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ANAEROBIC-AEROBIC WASTEWATER TREATMENT PLANT OF A POTATO CHIPS FACTORY

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ABSTRACT

The described full scale wastewater treatment plant of the potato chips factory is working with a two-stage anaerobic pretreatment followed by an aerobic purification with nitrogen and phosphorus removal. Extraordinary elements of the plant are the fixed-film methane reactor and the trickling filter used as a cooling element between the anaerobic stage and the activated sludge system. A sludge blanket was built up underneath the swimming support media of the fixed-film methane reactor. During the first year of operation the energy profit by methane production was 1 056 000 kWh, which is 50 % of the whole energy consumption of the wastewater treatment plant.

KEYWORDS

Food processing industry; potato chips wastewater treatment; anaerobic pretreatment; fixed-film methane reactor; nitrification; denitrification

INTRODUCTION

The good results obtained during experiments with potato chips wastewater and a fixed-film methane reactor led to the construction of this treatment plant. The layout was done in 1985. At that time a low cost COD and BOD reduction was the first aim and it was decided to have only nitrification in the aerobic stage. Meanwhile nitrogen removal is in Germany as important as BOD removal. Therefore the design for the activated sludge system was changed to a flexible system working with nitrification and denitrification.

By the anaerobic pretreatment the BOD:N-ratio is decreased from 6.75:1 (fresh process water) to under 0.5:1. This ratio which is insufficient for denitrification is improved by passing 25 to 40 % of the process water from the equalizing tank and all sanitary water directly into the denitrification zone of the activated sludge system.

The activated sludge system started to work in summer 1989; the anaerobic part of the plant is in operation since December 1989. Results of the first year of operation are presented.

WASTEWATER FLOW AND COMPOSITION

The wastewater of this potato chips factory is a composition of:

a) process water, the main wastewater stream. which is a mixture of potato washing water after sand separation and potato fruit water after starch recovery in the factory;
b) sanitary wastewater of 150 workers , including the water which is reused from the

effluent of the final sedimentation tank for cleaning needs in the treatment plant, expecially for the screens. This water, which is counted together with the sanitary wastewater, passes the activated sludge system twice;

c) fat-containing cleaning water which originates from cleaning of the deep-frying pans and the ground on Fridays and Saturdays.

During the year 1990 171000 m^3 of clarified wastewater were discharged into the river Rhein. In the same year 43 720 t of potatoes were processed with an average daily operational capacity of 200 to 250 t. The specific wastewater flow was 3.9 m^3/t potatoes.

The specific and the daily wastewater flow are the same as expected in the layout. Against that the concentrations are much lower than expected in the layout. The reason for this is the reduced time of contact between water and potato during the production. The COD load is only 60 % and the BOD load is only 42 % of the design load.

TABLE 1 Wastewater Flow and Composition

Parameter	Dim.	Process Water			Sanitary Wastewater			Cleaning Water		
		min.	max.	average	min.	max.	average	min.	max.	average
COD	mg/l	389	5899	3638	89	3868	933	1418	11436	3828
BOD	mg/l	155	3465	1977	18	1218	284	790	7100	2162
Total N	mg/l	88	509	296	36	172	94	16	100	32
Total P	mg/l	6	51	25	2	82	13	2	31	6
Lipophilic C.	mg/l	10	296	63	-	-	-	28	2651	613
Temperature	°C	15	27	21	11	26	20	18	32	25
Flow	m^3/d	5 days a week		790	5 days a week		60	once a week		max. 96

FULL SCALE TREATMENT PLANT

After screening, the process water is directly pumped into the equalizing tank. The fat containing cleaning water from the deep-frying pans is collected in two buffer tanks and continuously fed from Monday to Friday into the equalizing tank.

The sanitary wastewater is directly led into the first denitrification tank in the activated sludge system. Nevertheless the BOD:N ratio in the influent of the activated sludge system, which is a composition of the effluent of the trickling filter and the sanitary wastewater, is insufficient for an extensive denitrification. For this reason 25 to 40 % of the process water is pumped from the equalizing tank to the denitrification zone of the activated sludge system.

TABLE 2 Volume and Size of the Treatment Plant

Building	Total Volume	Effective Volume	Inside Diameter	Available Height
Equalizing tank	1200 m^3	1155 m^3	12.40 m	3.0 - 9.6 m
Fat buffer tanks	2 x 50 m^3	2 x 48 m^3	2.90 m	7.3 m
Methane reactor	1630 m^3	1530 m^3	14.40 m	9.4 m
Clarifier		406 m^3	12.00 m	av. 4.2 m
Trickling filter		136 m^3	6.00 m	4.8 m
Aerated tanks	4 x 558 m^3	4 x 500 m^3	10.00 m	6.5 m
Final clarifier		406 m^3	12.00 m	av. 4.2 m
Gasholder	200 m^3	200 m^3		

Equalization and Acidification Tank

This tank has two functions. On the one hand there is the equalization of flow and concentrations and on the other hand the acidification. 40 to 90 % of the filtrated COD is found as organic acids in the effluent of this tank.

The content of the tank is mixed by a recirculation pump of the heat exchanger. The heat exchanger is charged by 85 °C warm water. The heating of this water is achieved by heat recovery from the 130 °C hot exhaust vapours.

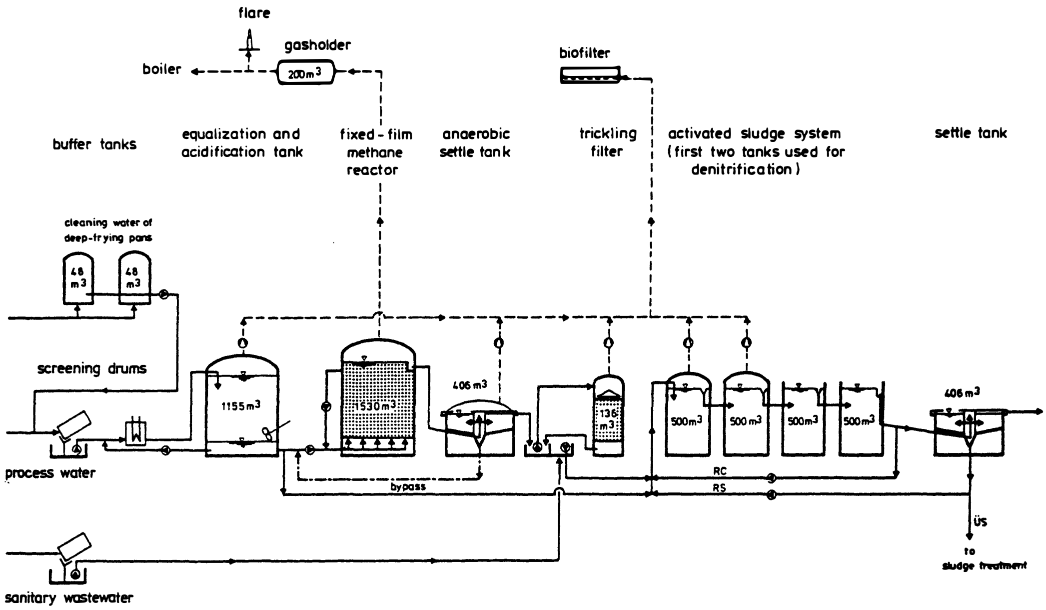

Fig. 1. Flow diagram of the anaerobic-aerobic wastewater treatment plant of a potato chips factory

Fixed-Film Methane Reactor

The total volume of the fixed-film methane reactor is 1630 m^3 including 100 m^3 gas room. The upper 6 m of the fluid volume (69 % of the effective volume) are filled with a loose-fill swimming polyethylene support media with a specific surface of 100 m^2/m^3.

The methane reactor is inoculated with 100 m^3 pellets of a sludge blanket reactor with SS 100 g/l, VSS 16 % and a settling velocity of 20 m/h. Two months after start up the pellets were dissolved. A new sludge blanket was built up underneath the support media with a very good settling velocity and with a high SS-concentration of more than 80 g/l. Based on these results connected with the biomass retention of the support media it is not necessary to use the settle tank. Up to now the settle tank is always used without sludge return.

The design load of the methane reactor was 2.6 kg COD/m^3 d. In practice the COD space loading rate was between 0.64 and 1.25 kg COD/m^3 d caused by the much lower influent concentrations and by the requirement of a high denitrification rate. The effluent data (COD 530 mg/l and BOD 110 mg/l in the average, maximum of organic acids 28 mg/l) show that a further anaerobic degradation is not possible.

Trickling Filter

The high-rate plastic media biological filter is a cooling system. For this reason it is equipped with a 3-step blower (5, 7.5 and 21 kW). It depends on the outside temperature which of these steps is used. During the design in 1985 the two functions of the trickling filter as cooling element and as a stage for COD and BOD degradation were seen equivalently. Meanwhile the nitrogen removal got much more important than before. Today the COD and BOD elimination is a negative attendant.

The average temperature could be lowered by about 7 °C. Working with an average BOD space loading rate of 0.3 kg/m^3 d, the elimination rate is 20 % COD and 62 % BOD. The nitrification rate was between 12 and 31 %. During the intensive measuring weeks up to 66 mg/l nitrate were found in the effluent of the trickling filter.

Activated Sludge System

The activated sludge system consists of a cascade of four single tanks. The tanks are connected in a way that allows bypass of each tank. Four propulsion jet pumps standing outside of each reactor are used for mixing and/or aeration. By opening a slide surrounding air is sucked by the venturi tube into the water. This construction gives the possibility to use each tank for nitrification or denitrification. If not enough air can be brought into the system in this way additional blowers are switched on automatically.

Normally 50 % of the volume is used for denitrification. With the bypass from the equalizing tank the BOD:N ratio rises to 2.9:1 on average. The BOD space load is between 0.1 to 0.26 kg /m^3·d. The SS were 7.0 g/l in the average with 60 % VSS. Simultaneous P-precipitation is done by $FeCl_3$ dosage in the 3rd tank.

TABLE 3 Effluent concentrations during 6 intensive measuring weeks in 1990 [mg/l]

Parameter	Minimum	Maximum	Average	Control Value
COD homogenized	43	149	83	160
COD filtrated	17	88	31	-
BOD homogenized	1	7	3.5	30
NH_4-N	0.035	0.7	0.18	10
NO_3-N	0.5	88*	33	-
Total P	0.4	6.2	2.7	-

* only three tanks in operation, two aerated, one for denitrification

CONCLUSIONS

In our opinion there are no more problems in treating wastewater from potato chips production anaerobically-aerobically. In spite of the relatively unfavourable BOD:N ratio of 6.1:1 to 7.1:1 in the fresh process water, an anaerobic pretreatment seems to be useful. It could be shown that it is possible to have a high rate of nitrogen removal and at the same time a high rate of energy recovery from biogas at about 50 % of the whole energy need of the treatment plant.

It became obvious that it is not necessary to have an anaerobic settle tank if the methane reactor is built as a fixed-film methane reactor.

It is intended to double the production capacity of the factory in the following years. As the operating results obtained have shown the methane reactor, the trickling filter and the activated sludge system can deal with this higher load. Problems will occur with the final clarifier. The anaerobic settle tank which has the same size as the final clarifier should be used additionally as a final clarifier.

More than that it is planed to install a filtration after the final clarifier as the last cleaning step. The filtration will be combined with a post precipitation. Though it will be possible to reach the high future discharge consent conditions of at least 2 mg P/l. This will as well lead to a much higher efficiency in the elimination of suspended solids and COD which can be seen in table 3.

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