Environmental impacts relative to soil quality caused from the disposal of olive oil mills' wastes. Case study: A municipality in Crete, Greece

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ABSTRACT

Olive oil mills wastes (OOMW), a by-product of the olive mill industry, are produced in large quantities in Mediterranean countries. OOMW contain high organic load, substantial amounts of plant nutrients but also several compounds with recognized toxicity towards living organisms. The effect of the disposal of untreated OOMW on soil chemical properties was investigated by collecting and analyzing soil samples from areas near evaporation lagoons in the island of Crete, south Greece.

1. INTRODUCTION

In Greece there are about 10^8 olive trees and 2800 olive oil mills while the average oil production in cultivation period of 2006/2007 was about 250.000 tn. Although the disposal of untreated mills wastes in the environment is not permitted, it is estimated that up to 1.5 million tonnes of wastes are disposed each year. The usual treatment and disposal method in Greece is the evaporation in lagoons/ponds after neutralization with lime. There are also many cases of sea, river and underground disposal. In practice the evaporation lagoons/ponds are rarely of proper size and construction and wastewaters often overflow affecting the neighbouring systems (soil, surface and groundwater) but also professional activities of the residents (agriculture, livestock farming). The base of the lagoons is in most cases, permeable and thus, the probability for groundwater and deep soil horizons contamination is high.

Due to the serious environmental problems caused by the uncontrolled disposal of these wastes, European Commission co-funded in the framework of LIFE+ funding scheme a four-year project entitled "*Strategies to improve and protect soil quality from the disposal of olive oil mills' wastes in the Mediterranean region*" (Acronym: PROSODOL; start date: 1st January, 2009). Five Institutions from the three major olive oil productive countries worldwide (Spain, Italy, Greece) participate in the project, which aims to:

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

One of the main project's technical part is the development of a soil and water monitoring system which foresees soil and water sampling every two months. First results regarding soil quality and its potential degradation due to wastes disposal are presented in this work.

2. SOIL SAMPLING AND ANALYSIS

2.1 Implementation area

The project area is located in the municipality of Nikiforos Fokas, prefecture of Rethymnon, Crete. The municipality's jurisdiction extends over fourteen former community wards, comprises a total of 21 villages, has a total area of 95 km^2 and a population of approximately 6600. Geological formations of the area under study are mainly identified as limestones, dolomites and marbles. Soils are slightly alkaline to alkaline (pH between 7,3 and 8,0), rich in carbonates (40 %-60 %) and clay or silty clay in texture.

Soil samples were collected from five disposal areas: three active and one inactive for 5 years.

All of them contain lagoons which were built by excavating the superfacial materials of soil, and (for some of them) by heaping excavating materials around the lagoon to form low retaining walls. Protective impermeable membranes or other protective media were not used. The disposed wastes derived from three-phase mills with continuous centrifuge extraction systems.

In this work data from two active disposal areas, NFR and NFC (Photo 1, Table 1), are presented. Both lagoons are used for waste disposal for more than 10 years.

Sampling took place one month after completion of wastes disposal, between 6^{th} and 9^{th} May, 2009.

2.2 Soil parameters

Soil samples were collected from different places and depths of 0-25 cm, 25-50 cm, 50-75 cm, 75-100 cm, 100-125 cm and 125-150 cm. The preparation of samples for analysis was performed according to ISO 11464:2006 method.

Laboratory determinations were performed according to the methods usually used for soil characterization (Miller and Keeny, 1982). Particle size distribution analysis was carried out by Bouyioukos method; the pH and the Electrical Conductivity (EC) were measured in paste extract; organic matter (OM) was determined by dichromate oxidation; carbonates by using Bernard calcimeter; total N by the Kjeldahl method (ISO 11261:1995); available phosphorous with sodium hydrogen carbonate extraction (ISO 11263:1994); Cation Exchange Capacity (CEC) and exchangeable K, Ca and Mg by $BaCl_2$ extraction (ISO 11260:1994); and available Mn and Fe with DTPA extraction (ISO 14870:2001).

Photo 1: The two sampling disposal areas in Municipality of Nikiforos Fokas, Rethymnon, Crete.

3. RESULTS EVALUATION

Regarding OM content, it was observed that there was no substantial difference among sampling locations in NFR site (Fig. 1). Since mills' owners, as they say, do not dispose wastes directly on land (except one of them-NFC area), these results are expectable and are similar to values for uncultivated areas. Further investigation of factors potentially affecting OM content should be carried out.

For NFC place the surface disposal resulted in substantial increase in OM content at all soil depths for most sampling locations (Fig. 2) due to waste sedimentation on the soil surface and infiltration to other horizons.

In general, soil samples collected were carbonate rich and have basic pH. These two parameters buffer wastes' acidity (pH ~ 4.6). This,

Table 1: Sampling sites of NFR and NFC disposal areas.

Sampling Site	Characteristics
NFR 1	Internal lagoon's walls
NFR 2	2m from the lagoon, (h)
NFR 3	4m from the lagoon, (u)
NFR 4	10m from the lagoon, (u)
NFR 5	12m from the lagoon (u)
NFR 6	Unaffected-Control
NFC 1	External lagoon's wall (u)
NFC 2	3m from the lagoon, (u)
NFC 3	3m from the lagoon, (u)
NFC 4	25m from the lagoon, surface disposal, (u)
NFC 5	50m from the lagoon, surface disposal, (u)
NFC 6	75m from the lagoon, surface disposal, (u)
NFC 7	75m from the lagoon, surface disposal, (u)
NFC 8	External lagoon's wall (e)
NFC 9	Unaffected-Control

(h):higher from wastes level; (u):under the wastes level; (e): at the waste level

in turn, results in carbonates decrease in relation to that of the control sample (Fig. 3).

With regard to EC, the values for affected soils are in general higher than those for the control (Fig. 4).

According to Paredes et al., (1987) and to Sierra et al., (2001), the increase in soil EC appears to be irreversible and is correlated with

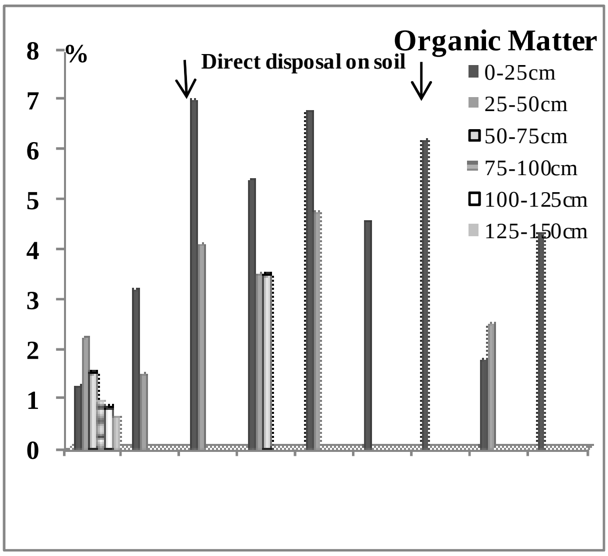

Figure 2: OM content for NFC disposal area. The content of the sample taken from the internal wall of the lagoon was 36.1%.

wastes' content in potassium, chloride, sulfate, and nitrates produced through wastes mineralization and transformation. EC increase is correlated with seed germination toxicity and thus, toxic effects can be expected in soils where mills' wastes have been disposed more than 2 months previously.

For NFR area there was considerable enrichment of exchangeable K (Fig. 5). Particularly for NFR2 location (2 m from the lagoon) the concentration of exchangeable K was very high which, in turn, may result in phytotoxicity. In general the increase in the content of K and

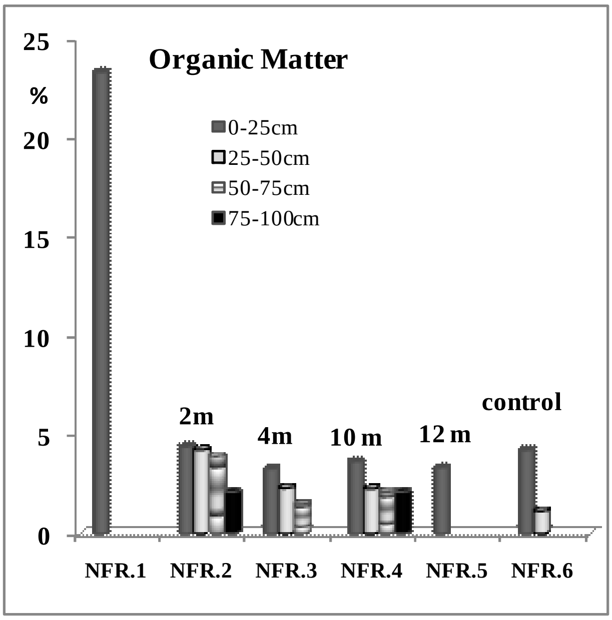

Figure 1: OM content for NFR disposal area.

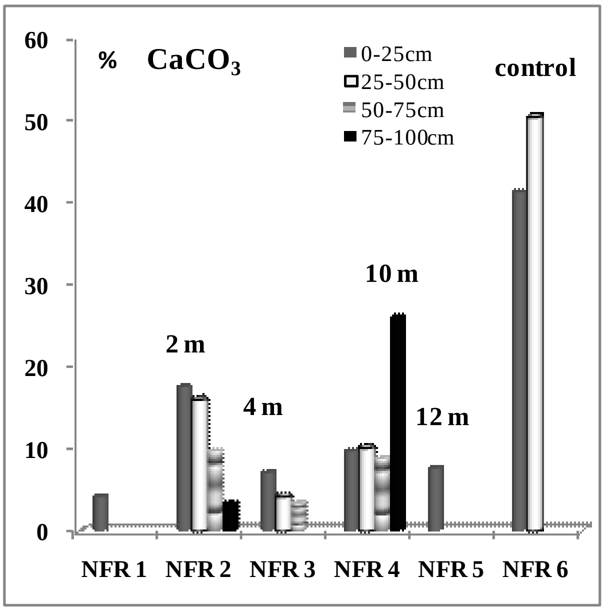

Figure 3: Carbonate content for NFR disposal area.

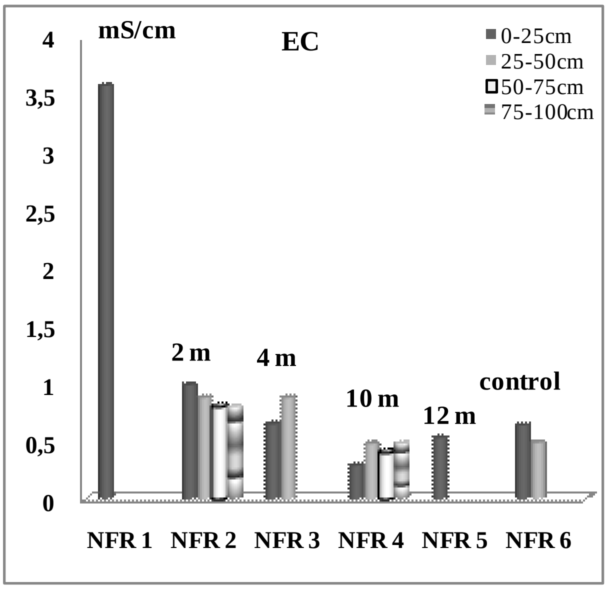

Figure 4: Electrical Conductivity for NFR disposal area.

other nutrients (N, P) as well as, OM could have beneficial effect on soil fertility therefore olive oil mills wastes could help to reduce, or avoid the application of chemical fertilizers. However, the significant increase in cations content (e.g. K) causes increase in soil electrical conductivity and contributes to the increase of soil salinity and thus to desertification.

Total nitrogen (Fig. 6) and available phosphorous (Fig. 7) content were also higher in affected soils, with concentrations decreasing with depth and distance from the lagoon. For nitrogen the increase in content appeared mainly on deeper horizons since the surface samples con-

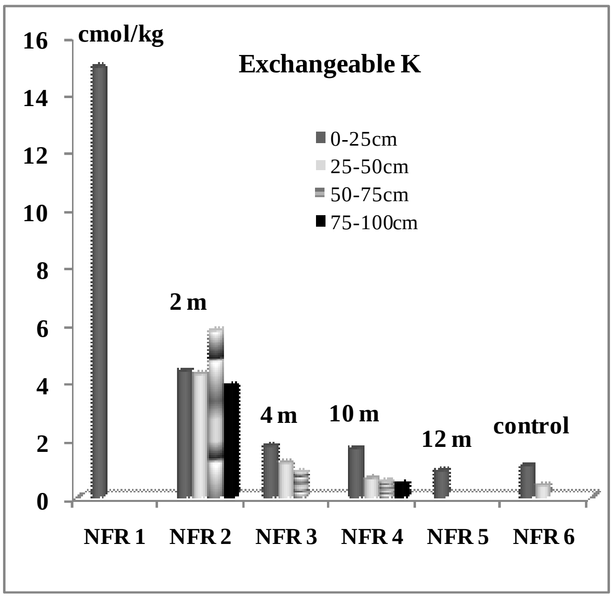

Figure 5: Exchangeable K for NFR disposal site.

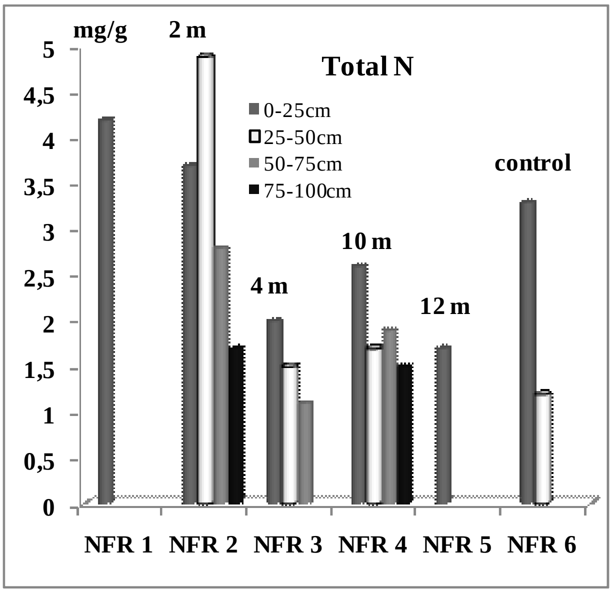

Figure 6: Total N for NFR disposal site.

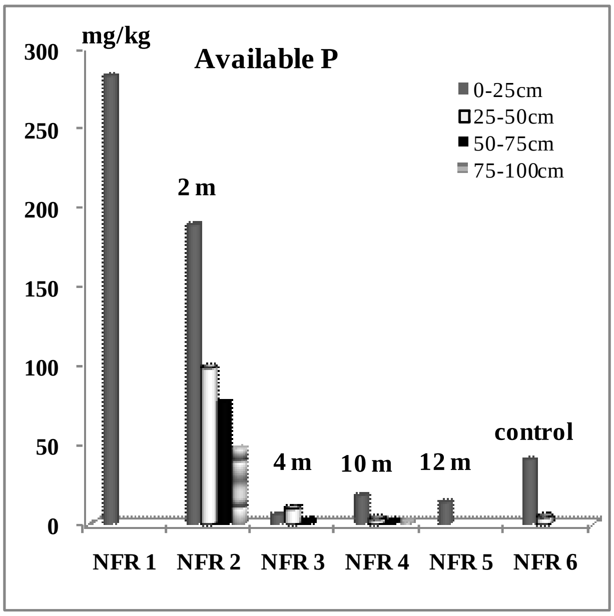

Figure 7: Available phosphorous for NFR disposal site.

tent did not differ considerably compared to control. With regard to phosphorous there was a notable decrease at all soil depths with the distance from the lagoon while, for NFR2 place, like K, the P content was very high.

Exchangeable Mg was also affected from the disposal. As Figure 8 presents, all sampling sites have higher content of Mg than the control.

However, no relation was observed between Mg content and distance from the lagoon.

Exchangeable Ca content was not affected by the disposal since, all samples were similar in content to the sample taken from the internal lagoon's wall and slightly higher than the control

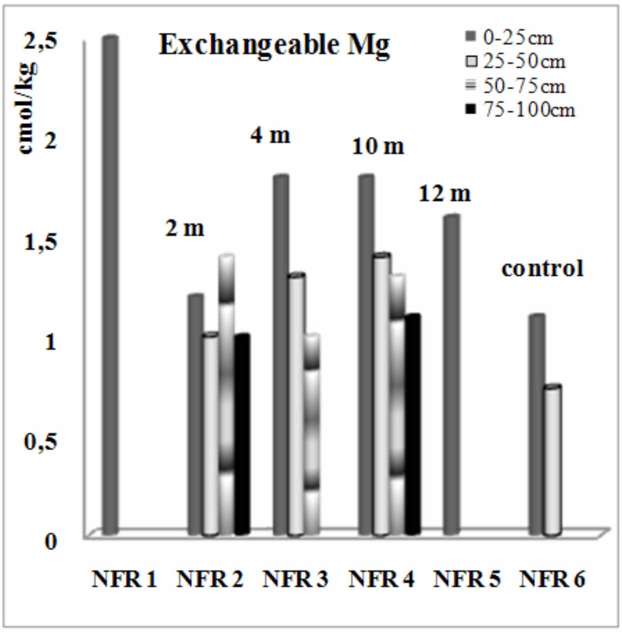

Figure 8: Exchangeable Mg for NFR disposal site.

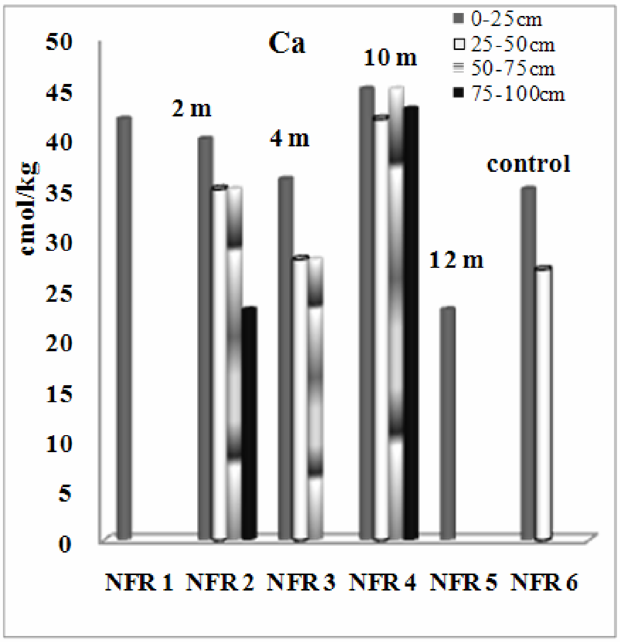

Figure 9: Exchangeable Ca for NFR disposal site.

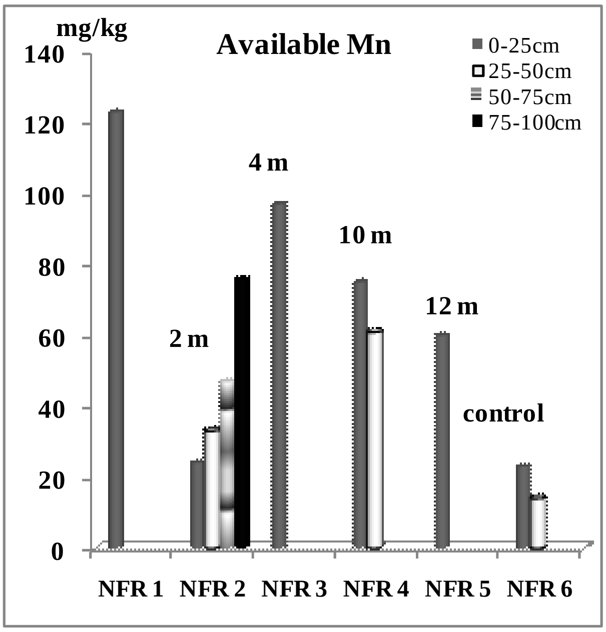

Figure 10: Mn content for NFR disposal area.

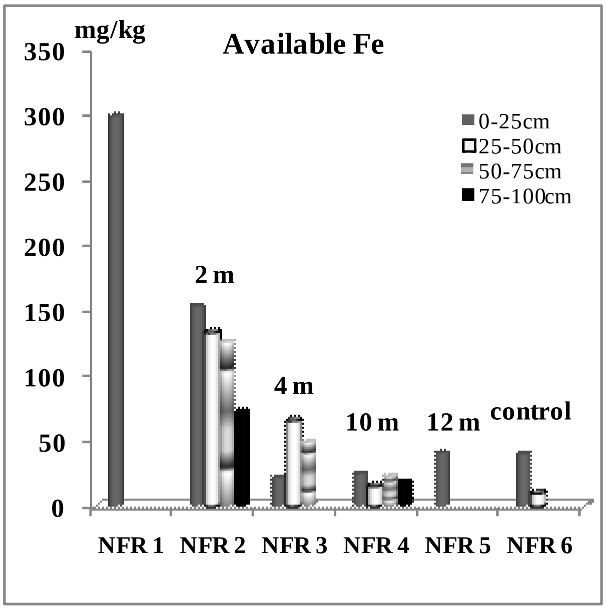

Figure 11: Fe content of NFR disposal area.

(Fig. 9).

In general, the increase in exchangeable cation content after the disposal was followed by enhancement of CEC (data not shown).

Regarding available Mn and Fe, there was markedly decrease in their concentrations with the distance from the lagoon, except the 2 m sampling location for Mn, which will be further investigated during the future monitoring of the area (Figs. 10, 11).

According to Piotrowska et al., (2006), Mn and Fe catalyze the oxidative transformation of phenols entering the soil with wastes.

In this process, polyphenols are oxidized to polyquinones, which then polymerized with amino acids to form humic materials. This oxidative polymerization reaction is catalyzed by polyphenol oxidase enzymes such as tyrosinase, however, Fe and Mn oxides promote also the reaction (McBride, 1987). Thus, Mn(IV) oxides are reduced to extractable forms of Mn^{2+} while Fe(III) is reduced to Fe(II) and then oxidized again by the reaction's products (i.e. quinones) and liberated to the soil solution phase as Fe^{3+}

(Kung and McBride, 1988).

3. CONCLUSIONS

Disposal of untreated OOMW at evaporation lagoons without using protective materials (e.g. impermeable membranes) has significant effect on soil chemical properties. Soil samples collected one month after the completion of wastes disposal are characterized by enhanced content in nitrogen; OM; exchangeable K, Mg; CEC; available Mn and Fe as well as increased EC and decreased $CaCO_3$. Changes in soil properties were depended on depth and distance from the disposal lagoon.

REFERENCES

Kung, K.-H., M.B. McBride, 1988. Electron transfer processes between hydroquinone and iron oxides. Clays and Clay Minerals 36: 303-309.

McBride, M.B., 1987. Adsorption and oxidation of phenolic compounds by iron and manganese oxides. Soil Sci. Soc. Amer. J. 51: 1466-1472.

Miller, R.H. and D.R. Keeny, 1982. Methods of Soil Analysis, Part 2. Madison: American Society of Agronomy.

Paredes, M.J., E. Moreno, A. Ramos-Cormenzana and J. Martinez, 1987. Characteristics of soil after pollution with waste waters from oil extraction plants. Chemosphere 16: 1557-1564.

Piotrowska, A., G. Iamarino, M.A. Rao and L. Gianfreda, 2006. Short-term effects of olive mill waste water (OMW) on chemical and biochemical properties of a semiarid Mediterranean soil. Soil Biology & Biochemistry 38: 600-610.

Sierra, J., E. Marti, G. Montserrat, R. Cruanas and M.A. Garau, 2001. Characterization and evolution of a soil affected by olive oil mill wastewater disposal. Science of the Total Environment 279: 207-214.