissions if volatile constituents are present, soil and groundwater monitoring to detect potential migration of constituents, and runoff water sampling (if applicable) for discharge permits. The method for soil collection, the number of samples collected from the area and the sampling locations should be in accordance with national regulations. A typical monitoring plan is shown in Table 21.

Table 21: Typical Monitoring Plan for Bioremediation implementation

Medium to be monitored	Sampling frequency	Parameter to be analyzed
Soil under treatment	Monthly to quarterly during the	Bacterial population,



	bioremediation period	pollutant concentrations, pH, ammonia, phosphorus, moisture content, other rate limiting conditions
Air	During the first two aerations, quarterly or to meet air quality requirements	Volatile pollutants, particulates
Runoff water	As required by national regulations	Soluble or suspended constituents as specified by national regulations
Soil from deeper horizons	Quarterly or twice during bioremediation period	Hazardous constituents
Groundwater	Annually during the bioremediation period	Hazardous, soluble constituents

Soils under treatment should be monitored at least quarterly during the bioremediation implementation period in order to determine pH, moisture content, bacterial population and nutrients content and pollutant concentrations. The results of these analyses, which may be done using electronic instruments, field test kits, or in a field laboratory are critical to the optimal performance of the bioremediation technique. The results may indicate that an adjustment of aeration frequency, nutrient application rates, moisture addition frequency and quantity, and pH is required. This is why, the implementation plan should be flexible and can be easily and without consequences re-adjusted in order to maintain optimal ranges for the crucial parameters and to achieve maximum degradation rates.

Finally, it is worth noting that polyphenols content should be periodically monitored. It is also necessary to consider, that the addition of OMW on soils cause not only an increase in polyphenolic compounds, but also could provoke substantial changes in many physicochemical soil properties such as inorganic elements content, electrical conductivity, pH. Thus, for the detailed monitoring of bioremediation progress and effectiveness, soil microbial parameter (i.e. microbial biomass C, microbial respiration and dehydrogenase) are important for the determination of the evolution of the microorganism activity extent, as well as physicochemical parameters are important for the further identification of soil quality and health. For this fact, it is necessary to monitor the evolution of all these parameters during a bioremediation treatment. Additionally, the determination of polyphenolic content in deeper soil horizons would be interesting and may offer useful conclusions. More instructions and details on how to carry out bioremediation monitoring is given in Annex 5.

4.3.2.2 Zeolite application

Zeolites are materials (natural and synthetic) in which $(\text{SiO}_4)^{4-}$ and $(\text{AlO}_4)^{5-}$ tetrahedra are linked by sharing oxygen atoms to give ring structures, which, in turn, are linked to give an overall three-dimensional structure which contains regular channels and cavities

(like honeycomb) of sizes similar to those of small to medium-sized molecules (Fig.7a). As such, they are ideal molecular sieves, and, in view of the AlO_4^- acid sites they contain, a high level of selectivity can be achieved in catalysis and ion-exchange (Shaw, 1992). In many zeolites these frameworks are open, so cations and water molecules, contained in cavities and channels within the frameworks, have freedom of movement. This facile movement is recognized as promoting ease of cation exchange and water loss (Dyer, 1995).

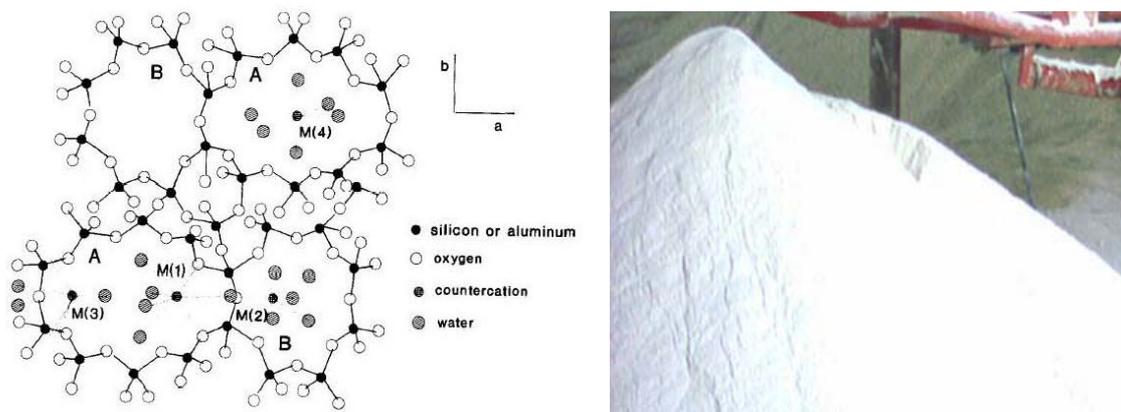


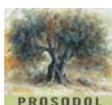
Figure 7: (a) clinoptilolite structure (b) Clinoptilolite in dust form.

The unique structure of channels, cavities and cages results in large internal surface available for a variety of reactions, and it is this surface that controls most of the useful properties of zeolites. Zeolites have often been characterized as sponges with large internal surface available for use. The extent of this voidage varies with zeolite molecular architecture.

Clinoptilolite

Clinoptilolite belongs to the heulandite group of minerals. The general type of heulandite (a natural zeolite) is $(\text{Na},\text{K})\text{Ca}_4[\text{Al}_9\text{Si}_{27}\text{O}_{72}]\cdot 24\text{H}_2\text{O}$, is of $\text{C}2/\text{m}$ symmetry and its framework consists of 10- and 8-membered rings. Clinoptilolite has the same structure as heulandite but its Si/Al ratio is higher (≈ 5.0) and for this clinoptilolite is known as “*high-silica heulandite*” (Doula et al., 2002). Clinoptilolite’s framework consists of four channels. Three channels are formed of 8-membered rings of oxygen and one channel of 10-member rings of oxygen. The 10-membered channel and one 8-membered channel are parallel with axis c , the second 8-membered channel is parallel with axis a , and the third channel lies at an angle of 50° to axis a (Bish, 1993).

The negative charge of clinoptilolite’s framework is counterbalanced mainly by monovalent cations (Na^+ , K^+), as well as by divalent cations (Ca^{2+} , Mg^{2+}).



Clinoptilolite has numerous uses and benefits in maintaining and improving the quality of air, water, solid wastes and wastewaters. Similarly as other natural zeolites but also synthetics, clinoptilolite has been widely studied regarding its suitability to be used in many different environmental applications worldwide, including protection, improvement and also remediation of soil quality. Unlike other soil amendments (e.g. lime) zeolites do not break down over time but remain in soil to improve nutrient retention. Therefore, addition to soil is anticipated to reduce water and fertilizer costs by retaining beneficial nutrients in the root zone, while the porous structure helps keeping the soil system aerated and moist. Zeolites are not acidic but marginally alkaline and thus they assist soil buffering in case of acidic waste disposal (as OMW).

In literature there are many published research works relative to the application of zeolites to soil remediation while their ideal buffer characteristics have also led some researchers to ascertain the use of natural zeolites as a liner for landfills (Kayabali and Kezer, 1998). The ability of zeolites to immobilize contaminants in polluted soils has been also extensively tested (Shanableh and Kharabsheh, 1996; Edwards et al., 1999). As they tend to have a high CEC, zeolites have been identified to be good candidates for the remediation of metals in soils and effluents. In general, the immobilization of metals in soil is due to an increase in soil cation exchange capacity and pH caused by the addition of zeolites. The increase in soil pH favors adsorption of metals and the formation of insoluble metal hydroxides.

Sodium toxicity due to application of zeolites in soil

Several studies have demonstrated that zeolites addition may cause Na ion release and consequently to increase soil salinity (Geebelen et al., 2002; Coppola et al., 2003). Thus, of serious concern during contaminated or degraded land remediation should be the possibility of 'Na toxicity' to the surrounding soil.

It should be noted, however, that all studies that found negative effects in soil due to the addition of zeolite had used zeolites with high sodium content. The use of zeolites with high sodium content as soil amendments is therefore not recommended. This is the reason why Mumpton, early in 1988, recommended **the selection of specific zeolite for the specific environmental application should be very careful**. It is suggested that the long-term effectiveness of zeolite amendment should be evaluated by aging studies, desorption studies and plant growth tests before large-scale application in the field. One must also consider the environmental conditions that may change the nature and effectiveness of the zeolite in the contaminated soil, e.g. change in pH, redox conditions, micro-organism activity, and the amount of clay minerals, or available electrolyte ions which may compete for the contaminants in the soil.

Implementation at OMW disposal areas



Prior to clinoptilolite application, preliminary land configuration activities should be carried out. In particular, the disposal area should be homogenized with the use of light field machines (e.g. tilling machines, excavators, mechanical shovel) up to almost 25cm soil depth. Stones should be preferably removed. The addition of clinoptilolite at 5% w/w is considered appropriate for OMW disposal areas considering that no further OMW disposal will occur. For 5% zeolite content the amount of clinoptilolite to be added is almost 150tn/ha. It is recommended that clinoptilolite should be of small grain size in order to be more effective and well distributed. Thus, it could be applied as dust with particles diameter <0.8mm (Fig. 7b), or of larger size (particle diameter of 0.8mm-2.5cm). Very small grain size, although more effective, is difficult to be distributed because of the dust produced during the application. However, it may be considered the possibility to use a mixture of clinoptilolite (in dust form and grain size of 0.8mm-2.5cm). Clinoptilolite should be distributed homogeneously and very well tilled.

After application, it is possible that periodical irrigation, in order to avoid excess sodium leaching would be necessary. The amount of applied water should be defined based on total cumulative net infiltration (subtracted estimated evaporation and adding precipitation), considering water parameters (chemical properties) and soil properties (e.g. soil bulk density, moisture content, electrical conductivity, texture, exchangeable cations). This management intends to achieve high leaching efficiency (i.e. remove the maximum salt possible per unit of leaching water) by using intermittent leaching with continuously unsaturated conditions on the soil surface, minimizing some surface ponding.

Monitoring soil quality

Soil quality should be monitored annually. Sampling and soil analysis should be carried out following the national and EC regulations. Results should be kept in an inventory and evaluated in order the total improvement or potential problems to be in time recorded and accordingly assessed. Soil samples should be analyzed for the proposed eight soil indicators.

As it was aforementioned, zeolite content in Na could be a restricted factor for zeolite application in soil due to the anticipated Na leaching which could lead to excess Na concentration in soil. Yet, the application of zeolite at the pilot area of the PROSODOL project and the subsequent soil monitoring revealed that concentration of exchangeable Na remains high for a short period (almost 2 months after application) while after that period very small Na amounts are anticipated to be found in soil.

It is thus recommended the inclusion of Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) determinations in the regular soil monitoring strategy. 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 ($13\text{cmol/kg}^{1/2}$ for SAR and



15% of ESP) for more than 3 continuous samplings then a contingency plan, which will include periodical soil irrigation, should be put in force.

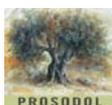
Anticipated benefits

In general, clinoptilolite succeeds to control the increase of the different soil parameters due to OMW disposal and thus, no rapid and irregular changes were recorded as may be recorded in soil that accepts OMW without zeolite treatment (an excellent example is the case of reduction and stabilization of soil organic matter and total nitrogen content).

In particularly, clinoptilolite is anticipated to positively affect

- Soil Organic Matter (OM) content. The use of clinoptilolite as soil amendment is anticipated to stabilize and to maintain soil OM values at constant values. This is owed to the improvement of soil aeration and thus to the enhancement of soil microorganism activity to biodegrade soil organic matter. Soil aeration can be improved by using zeolite of larger grain (0.8-2.5mm).
- Total nitrogen. The effect of zeolite on total N content is similar to that on OM content and due to the same reasons.
- Available Phosphorous. It is anticipated that available P will be reduced after zeolite application.
- Exchangeable Potassium and available metals (Fe, Cu and Mn). Exchangeable potassium and available metals (Fe, Cu and Mn) are anticipated to be increased in soil. The increase is owed to the retention of the ionic species 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, Fe, Mn, Cu 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.
- Soil Electrical Conductivity (EC), is anticipated to be reduced due to the retention of ions within zeolite framework. 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.
- Soil pH. For acidic soils and low in CaCO_3 , it is anticipated that the addition of clinoptilolite will enhance the neutralization of OMW's acidity.

On the other hand, no significant effect is anticipated on polyphenols content and for this reason it is proposed that in case of degraded areas that accept disposal of olive oil mills wastes the methods of bioremediation and application of clinoptilolite could be used in combination, however starting from bioremediation. It is thus anticipated that polyphenols will be degraded during bioremediation while the zeolite application will ensure the stabilization and reduction of the total organic matter nitrogen and phosphorous content, while at the same time will control the concentration of K, and available metals.

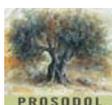


Moreover, clinoptilolite is proposed to be used as soil additive of no more than 2% w/w in case of use OMW for irrigation in order to assist soil system (especially soils rich in sand) to retain nutrients and increase cation exchange capacity, properties that are reduced due to the OMW acidity.

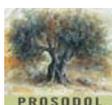
5 References

5.1 Literature

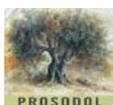
- Abreu, C.A., Raij, B., Abreu, M.F., González, A.P. 2005. Routine soil testing to monitor heavy metals and boron. *Scient. Agric.*, 62, 564-571.
- Adriaanse, A. (1993). *Environmental Policy Performance Indicators*. SDV Publishers, The Hague.
- Aggarwal, P.K., Means, J.L., Hinchee, R.E., Headington, G.L., and Gavaskar, A.R. (1990) "Methods to Select Chemicals for In-Situ Biodegradation of Fuel Hydrocarbons," Air Force Engineering and Services Center, Tyndall AFB, FL.
- Anastasiou C.C, Christou P., Michael A., Nicolaides D., Lambrou T. (2011), Approaches to olive mill wastewater treatment and disposal in Cyprus, *Environmental Research Journal*, 5(2), 49-58
- Arshad, M.A., Martin, S. 2002. Identifying critical limits for soil quality indicators in agro-systems. *Agric. Ecosys. Environ.*, 88, 153-160.
- Bish, D.L. (1993). *Natural Zeolites '93: Occurrence, Properties, Use*; Ming, D.W., Mumpton, F.A. (Eds), International Committee on Natural Zeolites: New York, USA, pp 259-269.
- Cabrera F., Lopez R., Martinez-Borditi A., Dupuy de Lome E., Murillo J.M. (1996), *Land Treatment of Olive Oil Mill Wastewater*, *International Biodeterioration & Biodegradation*, 215-225
- Carrow, R.N., Stowell, L., Gelernter, W., Davis, S., Duncan, R.R., Skorulski, J. 2004. Clarifying soil testing: III. SLAN sufficiency ranges and recommendations. *Golf Course Manag.*, 72, 194-198.
- Casa R., D'Annibale A., Pieruccetti F., Stazi S.R., Giovannozzi G., Lo Cascio B. (2003), Reduction of the phenolic components in olive-mill wastewater by an enzymatic treatment and its impact on durum wheat (*Triticum durum* Desf.) germinability, *Chemosphere* 50, 959-966



- CCME 2007. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Canadian Council of Ministers of the Environment.
- Chartzoulakis, K., Psarras, G., Moutsopoulou M., Stefanoudaki, E. 2010. Application of olive mill wastewater to a Cretan olive orchard: Effects on soil properties, plant performance and the environment. *Agric., Ecosys. Environ.* 138, 293-298.
- CLEA, Contaminated Land Exposure Assessment (project) 2005. SGV8, Soil Guidelines Values for Phenol Contamination, R&D publications.
- Coppola, E.I., Battaglia, G., Bucci, M., Ceglie, D., Colella, A., Langella, A., Buondonno, A., Colella, C. (2003). Remediation of Cd- and Pb-polluted soil by treatment with organozeolite conditioner, *Clays and Clay Minerals*. 2003; 51: 609–615.
- Council Directive 86/278/EEC. European Communities (Drinking Water) (No. 2) Regulations 2007. S.I. No. 278 of 2007. Dublin: The Stationary Office.
- Couwenberg, J. 2009. Emission factors for managed peat soils (organic soils, histosols). An analysis of IPCC default values Greifswald University Wetlands International, Ede, www.wetlands.org, UN-FCCC meeting, Bonn, June 2009.
- D'Annibale, A., Casa R., Pieruccetti F., Ricci M. and Marabottini R. (2004), *Lentinula edodes* removes phenols from olive-mill wastewater: impact on durum wheat (*Triticum durum* Desf.) germinability, *Chemosphere* 54: 887–894.
- Daly, D. 2004. Groundwater at Risk in Ireland - Putting Geoscientific Information and Maps at the Core of Land Use and Environmental Decision-making, John Jackson Memorial Lecture, Royal Dublin Society, November 2004.
- Di Serio, M.G., Lanza, B., Mucciarella, M.R., Russi, F., Iannucci, E., Marfisi, P., Madeo, A. 2008. Effects of olive mill wastewater spreading on the physico-chemical and microbiological characteristics of soil. *Int. Biodeter. Biodegr.*, 62, 403–407
- Doran, J.W., Parkin, T.B. 1996. Quantitative indicators of soil quality: a minimum data set. In: Doran, J.W., Jones, A.J. (eds.). *Methods for assessing soil quality*. Soil Science Society of America, Madison, WI, pp. 25-38.
- Doran, J.W., Sarrantonio, M., Liebig, M.A., 1996. Soil health and sustainability. *Advances in Agronomy* 56, 1–54.
- Doran, J.W., Zeiss, M.R., 2000. Soil health and sustainability: managing the biotic component of soil quality. *Applied Soil Ecology* 15, 3–11.

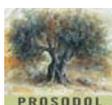


- Doula, M., Ioannou, A., Dimirkou, A. (2002) Copper adsorption and Si, Al, Ca, Mg and Na release from clinoptilolite. *Journal of Colloid and Interface Science*, 245, 237-250.
- Dyer, A. (1995). *Mineral Surfaces*, Vaughan, D.J., Patrick, R.A.D. (Eds), Chapman & Hall: London, UK., pp. 333-354.
- EC (2001), *Biological Treatment of Biowaste*, Working Document, 2nd Draft, European Commission
- EC (2004), *Draft discussion document for the ad hoc meeting on biowastes and sludges*, 15-16 January 2004, Brussels, Directorate General, European Commission
- EC (2006), *Thematic Strategy for Soil Protection*, European Commission
- EC (2006b), *Proposal for a Directive Of The European Parliament And Of The Council establishing a framework for the protection of soil and amending Directive 2004/35/EC*, European Commission
- EC (2007), *On the Interpretative Communication on waste and by-products*, Commission of the European Communities, Brussels
- EC (2008), *Green Paper On the management of bio-waste in the European Union*, COM(2008) 811 final, European Commission
- EC (2011), European Commission website, Environment/Waste webpage: <http://ec.europa.eu/environment/waste/sludge/index.htm>
- EC (2011b), European Commission website, Environment/Water webpage: http://ec.europa.eu/environment/water/water-urbanwaste/legislation/directive_en.htm
- EC (2012), *The implementation of the Soil Thematic Strategy and ongoing activities*, Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 13.2.2012
- EC-DG (2001) *Survey of wastes spread on land*, Final Report, European Commission, Directorate-General For Environment
- EC-DG (2001b), *Pollutants in urban waste water and sewage sludge*, European Commission, DG Environment, Luxembourg: Office for Official Publications of the European Communities
- EC-DG (2009), *Environmental, economic and social impacts of the use of sewage sludge on land*, Consultation Report on Options and Impacts, Report by RPA, Milieu Ltd and

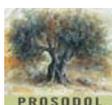


WRc for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r

- ECA (2010), Guidance on waste and recovered substances, Draft Version 3.2, European Chemicals Agency
- ECOIL (2005), LIFE+ project, “Life Cycle Assessment (LCA) as a Decision Support Tool (DST) for the ecoproduction of olive oil”, Deliverable 2, TASK 1, Recording and assessment of the existing situation, Chania, Greece
- Edwards, R., Rebedea, I., Lepp, N.W., Lovell, A.J. (1999). An investigation into the mechanism by which synthetic zeolites reduce labile metal concentrations in soils. *Environmental Geochemistry*, 21, 157–173.
- EEB (2005), EU Environmental Policy Handbook, A Critical Analysis of EU Environmental Legislation, European Environmental Bureau, Editor: Stefan Scheuer
- Environment Agency, 2001. Guidance on the disposal of contaminated soils. Version 3. UK, p. 32.
- EPA (2004), Landspreading of Organic Waste, Guidance on Groundwater Vulnerability Assessment of Land, Environmental Protection Agency, Ireland
- Eriksson E., Christensen N., Schmidt J.E., Ledin A. (2008), Potential priority pollutants in sewage sludge, *Desalination* 226, 371–388
- Feria, A.L. 2000. The generated situation by the O.M.W. in Andalusia, *Actas/Proceedings-Workshop Improlive*, Annex A1, 55-63. FAIR CT96 1420.
- Garner, A. 1981. Crevice corrosion of stainless steels in sea water: Correlation on field data with laboratory ferric chloride tests. *Corrosion* 37:178–184.
- Geebelen, W., Vangronsveld, J., Adriano, D.C., Carleer, R., Clijsters, H. (2002). Amendment induced immobilization of lead in a lead spiked soil: Evidence from phytotoxic studies. *Water, Air, Soil Pollution*, 140, 261–277.
- Hamdi, M. (1992), Toxicity and biodegradability of olive mill wastewaters in batch anaerobic digestion, *Appl Biochem Biotech* 37: 155–163
- HORIZONTAL (2012), Project website: <http://horizontal.ecn.nl/home/>
- Hu, Q., Qiu, Y. B., Guo, X. P., and Huang, J. Y. 2010. Crevice corrosion of Q235 carbon steels in a solution of NaHCO₃ and NaCl, *Corrosion Science* 52:1205–1212.



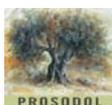
- Hytiris N., Kapellakis I.E., La Roij de R., Tsagarakis K.P. (2004), The potential use of olive mill sludge in solidification process, *Resources, Conservation and Recycling* 40, 129–139
- Ilico, B.V. 1985. *Agricultural Compendium, For Rural Development in the Tropics and Subtropics*. Elsevier.
- IMPEL (2003), *Olive Oil Project, European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL)*, EU
- IPPC BREF (2006) *Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the, Food, Drink and Milk Industries*, European Commission
- IPPC BREF (2006b) *Integrated Pollution Prevention and Control, Member States' national legislation and standards, Additional information provided by the TWG of the "Food, Drink and Milk Industries BREF"*, European Commission
- ISO 11268-1:1993: *Soil quality -- Effects of pollutants on earthworms (Eisenia fetida) -- Part 1: Determination of acute toxicity using artificial soil substrate*
- ISO 14238:1997. *Soil quality -- Biological methods -- Determination of nitrogen mineralization and nitrification in soils and the influence of chemicals on these processes*
- ISO 14240-1:1997. *Soil quality - Determination of soil microbial biomass -- Part 1: Substrate-induced respiration method*
- ISO 22030:2005. *Soil quality - Biological methods -- Chronic toxicity in higher plants*
- JHACE, *Journal of the Hellenic Association of Chemical Engineers*, Issue No 203, 6-10, 2012
- JRC (2012), *The State of Soil in Europe*, Joint Research Centre, European Commission
- Kabata-Pendias, A., Pendias, H. 1994. *Trace elements in soils and Plants*. CRC Press, Inc. Florida, USA
- Kapellakis I.E., Tsagarakis K.P., Avramaki C.H., Angelakis A.N. (2006), Olive mill wastewater management in river basins: A case study in Greece, *Agricultural Water Management* 82, 354–370
- Kapellakis I.E., Tsagarakis K.P., Crowther J.C. (2008), Olive oil history, production and by-product management, *Rev Environ Sci Biotechnol*, 7:1–26
- Karaouzas I., Skoulikidis N.T., Giannakou U., Albanis T.A. (2011), Spatial and temporal effects of olive mill wastewaters to stream macroinvertebrates and aquatic ecosystems status, *Water Research* 45



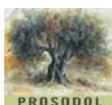
- Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F., Schuman, G.E. 1997. Soil quality: a concept, definition, and framework for evaluation. *Soil Sci. Soc. Am. J.*, 61, 4–10.
- Kavvadias V., Doula M.K., Komnitsas K., Liakopoulou N. (2010), Disposal of olive oil mill wastes in evaporation ponds: Effects on soil properties, *Journal of Hazardous Materials* 182, 144–155
- Kavvadias, V. Komnitsas, K., Doula, M. 2011. Long term effects of Olive Mill Wastes disposal on soil fertility and productivity. In: *Hazardous Materials-Types, Risks and Control*, S.K. Brar (ed.) Nova Science Publishers, inc, ISBN 978-1-61324-425-8.
- Kayabali, K., Kezer, H. (1998). Testing the ability of bentonite-amended natural zeolite (clinoptilolite) to remove heavy metals from liquid waste. *Environmental Geology*, 34, 95-102.
- Komnitsas, K., Guo, X., Li, D. 2010. Mapping of soil nutrients in an abandoned Chinese coal mine and waste disposal site *Mapping of soil nutrients in an abandoned Chinese coal mine and waste disposal site. Min. Eng.*, 23, 627-635.
- 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. *Environ. Forens.*, 12, 319-326.
- Langenkamp H., Part P., Erhardt W., Prüß A. (2001), Organic contaminants in sewage sludge for agricultural use, European Commission, Joint Research Centre, Institute for Environment and Sustainability, Soil and Waste Unit
- LIFE Focus (2010), LIFE among the olives, Good practice in improving environmental performance in the olive oil sector, European Commission Environment, Directorate-General
- Linzon, S.N. 1978 Phytotoxicity excessive levels of contaminants in soil and vegetation Report of Ministry of the Environment Ontario, Canada.
- MAAF 1988. Fertilizer Recommendations. Reference Book 209. HMSO, London.
- MAFF, Dept. of Environment. 1989. Code of Practice for agricultural use of sewage sludge. London.
- Marx, E.S., Hart, J., Stevens, R.G. 1999. Soil Test Interpretation Guide EC 1478 Extension & Station Communications, Oregon State University.



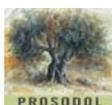
- McDowell, R.W., Condon, L.M., Mahieu, N., Brookes, P.C., Poulton, P.R., Sharpley, A.N. 2002. Analysis of Potentially Mobile Phosphorus in Arable Soils Using Solid State Nuclear Magnetic Resonance. *J. Environ. Qual.*, 31,450-456.
- Mechri, B., Ben Mariem, F., Braham, M., Ben Elhadj, S., Hammami, M. 2008. Changes in soil properties and the soil microbial community following land spreading of olive mill wastewater affects olive trees key physiological parameters and the abundance of arbuscular mycorrhizal fungi. *Soil Biol. Biochem.*, 40, 152-161.
- MED-EUWI (2007) Mediterranean Wastewater Reuse Report, Mediterranean Wastewater Reuse Working Group (MED WWR WG), November 2007
- MEECC (2012) Proposal for repealing of the Ministerial Decision on Sewage Sludge, Ministry of Environment, Energy and Climate Change, Greece
- Mekki, A., Dhouib, A., Sayadi, S. 2006. Changes in microbial and soil properties following amendment with treated and untreated olive mill wastewater. *Microbiol. Res.* 161, 93-101.
- Mekki, A., Dhouib, A., Sayadi, S. 2007. Polyphenols dynamics and phytotoxicity in a soil amended by olive mill wastewaters. *J. Environ. Manag.* 84,134–140.
- Mitra, G.N., Sahu, S.K., Nayak, R.K. 2009. Ameliorating effects of potassium on iron toxicity in soils of Orissa In: *The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage*. IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India.
- Modis, K., Papantonopoulos, G., Komnitsas, K., Papaodysseus, K. 2008. Mapping optimisation based on sampling in earth related and environmental phenomena. *Stoch. Environ. Res. Risk Assess.*, 22, 83-93.
- MORE (2008) Market of olive residues for energy, Intelligent Energy for Europe (IEE) project, Deliverable 3.1, One joint report for the 5 Regional “state of the art” reports from each involved area describing the current olive-milling residues market with a focus on energy uses
- MORE (2009) Market of olive residues for energy, Intelligent Energy for Europe (IEE) project, Deliverable 2.2 “Joint report gathering 5 roadmaps”



- Mumpton, F.A. (1988). Development of uses for natural zeolites: A critical commentary, Occurrence, Properties and Utilization of Natural Zeolites. Kallo D, Sherry H, (eds.). Akadémiai Kiadó, Budapest pp. 333-366.
- Nair N.G, Markham D.J. (2008), Recycling Solid Waste from the Olive Oil Extraction Process, RIRDC Pub. No. 08/165, Rural Industries Research and Development Corporation, Australian Government
- Niaounakis, M., Halvadakis, C.P. (2006). Olive processing waste management: literature review and patent survey, second ed. Elsevier, Amsterdam.
- Nikolaidis, N., Kalogerakis, N., Psyllakis, E., Tzorakis, O., Moraitis, D., Stamati, F., Valta, K., Peroulaki, E., Vozinakis I., Papadoulakis, V. 2008. Agricultural Product Waste Management in Evrotas River Basin-Envifriendly Technology Report #3 May 2008, LIFE05ENV/GR/00045, p 21.
- OECD (1993). Organization for Economic Cooperation and Development Core Set of Indicators for Environmental Performance Reviews. A Synthesis Report by the Group on the State of the Environment. OECD, Paris.
- Ouzounidou G., Zervakis G.I., Gaitis F. (2010), Raw and Microbiologically Detoxified Olive Mill Waste and their Impact on Plant Growth, Terrestrial and Aquatic Environmental Toxicology, Global Science Books
- Paraskeva, P. and Diamadopoulos E. (2006), Technologies for olive mill wastewater (OMW) treatment: a review, J Chem Technol Biotechnol 81: 1475–1485
- Paredes, M.J., Monteoliva-Sanochez M., Moreno E., Perez J., Ramos-Cormenzana A. and Martinez J. (1986), Effect of waste waters from olive oil extraction plants on the bacterial population of soil, Chemosphere 15: 659–664
- Pollak, M., Favoino, E. 2004. Heavy metals and organic compounds from wastes used as organic fertilisers. Final Report - July 2004 ENV.A.2./ETU/2001/0024
- RES-HUI (2006), Integrated Management of Olive Oil-Mill residues and wastewater/RES-HUI, Project num. C3-06, INTEREG IIIC project, Dipartimento di Energetica “Sergion Stecco”, Università degli Studi di Firenze
- Rodis, P.S., Karathanos, V.T., Mantzavinou, A. (2002), Partitioning of olive oil antioxidants between oil and water phases. Journal of Agricultural and Food Chemistry 50, 596-601



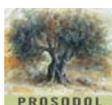
- Saadi I., Raviv M., Hanan A., Medina S., Laor Y. (2010), Fate and biodegradability of olive mill wastewater in a vetisol-type soil, Proceedings of the 2nd International Conference of IAMAW, June 17-19, Izmir, Turkey
- Shabou R., Zairi M., Kallel A., Aydi A., Dhia H.B. (2009), Assessing the effect of an olive mill wastewater evaporation pond in Sousse, Tunisia, *Environ Geol*, 58:679–686
- Shanableh, A., Kharabsheh, A. (1996). Stabilization of Cd, Ni, and Pb in soil using natural zeolite. *Journal of Hazardous Materials*, 45, 207–217.
- Shaw, D.J. (1992). Introduction to Colloid and Surface Chemistry, Butterworth-Heinemann Ltd., Oxford, UK, pp 123-124.
- Sierra J, Marti E, Garau AM, Cruñas R. 2007. Effects of the agronomic use of olive oil mill wastewater: field experiment, *Sci. Total Environ.*, 378: 90–94.
- Sierra, J., Martv, E., Montserrat, G., Cruñas, R., Garau, M.A. 2001. Characterization and evolution of a soil affected by olive oil mill wastewater disposal, *Sci. Total Environ.*, 279, 207–214.
- Sims, J.L., Sims, R.C., and Matthews, J.E., 1989. Bioremediation of contaminated surface soils. US EPA report n° EPA-600/9-89/073.
- Soil Science Society of America, 1986. Utilization, treatment and disposal of waste on land. Proc of a workshop held in Chicago 6-7 Dec., U.S.A.
- Stamatakis G. (2010), Energy and geo-environmental applications for Olive Mill Wastes. A review, *Hellenic Journal of Geosciences*, vol. 45, 269-282
- Streicher, M. A. 1974. Development of pitting resistant Fe-Cr-Mo alloys. *Corrosion* 30:77–91.
- Stylianou M.A, Inglezakis V.J., Moustakas K.G., Loizidou M.D. (2008), Improvement of the quality of sewage sludge compost by adding natural clinoptilolite, *Desalination*, 224, 240–249
- Swartjes, F. 1999. Risk-Based Assessment of Soil and Groundwater Quality in the Netherlands: Standards and Remediation Urgency. *Risk Anal.*, 19,1235-1249.
- Taccogna G. (2010), The legal regime of olive pomace deriving from olive oil extraction at olive mills, waste, by-products and biomass, Department of Public and Procedural Law, University of Genoa, on behalf of ARE s.p.a. - Agenzia regionale per l'energia della Liguria, member of the community project: “*MORE: Market of Olive Residues for Energy*”



- U.S-EPA. Environmental Protection Agency (1983) Hazardous waste land treatment. SW-874, U.S. Environmental Protection Agency, Cincinnati, OH
- UK Environmental Agency (2005), Hazardous Waste, Technical Guidance WM2, UK
- US-EPA (1991) “Understanding Bioremediation: A Guidebook for Citizens,” EPA/540/2-91/002, Office of Research and Development, Washington, D.C.
- Vidali, M. 2001. Bioremediation. An overview. *Pure and Applied Chemistry*, 73: 1163-1172.
- Whitehouse P. (2001), Measures for Protecting Water Quality: Current Approaches and Future Developments, *Ecotoxicology and Environmental Safety* 50, 115-126
- Zafra A., Juarez M.J.B., Blanc R., Navalon A., Gonzalez J., Vilchez J.L. (2006), Determination of polyphenolic compounds in wastewater olive oil by gas chromatography–mass spectrometry, *Talanta* 70, 213–218
- Zhou, Q. 1996. Soil-quality guidelines related to combined pollution of chromium and phenol in agricultural environments. *Human Ecol. Risk Assess. Int. J.* 2, 591 – 607.
- Zorpas A., Inglezakis V.J. (2011), *Sludge Management. From the past to our century*, Nova Science Publishers, Inc.
- Theocharopoulos, S. P., Trikatsoula, A., Davidson, D. A., Tsouloucha, F., Vavoulidou, E., 1998. A Land Information System as a tool to assist decisions on the application of sewage sludge on agricultural land in Greece. In: Heineke, H. J. et al., 1998 (eds) *Land Information Systems: Developments for planning the sustainable use of land resources*. European Soil Bureau, JRC, I-21020 Ispra ,pp. 373-380.

5.2 EU Legislation

- COM (2006) 231 final. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, “Thematic Strategy for Soil Protection”.
- Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances
- Council Directive 91/689/EEC of 12 December 1991 on hazardous waste
- Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control



Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management

Council Directive 86/279 on the protection of the Environment and in particular soil when sewage sludge is used in agriculture.

Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91

Decision 2006/799/EC of 3 November 2006 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to soil improvers

Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

European Communities, Commission Decision 2000/532/EC of 3 May 2000

European Regulation (EC) No 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures (CLP Regulation), adopting in the EU the Globally Harmonised System (GHS)

Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

Council Directive 1999/31/EC on the landfill of waste

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast)

Council Directive 75/440/EEC of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the Member States.

Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water.

Council Directive 76/464/EEC of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community.



Directive 2008/105/EC of the European parliament and of the Council of 16 December 2008, on environmental quality standards in the field of water policy.

Council Directive 78/659/EEC of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life.

Council Directive 79/923/EEC of 30 October 1979 on the quality required of Shellfish Waters.

Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances.

Council Directive 91/271/EEC concerning urban wastewater treatment was adopted on 21 May 1991 to protect the water environment from the adverse effects of discharges of urban waste water and from certain industrial discharges.

Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption.

Decision 2455/2001/EC of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC.

Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration.

Directive 2008/105/EC of the European parliament and of the Council of 16 December 2008, on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council.

5.3 National Legislation

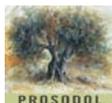
Decreto Legislativo, 3 Aprile 2006, n. 152, Norme in materia ambientale, pubblicato nella Gazzetta Ufficiale n. 88 del 14 Aprile 2006 – sup. Ord. n. 96



- Legge 11 Novembre 1996, N. 574 (Gu N. 265 Del 12/11/1996) Nuove Norme In Materia Di Utilizzazione Agronomica Delle Acque Di Vegetazione E Di Scarichi Dei Frantoi Oleari
- Legge ordinaria del Parlamento n° 748 del 19/10/1984, Nuove norme per la disciplina dei fertilizzanti, Doc. 284A0748.900 di Origine Nazionale e pubblicato/a su : Gazz. Uff. Suppl. Ordin. n° 305 del 06/11/1984, riguardante:AMBIENTE - Sostanze pericolose - Fitosanitari e Fertilizzanti
- D.Lgs. Governo n° 217 del 29/04/2006 Revisione della disciplina in materia di fertilizzanti, AMBIENTE - Sostanze pericolose - Fitosanitari e Fertilizzanti
- Ministério Do Ambiente, Decreto-Lei n.o 236/98 de 1 de Agosto, Diário Da República — I Série-A, N.o 176 — 1-8-1998
- Ministérios Da Agricultura, Do Desenvolvimento Rural E Das Pescas E Do Ambiente E Do Ordenamento Do Território, Despacho Conjunto n.o 626/2000 de 19 de Maio, Estabelece as normas de utilização das águas ruças para rega de solos agrícolas
- Ministero Delle Politiche Agricole E Forestali, Decreto 6 Luglio 2005, Criteri e norme tecniche generali per la disciplina regionale dell'utilizzazione agronomica delle acque di vegetazione e degli scarichi dei frantoi oleari, di cui all'articolo 38 del decreto legislativo 11 maggio 1999, n. 152
- Real Decreto 258/1989, De 10 De Marzo, Por El Que Se Establece La Normativa General Sobre Vertidos De Sustancias Peligrosas Desde Tierra Al Mar
- Decree 4/2011 of the Regional Government of Andalusia, Decreto 4/2011, de 11 de enero, por el que se regula el régimen del uso de efluentes de extracción de almazara como fertilizante agrícola
- Real Decreto 849/1986, de 11 de abril, por el que se aprueba el Reglamento del Dominio Público Hidráulico
- KYA 145116/2011, Καθορισμός μέτρων, όρων και διαδικασιών για την επαναχρησιμοποίηση επεξεργασμένων υγρών αποβλήτων και άλλες διατάξεις.
- Υπουργική Απόφαση, Όροι διαθέσεως των λυμάτων και υγρών βιομηχανικών αποβλήτων σε φυσικούς αποδέκτες και καθορισμός της ανώτερης τάξεως χρήσης των υδάτων τους στο Νομό Θεσσαλονίκης, ΦΕΚ 82/B/94 (10/2/1994)



Υπουργική Απόφαση: ΥΓ.179182/656/79, Περί διαθέσεως υγράναποβλήτων, από τις παραγωγικές διαδικασίες των βιομηχανικών περιοχών Μείζονος Πρωτεύουσας, δια του δικτύου υπνόμων και των ρευμάτων που εκτρέπονται στον Κ.Α.Α. και που αποπετούνται από τον Ο.Α.Π., με αποδέκτη τη θαλάσσια περιοχή Κερασινίου Πειραιώς (ΦΕΚ 582/Β/2-07-79)



6 ANNEX 1: Critical levels of some main soil properties

Table 1. Critical levels of some main soil properties.

Soil properties	normal/average range	high/rich	very high	excessive	Comments
pH	6-8 ^[1]				
EC				>4 mS/cm (salinity) ^[2-5]	
	2 mS/cm ^[1]				soil quality threshold
Soil organic matter	> 3.4% ^[6]	> 5% ^[2-5]			
Total Kjeldahl Nitrogen		> 0.3 % ^[2-5]			
Available P-Olsen	12-28 mg/kg ^[7]		40-50 mg/kg ^[2-5]		
			>33-36 ^[8]		
			>59 mg/kg ^[9] , >60 mg/kg ^[28]		potential high P mobility
Exchangeable Mg	1.2-2.2 cmol/kg ^[7]		> 2.2 cmol/kg * ^[2-5]		* -Nutrient imbalances due to Mg antagonism -Adverse effect on soil quality
Exchangeable K	0.26-0.60 cmol/kg ^[7]		>1.2 (cmol/kg) ^[2-5]	>2.0 cmol/kg ^[10]	
Exchangeable Ca	2.5-3.8 cmol/kg ^[7]		> 20 cmol/kg ^[2-5]		
Hot water soluble B	0.5-1.5 mg/kg ^[7]	1.6-3 mg/kg ^[11]		>3mg/kg ^[11]	For medium to heavy soils in texture
				>2.0 -3.0 mg/kg ^{[12]*} >5 mg/kg ^{[13]*}	* phytotoxicity
DTPA-Cu		> 3 mg/kg ^[2-5]		>20 mg/kg ^[29] *	* potential phytotoxicity
			1.6-15 mg/dm ³ ^[14]		
DTPA-Fe			> 50 mg/kg	> 100 mg/kg ^[15]	
			25-60 mg/dm ³ ^[14]		
DTPA-Mn			> 50 mg/kg ^[2-5]		
			10-50 mg/dm ³ ^[14]		
DTPA-Zn			> 8.1 mg/kg ^[2-5]		
			2.4-15 mg/dm ³ ^[14]	> 130 mg/dm ³ ^[12]	

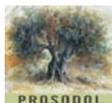
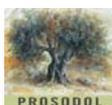


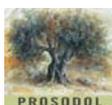
Table 2. Critical levels of some main soil properties.

Soil properties	normal/average range	high/rich	very high	excessive	Comments
Residual NO ₃ -N NO ₃			20-30 mg/kg ^[10] 88-132mg/kg	>30 mg/kg ^[10] >132 mg/kg	
NO ₃ ⁻ in soil solution	2-60 mg/l ^[38,39,43-45]				Average range
SO ₄ ²⁻ in soil leachate			144-150 mg/l ^[16]		Leachate Quality Threshold
SO ₄ ²⁻ -S in soil	>10 ppm ^[10] or > 30 ppm as SO ₄ ²⁻				
Cl in soil leachate			160-200 mg/l ^[16]		Leachate Quality Threshold
Cl ⁻ in soil	4-8 ppm ^[10]	>8 ppm ^[10]			
NH ₄ ⁺ in soil leachate			> 10 mg/L ^[17]		Leachate Quality Threshold
NH ₄ -N in soil	2-10 ppm ^[10] or up to 12.8 ppm in NH ₄ ⁺ form				
Extractable NH ₄ ⁺			28-280 mg/l ^[18]		
Phenols			target value : 0.05 mg/kg ^[19]		<target value: clean soil; <target value < intervention value: slight contaminated soil ; >intervention value: contaminated soil
			intervention value 40 mg/kg ^[19]		

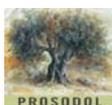


6.1 References of ANNEX 1

1. CCME 2007. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Canadian Council of Ministers of the Environment.
2. MAAF, 1988. Fertilizer Recommendations. Reference Book 209. HMSO, London.
3. Ilaco, B.V. 1985. Agricultural Compendium, For Rural Development in the Tropics and Subtropics. Elsevier.
4. Panagiotopoulos, L. 1995a. Potato fertilization, In: Sustainable Crop Fertilization, Review. Agriculture Crop and Animal Husbandry. The Greek Review of Science, Technology and Business in Agriculture, Agro Typos SA, pp 227-231.
5. Panagiotopoulos, L. 1995b. Cucumber Fertilization, In: Sustainable Crop Fertilization, Review. Agriculture Crop and Animal Husbandry. The Greek Review of Science, Technology and Business in Agriculture, Agro Typos SA, pp 250-256.
6. Loveland P., Webb, J. 2003. Is there a critical level of organic matter in the agricultural soils of temperate regions: a review *Soil Till Res.*, 70, 1–18.
7. Carrow, R.N., Stowell, L., Gelernter, W., Davis, S., Duncan, R.R., Skorulski, J. 2004. Clarifying soil testing: III. SLAN sufficiency ranges and recommendations. *Golf Course Manag.*, 72, 194-198.
8. McDowell, R.W., Sharpley, A.N. 2001. Approximating phosphorus release from soils to surface runoff and subsurface drainage. *J. Environ. Qual.*, 30, 508-520.
9. McDowell, R.W., Condon, L.M., Mahieu, N., Brookes, P.C., Poulton, P.R., Sharpley, A.N. 2002. Analysis of Potentially Mobile Phosphorus in Arable Soils Using Solid State Nuclear Magnetic Resonance. *J. Environ. Qual.*, 31,450-456.
10. Marx, E.S., Hart, J., Stevens, R.G. 1999. Soil Test Interpretation Guide EC 1478, Extension & Station Communications, Oregon State University.
11. Kelling, K.A. 1999. Soil and Applied Boron (A2522), University of Wisconsin System Board of Reagents and University of Wisconsin Extension, Cooperative Extension, Dept. Agri. , US
12. Alloway, B.J. 1995. Heavy metals in soils. London: Blackie Academic & Professional, p. 368.
13. Ponnampuruma, F.N., Lantin, R.S., Cayton, M.T.C. 1979. Boron toxicity in rice soils. *Int. Rice Res. Newsletter* 4, 8.
14. Abreu, C.A., Rajj, B., Abreu, M.F., González, A.P. 2005. Routine soil testing to monitor heavy metals and boron. *Scient. Agric.*, 62, 564-571.
15. Mitra, G.N., Sahu, S.K., Nayak, R.K. 2009. Ameliorating effects of potassium on iron toxicity in soils of Orissa In: The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage. IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India.
16. Environment Agency, 2001. Guidance on the disposal of contaminated soils. Version 3. UK, p. 32.
17. Komnitsas, K., Guo, X., Li, D. 2010. Mapping of soil nutrients in an abandoned Chinese coal mine and waste disposal site Mapping of soil nutrients in an abandoned Chinese coal mine and waste disposal site. *Min. Eng.*, 23, 627-635.
18. Wolt, J. 1994. Soil solution Chemistry: Applications to Environmental Science and Agriculture. John Wiley and Sons, New York.



19. Swartjes, F. 1999. Risk-Based Assessment of Soil and Groundwater Quality in the Netherlands: Standards and Remediation Urgency. *Risk Anal.*, 19, 1235-1249.
20. Rose, A.W., Hawkes, H.E., Webb, J.S. 1979. *Geochemistry in Mineral Exploration*. Academic Press, London, p. 657.
21. Levinson, A.A. 1974. *Introduction to Exploration Geochemistry*. Applied Publishing Ltd., Wilmette, Illinois, p. 614.
22. Kabata-Pendias, A., Pendias, H. 1984. *Trace elements in soils and plants*. CRC Press, Inc., Boca Raton, Florida, p. 315.
23. Komnitsas, K., Modis, K. 2009. Geostatistical risk estimation at waste disposal sites in the presence of hot spots. *J. Hazard. Mat.*, 164, 1185–1190.
24. Fergusson, J.E. 1990. *The Heavy Elements. Chemistry, Environmental Impact and Health Effects*. Pergamon Press, Oxford, UK.
25. Linzon, S.N. 1978 *Phytotoxicity excessive levels of contaminants in soil and vegetation* Report of Ministry of the Environment Ontario, Canada.
26. European Communities (Drinking Water) (No. 2) Regulations 2007. S.I. No. 278 of 2007. Dublin: The Stationary Office.
27. Pollak, M., Favoino, E. 2004. Heavy metals and organic compounds from wastes used as organic fertilisers. Final Report - July 2004 ENV.A.2./ETU/2001/0024
28. Parkin, T.B., Robinson, J.A. 1992. Analysis of Lognormal Data. *Advances in Soil Sciences*, Vol. 20, pp. 193-325.
29. CFL 1983. *Soil Analysis Service Interpretation Charts*. Consolidated Fertilizers Limited, Morningside, Queensland, Australia.



7 ANNEX 2: Soil Indicators-Determination and Evaluation

1. Electrical Conductivity

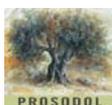
Definition: The potentiometric measurement in mS/cm or dS/m at 25°C of soil electrical conductivity in soil suspension at a monitoring site at a specific point in time (Rhoades, 1996).

Table 1.1 Salinity Risk classes based on the soil electrical conductivity (Ilaco, 1985; MAAF, 1988; CCME, 2007).

Salinity risk	Electrical Conductivity mS/cm
None to slight	2
Moderate	2-3
High	3-4
Very high	>4

Table 1.2 Routine and requirements for the determination of soil Electrical Conductivity

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for physico-chemical analyses
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Sample EC	ISO 1265:1994	Soil quality - Determination of the specific electrical conductivity



2. Organic Matter

Definition: The measured, gravimetric proportion of soil organic matter (%) in dry soil at a monitoring site at a specific point in time (Nelson and Sommers, 1987).

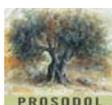
Table 2.1 Sufficiency levels of organic matter content of soils (Ilaco, 1985; MAAF, 1988; Loveland and Webb, 2003; CCME, 2007)

Sufficiency level of SOM	Organic Matter, %
very low	< 1
low	1-2
moderately sufficient	2-3
sufficient	3-5
rich	>5

Table 2.2 Routine and requirements for the determination of soil organic carbon content.

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for physico-chemical analyses
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Dry matter and water content	ISO 11465:1993	Soil quality-Determination of dry matter and water content on a mass basis-Gravimetric method
Organic Carbon	ISO 14235:1998	Soil quality - Determination of organic carbon in soil by sulfochromic oxidation.
Organic Carbon	ISO 10694:1995	Soil quality - Determination of organic and total carbon after dry combustion (elemental analysis)

3. Total Nitrogen



Definition: The measured, gravimetric proportion of total nitrogen in dry soil (mg/g) at a monitoring site at a specific point in time. Total soil N (mainly organic) is generally measured after wet digestion using the well-known Kjeldahl procedure. This procedure involves digestion and distillation.

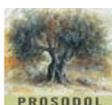
Table 3.1 Sufficiency levels of total soil nitrogen (Brady, 1990; Tisdale et al., 2003).

Sufficiency level	Total Nitrogen, mg/g
Very low	<1.1
Low	1.10-1.50
Moderately sufficient	1.50-2.00
Sufficient	2.00-3.00
Rich	>3.00

Table 3.2 Routine and requirements for the determination of soil total nitrogen.

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for physico-chemical analyses
Moisture content	ISO 11465:1993	Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method
Dry matter and water content	ISO 11465:1993	Soil quality-Determination of dry matter and water content on a mass basis-Gravimetric method
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Total Nitrogen	ISO 11261:1995.	Soil quality-Determination of total nitrogen-Modified Kjeldahl method.
Total Nitrogen	ISO 13878:1998	Soil quality-Determination of total nitrogen content by dry combustion (elemental analysis).

4. Total Polyphenols



Definition: The measured, gravimetric proportion of total polyphenols (mg/kg) dissolved in CH₃OH, in wet soil at a monitoring site at a specific point in time.

Olive Oil Mills Wastes are characterized by very high concentration of total polyphenols. The polyphenols concentration varied between 2-10 g/l and is depended on parameters such as the centrifugation system used by the olive oil mill, the quality and quantity of water used, the olive type and handling, etc. (Niaounakis and Halvadakis, 2006).

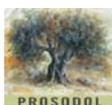
It is, thus, obvious that due to the very high polyphenols concentrations of OMW, soils that accept the disposal of OMW are under high degradation and phytotoxicity risks. Apart from the polyphenols content, the phytotoxicity of OMW has been attributed also to the presence of some organic acids such as acetic acid and formic acid, which are often produced along with other microbial metabolites during wastes storage (Della Greca et al., 2001)

Since no available thresholds are existed in the European legislative framework and in the literature, the most common practice is to set thresholds in a given sampling area by considering the polyphenols concentration of many control/clear samples. According to the international literature, soils normally contain no more than 40-50mg/kg polyphenols (Kavvadias et al., 2010). Regarding the methods for soil phenolics determination, the absence of an ISO prototype method, leads to the selection of one of the available methods in the literature, such as :

1. Extraction only with distilled water: Samples are mixed with water (1:10 w:v) and mechanically stirred during one hour. Another method refers the determination of polyphenols in an extract of a 2.5:1 water/soil ratio (Di Serio et al., 2008).
2. Extraction with distilled water and ethyl acetate. A 1/25 (w/v) soil/aqueous mixture is shaken for 12 h in a mechanical shaker and then the supernatant is extracted 3 times with ethyl acetate. The so collected organic fraction is dried and evaporated under vacuum. The residue is extracted twice with dichloromethane in order to remove the non-phenolic fraction (lipids, aliphatic and sugars). The liquid phase is discarded while the washed residue is proceeded to analyses (Allouche et al., 2004).
3. Extraction with methanol. Thirty ml of methanol/water (80:20) are added to 10g of soil and mixed at 15,000 g for 1 min and then centrifuged at 5000 x g for 10 min. The extraction is repeated two times. The combined methanolic extracts are concentrated in vacuum rotary evaporator at <35 °C and then the sample is dissolved in 5 ml gradient grade methanol and analyzed calorimetrically (Gutiérrez Gonzales-Quijano et al., 1977; Box, 1983)

The extracted polyphenols are quantified using Folin–Ciocalteu’s reagent (Box, 1983)

Table 4.1 Routine and requirements for the determination of soil polyphenols.



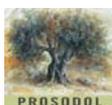
Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Moisture content	ISO 11465:1993	Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method
Dry matter and water content	ISO 11465:1993	Soil quality-Determination of dry matter and water content on a mass basis-Gravimetric method
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Polyphenols	Literature	1.Gutiérrez Gonzales-Quijano et al., 1977; Box, 1983; 2.Di Serio et al., 2008; Allouche et al., 2004

5. Available Phosphorous

Definition: The measured, gravimetric proportion of available phosphorous in mg/kg (i.e. P that can be taken up by plants), in dry soil at a monitoring site at a specific point in time.

Table 5.1 Methods for the determination of available Phosphorous (Olsen and Sommers, 1987).

Method	Extracting Solution	Restriction
Morgan	0.7N CH ₃ COONa 0.54N CH ₃ COOH, pH 4.8	Acid soils with CEC < 10meq/100g
Bray P1	0.03N NH ₄ F, 0.025N HCl	Acid soils (pH _{H2O} < 6.8), medium in soil texture
Bray P2	0.03N NH ₄ F, 0.1N HCl	Acid soils in which the main P source is phosphatic minerals and P is mainly bound to carbonates
Mehlich 1	0.05N HCl, 0.025N H ₂ SO ₄	Acid soils (pH _{H2O} < 6.5) with CEC < 10meq/100g and low organic content (<5%)



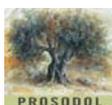
Olsen	0.5N NaHCO ₃ , pH 8.5	Neutral and alkaline soils, rich in calcium carbonate
AB-DTPA	1M NH ₄ CO ₃ , 0.005M DTPA pH 7.6	See Olsen method
Mehlich 3	0.2N CH ₃ COONa+0.015N NH ₄ F, 0.25N NH ₄ NO ₃ , 0.013N HNO ₃ , 0.001M EDTA	Acid soils
CaCl ₂	0.01M CaCl ₂ .2H ₂ O	All soil categories

Table 5.2 Sufficiency levels of available P in relation to the determination method (Tisdale et al., 2003).

P sufficiency level	Bray-Kurtz P1	Mehlich-3	Olsen
Very low	<5	<7	<3
Low	6-12	8-14	4-7
Medium	13-25	15-28	12-33
high	>25	>28	>33

Table 5.3 Routine and requirements for the determination of soil available phosphorous

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for physico-chemical analyses
Moisture content	ISO 11465:1993	Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method
Dry matter and water content	ISO 11465:1993	Soil quality-Determination of dry matter and water content on a mass basis-Gravimetric method
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Sample pH	ISO 10390:2005	Soil quality-Determination of pH
Olsen P	ISO 11263:1994.	Soil quality-Determination of



for soil pH \geq 7.0		phosphorous-Spectrometric determination of phosphorous soluble in sodium hydrogen carbonate solution.
Bray-Kurtz P1 Test for soil pH \leq 6.8	Literature	Bray and Kurtz, 1945; Olsen and Sommers, 1987
Mehlich-3 Test	Literature	Mehlich, 1984; Olsen and Sommers, 1987

6. Exchangeable Potassium

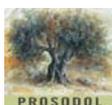
Definition: The measured, gravimetric proportion of exchangeable Potassium in cmol/kg (i.e the primary source of K for plant uptake), in dry soil at a monitoring site at a specific point in time. The exchangeable form is considered the primary source of K for plant uptake and is commonly determined through the determination of the soil Cation Exchange Capacity which includes extraction of the exchangeable cations (i.e. K^+ , Ca^{2+} , Mg^{2+} , Na^+). (Rhoades, 1982).

Table 6.1 Sufficiency levels of available K in relation to the determination method (MAAF, 1988; Marx et al., 1999).

Sufficiency level	Exchangeable Potassium, cmol/kg
Very low, low	< 0.1-0.2
Medium, sufficient	0.26-0.60
Very high	> 1.20
Excessive	> 2.00

Table 6.2 Routine and requirements for the determination of soil exchangeable Potassium.

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for physico-chemical analyses
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Moisture content	ISO 11465:1993	Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method
Dry matter and water content	ISO 11465:1993	Soil quality-Determination of dry matter and water content on a mass basis-Gravimetric method



Exchangeable Potassium	ISO 11260:1994	Soil quality-Determination of effective cation exchange capacity and base saturation level using barium chloride solution.
Exchangeable Potassium	ISO 13536:1995	Soil quality-Determination of the potential cation exchange capacity and exchangeable cation using barium chloride solution at pH=8.1.
Exchangeable Potassium	ISO 23470:2007	Soil quality-Determination of effective cation exchange capacity (CEC) and exchangeable cations using hexamminecobalt trichloride solution.
Exchangeable Potassium	Literature	Extraction with Ammonium Acetate at pH 7.0 (Schollenberger, 1927; Knudsen et al., 1987)

7. Available Iron

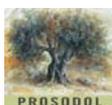
Definition: The measured, gravimetric proportion of available iron in mg/kg (i.e Fe available to plants), in dry soil at a monitoring site at a specific point in time. The readily available to plants part of the total quantity of iron includes the ionic amounts in solution plus the complexed and adsorbed quantities that are in equilibrium with that which exists in solution as dissociated cations (Olson and Ellis, 1987).

Table 7.1 Sufficiency levels of available Iron (Abreu et al., 2005).

Sufficiency level	Available Iron, mg/kg
Very low	<3
Low	4-11
Medium	12-24
High	25-50
Very high	>50
Excessive	>100

Table 7.2 Routine and requirements for the determination of soil Available Iron.

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for physico-chemical analyses
Moisture content	ISO 11465:1993	Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric



		method
Dry matter and water content	ISO 11465:1993	Soil quality-Determination of dry matter and water content on a mass basis-Gravimetric method
Extraction of Available Iron	ISO 14870:2001.	Soil quality-Determination of trace elements by buffered DTPA solution.
Iron measurement procedure	ISO 11047:1998	Soil quality-Determination of Cd, Cr, Co, Cu, Pb, Mn, Ni, and Zn in aqua regia extracts of soil-Flame and electrothermal atomic absorption spectrometric methods)

8. Soil pH (mainly for acidic soil types)

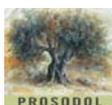
Definition: The activity of ionized hydrogen (H^+) in the soil solution measured in a suspension of dry soil in water (or in a salt solution, e.g. KCl) at a monitoring site at a specific point in time..

Table 8.1 Soil characterization regarding pH value (CCME, 2007).

pH value	Characterization
< 4.5	Excessively acidic
4.5 – 5.0	Very strongly acidic
5.1 – 5.5	Strongly acidic
5.6 – 6.0	Moderately acidic
6.1 – 6.5	Mildly acidic
6.6 – 7.3	Neutral
7.4 – 7.8	Mildly alkaline
7.9 – 8.4	Moderately alkaline
8.5– 9.0	Strongly alkaline
>9.1	Very strongly alkaline

Table 8.2 Routine and requirements for the determination of soil pH

Required Procedures and Parameters	Analysis Methods	Description
Selection of sampling site	ISO 10381-1:2002	General principles to be applied in the design of sampling programmes for the purpose of characterizing and controlling soil quality and identifying sources and effects of contamination of soil and related material
Sample collection	ISO 10381-2:2002	Soil quality - Sampling - Part 2: Guidance on sampling techniques
Safety on sampling	ISO 10381-3:2001	Soil quality - Sampling- Part 3: Guidance on safety
Sample pretreatment	ISO 11464:1994	Soil quality - Pretreatment of samples for



		physico-chemical analyses
Water for analysis	ISO 3696:1987	Water for analysis-Specification and test methods
Sample pH	ISO 10390:2005	Soil quality-Determination of pH

7.1 References of ANNEX 2

- Abreu, C.A.D., Raij, B.V., Abreu, M.F.D., Gonz lez, A.P. 2005. Routine soil testing to monitor heavy metals and boron. *Scientia Agric.*, 62, 564-571.
- Allouche, N., Fki, I., Sayadi, S., 2004. Toward a high yield recovery of antioxidants and purified hydroxytyrosol from olive mill wastewaters. *J. Agric. Food Chem.*, 52, 267–273.
- Brady. N.C. 1990. The nature and properties of soils. 10th Edition, Macmillan Publishing Company, New York, pp 315-338.
- Box, J.D. 1983. Investigation of the Folin–Ciocalteu phenol reagent for the determination of polyphenolic substances in natural waters. *Water Res.*, 17, 511–525.
- Bray, R. H., Kurtz. L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Sci.*, 59, 39-45.
- CCME 2007. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Canadian Council of Ministers of the Environment.
- Della Greca, M., Monaco, P., Pinto, G., Pollio, A., Previtiera, L., Temussi, F. 2001. Phytotoxicity of low-molecular-weight phenols from olive mill waste waters. *Bull. Environ. Toxic.*, 67, 352–359.
- Di Serio, M.G., Lanza, B., Mucciarella, M.R., Russi, F., Iannucci, E., Marfisi, P., Madeo, A. 2008. Effects of olive mill wastewater spreading on the physicochemical and microbiological characteristics of soil. *Int. Biodeterioration Biodegradation.*, 62, 403-407.
- Guti rrez Gonzales-Quijano R, Janer del Valle C, Janer del Valle ML, Guti rrez Rosales F, Vazquez Roncero A. 1977. Relationship between polyphenol content and the quality and stability of virgin olive oil. *Grasas y Aceites* 28, 101-106.
- Ilaco, B.V. 1985. *Agricultural Compendium, For Rural Development in the Tropics and Subtropics*. Elsevier.
- Kavvadias, V., Doula, M.K., Komnitsas, K., Liakopoulou, N. 2010. Disposal of olive oil mill wastes in evaporation ponds: Effects on soil properties. *J. Hazard. Mat.*, 182, 144-155.
- Knudsen, D., Peterson, G.A., Pratt, P.F. 1987. Lithium, Sodium and Potassium In: *Methods of Soil Analysis Part 2 “ Chemical and Microbiological Properties*. Page A.L., Miller, R.H. Keeney, D.R. (Eds.) 2nd ed. American Society of Agronomy Inc. and Soil Science Society of America, Inc; Madison, Wisconsin, USA, pp 225-246.
- Loveland P., Webb, J. 2003. Is there a critical level of organic matter in the agricultural soils of temperate regions: a review *Soil Till Res.*, 70, 1–18.
- MAAF, 1988. *Fertilizer Recommendations. Reference Book 209*. HMSO, London.
- Marx, E.S., Hart, J., Stevens, R.G. 1999. *Soil Test Interpretation Guide EC 1478 Extension & Station Communications*, Oregon State University.
- Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Comm. Soil Sci. Plant Anal.*, 15, 1409-1416.

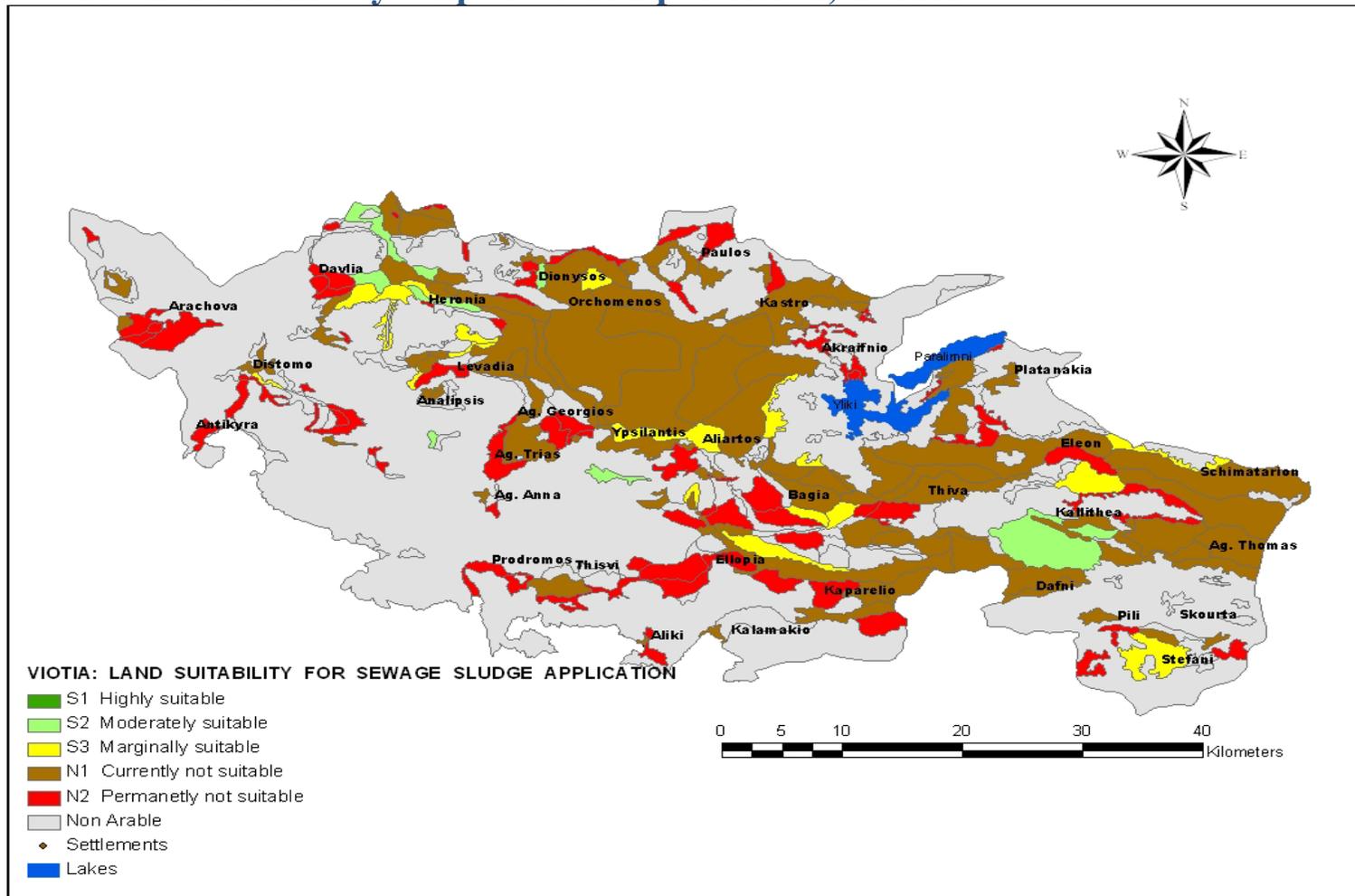


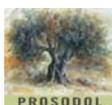
- Nelson, D.W., Sommers, L.E. 1987. Total Carbon, Organic Carbon, and Organic Matter, In: Methods of Soil Analysis Part 2 “Chemical and Microbiological Properties. Page A.L., Miller, R.H. Keeney, D.R. (Eds.) 2nd ed. American Society of Agronomy Inc. and Soil Science Society of America, Inc; Madison, Wisconsin, USA, pp. 539-579.
- Niaounakis, M. Halvadakis, C.P. 2006. Olive processing waste management-Literature Review and Patent Survey. 2nd edition. Elsevier Ltd, p. 30.
- Olsen, S.R. Sommers, L.E. 1987. Phosphorous, In: Methods of Soil Analysis Part 2 “Chemical and Microbiological Properties. Page A.L., Miller, R.H. Keeney, D.R. (Eds.) 2nd ed. American Society of Agronomy Inc. and Soil Science Society of America, Inc; Madison, Wisconsin, USA, pp. 403-430.
- Olson, R.V., Ellis, R. Jr. 1987. Iron In: Methods of Soil Analysis Part 2 “Chemical and Microbiological Properties. Page A.L., Miller, R.H. Keeney, D.R. (Eds.) 2nd ed. American Society of Agronomy Inc. and Soil Science Society of America, Inc; Madison, Wisconsin, USA, pp 301-312.
- Rhoades, J.D. 1982. Cation exchange capacity. In: Page, A.L. (ed.) Methods of soil analysis, Part 2 Chemical and microbiological properties, 2nd edition. Agronomy 9: 149-157.
- Rhoades, J.D. 1996. Salinity: Electrical conductivity and total dissolved solids. In Methods of Soil Analysis: Chemical Methods. Part 3. D.L. Sparks, editor. Soil Sci. Soc. of Am., Madison WI.
- Schollenberger, C.J. 1927. Exchangeable hydrogen and soil reaction. *Science*, 35, 552-553.
- Tisdale, S.L., Nelson, W.L., Beaton, J.D., Havlin, J.L. 2003. Soil; fertility and fertilizers. 5th Edition, Prentice-Hall of India, New Delhi, p. 205.
- Olsen, S. R., Cole, C.V., Watanabe, F.S., Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA circular 939. U.S. Govt. Printing Office, Washington, D.C.





8 ANNEX 3: Land Suitability Map for Viotia prefecture, Greece





9 ANNEX 4 Development of interpolation surfaces for soil monitoring

9.1 Interpolation surfaces

The development of interpolation surfaces that indicate the distribution of different chemical parameters of an area, in order to present the diffusion of the soil parameters and the degree of risk in the vicinity of the waste disposal areas, requires the collection of many soil samples and data around the vicinity of the OMW disposal areas. It has to be mentioned that surfaces could only be interpolated for more than 4 known values of each parameter of a specific sampling site. In cases where the measured values are less than 4 for each sampling site and also if sampling doesn't cover a wide area around the targeted area, no accurate results are anticipated and thus it is not possible to interpolate surfaces.

Among the different interpolation algorithms, the most appropriate way of mapping the specific parameters, without creating secondary effects (e.g. bull's eye effect around isolated sample points, extreme trends away of the sample areas, etc) is the Inverse Distance Weighting (IDW). IDW calculates cell values by averaging the values of sampling points in the vicinity of each cell based on distance. Consequently, the closer a point is to the centre of the cell being calculated, the more influence or the more significant weight it has in determining the final output value. This method assumes that the values of the chemical feature being mapped decrease in influence with distance from the sampled locations. Furthermore, IDW offers the potential to the user to define the power of known values as an individual parameter. The power controls the significance of measured values on the interpolated cells, based on their distance from the sampling points. By defining a high power, more influence is given to the nearest points and the resulting surface will have more local detail. On the contrary, a lower power will emphasize the points located further away. For the PROSODOL project, all the interpolated surfaces were created by defining a power of 2 for the known values.

There are several tools and techniques in order to present the interpolated surfaces via an understandable and easy to use interface. In order to present these interpolated surfaces (i.e. images actually) inside a website, so at the end a web-based application to be developed in order to be used and handled by local and regional authorities, integration of the entire interpolation process results into a Map API such as Google API, or Google Earth API, flash maps techniques (Flash Builder software) should be performed, so that users can view the interpolated surface area images simultaneously above a topographic/satellite map provided by those APIs.

Google Earth API is suggested as being the most appropriate to use, which integrates time tagged images via EXtensible Markup Language (XML), a language designed to transport and store information data.

ArcGIS Desktop could be used for creating the interpolated surface maps using the ArcGIS ModelBuilder Tool. ModelBuilder is an application in which user can create, edit, and manage models.

9.2 The ArcGIS ModelBuilder

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 project' collected 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 needed for the model. Fig. 1 shows how such a process works.



Figure 1. Tool for building a model

The Input Data needed for the model are stored as a shape file and presented as a layer in the ArcMap application as in Fig. 2.

The Derived Data are going to be the XML files that contain the interpolated surface maps with time variation tags, in order to be given as input to the Google Earth web application. As previously said, the tool, is a process, actually a group of several processes that have to take place in order to export out interpolated surfaces to XML files. These tools are going to be described step by step. The Model for the interpolation of the surfaces for one measurement variable (chemical parameter) is presented in Fig. 3.



FID	Shape *	AreaCode	Measuremen	Date_	Depth	Lat	Lng	Sand	Code	EC	Saturation	TotalSalts	OrganicMat
0	Point	NF1.1	64082	6/5/2009	0-24	35.321534	24.412785	34	C/CL	0.99	48	0.03	4.41
1	Point	NF1.2	64086	6/5/2009	0-24	35.321489	24.412927	38	C/CL	0.65	43	0.01	3.28
2	Point	NF1.3	64089	6/5/2009	0-24	35.32167	24.412785	32	C	0.29	54	0.01	3.65
3	Point	NF1.4	64093	6/5/2009	0-24	35.321705	24.412852	52	SCL	0.53	52	0.01	3.34
4	Point	NF1.5	64094	6/5/2009	0-24	35.321464	24.412344	56	SCL	3.59	79	0.18	23.4
5	Point	NF1.6	64095	6/5/2009	0-24	35.321587	24.412137	34	CL	0.64	68	0.02	4.24
6	Point	NF2.1	64097	6/5/2009	0-24	35.323337	24.413058	68	SL	2.72	52	0.18	36.1
7	Point	NF2.2	64098	6/5/2009	0-24	35.323327	24.413179	32	C	0.71	53	0.02	1.63
8	Point	NF2.3	64099	6/5/2009	0-24	35.323354	24.41319	22	C	0.34	64	0.01	2.05
9	Point	NF2.4	64100	6/5/2009	0-24	35.323363	24.413179	8	C	0.23	85	0.01	0.33
10	Point	NF2.5	64102	6/5/2009	0-24	35.323444	24.413212	37	C	0.33	59	0.01	0.61
11	Point	NF2.6	64104	6/5/2009	0-24	35.323184	24.412881	40	CL	0.44	58	0.01	4.72
12	Point	NF4.1	64218	6/5/2009	0-24	35.309379	24.368447	24	C	0.73	68	0.03	4.78
13	Point	NF4.10	64129	6/5/2009	0-24	35.309667	24.368592	30	CL	1.22	73	0.05	6.2
14	Point	NF4.11	64130	6/5/2009	0-24	35.309629	24.368604	38	CL	0.67	62	0.02	1.79
15	Point	NF4.12	64132	6/5/2009	0-24	35.309694	24.368459	28	C	0.61	68	0.02	4.34
16	Point	NF4.2	64222	6/5/2009	0-24	35.30948	24.368497	26	C/CL	1.01	67	0.04	4.21
17	Point	NF4.3	64109	6/5/2009	0-24	35.309485	24.367803	22	C	1.92	103	0.12	41.62
18	Point	NF4.4	64113	6/5/2009	0-24	35.309522	24.367841	46	SC	0.88	61	0.03	1.24
19	Point	NF4.5	64119	6/5/2009	0-24	35.309557	24.367845	30	C	1.4	57	0.05	3.19
20	Point	NF4.6	64121	6/5/2009	0-24	35.309292	24.367369	32	C/CL	0.93	64	0.03	7.01
21	Point	NF4.7	64123	6/5/2009	0-24	35.309551	24.368151	32	CL	1.61	68	0.07	5.42
22	Point	NF4.8	64126	6/5/2009	0-24	35.309694	24.36846	30	CL	1.34	55	0.04	6.79
23	Point	NF4.9	64128	6/5/2009	0-24	35.309811	24.368658	26	CL	1.71	63	0.06	4.57
24	Point	NF5.1	64133	6/5/2009	0-24	35.309476	24.368987	26	C/CL	1.35	78	0.06	7.9
25	Point	NF5.2	64136	6/5/2009	0-24	35.309521	24.369207	26	C	0.72	63	0.02	4.34
26	Point	NF1.1	64083	6/5/2009	25-49	35.321534	24.412785	36	C/CL	0.88	43	0.02	4.26
27	Point	NF1.2	64087	6/5/2009	25-49	35.321489	24.412927	40	CL	0.88	43	0.02	2.31
28	Point	NF1.3	64090	6/5/2009	25-49	35.32167	24.412785	34	C	0.48	54	0.01	2.28

Figure 2. Input data needed for the model development

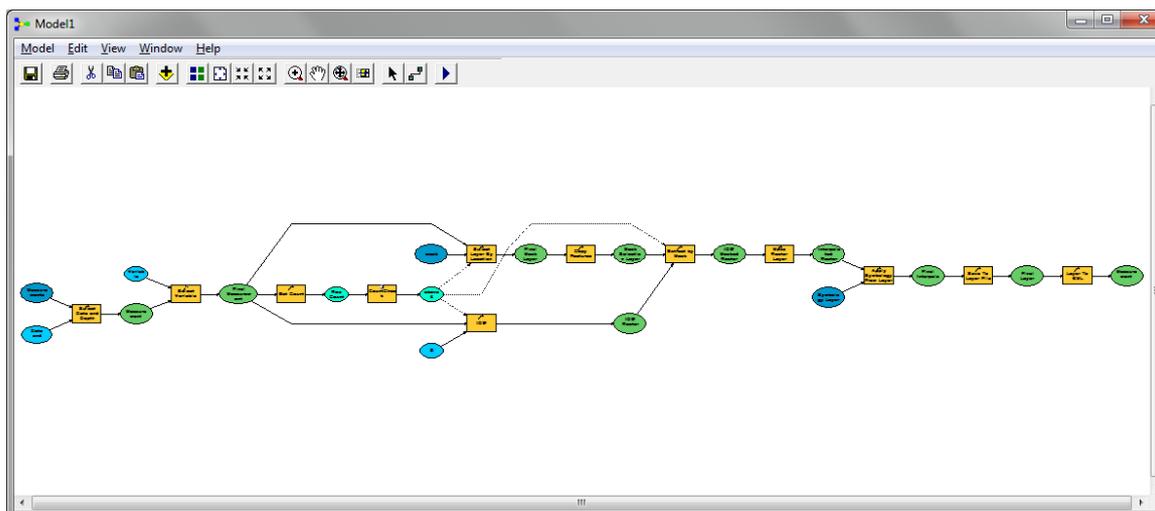


Figure 3. Model for the interpolation of the surfaces for one measured variable.

Several tools (processes) that need to be performed in order to achieve the expected result are shown in figure 3. 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, as shown in figure 4.

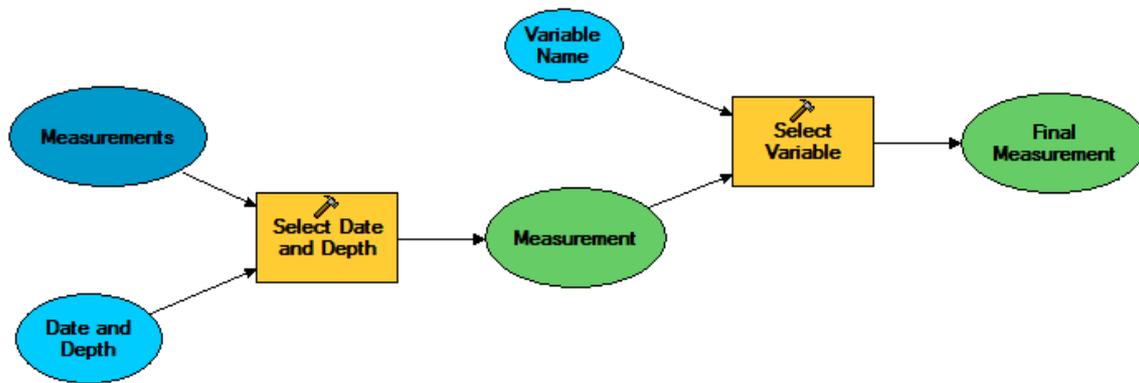


Figure 4. Selection Tool, which selects the date, depth and the variable (chemical parameter) from the input measurements shape file.

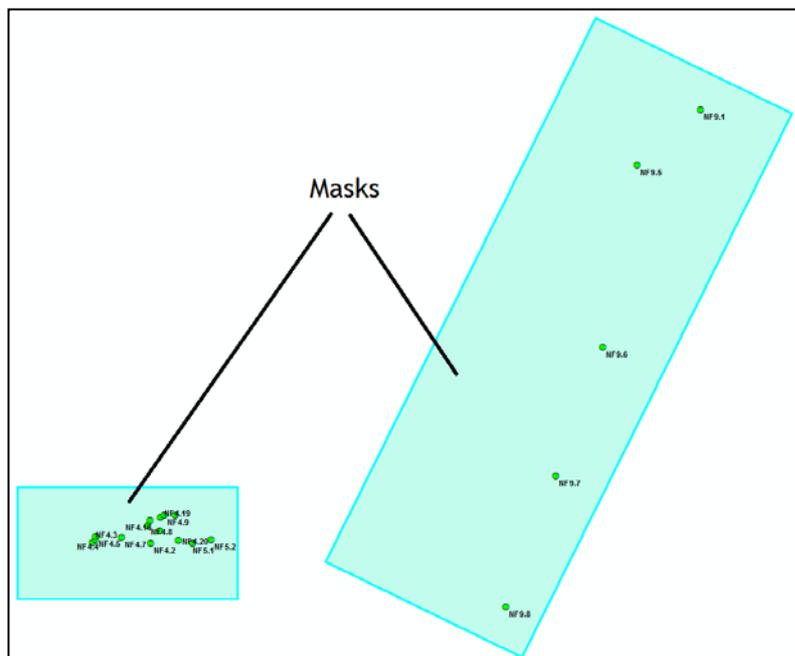


Figure 5. Mask for the determination of the interpolated area bounds.

The next step, which is the most important one, is where the interpolation process takes place. It should be noted that the interpolation of a surface, in other words, the diffusion of a chemical parameter in an area, has no meaning above a radius, or a long distance from the measurement points. For this reason a Mask should be provided in order to determine the interpolated area bounds as shown in Fig. 5. The Mask is actually a polygon that surrounds the measurements area and inside this polygon the interpolation of the surface is only going to take place. The mask is provided to the Model as a layer or shape file. In figure 5 the measurement targeted areas are provided as points (green dots), while the mask areas surrounding them are provided as polygons (blue squares).

As mentioned above, the surfaces can only be interpolated for more than 4 known values (points). So, after the first step is completed, the Final measurements number with the Get Count tool should be checked, and only if the result is above 4 measurements for a targeted

area, then the interpolation takes place, as shown in figure 6 (handled by script). If this constraint is true then interpolation of the entire surface with the IDW tool is performed, providing the corresponding chemical parameter and area limits, and simultaneously selecting the corresponding mask areas (polygons), intersecting measurement (point) locations.

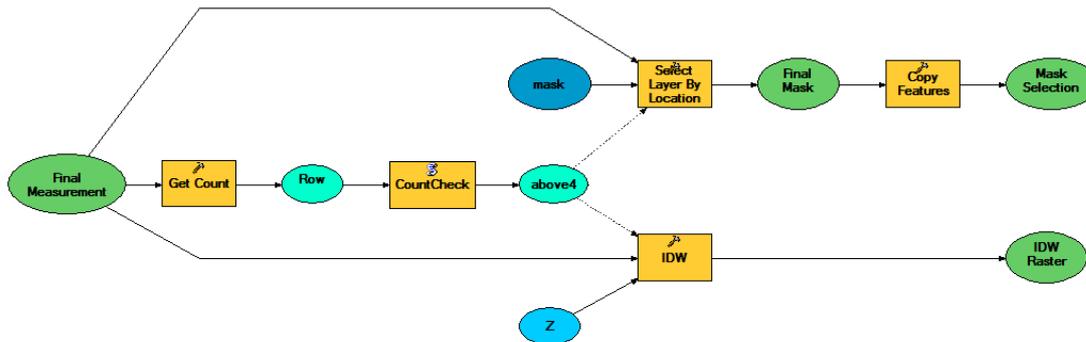


Figure 6. Interpolation after checking the number of the measurements.

The Inverse Distance Weighting (IDW) interpolation method produces the most satisfying results, and that is the method 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.

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

At this phase of the model building the entire interpolated surface was constructed, with the corresponding mask areas, depending on the measurements (more than 4) according to depth, date and chemical parameter selection. The next step which is described in figure 7 is to extract the masked interpolated surface map. This process could be done with the Extract-by-Mask tool that outputs the result as a raster file, which is converted to a layer file with the Make-Raster-to-Layer tool.

The extracted layer file is needed in order to provide a symbology layer upon it, which denotes the degree risk with a color scheme as shown in Fig. 8. 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.

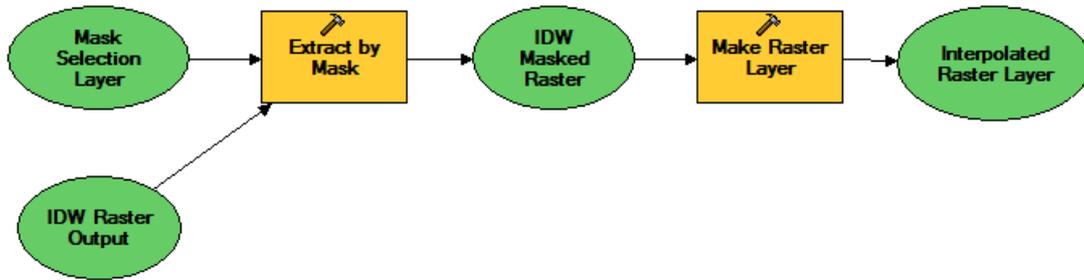


Figure 7. Extraction of the masked interpolated surface map.

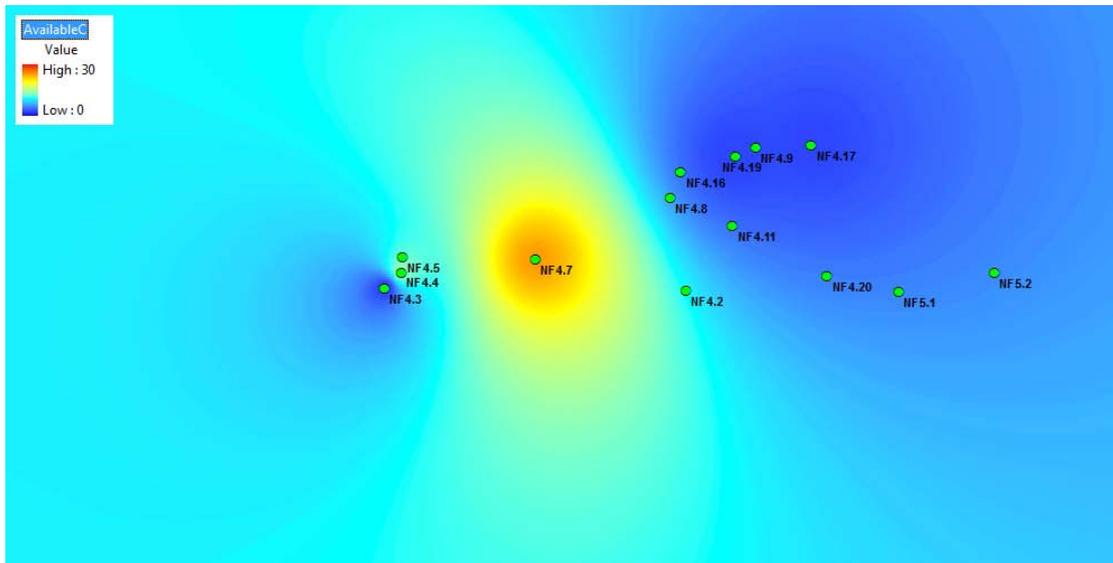


Figure 8. Symbology layer which denotes the degree risk with a color scheme.

Because the ModelBuilder constructs in its process step (tool) the derived layers temporarily, only the final layer, the interpolated, masked, symbology applied layer, needed to be saved in order to provide it as an input to the Layer-to-KML tool, which constructs the final KML file, an XML format file suitable for the Google Earth API application that, later on will be integrated to the website. The final process steps are shown in figure 9.

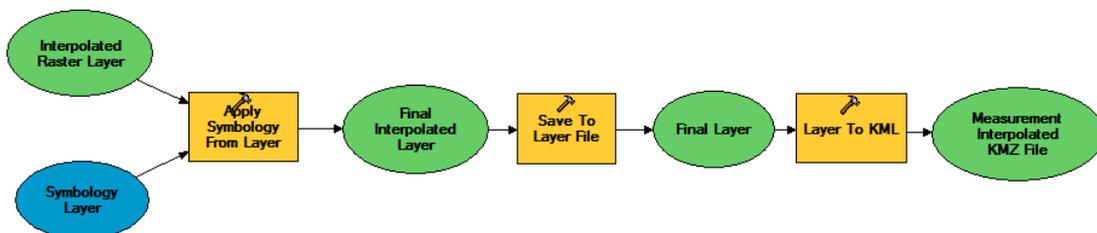


Figure 9. Process which constructs the final KML file.

The whole surface interpolation process described, as shown in figure 3, was just for one variable, while the flowchart of the entire Model for all chemical parameters is shown in figure 10.

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.

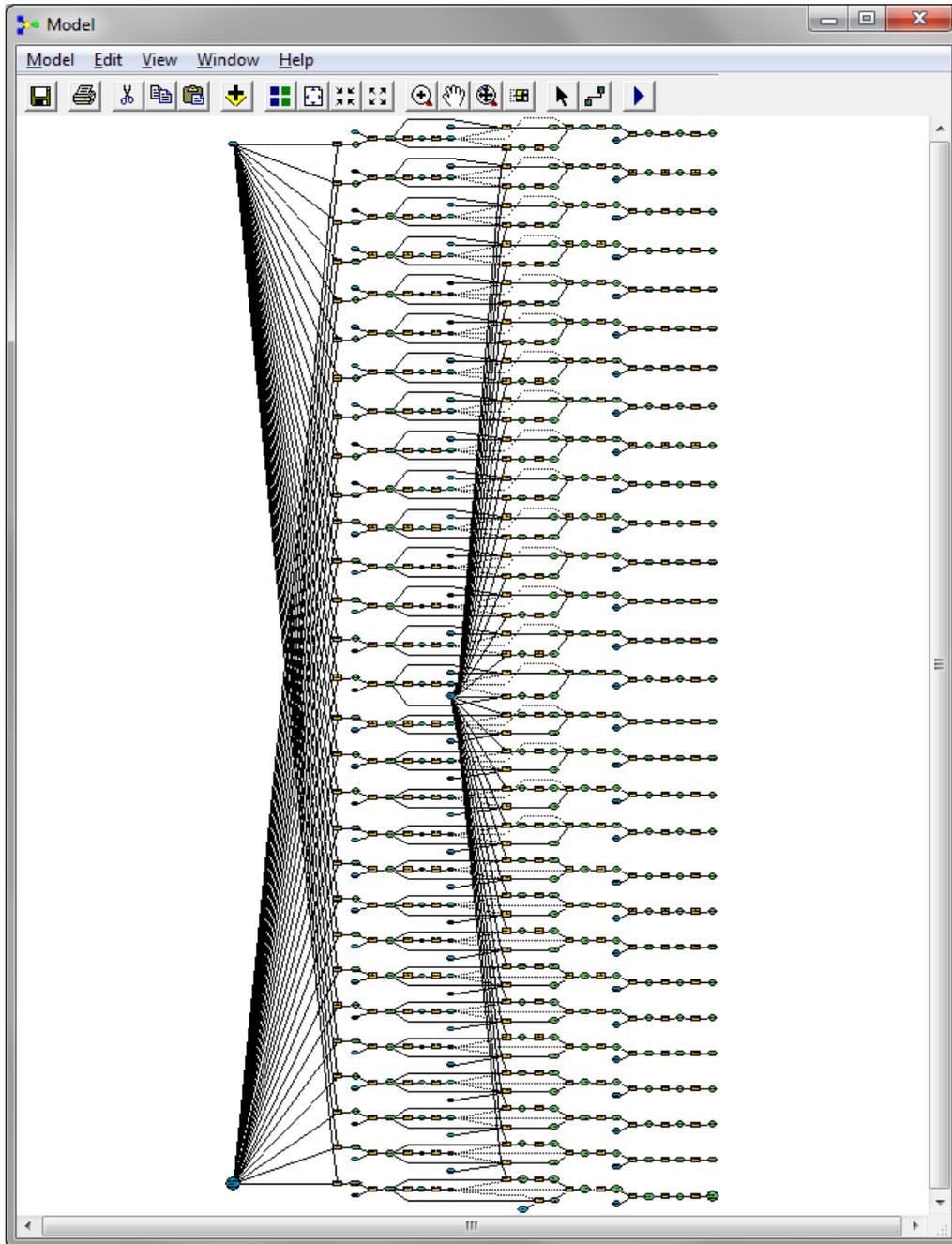


Figure 10. Flowchart of the entire Model for all chemical parameters.



9.3 Google Earth API Application

The Google Earth API is a JavaScript API which lets embedding Google Earth, a 3D digital globe, into a website (see example at <http://www.prosodol.gr>). KML files are loading using the API, allowing the build of a 3D map application. The reason for which API is used 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 could be handled with JavaScript over PHP pages of a given 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.



10 ANNEX 5. Instructions on how to carry out bioremediation monitoring

10.1 Statistical considerations

A limitation in field sampling is the large number of samples required to ensure that the measured mean value of a particular parameter is within a given range around of a true value. This limitation is due to the natural spatial variability of soil properties. It is therefore necessary to take a significant number of replicate samples, representative of the area being sampled. Realistic, unbiased data are required so that valid comparison can be made between the values of monitored parameters and background values.

The polluted/degraded site should be divided into uniform areas for sampling purposes. These areas may be according to soil series or to phases based on surface texture within a series. If known “hot spots” of pollutants or significant differences in types of pollutants occur at the site, these areas should also be monitored separately. For each medium sampled, appropriated background sampling sites should be monitored.

10.2 Soils sampling in the treatment zone and in the underlying unsaturated zone

Soil cores and borings are used to measure the vertical movement of pollutants as well as to determine the progression of treatment in the soil treatment zone. Soil core sampling in the treatment zone is used as a management tool. The extent of treatment (i.e., degradation, transformation, and/or immobilization) of the hazardous constituents can be monitored as well as, factors which may affect the execution of the treatment, such as nutrients and pH. Soil core sampling below the treatment zone is used to determine whether significant concentrations of hazardous constituents are moving below the treatment zone. If unacceptable leaching of contaminants is occurring, contingency plans should provide means to prevent groundwater contamination, such as the use of a grout bottom seal.

Soil sampling methods used by soil scientists to evaluate physical properties of soils are also suitable for determining chemical constituents in the upper layers of soils. The split spoon sampler is a barrel-type auger, with one side which pivots on a hinge. A tube-type sampler consists of a tube beveled and sharpened on one end to aid insertion in the soil. A drive hammer is used to force the tube to the desired depth, and an intact soil core is removed from the tube. Soil samples from lower soil depths are more easily obtained by the use of powered coring or drilling equipment. After soil core sampling, holes should be backfilled with native soil (compacted to field bulk density), clay slurry, or other suitable materials in order to prevent the channelling of hazardous constituents down the holes.



10.3 Soil pore liquid sampling in the unsaturated zone

Water added to a site by precipitation or irrigation while percolating through the treatment zone may rapidly transport some mobile hazardous constituents or transformation products through the unsaturated zone to the groundwater. The purpose of soil-pore liquid monitoring is to detect these rapid pulses of contaminants. Heavy precipitation, snow melt, and irrigation events are often responsible for such pulses, and sampling periods should be scheduled to correspond to such events. Soil texture and structure and other soil properties, as they affect infiltration and percolation rates, also determine to what extent precipitation events cause rapid water movement in a particular soil. Soil pore liquid sampling may also indicate the amount of materials leaching to the groundwater. Samples of groundwater do not provide this information due to the diluting effect of the groundwater. In addition, analysis of the soil pore liquid can provide an early warning signal that remedial action is required for the management of the treatment process.

Since water in the unsaturated zone is held under negative pressure (suction), wells and open cavities cannot be used to collect the flowing water. Therefore samplers in the unsaturated zone are called suction sampling devices, and they are classified as:

- A. Ceramic-type samplers:
 1. Suction cup:
 - a. Vacuum-operated soil-water samplers.
 - b. Vacuum-pressure samplers.
 - c. Vacuum-pressure samplers with check valves.
 2. Filter candle.
- B. Cellulose-acetate hollow fiber samplers.
- C. Membrane filter samplers.

10.4 Water samples from the saturated zone (i.e., groundwater)

Groundwater sampling will indicate whether hazardous waste constituents have indeed migrated to the groundwater and may present a public health hazard, depending on the hydrogeological characteristics and uses of the groundwater system. If contamination has occurred and is deemed unacceptable, provisions must be made to recover and treat or otherwise handle the contaminated groundwater.

Sophisticated groundwater sampling equipment and procedures are not desirable for monitoring programs. Rather, to ensure long-term, efficient operation of the monitoring system, the devices should be simple, rugged, foolproof, and operable by trained, but not necessarily educationally skilled personnel. A list of saturated zone sampling methods and sample extraction techniques could include:

- Sampling devices
- Tile lines
- Collection pans and manifolds
- Wells



- Piezometers
- Multilevel samplers
- Groundwater profile samplers
- Sample extraction methods
- Hand bailers
- Air-lift and gas-lift pumps
- Suction lift pumps
- Piston pumps
- Centrifugal pumps
- Submersible pumps

Caution should be exercised in the choice of well casing material. The selection of casing depends on the constituents being monitored. Steel casing may contribute such contaminants as zinc and iron; therefore the use of PVC, fiberglass, or teflon is recommended.

10.5 Runoff water monitoring

To ensure the health and safety of off-site populations, runoff water, if any occurs, should be monitored for hazardous constituents or byproducts. If significant concentrations are found, provisions should be available for collecting, storing, treating, and/or recycling the water through the site.

10.6 Air monitoring

Air monitoring at hazardous waste sites is essential for the protection of health and safety of the remedial action team due to the volatile nature of many hazardous compounds anticipated at hazardous waste sites. An adequate air monitoring program allows the evaluation of the relative importance of vapor transport from the site, provides a means for evaluating the effectiveness of vapor suppression techniques, permits the identification of volatile daughter products from the various treatment techniques utilized, and is a requirement if vapor phase photolysis is used as a treatment alternative.

In addition to personal monitoring equipment, a perimeter sampling network should be established to detect off-site migration of gaseous and/or particulate emissions. Upwind and downwind sampling sites should also be used to determine background air quality as well as the extent of off-site contamination, if any.