ANAEROBIC TREATMENT OF PAPER MILL WASTEWATER

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Abstract

In this paper the performance of an anaerobic wastewater treatment plant during the first months of operation in the paper producing company "Visy Paper" in Brisbane, Australia, is presented. Key part of the plant is an ENVIROASIA-UASB (Upflow Anaerobic Sludge Bed) methane reactor. Despite high initial loading rates and the use of relatively poor quality seed sludge, start-up progressed fast, operation was stable and COD removal efficiencies of over 85 % were obtained. The consistently good performance was largely due to the use of a high performance three-phase separator, built in at the top of the methane reactor.
During operation it was noticed that production of different types of paper (Kraft paper) affects the operation data of the plant.

Introduction

Water consumption in the paper industry is often enormous. Up to 200 m^3 water per ton of paper is sometimes needed for paper production. Increasing efforts in water recycling have not only led to a lower specific water consumption but also to a higher wastewater COD concentration and temperatures. Today pulp and paper mill wastewaters are often highly loaded and often have temperatures above 30°C, ideal conditions for anaerobic wastewater treatment. COD concentration can be as high as 20,000 mg/l, though often related with high amounts of suspended solids like fibers, minerals, slime, which in general require separate treatment steps. During the last decades, anaerobic treatment of pulp and paper mill wastewater has gained significant importance. Several plants are up and running in the world, mostly based on so called UASB- or Contact- processes. Advantages of the anaerobic process compared with classic aerobic processes (e.g. activated sludge process) are multiple: moderate investment costs, very low operation costs, energy production, low space requirement. Anaerobic treatment remains however a pretreatment. For discharge in rivers, an aerobic polishing treatment remains necessary.

In 1996 Enviroasia built and started an anaerobic plant at Visy Paper, Brisbane, Australia. This new paper mill produces 135,000 tons of brown packaging paper annually from recycled paper and cardboard. The paper mill was built using the most modern technologies, which include the advanced wastewater treatment. For the outstanding design, construction and operation of the mill, Visy Paper won the 1997 Engineering Excellence Award from the Institution of Engineers Australia.

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Plant description

The wastewater from the factory first passes a pretreatment step, consisting of flocculation and separation of suspended solids by dissolved air flotation (DAF), followed by a sandfiltration. Then the wastewater is cooled to below 40°C and stored in a 1000 m^3 equalization basin.

The wastewater consists mainly of water wasted from the paper mill's (semi-)closed water circuit. The nature of the circuit is such that short time peaks are normally well levelled out. Partial acidification takes place in the circuit. Since excessive acidification is not desired, there is no need for a large acidification and equalization stage. A 1000 m^3 equalization basin remains however required for operational flexibility and safety. During normal operation the basin is always at least half empty.

From the equalization basin the wastewater is pumped continuously into the methane reactor through an influent distribution system at the bottom. The pH at the inlet is automatically corrected with NaOH, if necessary, to obtain an optimal pH (6.5-7.5) in the methane reactor. Urea (nitrogen) and phosphoric acid (phosphorous) are also added as nutrients for the biological growth process, as these compounds are deficient in paper mill waste water. The methane reactor is of the modern UASB type. Water flows from the bottom to the top, where a special three-phase separator is installed. Biogas is deflected and collected in biogas domes, sludge is separated from the clarified, final effluent and returns to the bottom of the methane reactor, by means of a gas lift driven internal circulation. This high performance device, developed by Biotim (Belgium), is equipped with lamella separator to ensure a good retention of settleable solids (sludge) under all circumstances. It has been used in over 100 plants in various industries with great success. The absence of any mechanical agitation in the UASB methane reactor allows a natural selection towards heavy, granular flocs of active methanogenic sludge. A selection pressure and sufficient mixing of the sludge bed is usually maintained by means of partial effluent recycle.

Biogas utilization (steam production) is foreseen for the future. At start-up however, the biogas was burnt in the (emergency) flare.

The effluent of the anaerobic plant is pumped to the adjacent municipal sewage treatment plant (activated sludge system) for final polishing prior to discharge in the river.

Table 1: Anaerobic plant design parameters

Parameter	Unit	Value
Maximum Flow	m^3/d	2,000
Hydraul. retention time	h	12-18
Influent COD	mg/l	5,000-6,000
Effluent COD	mg/l	1,500-1,800
COD Removal	%	>70%
Influent TSS	mg/l	50-200
Biogas production	m^3/d	3,000

Plant start-up and operation

The plant was put into operation in September 1996 and its performance was closely monitored in the first few months after start-up.

The equalization basin was operated so as to obtain an optimal balance between buffering and acidification, resulting from the conversion of part of the complex organic matter into mainly volatile fatty acids. Acidification occurred spontaneously and resulted in low pH values of 4.0-6.5 at the outlet. At the inlet of the methane reactor NaOH was dosed, in order to keep the pH in the methane reactor in the neutral range.

The reactor was seeded with ca. 450 m^3 locally available digested municipal sludge, with typically a low sludge activity of ca. 0.1 kg COD removal per kg sludge (TSS) per day and poor settling characteristics.

During the first three weeks, the loading of the anaerobic UASB-reactor was progressively increased to the point where all available wastewater was treated with a good COD removal efficiency (Figure 2). Figure 1 shows influent and effluent COD's during the first four months. Two periods could be distinguished, based on the influent COD. The first 2.5 months, the average influent and effluent COD were 4,700 mg/l and 1,300 mg/l respectively, corresponding to 70-75% COD removal efficiency. During the following 1.5 month, the average influent and effluent COD were higher, ca. 8,000 mg/l and 1,450 mg/l, corresponding to 80-85% removal efficiency, significantly better than the design values. The higher removal efficiencies were related to the higher influent COD concentrations and a possible different composition (with a higher fraction of anaerobically biodegradable compounds), but were also due to the progressively increasing amount and quality of sludge in the system. No excess sludge was wasted from the reactor at that time. Large COD fluctuations occur, also depending on the occasional production of a different kind of paper. The production of Kraft paper always gave a wastewater with much higher COD and TSS levels (~30%).

The reactor performance was exceeding expectations, even with wastewater characteristics deviating from the design basis. The TSS concentration of the incoming wastewater (100-800 mg/l) in particular was quite high, due to the initially poor and irregular performance of the pretreatment. High amounts of suspended solids tend to accumulate in the methane reactor, because they are only partially degraded. This has to be avoided, because it affects the sludge quality and activity negatively in the long run. After optimization of the pretreatment, the problem was solved.

The anaerobic sludge showed a clear evolution during the first few months of operation. Settling characteristics improved by more than 100%, the amount of sludge in the reactor doubled and reached a very high activity (>1 kg COD removed per day per kg sludge). After one year of operation, a net granulation of the sludge at the bottom part of the reactor had occurred.

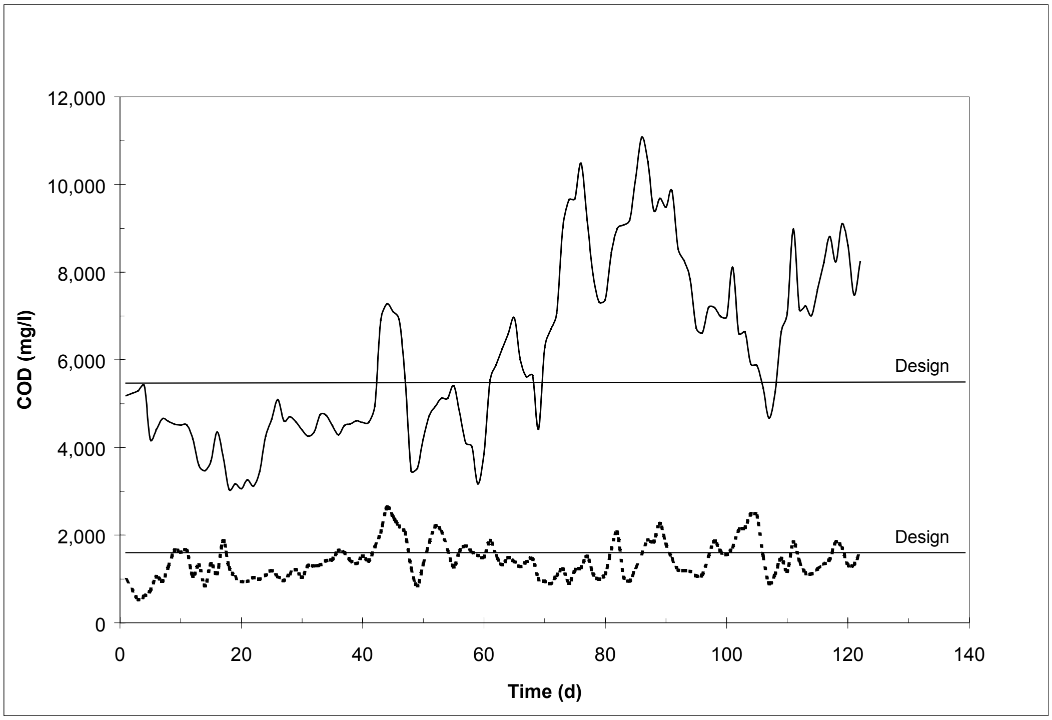

Figure 1: Influent and Effluent COD of the ENVIROASIA Methane Reactor.

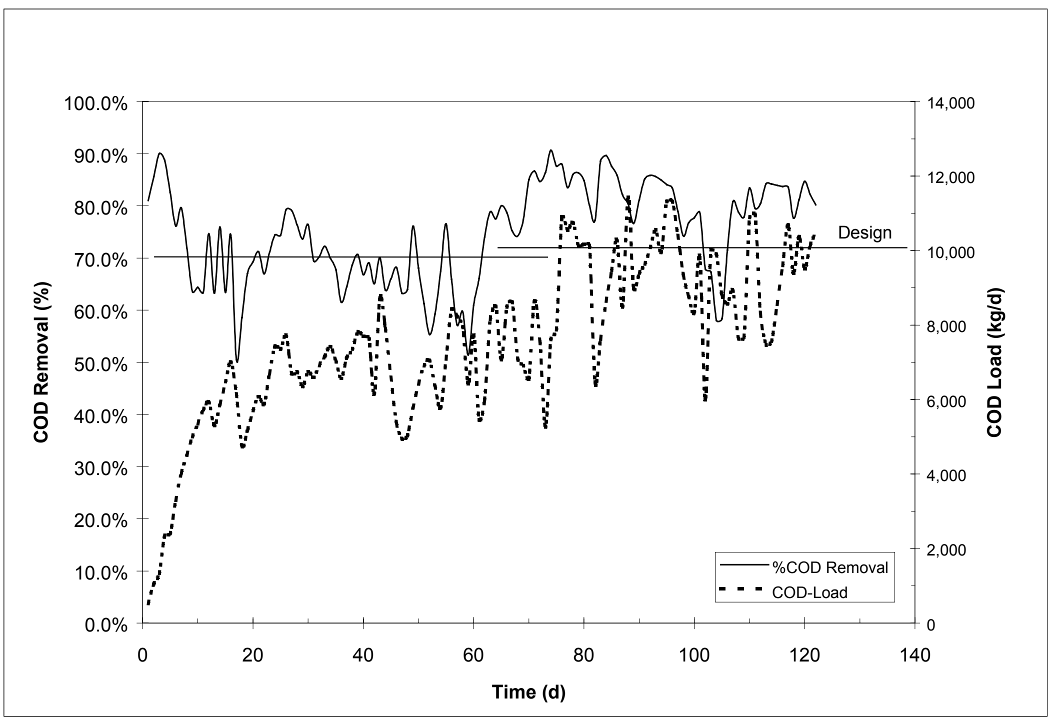

Figure 2: COD Removal efficiency and COD Load during start-up of the ENVIROASIA Methane Reactor.

Economical aspects

Anaerobic wastewater treatment plants allow a significant pollution reduction (80-95%) at moderate investment costs and no net operating costs. The biogas produced is as a valuable byproduct, compensating for the operating costs. The overall cost amounts to only 0.27 US$ per m^3 wastewater (see Table 2). The total cost, including an aerobic polishing treatment (with sludge treatment) would amount to 0.4-0.5 US$, or possibly more in case high taxes have to be paid for posttreatment in a municipal treatment plant. The combined anaerobic-aerobic treatment of industrial wastewater, at a scale comparable with Visy Paper, is always much more economical than aerobic treatment alone, which is reported to cost anything between US$ 0.7-3.5. And costs for aerobic treatment are rising rapidly, due to increasing costs for sludge disposal, chemicals (for nutrients and sludge dewatering) and power (for aeration).

Table 2: Overview of the anaerobic wastewater treatment costs for a paper mill (600,000 m^3/a at 5,000 mg/l COD)

Investment costs	US$	1,600,000
Annuities	US$/a	175,000
Annuities per m^3 wastewater	US$/$m^3$	0.29
Manpower	US$/a	10,000
Chemicals	US$/a	40,000
Sludge disposal	US$/a	0
Maintenance and spare parts	US$/a	7,000
Power	US$/a	7,000
Biogas production	US$/a	-75,000
Total net operating benefit	US$/a	11,000
Operating benefit per m^3 WW	US$/$m^3$	0.02
Total cost per m^3 WW	US$/$m^3$	0.27

Conclusions

Anaerobic treatment of paper mill wastewater is a reliable and economical way of treating wastewater. Practical experience on modern full scale plants like the one at Visy Paper, Brisbane, Australia, is quite satisfying. Proven state-of-the-art techniques, developed in the last 10 years, are now available and will find an increasing number of applications all over the world.