المؤتمر العربي الثالث للإدارة البيئية

الاتجاهات الحديثة في إدارة المُخلفات الملوثة للبيئة

مفهوم وأنواع المُخلفات الملوثة للبيئة وأساليب معالجتها

Management of Olive Mills Wastes in the Palestinian Territories

مخلفات الزيتون وإدارتها في المناطق الفلسطينية

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ملخص

تُعتبر مخلفات الزيتون السائلة والصلبة من المخلفات الضارة بالبيئة في المناطق الفلسطينية حيث تنتشر معاصر الزيتون في القُرى المختلفة ويتم التخلص من مخلفاتها السائلة بإلقائها في الوديان ومجاري الأنهار بما يلوث البيئة بالمخلفات العضوية ويعرض التربة ومصادر المياه الفلسطينية إلى ملوثات خطرة وخصوصاً خلال فترة موسم قطف الزيتون بين شهري تشرين أول وشباط، هذا عوضاً عن المخلفات الصلبة التي يتم أحياناً إعادة إستخدامها.

تتعرض الورقة إلى المخلفات الناتجة عن معاصر الزيتون بأنواعها المختلفة وتأثيراتها البيئية وكذلك إلى الطرق المختلفة المتبعة في التخلص من ومعالجة هذه المخلفات في البلدان المختلفة ومن ثم تأتي الورقة على معاصر الزيتون في المناطق الفلسطينية وطرق التخلص من مخلفاتها بطريقة عشوائية بإلقائها في الوديان بما يؤدي إلى تلوث التربة ومصادر المياه والحياة المائية في الأنهار التي تصب فيها هذه الوديان حيث يتم تقييم ذلك ودراسة تأثيره على البيئة. بعد ذلك تقدم الورقة لعدد من الدراسات والأبحاث التي تعنى بدراسة معاصر الزيتون في المناطق الفلسطينية وكذلك تلك التي تتعرض إلى إمكانيات إعادة إستخدام المخلفات الصلبة في مواد البناء وتزفيت الشوارع والاستخدامات الأخرى.

تخلص الورقة إلى مقترحات تخدم الإدارة السليمة لمخلفات الزيتون بما يتلائم مع الأوضاع الفلسطينية ويما يخدم البيئة الفلسطينية ويؤدي إلى تنمية وإدارة الموارد فيها بما يؤدي إلى حماية البيئة ويُساهم في تحقيق التنمية المُستدامة للموارد والبيئة الفلسطينية.

Abstract

The wastewater from the different olive mills located in and around the different villages in the Palestinian Territories is being disposed into the wadies. There, it is mixed with the untreated flowing municipal wastewater or with rainwater. The resulting high organic polluted wastewater affects the soil, the groundwater and the water courses downstream. This occurs mainly during the olive mill season from early October to late December. A decisive pre-condition for the achievement of any wastewater treatment project in the Palestinian Territories is the treatment/pre-treatment of Olive Mills Wastewater (OMW).

Different treatment technologies are reported to have been applied for treating olive mills wastes. Among these are the anaerobic combined with aerobic, forced evaporation, chemical and biological treatment methods. The reuse of the solid residue of olive mills is reported, among others, as burning material or as filter media. This paper evaluates the management options of the Olive Mill Wastewater (OMW) generated in the Palestinian Territories. It elaborates the different treatment and management alternatives and examines their effectiveness, impacts and research implications. A sample of 20 Mills has been surveyed in the Nablus-Tulkarem area and their wastewater quantities and characteristics are presented.

Introduction

In the Palestinian Territories, water is the most precious resource and its relative scarcity and quality is a major constraint on economic development. The random dumping of untreated wastewater into the wadies and watercourses is threatening the groundwater aquifers as the main source of water. The groundwater and surface water pollution by discharging wastewater into the wadies are determined by several projects as being among the core problems that should be solved in the Palestinian Territories.

During the past years and as part of the several activities related to the rehabilitation of the infrastructure of the Palestinian Territories, different projects have been implemented aiming at the construction of wastewater treatment plants. The sewerage project Tulkarem-region (DAR 1999) among other projects has stated that a decisive pre-condition for the achievement of the objectives and protection of the environment is the treatment/pre-treatment of industrial and olive mill wastes.

The olive mills contribute largely to the core problem of surface and groundwater pollution. The wastewater from the different olive mills located in and around the different villages in the West Bank is being disposed into the wadies. The Olive Mill Wastewater (OMW) is then mixed with the flowing untreated municipal wastewater or with rainwater. The high organic polluted wastewater affects the soil, groundwater and water courses downstream. This occurs mainly during the olive season, generally from early October to late December.

The wadi Zeimar in Nablus-Tulkarem region is one example, where OMW is discharged to flow with municipal wastewater to the west contributing to the flow of Alexander River behind the green line (the 1967 cease fire between Israel and Jordan) towards the Mediterranean. Thus, causing severe environmental problems and causing death to the aquatic life in the river.

The disposal of the untreated OMW into the open wadies and/or the water receiving bodies is considered as an urgent ecological problem that deteriorates the environment in the Palestinian Territories. It is also obsoleting the construction of wastewater treatment plants. The biological pollution due to the improper disposal of the high organic content OMW into the water bodies destroys the aquatic life and prevents its further development.

This paper investigates the possible treatment options of OM wastes. It presents the different treatment alternatives which are being used in other countries and assess their applicability to the Palestinian conditions.

Characteristics of Olive Mills Wastewater

Olive Mill Wastewater (OMW) generated by the olive oil extraction industry is a great pollutant because of its high organic load and also because of its high content of phytotoxic and antibacterial phenolic substances, which resist biological degradation (Saez et al., 1992). OMW is a major environmental problem in the Mediterranean area. The problems created in managing OMW have been extensivelly investigated during the last 50 years without finding a solution, which is technically fessible, economically viable and socially acceptable (Niaounakis and Halvadakis, 2004). Up-to-date the emphasis has been on detoxifying OMW prior to disposal to wastewater treatment plants. However, the present trend is towards further utilization of OMW by recovering useful by-products. Therefore a new strategy for olive waste management must be adapted.

The OMW characteristics in terms of both its quantity and quality are highly dependent on the extraction process. Olive oil is extracted mainly according to two methods; traditional (classical pressing) and continuous (centrifuging) methods starting from the pulp of olive fruits obtained by grinding them with stones or knife-edge spinal mills. In the traditional method the ground olives are pressed in bags then the oil is separated from the liquid mixer by resting in a serious of tanks or by using a centrifuge. In the continuous method the crushed olive fruits are pumped into a three-phase decanter and then the impure oil is centrifuged. The average values for the typical parameters of OMW samples obtained from nine different classical (traditional) and eight centrifugal mills (continuous) are presented in table 1 (Esra et al. 2001). The BOD_5 values of OMW are typically in the range of 40-200 g/l. The wide concentration range is again mainly due to variations in the extraction process adapted in the olive mill.

The traditional methods of extraction, based on press, and the continuous three phase decanting processes generate one stream of olive oil and two streams of wastes, an aqueous waste (OMW) and a wet solid waste (Zibar).

Table 1: Physical and chemical characteristics of OMW (Esra et al. 2001)

Characteristics	Average ± S.D	
	Traditional	Continuous
pH	4.5 ± 0.3	4.8 ± 0.3
Total solids g/l	44.4 ± 13.8	78.2 ± 13.6
Total suspended solids g/l	2.7 ± 1.1	27.6 ± 5.1
Volatile solids g/l	33.6 ± 12.3	62.1 ± 15.8
Volatile suspended solids g/l	2.5 ± 1.1	24.5 ± 5.0
Fixed solids g/l	10.8 ± 3.2	16.1 ± 7.7
Reduction sugar g/l	2.2 ± 1.7	4.7 ± 1.8
Oil-grease g/l	6.3 ± 10.1	12.2 ± 13.3
Polyphenol g/l	2.5 ± 0.7	3.8 ± 1.5
Volatile phenol mg/l	3.0 ± 2.6	3.1 ± 2.1
Nitrogen mg/l	43.7 ± 33.9	78.8 ± 39.6
COD g/l	65.7 ± 27.1	103.4 ± 19.5

In the waste from olive oil mills only constituents are found that come either from the olive or its vegetation water, or that come from outside due to the production process. The composition of the olive and its vegetation water cannot be influenced by the auxiliary agents that are seldom used in the production process. So the constituents of the vegetation water are decisive for the pollution load to be expected.

As illustrated by the mass balances in Figures 1 and 2, the specific water demand per ton of olive pulp for full-automatic olive mills is more than 3 times higher than the corresponding specific water demand of the semi-automatic olive mill. This consequently leads to a dilution effect and lower concentrations of all components found in the OMW of the full-automatic mills.

The olive itself consists of pulp (75-85% weight), nut (13-23% weight) and seed (2-3% weight) (Maesrto, 1989 in Improlive, 2000). The chemical composition of the olive is shown in table 2. OMW is the characteristic by-product of olive-oil production. Typically, the weight composition of OMW is 80-96% water, 3.5-15% organics, and 0.5-2% mineral salts (Guido Greco et al., 1999).

Table 2: Chemical composition of olives (Improlive, 2000)

Constituents	Pulp	Nut (stone)	Seed
Water	50-60	9.3	30
Oil	15-30	0.7	27.3
Constituents containing nitrogen	2-5	3.4	10.2
Sugar	3-7.5	41	26.6
Cellulose	3-6	38	1.9
Minerals	1-2	4.1	1.5
Polyphenols (aromatic substances)	2-2.25	0.1	0.5-1
Others	-	3.4	2.4
Values in percent by weight (%)			

Olive Mills in the Palestinian Territories

Olive oil production is a major contribution to the Gross National Income in Palestine. The annual production of olive fruits and olive oil reaches 120 and 24 thousands respectively. More than 200 olive mills are functioning in the West Bank generating more than 200 thousand cubic meter OMW. Approximately, $1.8x10^6$ tons of olive oil is produced annually worldwide with the majority (98%) of it being produced in the Mediterranean basin. It is reported that OMW resulting from the production process surpasses 30 million m^3 per year in the Mediterranean region (Baccari et.al. 1996).

The olive oil extraction process is a seasonal activity only carried out during the olive harvest season. The average harvest season period is approximately 60-90 days between October and January. In the West Bank, the olive mill capacity and thus the wastewater production rate is limited by the installed oil extraction equipment, which in case of good harvest results in the prolongation of the seasonal olive oil extraction period and not to the increase of daily olive extraction and wastewater generation rates.

Three types of oil extraction processes are applied in the West Bank; 1) the semi-automatic oil extraction process which utilizes vertical hydraulic presses, 2) the full-automatic oil extraction process which uses a horizontal 3-phase decanter and 3) the traditional oil extraction process. The traditional process is similar to the semi-automatic extraction with reduced olive oil yield.

Two types of effluents are generated by both basic types of olive mills. The relatively low or non-polluted effluents from the olive washing process and the extremely high organic loaded effluents generated from the oil extraction process itself (called Zibar).

The basic difference between the two main types of olive-oil production used in the Palestinian Territories is the oil extraction process itself. The semi-automatic oil extraction comprises hydraulic presses for the separation of the following two phases out of the prepared olive pulp:

- A liquid mixture of oil and Zibar which is further treated by means of a centrifuge to separate the olive oil from the Zibar, and
- A solid olive cake with water content of about 25% to 30% weight.

The full automatic oil extraction process comprises horizontal 3-phase decanters for the separation of oil, Zibar and olive cake.

In terms of the extraction processes, the situation in the Palestinian Territories is not much different from that in the European countries, where the huge producers of oilves are like Spain and Italy. Improlive has published the final report on the improvements of treatment of OMW from the two-phase olive mill extraction process (Improlive, 2000).

In the Palestinian Territories, the only treatment that is done to the wastes of olive mills is the partial reuse of the overall produced olive cake for the soap factories. The olive cake is collected and then extracted by hydrocarbons to extract the remaining oil to be used for producing soap. The olive oil soap is used in the region for bathing and washing. The remaining solid waste (Jifit) is dried and used as burning material to produce energy for the extraction process in the soap factories. The Jifit is also used partly for combustion to heat houses during the winter season. Nowadays, the remaining huge quantities of solid wastes (Jift) from the soap factories create environmental problems. One way to deal with the Jift is to increase its specific surface area and to use it as carbon filters. This needs further investigations.

Soap factories in the Palestinian Territories are mostly found in Nablus city. Additional quantiuties of olive cake and olive oil are imported from abroad to produce soap. This is specially done during poor olive seasons. Nowadays most of these factories have closed due to the economic situation and restrictions on export which are imposed by the Israeli occupation. This causes further huge quantities of olive solid waste to be dumped.

Figures 1 and 2 show the general mass balance for the two types of oil extraction processes (continuous) that are used in the Palestinian Territories other than the traditional method that is also still widely used. These balances have been obtained surveying twenty different olive mills in Nablus-Tulkarem region. The balances indicate that:

- The olive yield for both processes is in a similar range with 160 kg (semi automatic) and 180 kg (full automatic) of olive oil per ton of olive pulp.
- For the semi-automatic extraction process an average of 200 liter of water per ton of olive pulp is added, whereas for the operation of 3-phase decanters in the full automatic type more than three times this water amount is consumed.
- The water content of the olive cake for the full-automatic olive mill is 50%. This is double higher than the water content of the cake produced by the hydraulic presses. This will result in higher specific amount of wastewater (Zibar) generated by the full-automatic extraction process.
- On average, a surplus amount of wastewater of around 50% can be considered for the full-automatic oil extraction if compared to the semi-automatic process.

To compare the two mass balances with other literatures, table 3 presents the comparative data for the three different olive oil extraction processes (Improlive 2000).

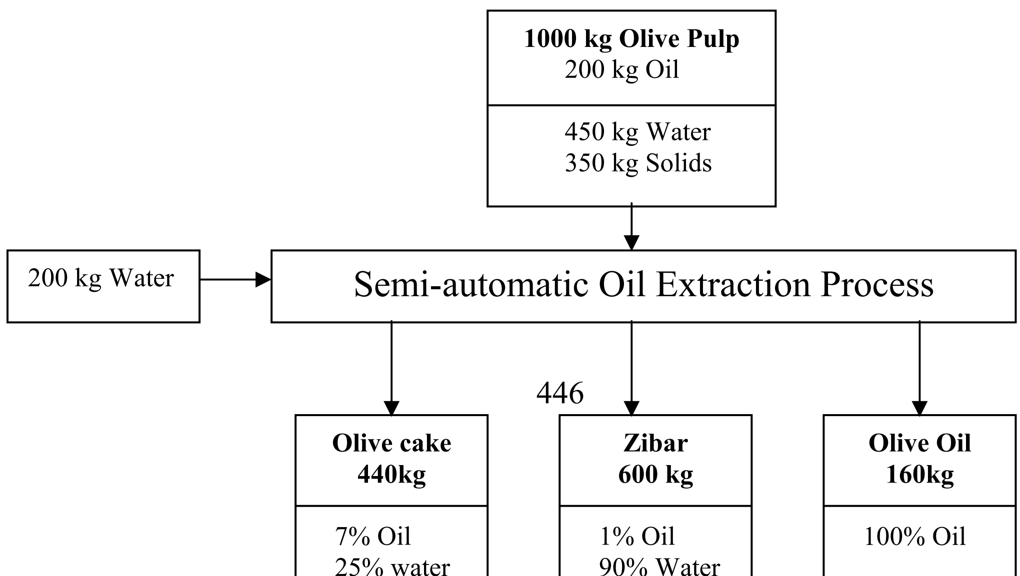

Figure 1: Mass Balance – Semi-automatic oil extraction process

Figure 2: Mass Balance – Full-automatic oil extraction process

Table 3 indicates that the traditional process generates higher organic content and less quantities of wastewater compared to the other two processes. In the Palestinian Territories the water shortages problems and the special social and economic situation currently exist have their implications on the Olive Mill Industry and the produced OMW. The water shortages imply that less water is used and higher pollution concentrations are encountered. The social and economic situation rejects or opposes the application of development measures. These have great impacts on the OMW problem and the management requirements.

Olive Mills Wastewater Amounts and Characteristics

Considering the specific data of olive oil extraction equipments installed in most of the Olive Mills in the Palestinian Territories, the daily wastewater generation rates for the different types of Olive Mills (Full-automatic, semi-automatic or traditional, 1 or 2 decanters, and 1 or 2 presses) have been calculated for 20 mills located in the region between Nablus and Tulkarem cities. The results are presented in table 4.

Table 3: Comparative data for the three olive oil extraction processes (Improlive, 2000)

Production Process	Input	Amount of Input	Output	Amount of Output
Traditional pressing process	- Olives - Washing water - Energy	1000 kg 0.1-0.12 m^3 40-63 kWh	- Oil - Solid waste (c. 25% water + 6% oil) - Wastewater (c. 88% water)	c. 200 kg c. 400 kg c. 600 kg
Two-phase decantor	- Olives - Washing water - Energy	1000 kg 0.1 – 0.12 m^3 < 90 –117 kWh	- Oil - Solid waste (c. 60% water + 3% oil)	200 kg 800 – 950 kg
Three-phase decantor	- Olives - Washing water - Fresh water for decantor - Water to polish the impure oil - Energy	1000 kg 0.1-0.12 m^3 0.5-1 m^3 c. 10 kg 90-117 kWh	- Oil - Solid waste (c. 60% water + 3% oil) - wastewater (c. 94% water + 1% oil)	c. 200 kg c. 500 –600 kg c.1000 –1200 kg

Out of the 20 mills operating in the region between Tulkarem and Nablus cities, 8 are full automatic, 9 are semi automatic, and 3 are traditional. During the olive mill season estimated at approximately 60 working days between September and December, the average olive processing capacity for the 20 mills is 355 tons olives per day. The total average wastewater flow is 330 m^3/day and the average amount of Zibar produced is 270 m^3/day. The maximum of these three production quantities from the 20 mills are 426, 393, and 320 m^3/day respectively. The most important figure is the maximum amount of Zibar (including decanter water) because of its extremely high organic content. The daily maximum amount of wastewater is not depending on the harvest, but on the maximum olive processing capacity of the installed extraction equipment.

Table 4: Daily total wastewater amounts of different types of olive mills for 20 mills (m^3/d)

Types of Wastewater	Type of Extraction Process											
	Full Automatic				Semi Automatic				Traditional			
	1 decanter		2 Decanter		1 Press		2 Presses		1 Press		2 Presses	
	Average		Maximum		Average		Maximum		Average		Maximum	
Wash water	3.0	3.5	6.0	7.0	1.0	1.5	2.5	3.0	1.0	1.5	2.5	3.5
Decanter Water	7.5	9.0	15.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grinding Water	0.0	0.0	0.0	0.0	1.0	1.0	2.0	2.5	1.0	1.0	2.0	2.0
Zibar	8.0	9.5	16.0	19.0	2.0	2.5	4.0	5.0	2.0	2.5	4.0	5.0
Total	18.5	22.0	37.0	44.0	4.0	5.0	8.5	10.5	4.0	5.0	8.5	10.5

As illustrated by the mass balance above (figures 1 and 2), the specific water demand (per ton of olive pulp) of full-automatic olive mills is more than 3 times higher than the corresponding specific water demand of the semi-automatic olive mills. This will consequently leads to a dilution effect with lower concentrations of all Zibar-components found in the wastewater of these mills.

Table 5 shows the average daily pollution loads generated at maximum olive mill production capacity from the 20 mills.

Table 5: Average daily pollution loads generated by the surveyed 20 Olive Mills

Pollution Parameter	Pollution Load (Olive Mill Production)

	Unit	Average	Maximum
Total Wastewater	m^3/day	269	320
Chemical Oxygen Demand (COD)	kg/day	32280	38400
Biochemical Oxygen Demand (BOD_5)	kg/day	10760	12800
Suspended Solids (SS)	kg/day	4035	4800
Total Phenols	kg/day	942	1120
Total Nitrogen	kg/day	81	96
Total Phosphorous	kg/day	54	64
Potassium (K^+)	kg/day	1883	2240
Chloride (Cl^-)	kg/day	323	384

To evaluate the effect of OMW in comparison to domestic wastewater, it is to present her the characteristics of domestic wastewater. Table 6 presents the characteristics of the raw wastewater in Nablus area (Nashsshibi 1995). The values have been attained through analysis of composite samples carried out for an 8-hour period and has not been related to flow.

Table 6: Wastewater characteristics in Nablus area

Parameter	Concentration	Parameter	Concentration
BOD_5	1185 mgO_2/l	SO_4^{2-}	137 mg/l
COD	2115 mgO_2/l	PO_4^{3-}	7.5 mg/l

TKN	120 mgN/l	Cl^-	1155 mg/l
NH_4^+	104 mgN/l	TSS	1188 mg/l
NO_3^-	1.7 $mgNO_3$-N/l		

The domestic wastewater data reported by Gearheart, Bahri and Al-Hmaidi, (1994) are different from the above. Their samples have been taken as grab samples and have showed lower BOD_5 and COD values (600 and 954mg/l) and higher Nitrate values (27.9$mgNO_3$-N/l). The Chlorides and the TSS gave about the same figures, but indicating extremely high concentrations. The TSS is high in Nablus due to the tannery wastes, which are released daily into the receiving stream.

Wastewater is mainly of domestic origin. But since water consumption is low, wastewater is concentrated and its strength is comparably high. Light and commercial industries are prevailing in the Palestinian Territories, which means that the heavy metal contamination is not probable. The discharge of the commercial wastewater into the sewage system leads also to high pH values, high temperature (due to hot wastes) and high content of chemicals. The chemicals are mainly from building stone, Tahena and tannery industries. During the olive oil extraction season and due to discharge of the OMW into the streams, wastewater samples have indicated BOD_5 values of more than 20g/l.

Treatment Alternatives of Olive Mill Wastes

Up to the early 70's and even in some of the European countries like Italy, Portugal, Turkey and Greece, the only method that is being applied for the treatment of OMW is storage and natural evaporation of these effluents in large ponds. All effluents generated during the olive oil production season are discharged to these ponds and are subjected to natural drying during the rest of the year until the start of the new campaign.

The great variety of components found in OMW requires different technologies to eleminate them where their application typically lead to generation of harmful effects on the environment. The Improlive project (Improlive 2000) has examined a good number of treatments and processes among all possible treatment methods for both solid and liquid waste of olive mills. However, these methods have to be re-examined rather critically because up to now very different treatment methods for OMW have been studied. The local conditions of applying these methods should also be considered. To evaluate appropriate treatment methods that are applicable to the conditions of the Palestinian Territories, factors including social, economical and even political, among other circumstances, should be evaluated. The treatment methods should also consider the profitable use of the final product by the olive oil industry, otherwise these methods are considered not useful.

For liquid waste of olive oil production the following treatment procedures are encountered:

- Aerobic treatment: Lagooning, bioremediation
- Anaerobic treatment
- Filtration: Ultrafiltration, membrane filtration
- Wet oxidation
- Precipitation/Flocculation
- Adsorption
- Evaporation

- Electrolysis
- Decolorisation

Fertilizer production and livestock feeding are two recycling methods that can be applied to liquid as well as solid waste from the olive oil industry. The processed solid residue of olive mill products was explored by Gharaibeh et al. (1998) to treat drinking water containing several heavy metals in trace concentrations. It was proved that the residue could be used to remove Pb(II) and Zn(II) from aqueous solutions by adsorption. In the following some treatment alternatives are presented.

a. Anaerobic treatment

Anaerobic treatment is considered as a cost-effective alternative, if compared to aerobic treatment especially for high organic industrial wastewater. The anaerobic wastewater treatment processes have been tested for the treatment of olive mill effluents in pilot scales. They have been tested in large scales as well, but only in combination with aerobic processing. A multistage system with first an anaerobic stage and a sequential aerobic treatment stage has been investigated by Steegmans (1978) and proved to be effective.

The low rate anaerobic sludge blanket type reactor is considered as the most efficient anaerobic reactor for the treatment of OMW. Due to the extremely high organic load with considerable portion of suspended COD and the generally limited biodegradation, the hydraulic retention times of the olive mill effluent should be increased. This will ensure sufficient BOD and COD removal prior to the discharge of the pretreated effluents to the aerobic post-treatment.

b. Forced evaporation

Natural evaporation can be considered as a low-cost solution for the incorporation of the wastewater pollutants in the dried sludge. But due to long evaporation periods, this technique is technically and economically feasible only for low to moderate wastewater flows. The constraints in applying the natural evaporation to OMW have led to the forced evaporation technologies. The principle is based on the physical phenomena of forcing evaporation by the diffusion of the wastewater in dry air stream. This treatment alternative has the advantage of generating dried sludge that can be disposed off or reused as fertilizer, burning material, etc.

c. Modified process for oil extraction

One other treatment alternative of OMW is the modification of the extraction process itself. The modification measures result in a significant reduction or even prevention of water pollution. The modified “ecological” oil extraction process has been widely applied in different countries using 2-phase decanters instead of 3-phase decanters. The last process results in producing two main mass flows. These are the olive oil as end product and a wet sludge comprising all water pollutants, which can be dried and reused. Among the treatment alternatives that have been evaluated for the treatment of wastewater from the two phase decanter are drying/evaporation, thermal treatment, biological treatment, composting, anaerobic treatment, and treatment by fungi. In the Improlive study (Improlive, 2000), it has been concluded that composting, as an individual method, has recognisable advantages. It takes place without serious emissions into air, water or soil and has rather low operational and personal costs.

d. Chemical and Biological Treatment

Several chemical treatment processes for OMW are found in the literature. Curi et al. (1980) have tested the treatment of OMW with a mixture of aluminum sulfate and ferric chloride, calcium hydroxide solution and also acidifying of the waste with hydrochloric acid solution. Tsonis et al. (1989) have used calcium hydroxide, aluminium sulfate and magnesium sulfate for the chemical treatment of OMW. The effect of lime treatment of OMW was investigated by Esra et al. (2001). Some biological processes have also been tested to eliminate the pollution effect of OMW by Hamdi et al. (1992) and Martinez et al. (1993).

Sabbah (Sabbah et al. 2001) has evaluated different techniques for the treatment of OMW. This included aerobic and anaerobic combined with physical treatment methods. Different types of reactors were checked such as stirred-tank reactor, fluidized bed reactor, and UASB reactor. UASB has showed promising technique of anaerobic treatment for OMW (Sabbah et al. 2004).

One further treatment option is the post-treatment of the effluents from anaerobic-aerobic reactors using mainly membrane systems so that treated OMW could be discharged directly to municipal wastewater treatment plants.

Management Options of OMW

1. Treatment options

The treatment options of OMW in the Palestinian Territories are limited by, both, their different characteristics due to traditional oil extraction processes and the seasonal limitations. Therefore other options for managing the OMW are encountered.

The following are some points that should be considered in management of OMW in the Palestinian Territories:

- The majority of the olive mills is located within the residential areas of smaller villages and is of small scale.
- The majority of the olive mills are operated in a kind of garage or workshop with very limited space available within or outside the olive mill.
- Technical capabilities of the olive mill owners and their part-time employees are limited.
- Financial capabilities of the olive mill owners especially if related to potential investment for on-site treatment facilities are rather limited.
- The effluent quantities generated by each individual olive mill are relatively small.
- The effluent OMW is of high suspended solids and oil contents.
- On-site treatment and disposal concept would require continuous monitoring in order to ensure long lasting operation of any facilities installed.

All the above factors and the on-site observations do clearly indicate the need for centralized OMW treatment plant. To ensure efficient, long lasting OMW treatment, there is a need for an appropriate collection and transport system to transfer the olive mill effluents from the individual olive mill sites to the centralized treatment facilities. The implementation of a piped OMW transport system would neither technically nor economically be feasible. Any collection system will encounter operational problems and clogging. Therefore the only feasible transport solution is the collection of olive mill effluents by means of suitable sized suction tankers.

As to the treatment technologies, the biological anaerobic pre-treatment has been ranked third in a pre-screening process applied to a variety of technologies ranging from natural irrigation and evaporation systems up to physical-chemical treatment systems (Shaheen 2004). In the Palestinian Territories, Subuh (1999) has conducted anaerobic digestion of OMW using laboratory scale Up-flow Anaerobic Sludge Blanket (UASB) reactor. He proved that removal efficiency of the soluble fraction of COD reached 76% using the UASB. Sabbah, et al. (2003) achieved a 95% removal of the phenolic compounds present in OMW using sand filtration and subsequent treatment with powdered activated carbon in a batch system. This pretreatment for OMW was found to enhance the anaerobic activity of the sludge in the batch system significantly. Using the UASB reactor, COD removal efficiency reached 80-85% at a hydraulic retention time of 5 days.

The other treatment technology of concerned is forced evaporation. This option is ranked second in the pre-screening process (Shaheen 2004). This option requires the delivering of the OMW to a central forced evaporation plant by tankers. A storage tank is needed, whose size depends on the treatment capacity of the evaporation system. The greenhouse-type evaporation tents are then constructed, where the OLW is diffused by means of a sufficient number of diffusion nozzles. At the same time the ambient air is introduced into the tents by means of ventilators located at one end of the tents. The dried solids are collected at the bottom of the tents and can be reused.

2. Extraction process modification

By means of process modification measures a significant reduction or even the prevention of water pollution can be achieved. The so called "ecological process" is based on the use of 2-phase decanters with only 2 main mass flows. These are the olive oil as final end product and the wet sludge comprising all water pollutants. The ecological oil extraction process modification has been applied in large scale in more than 200 full-industrial plants, predominantly in Spain and Italy, but also in Tunisia in comparatively short period of about 5 years. In the Palestinian Territories this modification can go parallel with the establishment of large scale olive mills at selected commercial locations to replace the scattered small scale mills.

The production of wet sludge, however, requires additional draying in order to ensure proper final disposal or potential reuse of the produced sludge. Therefore this management option is optimal if the establishment of centralized olive mills is combined with the construction of forced evaporation treatment plants. Due to the high holding water capacity of the wet sludge and to achieve proper sludge drying, rotary drying ovens are recommended. Natural drying can not achieve a maximum water content of 30 to 35%.

3. Reuse options

The reuse options have been investigated in the Palestinian Territories. The effect of adding OMW (Zibar) as an admixture on the durability and permeability of concrete and the effect of adding it as water replacement on fresh and hardened concrete have been investigated by Imseeh (1997). Using Zibar taken from an automatic mill has improved the workability of fresh concrete. It has increased the slump by 6% to 400% and the compressive strength at 28 days by 1 to 38% depending on the percentage of water replacement and the contents of concrete mix.

The use of Zibar, along with lime, as an admixture for the stabilization of soils has been also investigated. Test results indicated that the strength characteristics, represented in CBR values, increased considerably. Plasticity was reduced indicating good potential for the use of OMW for stabilization and improvement of road sub-grade characteristics.

Further researches on preparation, enhancement and utilization of activated charcoal from olive solid waste have been implemented at An-Najah University. The activated charcoal produced from olive waste is used in water purification from organic and inorganic contaminants. The use of modified olive solid waste activated carbon for treating wastewater from organic and inorganic waste in a recyclable manner has been tested. The use of the olive based activated carbon as catalyst support has also been investigated.

Conclusions

The uncontrolled dumping of untreated wastewater and OMW into the wadies and watercourses in the Palestinian Territories is a threat to the groundwater aquifers, water courses and the environment. The OMW involves a seasonal disturbance and an overloading for the receiving waters or for the sewage treatment plants.

Based on the general characteristics of OMW as well as the findings of the on-site investigations and the survey of 20 olive mills, the need for implementation of a management system for OMW in the Palestinian Territories is defined. The management system should be long- lasting, appropriate and environmentally sound. It should consider effluent collection, treatment and disposal or reuse. Three management options have been defined and elaborated. These are the treatment option using the biological anaerobic or forced evaporation, the process modification measures, and the reuse option.

There is a need for a centralized OMW treatment and disposal measures as the only practical option for the Palestinian Territories. Process modification in combination with forced evaporation is seen as the most appropriate management and treatment options.

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