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Management of Olive-Mills Wastewater in Palestine

إدارة المخلفات السائلة لمعاصر الزيتون في فلسطين

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Abstract

Different treatment technologies are reported to have been applied for treating olive-mills wastewater (OMW). 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 filtering media. This paper evaluates the treatment options of the OMW generated in Palestine. It elaborates on the different treatment and management alternatives and examines their effectiveness. A sample of 20 Mills has been surveyed in the Nablus-Tulkarem region and their wastewater quantities and characteristics are presented. Centralized treatment and disposal plants for OMW are recommended as a practical option for Palestine. Oil-extraction process modifications in combination with forced evaporation are recommended as the most appropriate management and treatment option.

ملخص

تتعرض الورقة إلى مخلفات معاصر الزيتون وإلى 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، حيث تم دراسة عينة من ٢٠ معصرة زيتون منتشرة في منطقة نابلس- طولكرم وتم التطرق إلى كمية وخواص المخلفات الناتجة من

هذه المعاصر. بعد ذلك تقدم الورقة لعدد من الدراسات والأبحاث التي تعنى بدراسة معالجة مخلفات معاصر الزيتون وكذلك تلك التي تتعرض إلى إمكانية إعادة استخدام المخلفات الصلبة في مواد البناء وتزفيت الشوارع والاستخدامات الأخرى. تخلص الورقة إلى مقترحات تخدم الإدارة السليمة لمخلفات الزيتون بما يخدم البيئة الفلسطينية ويؤدي إلى تنمية وإدارة الموارد فيها، وبما يؤدي إلى حماية البيئة ويُساهم في تحقيق التنمية المُستدامة للموارد والبيئة الفلسطينية.

Introduction

Wastewater from the different olive-mills located in and around the different villages in Palestine is being disposed of 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 and water receiving bodies. This occurs mainly during the olive season from early October to late December. The disposal of the untreated OMW into the open wadies and/or the water receiving bodies is, therefore, considered as an urgent ecological problem that deteriorates the environment in Palestine. The biological pollution due to the improper disposal of the high organic OMW into the water courses destroys the aquatic life and prevents its further development. The wadi Zeimar in Nablus-Tulkarem region is one example, where OMW is discharged to flow with municipal wastewater to Alexander River towards the Mediterranean.

OMW is a great pollutant because of its high organic load and its high content of phytotoxic and antibacterial phenolic substances, which resist biological degradation (Saez, et al., 1992, p.1261-1266). The problems created in managing OMW have been extensively investigated during the last 50 years without finding a solution, which is technically feasible, economically viable and socially acceptable (Niaounakis, and Halvadakis, 2004). Up-to-now 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 OMW management must be adapted.

This paper presents several treatment and management options of OMW. It elaborates on the different treatment technologies, which are being used in other countries and assesses their applicability to the Palestinian conditions. Through the survey of 20 Olive-mills, the paper evaluates the OMW quantities and characteristics. It concludes with the most appropriate OMW treatment and management options to the Palestinian conditions.

Characteristics of OMW

Olive oil production is a major contribution to the national income in Palestine. The annual average production of olive fruits and olive oil reaches 120 and 24 thousand tons respectively. More than 200 olive-mills are functioning in the West Bank generating about 200 thousand m3 per year of OMW (Subuh, 1999). For the sake of comparison, approximately 1.8 million tons of olive oil is produced annually worldwide. The majority, (98%) of it, is being produced in the Mediterranean basin. It is reported that OMW resulting from the production processes surpass 30 million m3 per year in the Mediterranean region (Niaounakis, and Halvadakis, 2004).

The olive oil extraction process is a seasonal activity only carried out during the olive harvest season, which is approximately 60-90 days between October and January. In Palestine, 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.

The characteristics of OMW in terms of 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 olives are pressed in bags then the oil is separated from the liquid mixer by resting in a series of tanks or by using a centrifuge. In the centrifugal methods, the crushed olive fruits are pumped into a two or three-phase decanter and then the impure oil is centrifuged.

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

The three types of oil extraction processes applied in Palestine are; 1) semi-automatic oil extraction process which utilizes vertical hydraulic presses, 2) full-automatic oil extraction process which comprises horizontal three-phase decanter, and 3) the traditional oil extraction process. The full automatic process uses the horizontal three-phase decanter for the separation of oil, Zibar and the wet solid waste (olive cake). The traditional method of extraction, based on pressing, generates one stream of olive oil and two streams of wastes, the Zibar and olive cake. The semi-automatic process comprises hydraulic presses for the separation of the 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 the solid olive cake with water content of about 25% to 30% by weight. The traditional method is similar to the semi-automatic in terms of a reduced olive oil yield.

The average values for 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, p. 2336-2340). The BOD_5 values of OMW are typically in the range of 40-200 g/l. The wide concentration range is mainly due to the variations in the extraction processes. The olive itself consists of pulp (75-85% weight), nut (13-23% weight) and seed (2-3% weight). Table 2 shows the chemical composition of the olive. Typically, the weight composition of OMW is 80-96% water, 3.5-15% organics, and 0.5-2% mineral salts (Improlive, 2000).

Table (1): Physical and chemical characteristics of OMW (Esra, et al., 2001, p. 2336-2340).

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

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

Constituent	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 (%)

OMW quantities and mass balance

Considering the specific data of olive oil extraction equipments installed in most of the olive-mills, the daily wastewater generation rates for 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. Out of the surveyed 20 mills, 8 are full automatic, 9 are semi automatic, and 3 are traditional.

The average olive processing capacity for the 20 mills is 355 tons of olives per day during the 60-90 days olive season. The total average wastewater flow of the 20 mills 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 tons/day, 393 m^3/day, 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 3 presents the daily total wastewater amounts produced by the different olive-mill types of the 20 surveyed mills.

Table (3): Daily total wastewater amounts of different olive mill types of the 20 mills (m^3/d).

Wastewater Amounts	Type of Extraction Process											
	Full Automatic				Semi Automatic				Traditional			
	1 Decanter		2 Decanters		1 Press		2 Presses		1 Press		2 Presses	
	Average	Maximum	Average	Maximum	Average	Maximum	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

Figures 1 and 2 show the general mass balances for the semi-automatic and full automatic oil extraction processes. The figures have been prepared in accordance with the data collected from the 20 surveyed olive-mills. As illustrated by the figures, 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 balances indicate that:

- The olive yield from both processes is in 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 kg of water per ton of olive pulp is added. Whereas, for the operation of

the 3-phase decanters in the full automatic type, more than 700 kg of water 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.
- The specific water demand of the full-automatic olive-mill is more than 3 times higher than that of the semi-automatic olive-mill. This will consequently lead to a dilution effect with lower concentrations of all Zibar-components of the full automatic olive-mills.

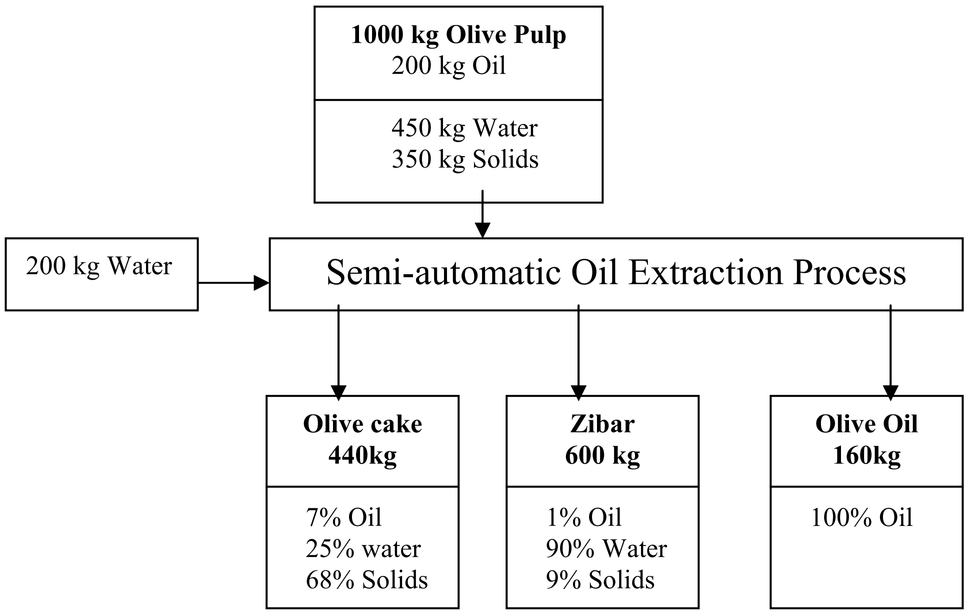

Figure (1): Mass Balance – Semi-automatic oil extraction process.

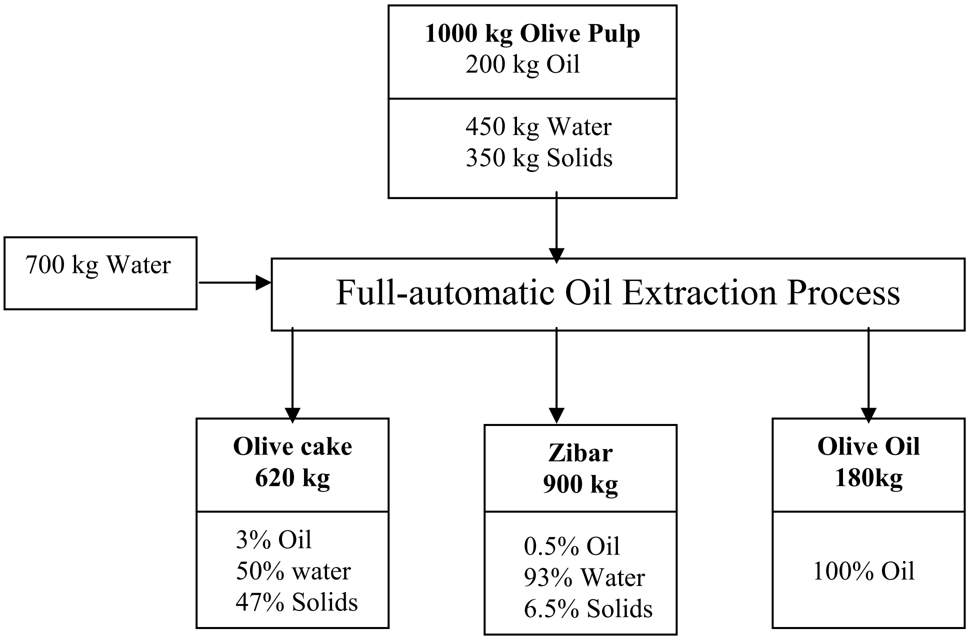

Figure (2): Mass Balance – Full-automatic oil extraction process.

Table 4 presents comparative mass balances for the three different olive oil extraction processes (Improlive, 2000). The table indicates that the traditional process generates higher organic content and fewer quantities of wastewater compared to the other two processes. In Palestine, the water shortage and the social and economic conditions have their implications on the olive-mill industry and the produced OMW. Less water is consumed and higher pollution concentrations are encountered. The social and economical conditions obsolete the process modification measures. These limitations have their impacts and implications on the OMW problem and the management options.

Table 5 illustrates the average daily pollution loads generated at maximum production capacity as obtained from the surveyed 20 olive-mills. The discharge of these pollution loads into the sewage system and water receiving bodies leads to high pH values, high temperature (due to hot wastes) and high content of chemicals. Wastewater samples taken from wadi Zeimar during olive oil extraction seasons have indicated BOD_5 values of more than 20g/l due to the discharge of OMW into the wadi.

Table (4): Comparative mass balances 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 (25% water + 6% oil) - Wastewater (88% water)	200 kg 400 kg 600 kg
Two-phase decanter	- Olives - Washing water - Energy	1000 kg 0.1 – 0.12 m^3 < 90 –117 kWh	- Oil - Solid waste (60% water + 3% oil)	200 kg 800–950 kg
Three-phase decanter	- 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 10 kg 90-117 kWh	- Oil - Solid waste (60% water + 3% oil) - wastewater (94% water + 1% oil)	200 kg 500–600 kg 1000–1200 kg

Table (5): Average daily pollution loads generated by the surveyed 20 olive-mills.

Pollution Parameter	Pollution Loads (Olive-Mills 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

Treatment alternatives of OMW

The great variety of pollution components found in OMW requires different technologies to eliminate them. Several treatment methods and processes for both solid and liquid wastes of olive-mills have been examined by the Improlive project. Improlive (Improlive, 2000) is a European project, which has published its final report on the improvements of treatment the of OMW from the two-phase olive-mill extraction process. Improlive (Improlive, 2000) has evaluated, among other treatment processes of OMW, drying/evaporation, thermal treatment, biological treatment, composting, anaerobic treatment, and treatment by fungi. It has concluded that composting, as an individual method, has recognizable advantages. It takes place without serious emissions into air, water or soil and has rather low operational and personal costs.

For OMW, different treatment methods and processes are encountered, among theses are:

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

These methods have to be re-examined rather critically because they are very different. The local conditions of applying these methods should also be considered. To evaluate appropriate treatment methods and examine their applicability to the Palestinian conditions, factors including social, economical, and even political should be considered. The following is a discussion of four selected treatment and management methods of OMW.

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 (Steegmans, 1987).

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 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.

Subuh (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 (Sabbah, et al., 2001, p. 535-540) have evaluated different techniques for the treatment of OMW including 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 a promising technique for anaerobic treatment of OMW (Sabbah, et al., 2001, p. 535-540).

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 of 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. This ecological oil extraction process has been widely applied in different countries using two-phase decanters instead of three-phase decanters. The two-phase decanter process results in producing two main mass flows. These are the olive oil as the end product and a wet sludge comprising all water pollutants, which can be dried and reused(Niaounakis, and Halvadakis, 2004).

d. Chemical and Biological Treatment

Several chemical treatment processes for OMW are found in the literatures. Curi et al (Curi, et al., 1998) 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. The effect of lime treatment of OMW was investigated by Esra et al(Improlive, 2000). Some biological processes have also been tested to eliminate the pollution effects of OMW[9, 10].

Management of OMW in Palestine

Management options

The management options of OMW in Palestine are limited by their different characteristics due to the traditional oil extraction processes, the economic and social conditions, and the seasonal limitations. The followings are among local limitations that should be considered:

- 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 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 treatment plants for OMW. To ensure efficiency, long lasting treatment, appropriate collection and transport systems to transfer the olive-mill effluents from the olive-mill sites to the centralized treatment facilities are needed. 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.

Treatment options

Considering the local conditions and the above stated limitations, the different OMW treatment and reduction options are screened. The screening process has also considered the topographical features of Palestine, the sensitivity of the groundwater aquifers, the lack of know-how and experiences, the energy consumption for the operation, the economic limitations, and the least-cost solutions. These factors have been grouped into four criteria groups and were considered in general. Subjective grades totaling 100 have been assigned to the groups. The percentage grades and groups are 30% for the environmental considerations, 30% for the operation requirements, 25% for the implementation requirements, and 15% for the status of development.

Table 6 presents the evaluation matrix of the seven different treatment options that are considered and states their assigned grades and ranks. The grades have been assigned consulting olive-mills owners, business men, environmental engineers and other experts.

Table (6): Evaluation Matrix for OMW treatment and reduction options.

Criteria Groups	**OMW Treatment Options**						
	Natural Evaporation	**Forced Evaporation**	**Incineration Distillation**	**Membrane Processes**	**Biological Treatment**	**Chemical-Biological Treatment**	**Extraction Process Development**
Status of development	15	9	6	4	13	8	12
Implementation requirements	9	19	17	17	14	14	25
Operation requirements	30	24	14	13	20	13	24
Environmental Impact	9	23	21	30	21	21	20
Total	**63**	**75**	**58**	**64**	**68**	**56**	**81**
Rank	**5**	**2**	**6**	**4**	**3**	**7**	**1**

The extraction process development is ranked first. By means of process modification measures, a significant reduction or even the prevention of water pollution can be achieved. The replacement of the traditional method and the 3-phase decanter for a 2-phase decanter will reduce the amounts of OMW as less water quantities are consumed, but higher chemical concentrations are produced. The modification of the oil extraction process has been applied in large scale in more than 200 industrial plants, predominantly in Spain and Italy, but also in Tunisia (Improlive, 2000). In Palestine, this modification should be considered and is recommended in any future development of the olive-mill industry. This can go parallel with the suggested idea of establishing large scale olive-mills at selected commercial locations to replace the scattered small scale mills.

The second ranked treatment option is forced evaporation. Therefore, it is recommended to establish centralized forced evaporation treatment plants, where OMW is collected from olive-mills, transported via vacuum tankers and treated. To facilitate the forced evaporation, a storage tank is needed, whose size depends on the treatment capacity of the evaporation system. Greenhouse-type evaporation tents are recommended, where OMW is diffused by means of sufficient number of diffusion nozzles. At the same time, 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. The production of wet sludge by the 2-phase decanter, semi-automatic process requires additional drying in order to ensure proper final disposal or potential reuse of the produced sludge.

Considering the subjectivity of the evaluation matrix, the development of the extraction process and the forced evaporation have got more than 75%, which is 7 points higher than the third ranked option. This allows for more than 10% error, therefore the combination of the two is the most recommended treatment option of OMW in Palestine. The oil-extraction process development has its economic constraints due to the current situation in Palestine.

As to the other treatment technologies, the biological anaerobic treatment is ranked third and the membrane process is ranked fourth. One further treatment option is the post-treatment of the effluents from anaerobic-aerobic reactors using mainly membrane systems (Sabbah, et al., 2001, p. 535-540).

Reuse options

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 (Gharaibeh, et al., 1998, p. 498-502) to treat drinking water containing several heavy metals in trace concentrations. It was proved that the residue could be used to remove Pb and Zn from aqueous solutions by adsorption. The activated charcoal produced from olive solid waste (olive cake) can be used in water purification from organic and inorganic contaminants (Gharaibeh, et al., 1998, p. 498-502).

In Palestine, partial reuse of the olive cake in the soap factories is still valid. 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 is dried and used partially as burning material to produce energy for the extraction process in the soap factories. The solid residue from the soap factories, which was previously used for combustion to heat houses, can be modified as carbon filters and catalyst support for water treatment.

The effect of adding OMW 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 (Imseeh, 1997). Using OMW taken from an automatic olive-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 the concrete mix.

OMW, along with lime, was tested as an admixture for the stabilization of soils. It has improved the strength characteristics and reduced the plasticity of the soils. The potential of using OMW for stabilization and improvement of sub-grade characteristics of roads is promising and require further investigations (Miri, 1992).

Conclusions

The uncontrolled dumping of untreated wastewater and OMW into the wadies and watercourses in Palestine is a threat to the groundwater aquifers, watercourses and the environment. The OMW involves a seasonal disturbance and an overloading for the waters receiving bodies or for the sewage systems and treatment plants. The high organic polluted OMW affects the soil, groundwater and watercourses. This occurs mainly during the olive season, generally from early October to late December.

Based on the general characteristics of OMW as well as the findings of the onsite investigations and the survey of 20 olive-mills, the need for implementing a management system for OMW in Palestine is defined. Different management and treatment options have been presented and elaborated. An evaluation matrix was developed to grade and rank seven different OMW reduction and treatment technologies. The management and treatment system should be long lasting, appropriate and environmentally sound. The selection has considered the local Palestinian conditions including social, economic and technical limitations. The Olive-mills effluent collection, transport, treatment and reuse are considered by the developed management and treatment system of OMW.

The paper recommends centralized treatment and disposal plants for OMW. The modification of oil-extraction process using the ecological 2-phase decanters in combination with forced evaporation are concluded as the most appropriate management and treatment option for OMW in Palestine. In this option, OMW is collected from the olive-mills, transported via vacuum tankers and treated at the centralized treatment plants. To facilitate the forced evaporation, a storage tank is necessary, whose size depends on the treatment capacity of the evaporation system. Greenhouse-type evaporation tents are recommended, where the OMW is diffused by means of 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 are reused.

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