Oxygen Demand Monitoring

CONTINUOUS FOLLOW-UP OF AERATED GRANULAR BIOFILTERS WITH ON-LINE SENSORS

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Abstract
A simplifiee method for continuons evaluation of the COD concentration of wastewater is presented, based on UV adsorption. The on-line sensors were installed before and after an innovative biological reactor to verify the reliability and accuracy of the instruments. The instruments proved reliable and the maintenance requirement was about once a week. The influent and effluent streams were analysed both by conventional methods with periodical sampling and on-line monitoring. Detailed performance of both sensors and the biological aerated filter will be given.
The biological aerated filter is a compact treatment technology that combines biological degradation of pollutants with filtration. The performance of a large facility and its reaction at peak loadings was evaluated with the on-line sensors. Three weeks of onsite testing was carried out, and during each week one detailed 24 h profile with conventional measurements was perforned. The loading on the filter varied from 3 kg COD/m3d at nightime to almost 20 at peak. The average effluent quality was rather stable below 90 mg COD/1 at an average load of 7 kg COD/m3d.

Keywords
UV-Adsoiption,COD, BOD-Analysis, On-Line Sensors, Biofiltration, Peak

Loading Introduction

Increasing necessity to monitor pollution, both for the protection of receiving waters and the control of treatment process performance, has led to a variety of sensors. These devices measure directly or through correlations soluble and particulate matters. In drinking water treatment or surface water monitoring (1), contiuous measurements for toxicity (2), total organic carbon (3), suspended solids or nitrogen (4) or heavy metals (5) are applied in practice.
To optimise the operation of conventional activated sludge plants, process variables such as dissolved oxygen or redox potential in the mixed liquor (6), suspended solids of the sludge (7), sludge blanket levels in the clarifier and turbidity of the effluent (8) are measured. Respiration of sludge can be used for measuring the activity of biomass in degrading a certain effluent (9,10), and BOD probes have been developed on this principle (11). More and more, for advanced effluent objectives, plant adjustments are made according to the results of phosphorus (12) or nitrogen measurements (13), and complete expert systems to manage sewage treatment plants are implemented (14).
The objective of this study was to test a simplified measurement for influent characteristics and effluent quality of a wastewater treatment plant. At the same time, the performance of the process, an advanced biofilm reactor, could be followed continuousiy on large scale.

UV absorption

The possibility to correlate carbon concentrations with UV absorbance was applied to a variety of wastewaters (15) and surface waters (16). Insaturated molecules present a maximum of absorption in the ultraviolet spectrum with wavelengths between 250 and 280 nanometers (17). The main problem remaining was to develop an industrial device at low cost, that would be easy to install and maintain as well as present reliable operation (18).
The first industrial application of this system was to adjust reagent dosing in physico-chemical wastewater treatment (19). It is installed on a large underground treatment plant using lamella settlers to clarify sewage of about one million population equivalents (20). Continuous operation of the Ecofloc system allowed to produce an effluent of superior quality with lower reagent dosages (21).
For the influent, carbon concentration was measured by UV adsorption at 254 nm. The correlation between the measured COD and the optical density established by the sensor is given in Figure 1. A more sensitive instrument was used to follow the effluent quality, based on the same principle. The percentage transmittance at 254 nm was monitored continuousiy and correlated to the measured COD residual. The resulting curve is given in Figure 2. These curves have to be verified periodically and have to be adjusted for each specific wastewater.

Biological Aerated Filter

The biological aerated filter (Biocarbone) is an innovative technology that combines aerobic degradation of pollutants and physical retention of suspended matter in one reactor. A high concentration of active biomass can be achieved in thepacked bed reactor, and nitrifying bacteria can be retained on the filter media, allowing ammonia oxidation independently of sludge age (22). Because of the fixed biomass and the granular filtration effect, no sludge settling or biomass recirculation is necessary.
This technology is used on large scale with about fifty installations Worldwide (23). It can be used for removal of BOD and SS only, as for industrial wastewater (24), or for simultaneous oxidation of carbon pollution and ammonia (25). Also, biological filters can be used behind convenrional treatment to upgrade for nitrogen or phosphorus removal (26), as well as for complete removal of nitrogen (27). Their performance has been evaluated by numerous government agencies (28, 29).

Le Touquet Biofiltration Plant

The Le Touquet sewage treament plant is located on the Channel Coast in the Northwest of France. The population in this resort area varies widely throughout the year. The nominal loading of about 10 000 population equivalents is multiplied by five during the summer month. The design of biofilters in multiple parallel cells allows to adjust the number of reactors in operation to the actual plant loading. Because of the high concentration of fixed bacteria, rapid startup is possible and practised on a number of installations in the coastal regions of France (30).
In a first stage, the wastewater treatment plant is designed for a maximum of 53000 population equivalents. Primary treatment consists of an arated grit chamber, and two lamella settlers with 53 parallel plates in a tank of 8.5 m x 4.3 m. The biological reactor is comprised of six aerated filter cells with dimensions of 8.78 m x 3.8 m. They are filled with about 1.6 m of expanded shist. Final effluent requirements are below 20 mg/1 for BOD and 30 mg/1 for SS, and the effluent is chlorinated before ocean discharge. Sludge is thickened and stabilized with lime. After band filter press dewatering, the sludge cake is used for agricultural and horticultural applications. Figure 3 shows a flowscheme of the plant and the location of the on-line sensors.

Fig. 1: Correlation between influent COD and UV absorption

Droite de correlation DO-UV 254 / DCO Eau décantée mg/l Droite N°2

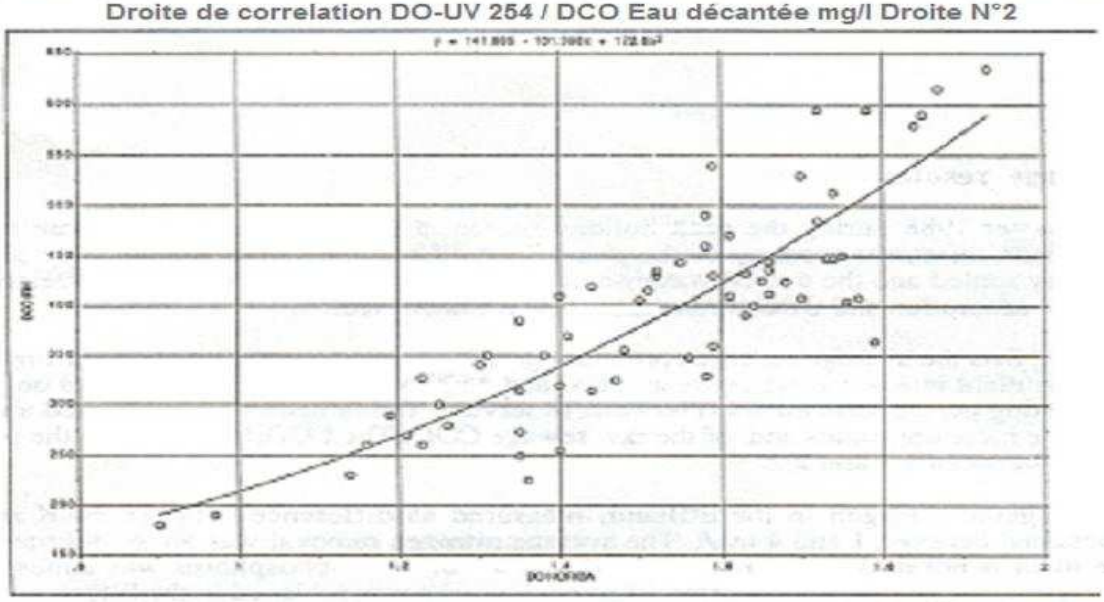


Fig. 2: Correlation between effluent COD and UV absorption

Droite de correlation DO-UV 254 / DCO Eau épurée mg/l Droite N°5

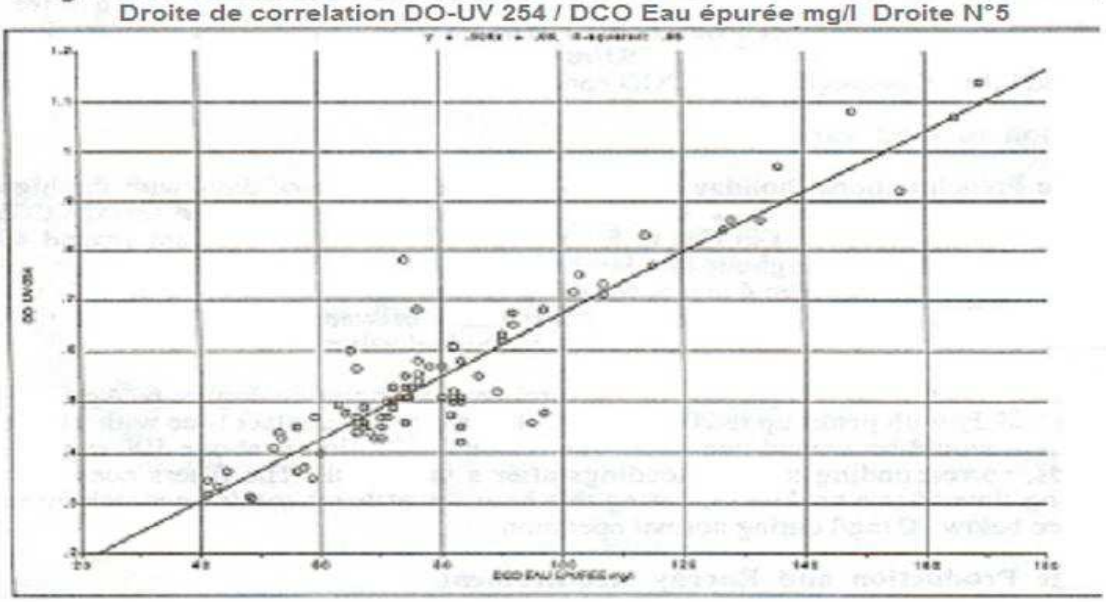


Table 1: Le Touquet Biocarbone: Daily Averages

Parameter	July 5/6	July 12/13	July 19/20
Flow m3/d	3820	4120	4653
Load kg/m3 d	5.7	7.5	6.9
Concentrations mg/l			
COD in	270	413	380
Nitrogen TK	69	65	61
Phosphorus TP	8.5	13.3	8.1
Residuals mg/l			
SS	20	19	15
COD	81	92	92
N-NH4	26.3	34.7	31.7
P-PO4	6.1	9.6	6.4

Average results

In summer 1988 during the peak holiday season, a special test series was run to assess the maximum treatment capacity of the plant. Two different UV-instruments were placed on the primary settled and the treated wastewater. Grab samples were taken and a correlation between the UV adsorption and COD measurements was established.
Table 1 lists the averages of three pollution profiles carried out once a week during three weeks in July. Plant inflow varied between 3800 and 4600 m3/d (1 to 1.2 MGD), and only during the last testing period were all six filter cells in service. The lamella settler removed about 43 % of both the incoming solids and of the raw sewage COD. The COD/BOD ratio in the plant influent varied between 1.7 and 2.2.
The organic nitrogen in the effluent, measured as difference between NTK and N-NH4, fluctuated between 1 and 4 mg/1. The average nitrogen rernoval was 50 %, despite the fact that the plant is not designed for nitrification. In the effluent, phosphorus was almost completely converted to PO_4 and a 25 % removal through uptake was achieved in the filters.
The relationship between filter loading and effluent COD is illustrated in Fig. 4 for periods that are not disturbed by high load variations. The COD removal rate drops from 90 % to 80 % when the loading is increased to 10 kg COD/m3d, allowing to keep the effluent residual below the required 90 mg/1 of daily average COD concentration normally required by French legislation.

Reaction to load variations

For the French national holiday of July 14, considered one of days with the highest loading throughout the year in the summer resorts, the hourly values of settled sewage COD, flow and effluent quality are shown in Figure 5. Influent COD is rather constant around 400 mg/1, but flow varies widely throughout the day between 100 and 250 m3/h. The number of cells in service was varied between 4 and 5, resulting in loadings below 5 to 15 kg COD/m3d with an average of 7,5. The effluent quality is rather stable between 90 and 100 mg/1 COD, but large peaks provoke a long period of slightly higher residual values.
The filter reaction over a period of several days is shown in Figure 6. Again, filter loading varies widely with peaks up to 20 kg/m3 d. The empty bed contact time with a peak flowrate of 250 m3/h would be around one hour. The residual pollution is above 100 mg/1 only for short periods, corresponding to peak loadings after a backwash. The filters need about one hour ripening time after a backwash, during this hour the effluent solids approach 30 mg/1 whereas they are below 20 mg/1 during normal operation.

Sludge Production and Energy Requirement

Backwash was performed automatically every night after 24 h. The sludge evacuated per day is about 500 kg of 90 % volatile matter, corresponding to a sludge production of the biological reactor of 0.8 kg TSS/kg BOD removed. The backwash water has an average TSS concentration of 500 mg/1 and is returned to the primary settler, where the sludge is extracted with the primary sludge. The backwash water quantity approached 30 % in some periods.
The overall daily energy consumption of the plant was around 1800 kWh, out of which between 15 and 20 % for backwash. Including pretreatment and sludge handling, the total energy needs thus approached 1.5 kWh / kg BOD removed, or about 0.5 kWh / m3 treated. Air requirements can be established on the basis of incoming pollution load, measured by UV-absorption, and energy supply can thus be optimised. For an average wastewater, air requirements were established as 32 m3 / kg Oxygen Demand, where the oxygen demand is defined as 0.9 soluble COD + 0.2 suspended COD and 4.5 eliminated NH4.

Figure 3: Flowscheme of Le Touquet Sewage Treatment Plant

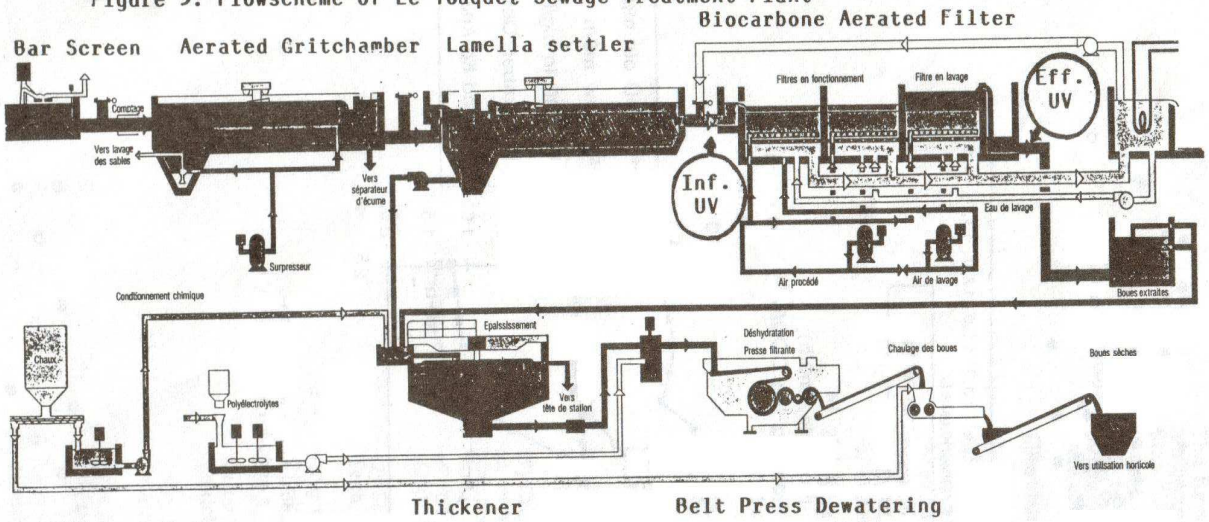


Figure 6: Le Touquet Biocarbone Plant: Period from July 7 to 11
Hourly loading (kg COD/m3 d) and effluent quality (mg COD/l

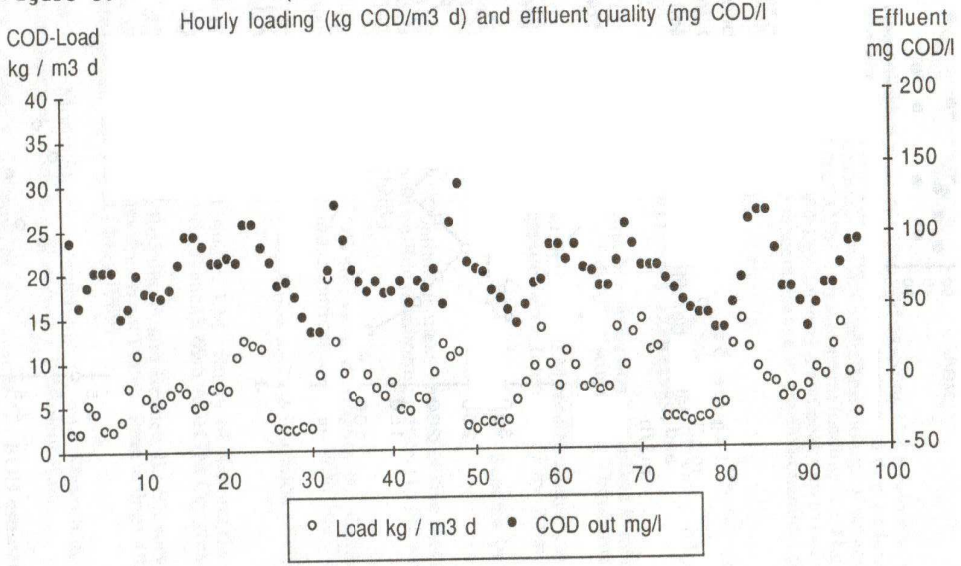


Fig. 4 HOURLY EFFLUENT COD AND REMOVAL EFFICIENCY IN DEPENDENCE OF LOADING (LE TOUQUET BAF)

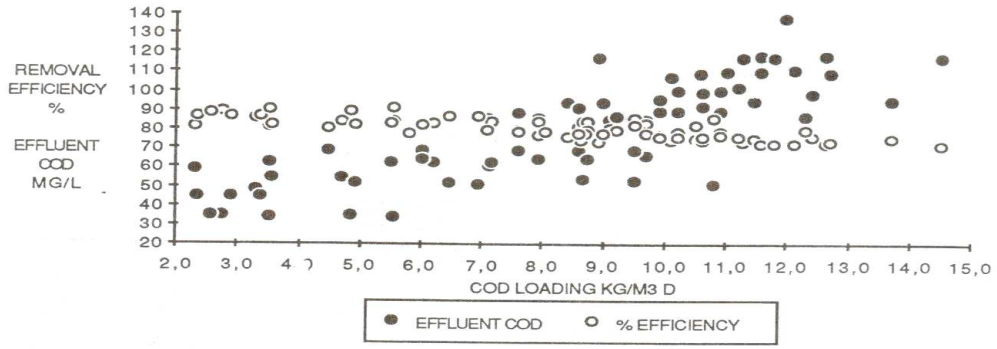


Figure 5: Le Touquet Biocarbone: Day of July 14
Influent and Effluent COD (mg/l), Flowrate (m3/h),
Number of Filter Cells in Operation and Loading (kg COD/m3 d

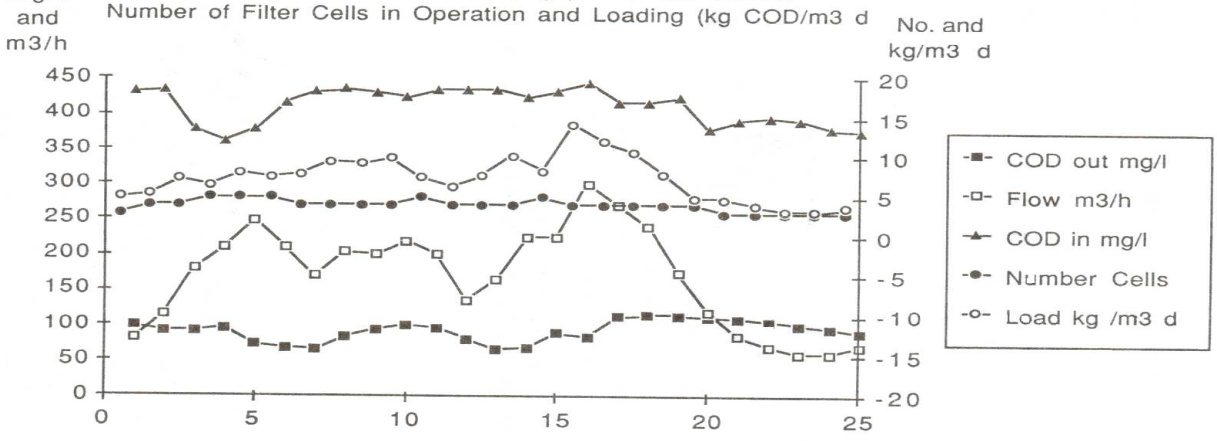
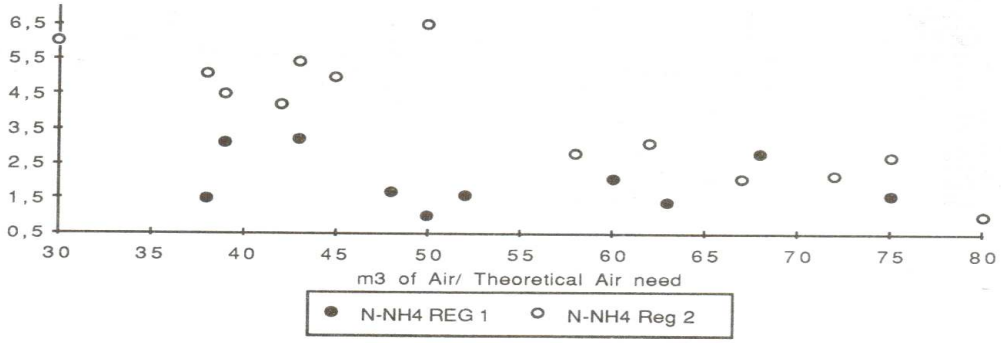


Figure 7
Biocarbone Geneva: Residual Ammonia Nitrogen
in Dependence of Air Flowrate and Air Regulation Mode



This formula and the continuous regulation based on incoming pollution was verified on a nitrifying demonstration biofilter. The city of Geneva conducted a year long test of a full scale filter cell for simultaneous BOD removal and nitrification of pretreated water (31). The effluent ammonia-nitrogen in dependence of air flowrate is shown in Fig. 7. Two different formulas were used to correlate the pollution signal. When all conditions were met (ammonia and carbon pollution loading below the limits, air needs covered), very low residual nirrogen concentrations were achieved.

Conclusion

Simplified on-line pollution sensors were used based on UV absorption to measure influent and effluent COD concentration . An innovative bioreactor could thus be followed continuously to assess its reliability and performance on full scale. The biological aerated filter delivered a secondary effluent below 90 mg COD/1 with a constant loading of 10 kg COD/m3 d, or a fluctuating load with an average of 7 kg COD/m3d and peaks up to twice that value. The UV-instruments are applied to regulate reagent dosage in physico-chemical plants or adjust air-flowrates in biological reactors.

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