Low Cost Treatment and Disposal of Olive Mill Wastewater

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During the extraction of oil from olives, large amounts of potable water are used, solid waste, and olive mill wastewater (OMW) are generated. OMW is phytotoxic, has antibacterial effects, and high pollution potentials. Azraq bentonite (AB), reddish volcanic tuff (RVT), lime (CaO), aluminum sulfate (alum), ferric chloride, and sodium carbonate were used to remove turbidity (NTU) and non-specific organic compounds (COD) from OMW. The results showed that RVT, ferric chloride, and sodium carbonate are not efficient in removing turbidity (NTU) and COD from OMW. The removal of NTU and COD using alum was 95% and 65% respectively. Alum is not recommended, since it is expensive to use. The removal of NTU and COD using lime were 99% and 69% respectively. AB showed 96% removal of NTU and 37.5% removal of COD. Lime and AB are inexpensive and locally available materials. The treated OMW can not be used in agriculture because of their high dissolved solids content; therefore, natural evaporation in shallow ponds, after lime or AB treatment, might be an acceptable solution.

Introduction

During the extraction of oil from olives, large amounts of potable water are used, solid waste, and olive mill wastewaters (OMW) are generated. The OMW streams are from wash water, water contained in the olives, and the water added to facilitate centrifugation.

OMW has very high organic load, acidic pH, intensive odor, high concentrations of dissolved solids, and varies in color from light green to red to black. Moreover, OMW is phytotoxic and has antibacterial effects (Gonzaez et al., 1990; Spandere and Dellomonaco, 1996). The organic load in the OMW is found in soluble, colloidal, and suspended forms. The organic compounds include phenols, polyphenols, chlorophyll, humic acids, lipids, polyalcohol, sugar, etc. (Yesilada et al., 1995).

The acidic pH of the OMW can be related to the phenol compounds. The colors depend on the color of olives processed, fruit variety, ripeness, storage conditions, method of oil extraction, and age of the OMW. The phytotoxicity effects are related to the high concentration of phenols, suspended solids and high content of dissolved solids. Phenol is protoplasmic poison that damages all kinds of cells (Manahan, 1994). Moreover, the roots of higher plants depend on the oxygen in the soil atmosphere to meet their metabolic needs; suspended solids from OMW decrease the soil aeration. The dissolved solids also affect negatively the growth of the green plants. The antibacterial effects are related to the high concentration of phenol compounds with low molecular weight (Gonzalez et al., 1990).

Several problems are associated with the treatment of OMW. Aerobic treatment of OMW is expensive, needs high residence time, dilution, pH adjustment, and acclimatization of microorganisms; anaerobic treatment and biogas production could be an acceptable solution (Tsonis and Grigoropoulus, 1993; Marrtin et al., 1994). The aim of this study was to search for a cost-effective treatment and disposal method for OMW in order to reduce their pollution effect.

Materials and methods

OMW samples were collected from Dajani centrifugal olive oil mill in northern Jordan. The OMW samples were taken from the centrifuge that separates the olive oil from the OMW. Table 1 shows some physicochemical characteristics of average OMW samples.

Table 1: Some physicochemical characteristics of average OMW samples from Dajani olive oil mills.

Parameter	Average values	Parameter	Average values
pH (SU)	4.6	Volatile solids (g/l)	27
COD (g/l)	70	Phenols (g/l)	202
BOD_5 (g/l)	20	K^+ (mg/l)	271
Turbidity (NTU)	35950	K^+ (mg/l)	889
TS (g/l)	115	Ca^{2+} (mg/l)	1447
TDS (g/l)	17	NO_3- (mg/l)	9
TSS (g/l)	22	PO_4^{3-} (mg/l)	6

Sedimentation, filtration, and flotation experiments were conducted to treat OMW. Moreover, Azraq bentonite (AB), reddish volcanic tuff (RVT), lime (CaO), aluminum sulfate (alum) ferric chloride, and sodium carbonate were used in the treatment of OMW.

AB samples were collected from Ain Al-Baida area in the Azraq basin, Jordan. The AB samples were crushed; particles larger than 63μm were removed by wet sieving. The 63μm clay fraction was dried at 55°C to prevent changes and collapse of the clay minerals. These fractions were used in the treatment of OMW. Powder RVT samples were provided by the Green Technology Group, Jordan. Lime, alum, ferric chloride, and sodium carbonate were provided by Fisher Scientific Laboratory, Fluka and Interchem respectively. X-Ray diffraction (XRD) of AB, and RVT, using the < 63 μm samples, were accomplished using XRD 6000 instrument, manufactured by Shimadzu-Japan. The XRD pattern of AB indicates that AB mainly consists of montmorillonite. The non-clay mineral appeared as albite and quartz. The XRD pattern of RVT indicates that phillipsite is the primary zeolitic mineral, while calcite is the primary non-zeolitic mineral.

The surface characterization of AB and RVT were done using Scanning Electron Microscope model Quanta 2000. AB and RVT scanning electron micrographs are shown in figures 1, and 2 respectively.

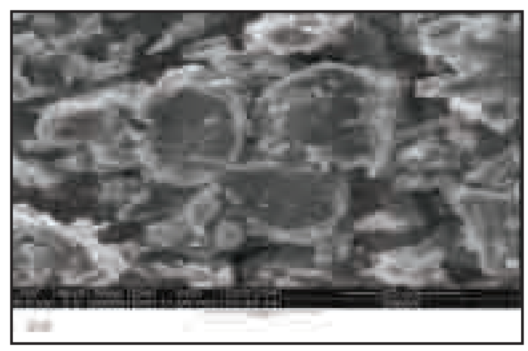

Figure 1: Scanning electron micrograph of Azraq bentonite showing platelets.

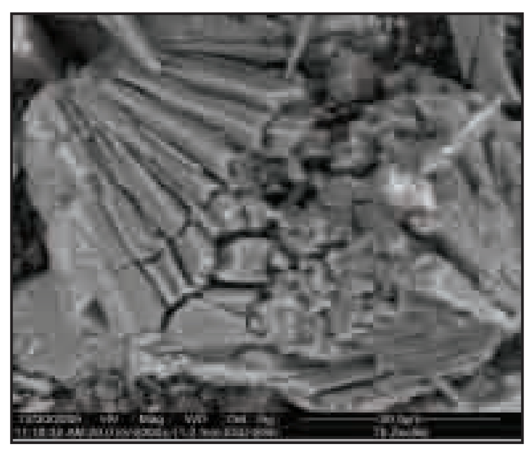

Figure 2: Scanning electron micrograph of reddish volcanic tuff showing phillipsite rods connected with each others with channel framework.

Experimental procedure

In order to determine the optimum dosing of the used reagent preliminary experiments were carried out. Moreover, to ensure the reliability of the data, control samples were prepared for each test. The weighed reagent was thoroughly mixed with a 100 ml OMW sample for 10 min. After 2 hrs of sedimentation the efficiency of the used reagent was evaluated by measuring turbidity, pH, and COD, in the OMW sample according to the Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1998). The resulting sludge consists of the used reagent, organic materials, phosphorous, etc., and therefore has a potential to act as soil conditioner in sandy soils.

Results and discussion

Sedimentation experiments were conducted to determine the amount of the settable solids in the OMW using Imhoff-cone. The experiments showed that the settled solid fraction was negligible (8-18 ml/l), even after 24 h of sedimentation. The sediments consist mainly of dirt materials from the olives. Moreover, sedimentation experiments were made by diluting the OMW with distilled water (1:5, 2:5, 3:5, and 1:1), but the sedimentation results were not improved. Gravity filtration experiments with OMW using tuff materials showed also no satisfactory results. Flotation experiments by injection air into the OMW samples for 30 min showed also no successful results. Moreover, the use of ferric chloride, sodium carbonate, and reddish volcanic tuff, as treatment reagents, did not give satisfactory results.

Removal of turbidity and COD from OMW using optimum dose of alum, Azraq bentonite (AB), and lime separately.

Figure 3 shows the removal of turbidity (NTU) and COD from OMW using optimum dose of alum, AB, and lime separately.

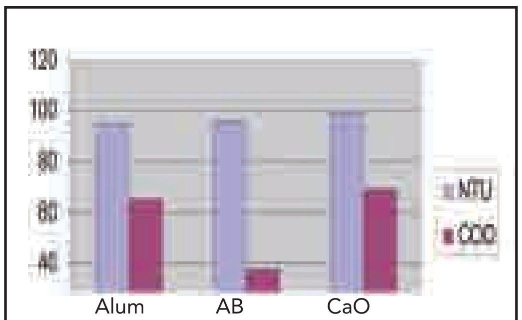

Figure 3: % Removal of turbidity (NTU) and COD from OMW using optimum doses of alum (0.25g/100 ml), Azraq bentonite (AB) (1g/100 ml), and lime (0.3g/100 ml).

The removal of turbidity and COD from the OMW using optimum dose of alum (0.25g/l00 ml) was about 95% and 65% respectively. The removal efficiency of the turbidity and COD is due to alum precipitation. This settles slowly, taking colloidal particles and suspended solids with it. Moreover, some dissolved organics such as phenols and humic acids are adsorbed to the sediment materials and are removed from the OMW (Duan et al., 2003).

The removals of turbidity from OMW using optimum dose of AB (1g/l00 ml) was about 96 %, while the removal of COD, was about 37.5 %. AB acts as an adsorbent, since it has capabilities of adsorbing a wide variety of organic compounds into the submicroscopic platelets (figure 1). This results in swelling of the bentonite, which means that the interlayers are available for more adsorption. The removal capabilities result also from the negative charges on the structure of AB, which make it capable to adsorb positively charged species. The raise of pH, from 4.8 to 5.5 after the treatment, is due to the adsorption of phenols onto the AB, which are acidic in water.

The removal of turbidity and COD from the OMW using optimum dose of lime (0.3g/l00 ml) was about 99%, while the removal of COD, was about 69 %. The effect of lime on organic compounds depends on their structures. Phenol compounds with two phenolic groups in the molecule, like catechin, are totally removed, compounds which contain both phenolic and carboxyl groups, such as vanillic acid, syrigic acid are partially and compounds which have only one phenolic or carboxyl group such as tyrosol and veratric acid are not effected by lime (Aktas et al., 2001). The removal of phenols and other organic materials is due to lime precipitation (Lolos et al, 1994). Therefore, lime is an inexpensive and a safe substance for organic stabilization because nothing is oxidized and no dangerous compounds are formed.

The lime treatment of OMW increased the pH from 5.1 until 12. This treatment volatilizes the nitrogen and precipitates the phosphorous along with other suspended and dissolved solids. The high pH also precipitates most metals and trace elements that are present in the OMW, and reduces their solubility and mobility. After the lime treatment the effluent should be re-carbonated with CO_2 to precipitate out the excess lime and lower the pH to about 8.

Removal of turbidity and COD from OMW using different mixtures.

Figure 4 shows the results of removing turbidity and COD from OMW using two different mixtures.

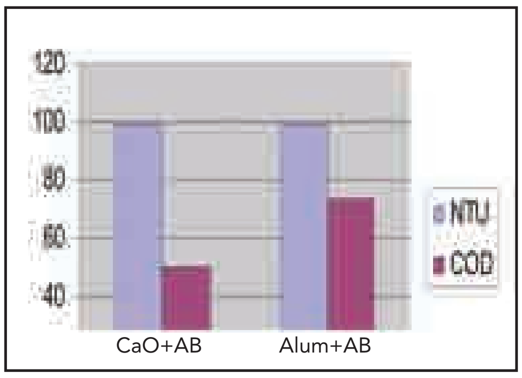

Figure 4: % Removal of turbidity (NTU) and COD from OMW using mixtures of (0.3g) CaO + (1g) AB per 100 ml & (0.25g) alum + (1g) AB per 100 ml.

The removal of turbidity and COD from the OMW using (0.3g) CaO + (1g) AB per 100 ml OMW were 99% for turbidity and 50% for COD, while using (0.25g) alum + (1g) AB per 100 ml OMW removed 99% of turbidity and 73% of COD. The higher removal of COD could be related to alum; dissolved materials which were not adsorbed by AB have been adsorbed to the precipitates and are removed from the OMW.

Removal of turbidity and COD from OMW using two different reagents as successive steps.

Table 2: Treatment of OMW using CaO as first step and Azraq bentonite (AB) as a second step.

Parameter	% Removal of NTU	% Removal of COD	pH (SU)
1st step (0.3g/l00 ml) CaO 2nd step (1g/l00 ml) AB	99.9	68.8	11.85
1st step (1g/l00 ml) AB 2nd step (0.3g/l00 ml) CaO	99.6	70	12

Table 2 shows the results of treating OMW using lime as first step and AB as second step.

The removal of turbidity and COD from the OMW, using (0.3g/l00 ml) CaO as a first step and (1g/l00 ml) AB as a second step, were about 99.9 and 68.8 respectively. While when using (1g/l00 ml) AB as first step and (0.3g/100 ml) CaO as second step the results were almost the same.

Disposal of OMW in shallow ponds.

The effluent of the OMW can not be used in agriculture without dilution because of their high dissolved solids content, but the sludge could be used as soil conditioner in sandy soils. Considering the climatic conditions in most olive oil producing countries, such as aridity, high solar energy and wind velocity, natural evaporation of the treated OMW in shallow ponds might be an acceptable solution. The natural evaporation is optimized by treating the OMW first with lime or AB, since floating materials negatively affect the evaporation by forming an impermeable film on the surface of the OMW in the ponds. Figure 5 shows shallow ponds used for the natural evaporation of OMW in northern Jordan.

Figure 5: Shallow ponds at the Akider waste dump site, north Jordan, containing OMW.

Conclusions

OMW is a significant point source of pollution. Reddish volcanic tuff (RVT), ferric chloride, sodium carbonate, sedimentation, filtration, and flotation are not efficient in removing turbidity or COD from OMW. Alum is an efficient reagent, but it is not recommended, since it is expensive to use. Lime and Azraq bentonite (AB) are low cost, locally available, and efficient in removing turbidity and COD from OMW. The effluent of the OMW can not be used in agriculture, but the sludge could be used as soil conditioner in sandy soils. Considering the climatic conditions in the olive oil producing countries, natural evaporation of the treated OMW in shallow ponds should be considered as an acceptable solution.

Acknowledgments

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