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Beverage industry wastewater treatment with two–stage MBBR plant

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Abstract: Beverage industry wastewater treatment was studied, first on pilot-scale and then on full-scale, with two-stage moving bed biofilm reactor (MBBR). The pilot plant was made of a pure biofilm aerated MBBR (210 L) with filling degree 60%, a hybrid aerated MBBR (370 L) with filling degree 60%, and a lamellar settler (350 L) with plates sloped 60° from horizontal; carriers specific surface was 500 m^2/m^3. The pilot plant treated 12 L/h wastewater with 5000-10000 mg/L COD and removed COD with average efficiency 73%. The full-scale plant was made of two parallel pure biofilm aerated MBBR (18 m^3 each) with filling degree 60%, two parallel hybrid aerated MBBR (32 m^3 each) with filling degree 60%, two parallel lamellar settlers (7 m^3 each) with plates sloped 60° from horizontal, and a final quarzite filter. The full scale plant treated 39-175 m^3/d (average 70 m^3/d) wastewater with 490-4900 mg/L COD (average 1793 mg/L) and removed COD with average efficiency 97%; the final effluent respected always emission limits.

Keywords: wastewater treatment; beverage industry; moving bed; biofilm

I. Introduction

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, while in hybrid reactors there are both biofilm and suspended activated sludge. For concentrated wastewater treatment, several authors report results of plants with a first roughing MBBR and a second MBBR or an activated sludge reactor. Broch-Due et al. (1997), Dalentoft & Thulin (1997), Hem et al. (1994) report results with paper industry wastewater: with organic loads between 13–27 kg_{COD}/m^3d, COD removal efficiencies are 55–90%. Johnson et al. (2000) report results with slaughter wastewater: with organic loads between 5–11 kg_{COD}/m^3d, 88% of COD is removed. This paper is focused on a two-stage plant that treats beverage industry wastewater; after a pilot-scale study, a full-scale plant has been realized and now is working in the beverage industry area.

From pilot-scale study to full-scale plant

A pilot plant was installed at the industry FICIT of Cornedo Vicentino (VI, Italy); that plant was fed with 12 L/h beverage industry wastewater containing 5000–10000 mg/L COD, 2500–5000 mg/L BOD_5, 100 mg/L TSS, 20 mg/L total nitrogen, 8 mg/L total phosphorus, and was made of (fig. 1):

- a stirred accumulation tank (480 L) with pH correction (set point 7) and addition of urea and ammonium monophosphate in such amounts to have a ratio BOD:N:P = 100:5:1 in the influent;
- a pure biofilm aerated MBBR roughing tank (210 L), with filling degree 50%;
- a hybrid aerated MBBR tank (370 L), with filling degree 60%; it received wastewater from the first MBBR and sludge recirculation from the settler (~200% of incoming hydraulic load);
- a lamellar settler (350 L) with plates sloped 60° from horizontal and total settling surface 3 m^2.

Carriers (fig. 2) used in the pilot-scale study and in the full-scale plant are made of HD polyethy-lene, their effective specific surface is 500 m^2/m^3 and in 1 L of this material there are 288 pieces.

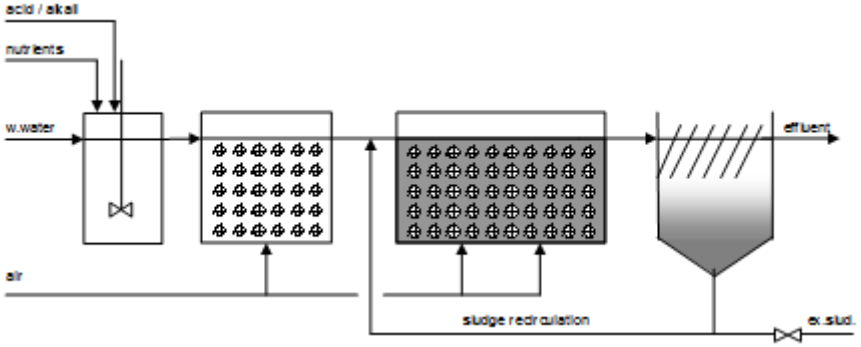

Figure 1: Scheme of the pilot-plant.

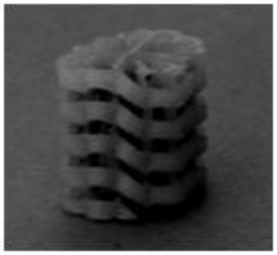

Fig. 2: Carrier.

In both MBBR reactors biofilm was visibly grown two months after carriers introduction. Average incoming organic load was 2.3 kg_{COD}/d; volumetric load was 4 kg_{COD}/m^3d related to the volume of the whole plant, 11 kg_{COD}/m^3d related to the first MBBR (so surface organic load was 44 g_{COD}/m^2d).

In the first MBBR average biofilm concentration was 2.3 g_{TS}/L tank i.e. 9.2 g_{TS}/m^2 carrier; in the hybrid MBBR average biofilm concentration was 0.9 g_{TS}/L tank i.e. 2.8 g_{TS}/m^2 carrier, suspended sludge concentration was 3.4 g_{TSS}/L tank. The first MBBR removed COD with efficiency 29–42% (average 34%), and the whole plant removed COD with efficiency 52–99% (average 73%); lowest values were encountered in the first month after biofilm growth, highest values after four months since biofilm was more developed. Specific oxidising activity of sludge and biofilm was determined with a batch test: 1 L wastewater was put in an aerated vessel with 50 mL sludge or 100 carriers, at the beginning and every 30 min COD was determined on filtered wastewater; specific oxidising activity was calculated by dividing COD removed in 120 min by sludge or biofilm quantity. For biofilm of the first MBBR the average value was 0.58 $g_{COD}/g_{TS}h$, for biofilm of the hybrid MBBR the average value was 0.31 $g_{COD}/g_{TS}h$ and for suspended sludge it was 0.17 $g_{COD}/g_{TSS}h$.

After the positive results of the pilot-scale study, a full-scale plant was installed in the area of the beverage industry. The plant was dimensioned to treat an average hydraulic load of 60 m^3/d wastewater containing 10000 mg/L COD, 5000 mg/L BOD, 21 mg/L TKN and 8 mg/L phosphorus. Emission requirements are: for COD minimal removal efficiency 90%, BOD < 50 mg/L, TKN < 5 mg/L, P < 2 mg/L. The plant has the same scheme of the pilot-plant of fig. 1 and is made of:

- a stirred accumulation tank (150 m^3) with pH correction (set point 7) and ~~urea~~ addition of urea as nitrogen source; phosphorus in wastewater was enough (60–100 mg/L P, 500–2000 mg/L BOD);
- two parallel pure biofilm aerated MBBR roughing tanks (18 m^3 each), with filling degree 60%;
- two parallel hybrid aerated MBBR tanks (32 m^3 each), with filling degree 60%;
- two parallel lamellar settlers (7 m^3 each), plates sloped 60° and settling surface 20 m^2 each;
- a final quartzite filter with surface 1 m^2 and volume 1 m^3.

Air is supplied to the two pure biofilm MBBR tanks by a 300 Nm^3/h blower, to the two hybrid MBBR tanks by a 250 Nm^3/h blower; diffusers are medium-bubbles tubes.

II. Results and discussion

The plant was started in January 2011, during the first 6 months it treated a hydraulic load between 39–175 m^3/d (average 70 m^3/d); pollutants concentrations in the influent were 490–4900 mg/L COD (average 1793 mg/L) and 374–1612 mg/L BOD_5 (average 881 mg/L); after the first MBBR stage COD was 143–2170 mg/L (average 1071 mg/L), values in the final effluent were 14–272 mg/L COD (average 62 mg/L) and 10–50 mg/L BOD (average 29 mg/L). So volumetric organic load was 1.25 kg_{COD}/m^3d related to the whole plant, 3.5 kg_{COD}/m^3d related to roughing MBBR tanks i.e. 12 g_{COD}/m^2d as surface organic load. The first stage removed ca. 42% of COD, the whole plant removed COD with efficiency 97%. The final effluent respected always emission limits.

III. Conclusions

These results confirm that MBBR are a suitable technology to treat high organic load beverage industry wastewater. In the first MBBR, biofilm removes 42% of COD; the following hybrid MBBR combines action of biofilm and suspended sludge and the whole plant removes 97% of COD. High efficiency of MBBR tanks is due to the specific oxidising activity of the biofilm (much higher than values for activated sludge) rather than its concentration (lower than values of sludge).

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