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COMBINED TREATMENTS OF URBAN AND OLIVE MILL EFFLUENTS IN APULIA, ITALY

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ABSTRACT

The effluent from olive mill plants (OME) presents a seasonal problem, as although small in volume it has very high organic content, and in consequence it is particularly difficult to meet Italian law discharge limits. This problem has been carefully studied in Apulia where, during the olive milling season, organic pollution exceeds that from domestic use by a factor of three. Preliminary research allowed the estimation of organic load per ton of milled olives, and the comparison of the effectiveness of feasible treatment processes. The results have been utilized in the Water Reclamation Plan of the Apulia Region (WRP).

This Plan permits the discharge of OME into public sewers only when its contribution is less than 20% of urban wastewater's (UW) organic load, or provides the transport of a controlled amount to treatment facilities, over a period ranging from 100 to 300 days.

Results of full-scale and pilot biological treatment plants for combined UW and OME effluents are reported, together with the main project parameters. Anaerobic processes are more economical but their successful operation needs to be confirmed on full-scale plants.

KEYWORDS

Olive mill effluents; anaerobic co-digestion; UASB.

INTRODUCTION

One tenth of the world's olive oil processing is localized in the Apulia Region of South Italy. This production is carried out either in a discontinuous process, by pressing milled olives and recovering the oil with a centrifuge, or else in a continuous one by a solid/liquid centrifuge system. Both processes produce liquid effluents (OME) with very high organic and inorganic content, but higher volumes of more diluted wastewaters are discharged by the continuous process, 1.5 m^3 instead of 0.6 m^3 per ton of worked olives. This excess is due to the water added to improve solid/liquid separation.

An analytical survey carried out by IRSA-CNR (Balice et al., 1983) showed that the organic polluting load per unit weight of olives is quite independent of their maturity degree or of the process used and amounts to 45-50 $kgBOD_5$ per ton of milled olives. A small factory milling 10 t/d of olives has a polluting organic load equivalent to that of a town of 8500 inhabitants, assuming a specific load of 0.054 $kgBOD_5$/E.I. d and discharge of 6 to 15 m^3/d of water, depending on the process. This occurs over a season that normally lasts 100 days.

The equivalent organic load of OME has been evaluated, for the Apulia Region, to be 11500000 E.I.; three times more than the contribution from the residents. This organic overload can be considerably reduced by storing a part of OME and discharging it throughout the year.

PROVISIONS OF APULIA WATER RECLAMATION PLAN

In Apulia 1984 oil mills are scattered through the territory, often inside urban areas and mostly with a small production (only 4.6% of them process more than 20 tons/d of olives).

The WRP, in force since 1983, provides that OME should be discharged into sewers only when its contribution is less than 20% of the UW organic load, or else to transport a controlled amount of it to treatment facilities.

In certain areas, where OME production is particularly high, centralized plants are envisaged, in all 27. These will serve many towns and will treat about 70% of the OME organic load over a period of 300 days, by storage in reservoirs. It was decided to treat biologically OME together with UW where sufficient dilution permits the COD limit to be met. Only six plants will treat OME alone by evaporation and then mixing concentrates with mill residual solids.

TABLE 1 Hydraulic and organic loads for centralized biological UW and OME joint treatment

Town	No of sites connected	Flow rates (m^3/d) Q_1(*)	Q_2(*)	$Q_2/(Q_1+Q_2)$%	Organic loads ($kgBOD_5$/d) C_1(*)	C_2(*)	$C_2/(C_1+C_2)$%
San Severo	11	20541	77	0.37	5535	5891	51.6
Ischitella	2	1226	8	0.62	542	543	50.1
Foggia	2	60540	25	0.04	11054	1937	14.9
Anzano	2	286	1	0.42	155	90	36.9
Cerignola	2	19165	28	0.15	6005	2155	26.4
Andria	3	25438	209	0.81	6629	15975	70.7
Terlizzi	4	10242	122	1.18	3306	9311	73.8
Bitonto	3	**13819**	**151**	**1.07**	**4209**	**11571**	73.3
Palo del C.	8	4090	100	0.02	1500	7648	83.6
Bari	9	124175	117	0.09	24803	8987	26.6
Martina F.	4	15764	37	0.02	4256	2818	39.8
Carovigno	3	7486	84	1,11	2766	6360	69.7
Mesagne	4	10619	67	0,63	3963	5148	56.5
Torre S.S.	2	3409	36	1,04	1347	2699	66.7
San Pietro V.	2	5015	19	0,38	1849	1447	43.9
Manduria	2	10649	29	0,27	3376	2219	39.7
Lizzano	3	2483	18	0,71	1593	1362	46.1
Pulsano	2	195	1	0,51	1008	75	6.9
Carosino	2	3066	3	0,10	1284	236	15.5
Monteiasi	2	8393	15	0,18	2478	1124	31.2
Mottola	2	3753	31	0,82	1129	2340	67.4

(*) 1: UW; 2: OME

Table 1 summarizes the organic and hydraulic load of 21 biological centralized plants which together will treat about 44% of the OME from around the Apulia Region.

AEROBIC OME-UW JOINT TREATMENT

The wastewater treatment plant at Bitonto, a town in the center of Apulia, has been operating since 1980 for the joint purification of urban wastes and OME discharged directly into sewers. The process consists of primary sedimentation aided by coagulation followed by two-stage aeration.

Operating data from an entire milling season (Giorgio et al., 1981) show that OME organic load, in accordance with the above-mentioned CNR survey, is four times higher than the value of 10.8 $kgBOD_5$ per ton of milled olives assumed on the project. In Table 2 process parameters of the most important units are reported for the final milling periods when, due to a smaller olive amount harvested, OME organic load was within WRP limits.

TABLE 2 Mean values of some process parameters for Bitonto aerobic plant from two periods at the end of milling season

Period	Parameters	Units	Feed	F+S	A O I	A O II	Overall
18/2-3/3 1981	BOD_5	mg/l	1132	578		141	72
	" "	kg/d	6696		3412	823	425
	" "	% removed		49	74	48	94
	COD	mg/l	1997	1051		443	286
	" "	kg/d	11790		6205	2562	1688
	" "	% removed		47	59	34	86
	SS	mg/l	1326	392	4708	3287	199
	Bx	$kgBOD_5$/kgMLSS d			0.62	0.15	
	Bv	$kgCOD/m^3$ d			5.28	1.56	
	Ec	$kWh/kgBOD_5rem$			1.13	4.85	1.86
	"	kWh/kgCODrem			0.80	1.71	1.10
4/3-16/3 1981	BOD_5	mg/l	1096	530		54	29
	" "	kg/d	4945		2311	243	130
	" "	% removed		53	89	46	97
	COD	mg/l	1879	875		188	117
	" "	kg/d	8478		3948	849	527
	" "	% removed		53	78	38	94
	SS	mg/l	948	141	4626	2760	54
	Bx	$kgBOD_5$/kgMLSS d			0.44	0.05	
	Bv	$kgCOD/m^3$ d			3.36	0.52	
	Ec	$kWh/kgBOD_5rem$			1	14.51	1.93
	"	kWh/kgCODrem			0.69	4.60	1.23

The percentage of removal of organics was higher than 90% for soluble COD. The lowest food to microorganism ratio of the final period, during the second aerobic stage, has given rise to higher specific energy consumption, together with the absence of equipment to regulate air supply.

Other aerobic plants for the same purpose were built in Andria and San Severo towns utilizing, in the latter case, percolating filters on the first stage. All these plants are now being rebuilt, taking into account OME organic loads of WRP.

ANAEROBIC DIGESTION

OME anaerobic treatment, using contact digesters, has been tested in Italy both by IRSA-CNR (Antonacci et al., 1981), and by Breda Research Institute (Aveni, 1984). Organic loads were 2.5 $kgCOD/m^3$ d, but steady-state conditions could not be maintained due to high concentration of inhibitory substances such as polyphenols and potassium.

To overcome such problems, research has been conducted by IRSA-CNR on the laboratory and pilot scales of Upflow Anaerobic Sludge Blanket reactors (UASB), operating with more dilute wastewaters. From these experiments (Boari et al., 1984) higher organic load resulted, between 15 and 21.5 $kgCOD/m^3$ d, with removal efficency near 75%. However in these experiments instability and poor reproducibility of the start-up were experienced.

Experimental results (Rozzi et al., 1988) indicated that appreciable amounts of alkalis are needed for stable process operation and intermittent lime addition enhances sludge settleability.

Finally, taking into account that the solubility of particulate organic matter, and not methanogenesis, is the rate-limiting reaction of sludge digestion (De Baere et al., 1981), the combined treatment of soluble substrates and sludges has been tested (De Baere et al., 1982).

Tests, at laboratory scale (Carrieri et al., 1986, 1988), on OME and surplus sludge co-digestion, have shown that it is possible to increase loading rates of conventional digesters by at least 50% of COD and still operate in stable conditions. Nutrients, such as ammonia, and buffers are provided by degradation of proteineous substances. Soluble and particulate COD removal for OME and sludges was 70 and 45% respectively.

From these results, the many combined treatment plants provided for by WRP and reported in Table 1, may be designed with anaerobic co-digestion process. Two such plants, Mottola and Terlizzi, are presently going into operation.

BIOLOGICAL UW-OME JOINT TREATMENT PROCESSES EVALUATION

Two different treatment alternatives have been compared in order to evaluate the capacity and energy balances of biological reactors. Process units illustrated in Table 3 that were considered were:

-Layout A: UW-OME primary sedimentation aided by coagulation, two-stages aerobic oxidation and followed by sludge anaerobic digestion.

-Layout B: UW primary sedimentation, single-stage aerobic joint oxidation of UW and OME pretreated by co-digestion with sludges.

TABLE 3 Process parameters, biological reactor volumes and energy balance for OME aerobic or anaerobic co-digestion processes

LAYOUT A

Parameters	Units	F+S	A O I	A O II	A D	All reactors	Energy balance
Organic load	kgCOD/d		21000	7350	23600		
Volumetric load	kgCOD/m³ d		4.30	1.50	3		
Reactor volume	m³		4880	4900	7860	17640	
COD Efficiency	%	40	65	70	55		
Specific energy requirement	kWh/kgCODrem		0.75	1.80			
Energy required or produced	kWh		-10240	-9260	10300		-9200

LAYOUT B

Parameters	Units	S	A O	A D	All reactors	Energy balance
Organic load	kgCOD/d		13880	34900		
Volumetric load	kgCOD d/m³		1.80	4.50		
Reactor volume	m³		7700	7750	15450	
COD Efficiency	%	30	84	45 VS 70 OME		
Specific energy requirement	kWh/kgCODrem		1.40			
Energy required or produced	kWh		-16750	17720		1370

The main process parameters for biological units evaluation are reported in Table 3. Organic loads are those provided for by the WRP for the Bitonto plant, as reported in Table 1. Conversion factors of BOD_5 to COD were fixed at 2 and 2.3 for UW and OME respectively. Organic loads, efficiencies and specific energy consumptions derive from pilot and full-scale tests previously reported, considering the different UW and OME flow rates together with the amount of organic and nitrogen substrates in the different aerobic reactors.

In Fig. 1 and Fig. 2 COD mass balances and the consumption or production of electrical energy for the two different layouts are reported.

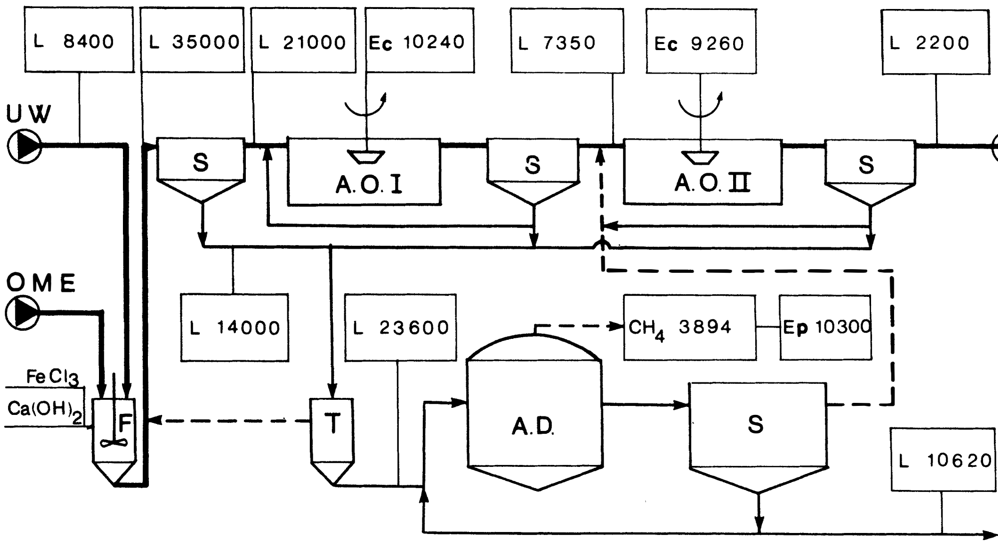

Fig. 1. Daily organic substrate L (kgCOD), energy consumptions E_c (kWh) and energy production E_p (kWh) for layout A

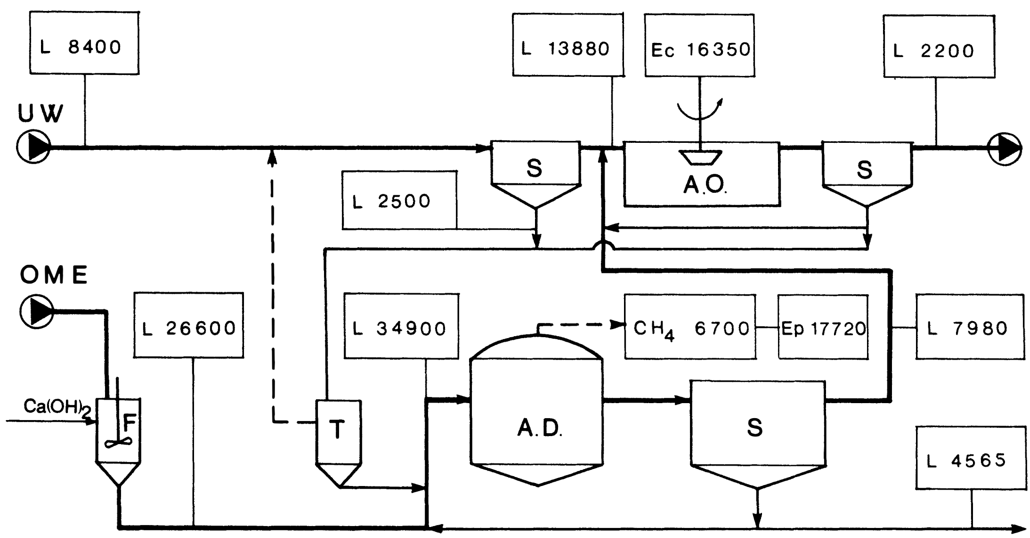

Fig. 2. Daily organic substrate L (kgCOD), energy consumption E_c (kWh) and energy production E_p (kWh) for layout B

CONCLUSIONS

OME purification has been evaluated in the Apulia Region (South Italy) with full-scale and pilot plants, in order to solve serious organic pollution problems. The WRP had provided for mostly joint UW-OME treatments by aerobic biological oxidation, either in single plants or centralized ones serving several mills.

Researches on OME anaerobic co-digestion with sludge have shown very promising results and many full-scale plants are now under construction. If pilot-plant results concerning COD mass balance and biogas production are confirmed in the full-scale digesters now ready for operation, the energy balances show that it would be possible to produce all the electrical energy for aerobic oxidation without increasing biological reactor volumes.

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NOMENCLATURE

A D = Anaerobic Digestion
A O = Aerobic Oxidation (I, II = first and second stage)
F = Flocculation
S = Sedimentation
T = Thickening