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Food Industry Wastewater Treatment Plant based on Flotation and MBBR

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Abstract: This paper deals with a plant that treats wastewater of an Italian food industry. The plant is made of a pumping station, a fine screen, an accumulation tank (182 m^3), two parallel dissolved air flotation tanks with lamellae (each with footprint 5.6 m^2, projected surface 14.4 m^2, volume 3.4 m^3), a hybrid MBBR oxidation tank (148 m^3) filled with 35% AnoxKaldnes^{TM} polyethylene carriers followed by an activated sludge oxidation tank (292 m^3) and a sedimentation tank (surface 33 m^2, volume 73 m^3); sludge is thickened and dehydrated. On average basis, the plant has treated 152 m^3/d wastewater with 9657 mg/L COD, 7848 mg/L BOD and 308 mg/L greases; the primary flotation has removed 64% of COD, 70% of BOD and 65% of greases; the whole plant has removed 97% of COD and 99% of greases, and has a significant residual capacity.

Key words: activated sludge, biofilm, food industry wastewater, flotation, moving bed

1. Introduction

Food and beverage industry wastewater treatment requires a specific design approach, and often it shall be carried out with a complex sequence of chemical and biological process units. First of all, hydraulic load varies significantly during work days and sometimes it is zero during holidays; main pollutants are suspended solids (TSS), organic substances (determined as COD and BOD), oils/greases, nitrogen and phosphorus, their concentrations are extremely variable and strongly affected by the specific production cycle and its phases. The investigation report [1] includes results of a large scale study on food processing wastewater in Canada and USA, with attention to winery, brewery, dairy, meat processing, fish processing, fruit and vegetable industry. Rajagopal et al. [2] report characteristics of several kinds of food and beverage industry wastewater collected from several authors; Chowdhury [3] reports data about fish processing industry, while Farizoglu [4] reports data about dairies and Simate [5] reports data about breweries. Table 1 has been elaborated on basis of these data and resumes main pollutant concentration ranges in food and beverage industries wastewater; when an author has reported different concentration ranges for different production cycles among the same activity (e.g., different cycles in fish processing), the widest variability range has been included in Table 1. Moreover, small quantities of chemicals can be found in food and beverage industry wastewater, since they are used for washing and disinfection. Thus, every wastewater requires a specific sequence of treatments, although sedimentation is widely used for primary TSS removal, and biological processes (activated sludge or biofilm, one or more stages, aerobic or anaerobic, with settler or membranes) are applied for BOD removal.

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Table 1 Main Pollutants Concentration Ranges in Food and Beverage Industry Wastewater

Kind of industry	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	N (mg/L)	P (mg/L)	pH	Refer.
Brewery	137-1909		820-8267				[1]
	2900-3000	2000-6000	1200-3600	25-80	10-50	3.0 - 12.0	[5]
Dairy	44-1162		40-10077	44.0-133.2	4.9-84.0	6.1 - 8.0	[1]
	1100-1600	1400-2500	800-1000				[2, 6]
	250-2750	400-15200	650-6250	10.0-90			[2, 7]
	1600-3900	23000-40000		400-700	60-100		[2, 8]
	134-804	921-9004	483-6080	8-230	9-111.5	5.5-5.8	[4]
Fish processing	30-1305		60-6698	0.9-69.7	2.1-44.2	4.0-7.4	[1]
	14-12375	10-90000	12-78000	77-3000		3.8-10	[3]
Fruit and vegetable	177-4133		190-6113		3.1-8.6	6.0-7.7	[1]
Meat process.	48-6203		40-5749	30.5-62.9	3.7-127.2	5.9-7.3	[1]
Olive mill	75500	130100		460			[2, 9]
Potato chips	5000	6000	5000	250	100		[2, 10]
Soft drinks	23-667		608-4200				[1]
Sugar and sweets	47-2153		177-26185		20.1-22.2	5.9-7.2	[1]
Sugar beet	6100	6600		10	2.07		[2, 11]
Winery	27-618		213-2400				[1]
	150-200	18000-21000		310-410	40-60		[2, 8, 12]

The investigation report [1] compares technologies which are commonly applied for food and beverage wastewater treatment. Primary treatments can remove most of TSS (40-90% with gravity separation, 60% with coagulation, 40-80% with dissolved air flotation, 80-93% with dissolved air flotation and chemical addition) and most of oils and greases (50-90% with gravity separation, 60-95% with dissolved air flotation, 85-99% with dissolved air flotation and chemical addition). Although primary treatment can remove also part of COD and BOD, these pollutants are mostly removed by biological processes.

The classical aerobic activated sludge treatment is common for wastewater with less than 2000 mg/L BOD and can reach 80-97% removal efficiency. Other authors report BOD removal efficiencies higher than 90% with membrane biological reactors (MBR) both on pilot-scale and full-scale [13]. For very concentrated wastewater anaerobic processes are often preferred as roughing treatment because of energy saving; they remove 60-95% of BOD on average basis [1]. In particular, upflow anaerobic sludge blanket reactors (UASB) are applied with good results at high organic load as reported by Hajipakkos [14] for coffee wastewater, Jeganathan [15] for oily wastewater and Ahn [16] for brewery wastewater.

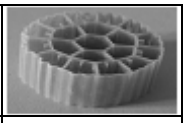
In moving bed biofilm reactors (MBBR) the biomass grows as a biofilm on small plastic carriers that move freely into the wastewater; in pure biofilm reactors the biomass grows only on carriers, in hybrid reactors there are both biofilm and suspended activated sludge. Several authors report results of plants with a first roughing MBBR and a second MBBR (pure or hybrid) or an activated sludge reactor for food and beverage industry wastewater treatment. Rusten et al. [17] report that a two-stage pure MBBR treated dairy wastewater with 4420 mg/L COD and removed 98% of COD; Johnson et al. [18] report that a two-stage pure MBBR treated slaughterhouse wastewater with 5100 mg/L COD and removed 88% of COD. Falletti et al. [19, 20] report two cases of plants that treat beverage industry wastewater; in the first one a two-stage pure biofilm MBBR treated brewery wastewater with 1740 mg/L COD and removed 98% of COD; in the second one a

series of a roughing pure MBBR and a hybrid MBBR tank treated light drink wastewater with 1790 mg/L COD and removed 97% of COD.

2. Plant Description

The plant was projected to treat 240 m^3/d with 7800 mg/L COD, 4500 mg/L BOD, 400 mg/L oils and greases; expected pollutant loads were 1870 kg_{COD}/d, 1080 kg_{BOD}/d and 96 kg/d oils and greases. Nitrogen and phosphorus were only a few mg/L, so they must be added as chemicals in biological section. The final effluent is discharged into public sewer network, so it must respect these limits stated by the Italian national law 152/2006: TSS ≤ 200 mg/L, COD ≤ 500 mg/L, BOD ≤ 250 mg/L, oils and greases ≤ 40 mg/L. The plant (fig. 1) is made of a pumping station, a drum fine screen (2 mm holes), a stirred accumulation tank (182 m^3), two parallel dissolved air flotation tanks with lamellae (each tank with footprint 5.6 m^2, projected surface 14.4 m^2, volume 3.4 m^3), a biological section and the sludge treatment line (thickening, filter belt press). The biological section is made of a hybrid MBBR oxidation tank (148 m^3) followed by an activated sludge oxidation tank (292 m^3) and a settler (surface 33 m^2, volume 73 m^3).

Table 2 Characteristics of AnoxKaldnes™ Carriers

Shape	
Lemgth (mm)	12
Diameter (mm)	25
Density (g/cm^3)	0.95
Nr. Carrier pr. m^3	144000
Maximum filling degree	66%
Effective specific surface (m^2/m^3 carriers)	500

The hybrid MBBR is filled with AnoxKaldnes™ polyethylene carriers (Table 2) with filling degree 35%. Each biological reactor is aerated by a 480 Nm^3/h blower controlled by an inverter; air is sent to the hybrid MBBR through medium bubble diffusers, to the activated sludge tank through micro bubble diffusers. It was estimated that flotation should remove ca. 50% of COD, 40% of BOD and 75% of oils and greases; therefore the biological section was designed to treat 900 kg_{COD}/d, 600 kg_{BOD}/d and 24 kg/d oils and greases. The first-stage hybrid MBBR was dimensioned to remove ca. 50% of this amount of COD and BOD, thus the second-stage activated sludge reactor was dimensioned to remove ca. 85% of COD and BOD so that the final effluent could respect emission limits.

3. Results and Discussion

The plant was started in 2012 and has been studied during year 2013. In this year the hydraulic load has varied between 55-237 m^3/d (average value 152 m^3/d); pollutant concentrations in raw influent wastewater, after flotation (average values) and in final treated effluent are listed in Table 2. On average basis, flotation

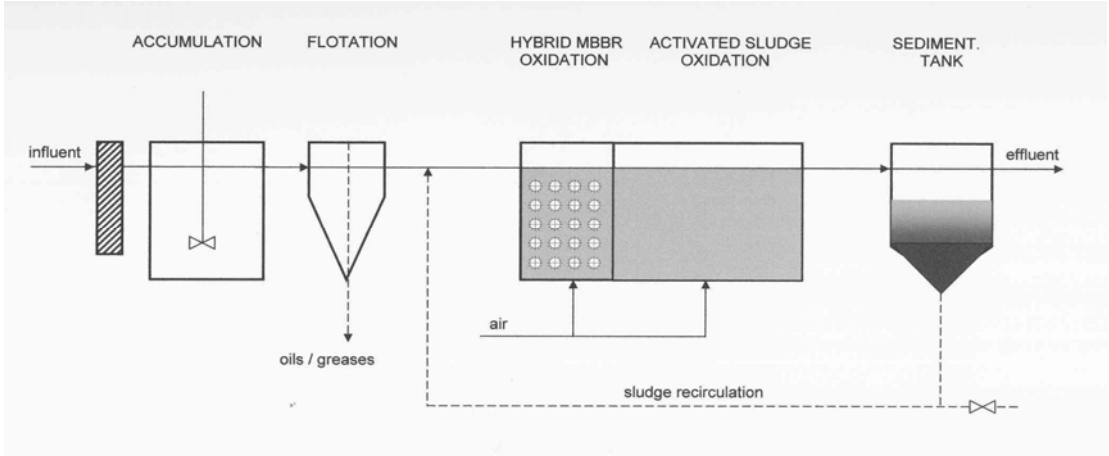


Fig. 1 Scheme of the Food Industry Wastewater Treatment Plant

units has removed ca. 64% of COD and 65% of oils and greases; the whole plant has removed 97% of COD and 99% of oils and greases, and the effluent has always respected emission limits. Therefore effective pollutant loads are respectively 1468 kg_{COD}/d, 1193 kg_{BOD}/d and 47 kg/d oils and greases; the biological section treats 535 kg_{COD}/d, 354 kg_{BOD}/d and 16 kg/d oils and greases. These values are lower than expected ones, so the plant has a significant residual capacity that will be important if production (and so, wastewater to be treated) increases in the future. The biological section removes 92% of COD and 96% of oils and greases that it receives; but it is not possible to evaluate performances of the hybrid MBBR alone since no intermediate data are available. Average sludge concentration in biological reactors is 12.0 kg_{TSS}/m^3, sludge recirculation rate varies between 100%–150% of raw influent hydraulic load.

Table 3 Pollutant Concentrations at the Wastewater Treatment of the Food Industry

Parameter		Raw influent			After	Final effluent			Removal %	
		min	average	max	Flotation	min	average	max	Flotation	Plant
COD	(mg/L)	2260	9657	22100	3520	70	280	437	64%	97%
BOD	(mg/L)	1660	7848	15600	2325				70%	
Oils/greases	(mg/L)	120	308	560	108	< 0.5	3.8	21.6	65%	99%
NH_4-N	(mg/L)	< 0.5	3.8	33.0		< 0.5	2.9	5.3		
NO_2-N	(mg/L)					< 0.1	< 0.1	< 0.1		
NO_3-N	(mg/L)					< 1.0	< 1.0	< 1.0		
Total P	(mg/L)	3.2	18.3	29.8		< 0.5	4.8	12.8		

Note: nitrogen and phosphorus are added as chemicals after flotation, since in raw wastewater their concentrations were lower than values necessary for biomass growth; so removal efficiencies are not calculated; there are no data available for BOD in final effluent.

4. Conclusions

These results confirm that flotation and MBBR in combination with activated sludge are suitable technologies to treat concentrated food industry wastewater. In this plant, flotation had removed 64% of COD, 70% of BOD and 65% of oils and greases, and the remaining amount has been removed with very high efficiencies by the biological section. Effective pollutant loads are lower than expected values, so this plant has a significant residual capacity that will be important if production (and thus, wastewater to be treated) increases in the future.

References

[1] Altech Environmental Consulting Ltd, Ontario Centre for Environmental Technology Advancement, *A Review of Wastewater Management & Best Practices for Dischargers in the Food Processing Sector*, 2005.

[2] R. Rajagopal, N. M. C. Saady, M. Torrijos, J. V. Thanikal and Y. Hung, Sustainable agro-food industrial wastewater treatment using high rate anaerobic process, *Water* 5 (2013) 292-311.

[3] P. Chowdhury, T. Viraraghavan and A. Srinivasan, Biological treatment processes for fish processing wastewater — A review, *Bioresource Technology* 101 (2010) 439-449.

[4] B. Farizoglu and S. Uzuner, The investigation of dairy industry wastewater treatment in a biological high performance membrane system, *Biochemical Engineering Journal* 57 (2011) 46-54.

[5] G. S. Simate, J. Cluett, S. E. Iyuke, E. T. Musapatika, S. Ndlovu, L. W. Walubita and A. E. Alvarez, The treatment of brewery wastewater for reuse: State of the art, *Desalination* 273 (2011) 235-247.

[6] M. Gotmare, R. M. Dhoble and A. P. Pittule, Biomethanation of dairy waste water through UASB at mesophilic temperature range, *Intern. Jour. Adv. Eng. Science & Technology* 8 (2011) (8) 1-9.

[7] M. Passeggi, I. Lopez and L. Borzacconi, Integrated anaerobic treatment of dairy industrial wastewater and sludge, *Water Science & Technology* 59 (2009) 501-506.

[8] R. Rajagopal, Treatment of agro-food industrial wastewaters using UAF and hybrid UASB-UAF reactors, Ph.D. Thesis, Indian Institute of Technology Roorkee, Roorkee, India, 2008.

[9] M. R. Gonçalves, J. C. Costa, I. P. Marques and M. M. Alves, Strategies for lipids and phenolics degradation in the anaerobic treatment of olive mill wastewater, *Water Research* 46 (2012) 1684-1692.

[10] E. Senturk, M. Ince and O. G. Engin, Treatment efficiency and VFA composition of a thermophilic anaerobic contact reactor treating food industry wastewater, *J. Hazard. Mater.* 176 (2010) 843-848.

[11] E. Alkaya and G. N. Demirer, Anaerobic acidification of sugar-beet processing wastes: Effect of operational parameters, *Biomass Bioenergy* 35 (2011) 32-39.

[12] R. Ganesh, R. Rajagopal, M. Torrijos, J. M. Thanikal and R. Ramanujam, Anaerobic treatment of winery wastewater in fixed bed reactors, *Bioprocess Biosystem Eng.* 33 (2010) 619-628.

[13] T. Stephenson, S. Judd, B. Jefferson and K. Brindle, *Membrane Bioreactors for Wastewater Treatment*, IWA Publishing, London, UK, 1999.

[14] C. Hajipakkos, The application of a full-scale UASB plant for the treatment of coffee waste, *Water Science & Technology* 25 (1992) (1) 17-22.

[15] J. Jeganathan, G. Nakhla and A. Bassi, Long-term performance of high-rate anaerobic reactors for the treatment of oily wastewater, *Environmental Science & Technology* 40 (2006) 6466-6472.

[16] Y. H. Ahn, K. S. Min and R. E. Speece, Full scale UASB reactor performance in the brewery industry, *Environmental Technology* 22 (2001) (4) 463-476.

[17] B. Rusten, J. G. Siljudalen and H. Strand, Upgrading of a biological-chemical treatment plant for cheese factory wastewater, *Water Science & Technology* 34 (1996) (11) 41-49.

[18] C. H. Johnson, M. W. Page and L. Blaha, Full scale moving bed biofilm reactor results from refinery and slaughter house treatment facilities, *Water Science & Technology* 41 (2000) (4-5) 401-407.

[19] L. Falletti, L. Collareda, M. Vanalli and C. Romano, Brewery wastewater treatment with two-stage MBBR process and dissolved air flotation, *International Symposium on Sanitary and Environmental Engineering*, Milan, 2012.

[20] L. Falletti, M. Pozza and N. Veggo, Beverage industry wastewater treatment with two-stage MBBR plant, *Intern. Congress ECOSTP*, Santiago de Compostela, 2012.