

New trends in anaerobic treatment:

ANAEROBIC EFFLUENT TREATMENT AS AN INTEGRAL PART OF INDUSTRIAL PROCESSES

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ABSTRACT

Anaerobic effluent treatment plants produce valuable energy (biogas) and facilitate recovery of valuable resources. As a result, rather than being regarded as end-of-pipe solution, effluent treatment plants comprising anaerobic treatment, are increasingly being used as an integrated part of the production process of industrial plants. The potential of anaerobic treatment as a more or less integrated part of the industrial production process is illustrated by three cases: a paperboard mill, a food factory and a metal refinery.

KEYWORDS

Anaerobic, Biogas, End-of-pipe, Energy, Industry, Integrated, Recovery, Resources

INTRODUCTION

Anaerobic treatment is a recognized, well-established and proven technology for the treatment of various industrial effluents. Currently over 1000 anaerobic treatment plants have been constructed worldwide treating industrial effluent like for example the beverage industry, food industry, pulp and paper industry and (petro) chemical industry. The production of valuable energy rich biogas, the relatively small production of biological excess sludge and the development of more compact reactor types have largely contributed to the successful application of anaerobic treatment in the industry.

In general biological effluent treatment plants are regarded as end-of-pipe solutions for purification of the effluent produced as a result of industrial activity. More recently effluent

treatment plants comprising anaerobic treatment, have been implemented as a more or less integral part of the industrial production process. Beside the utilization of the produced biogas, anaerobic treatment additionally enables the re-use/reduction of other valuable resources like process water. This paper presents the set-up of combined anaerobic/aerobic effluent treatment plants at three different industrial factories in which the treatment plant is in some way integrated with the industrial production process.

Case 1: paper board mill

Background

A German paper mill producing linerboard and corrugated medium from recycled wastepaper was operating a fully closed water circuit for more than 25 years. However paper quality was negatively affected as a result of accumulation of organic compounds (especially volatile fatty acids) and salts (e.g. calcium, sulfate etc.). To overcome these problems, while remaining the water circuit closed, in 1995 a biological treatment plant was integrated with the closed water circuit of the board mill.

Description of effluent treatment plant

Clarified wastewater from the board mill is first cooled down from 55 °C to 35 °C. The cooled wastewater is pumped into a buffer/pre-acidification tank (600 m³). The buffer/pre-acidification tank will smooth out fluctuations in flow and COD and allows time for partial acidification. Urea (N) and phosphoric acid (P) are dosed in order to provide a sufficient high level of nutrients necessary for the biological process. From the buffer tank the wastewater is pumped into two Biopaq[®]-UASB reactors (725 + 1250 m³). The produced biogas is buffered by a gas buffer and subsequently treated in a biological Thiopaq[®]-desulfurization unit, comprising a gas scrubber and a bioreactor. In this scrubber the biogas is brought in a counter-current mode with the alkaline liquid of the bioreactor causing the H₂S in the biogas to be absorbed in the liquid phase (equation 1). In the bioreactor the absorbed H₂S is converted to elemental sulfur (equation 2).



Figure 1 presents a schematic flow diagram of the biological Thiopaq[®] biogas scrubber.

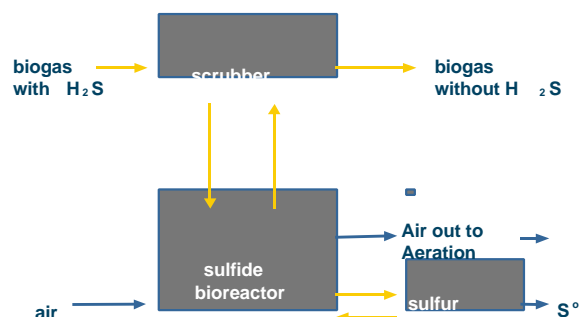


Figure 1: General flow schematic of Thiopaq[®] desulfurization plant

Table 1: Typical operational data of fully process integrated treatment plant at paper mill

Parameter	Unit	Anaerobic	Total
Flow	m ³ /d	2650-4000	2650-4000
COD load	kg/d	28000	28000
BOD load	kg/d	14000	14000
COD removal	%	75	85-90
BOD removal	%	80-85	98
TSS removal	%		97
Biogas production	m ³ /d	9000	

In-line biological treatment of a fully closed recycle paper mill comprising anaerobic treatment offers the following benefits:

- Improved paper quality compared to the situation the mill runs with zero-discharge without treatment
- No costs for effluent discharge levies
- Less fresh water is needed because of process water recycling
- No biological aerobic sludge handling
- Energy savings up to 4 % of the board mill's energy requirements by utilization of biogas in steam boiler (Habets and Knelissen, 1999)
- Energy savings for increasing process water temperature as less (cold) fresh water is required.

Based on the long-term experience at the aforementioned paper mill several in-line biological effluent treatment plants have been installed at waste paper based board mills. These new treatment plants are characterized by the use of a high-rate compact Biopaq[®]-IC reactor (instead of UASB) and a simpler post-aeration unit. Some of these paper mills have the possibilities to operate at thermophilic temperatures (45-55 °C) giving additional energy savings as heating of the treated effluent becomes obsolete (Habets, 2000).

Case 2: Food industry

Background

This case concerns a food processing company in Belgium handling fresh vegetables, producing deep frozen products. From 1989 till 1999 the company has grown rapidly raising production capacity from 17,000 ton per year final product up to 55,000 ton per year. The company has been using groundwater as a source for water supply. The advantages of using groundwater are evident, it is bacteriological safe and it can be used without any further treatment. However the use of groundwater became more difficult due to:

- Decreasing groundwater tables (water withdrawal from a minimal depth of 300 m)
- Deteriorating groundwater quality (table 2)

Table 2: Groundwater quality and guidelines for drinking water quality (10.3.2000)

Parameter	Unity	Groundwater	WHO guidelines
pH		8.3	6.5 – 8.5
SO ₄ ²⁻	mg/l	126	400
HCO ₃ ⁻	mg/l	552	
Cl ⁻	mg/l	550	250
Conductivity	mS/cm	2.6	0.25
TH	mmol/l	0.3	

In an attempt to further reduce groundwater consumption, alternative water sources are investigated: drinking water, surface water and wastewater. In the search for alternative water sources, the food factory has chosen for partial reuse of treated effluent within their production process. Simultaneously the existing effluent treatment plant (comprising an activated sludge plant of 8000 m³) was extended in order to cope with the increased pollution loads due to the increased production. In 2000 the full-scale installation came in operation.

Description of effluent treatment plant

In figure 3 the global water flows are given after introduction of the advanced treatment. Anaerobic pre-treatment (UASB: 5,000 m³) was installed, increasing the COD treatment capacity (30,000 kg COD/d) of the treatment plant and leading to an increased stability of the overall treatment process. This was especially important as due to the large variety of different types of vegetables that are processed, COD load and wastewater composition changes considerably. The produced biogas is currently used for heating of the incoming effluent. Further use of the biogas might be considered, especially as the factory changed to steam peeling instead of caustic peeling. After aerobic treatment and sedimentation, Astrasand[®] continuous polishing filtration was installed producing an effluent (maximal 100 m³/h) sufficient high in quality to enable partial reuse for low-grade applications in the food factory (machine cleaning and cooling).

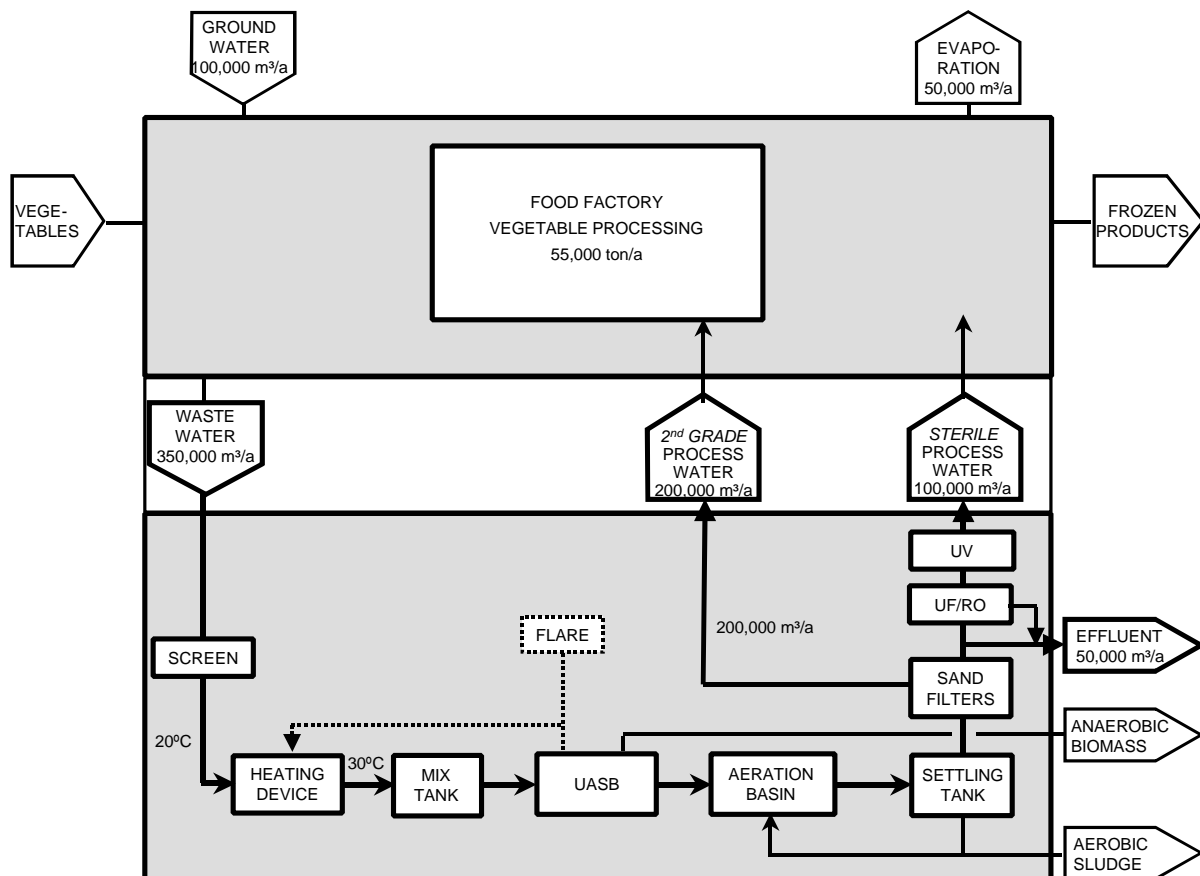


Figure 3: Process flow diagram of effluent treatment plant of food processing plant (flows expressed in m³/year)

The advanced treatment consists of Astrasand[®] flocculation filtration for extended solids removal and organic load reduction. After pH correction the effluent is now ready for further

treatment in the membrane ultra-filtration (UF, semi dead end, operating pressure = 0.5-1.0 bar), which acts as pre-treatment for the additional two-step reverse osmosis unit (RO, spiral wound membranes, operating pressure = 8-10 bar). The membrane filtration unit retains bacteria, micro molecules, viruses and proteins effectively, resulting in a microbiological safe permeate which is free from suspended solids and contains almost no salts. UV radiation is nevertheless implemented for extra security.

The produced water is mixed up with ground water and pumped into the production process. The produced waste streams (wash water of the sand filters, UF backwash water, rinsing liquid from the UF) are recycled to the biological treatment; only the RO concentrate is discharged with the excess flow.

Results

The extension of the biological treatment plant has resulted in a reliable guaranteed effluent quality, which after membrane filtration is microbiologically safe for reuse in the food factory. The typical wastewater composition at the different stages of the effluent treatment plant is presented in table 3.

Table 3: Typical water quality data at treatment plant of food factory (Wouters, 2001)

Parameter		Waste water	Anaerobic Treatment	After Sedimentation ¹	Sand filtrate polishing	Sterile water	Ground water ²
COD	mg/l	12,000	1,200	114		0	0
pH		8.5	7	8.3	8.2	5.5	8.3
Total-P	mg/l			34	34	<0.5	<0.5
NH ⁴⁺ -N	mg/l			<2	<2	<2	0.17
Fe (mg/l)	mg/l					0.03	0.23
TH	mmole/l			1.0	1.0	<0.3	0.3
HCO ₃ -	g/l			2,9	2,9	<0.3	<0.1
Conductivity	mS/cm	4.3		4.3	4.2	0.15	2.6
Turbidity	NTU			16	4.3	0	
CFU	1/ml					0	0
E-Coli	1/ml					0	0

¹ data 26-06-2000; ² data 10-03-2000.

The installed treatment plant has created the following important benefits:

- Less scarce and costly fresh water is needed
- Decrease of groundwater consumption (according governmental regulations)
- Savings on discharge levies as less effluent is produced
- Possible future use of the biogas in steam boiler for steam production
- Less excess aerobic sludge production because of anaerobic pretreatment
- Less aeration energy in aeration system is needed because of anaerobic pre-treatment

Case 3: Metallurgic Industry

Background

Besides mainly being applied for removal of organic compounds (COD) anaerobic treatment has also been successfully applied for the removal of inorganic compounds like metals and sulfate. An example is the biological metal and zinc removal installation at a zinc refinery in the Netherlands. The zinc refinery produces over 200,000 t/a zinc. As a result of zinc refining

by various companies over 100 years in the past, soil and groundwater have been contaminated with metals and sulfate. A geohydrological containment system was developed to prevent further contamination of nearby drinking water aquifers (Scheerer *et al*, 1993). Since 1992 the extracted contaminated groundwater (300-400 m³/h) is treated in a biological treatment installation incorporating an anaerobic sulfate reduction reactor.

Description of biological metal and sulfate removal plant

Figure 4 presents a schematic process flow diagram of the effluent treatment plant in relation to the zinc refinery. The extracted contaminated groundwater is firstly heated up to around 25 °C, after which it is pumped into a mix tank. As the groundwater is lacking essential macronutrients and organic compounds (electron donor) for the biological process, nitrogen, phosphorous and ethanol are dosed in the mix tank. From the mix tank the groundwater is fed to the anaerobic reactor (UASB) in which sulfate reducing bacteria convert the sulfate into sulfides (equation 3) and simultaneously metals (mainly Zn) are precipitated as sulfide salts (equation 4). The produced biogas is treated in a caustic scrubber to remove H₂S before it is incinerated in a flare. Excess sulfides, not precipitated in the anaerobic reactor, are biologically converted to elemental sulfur in a Thiopaq[®] sulfide oxidation reactor (equation 5).

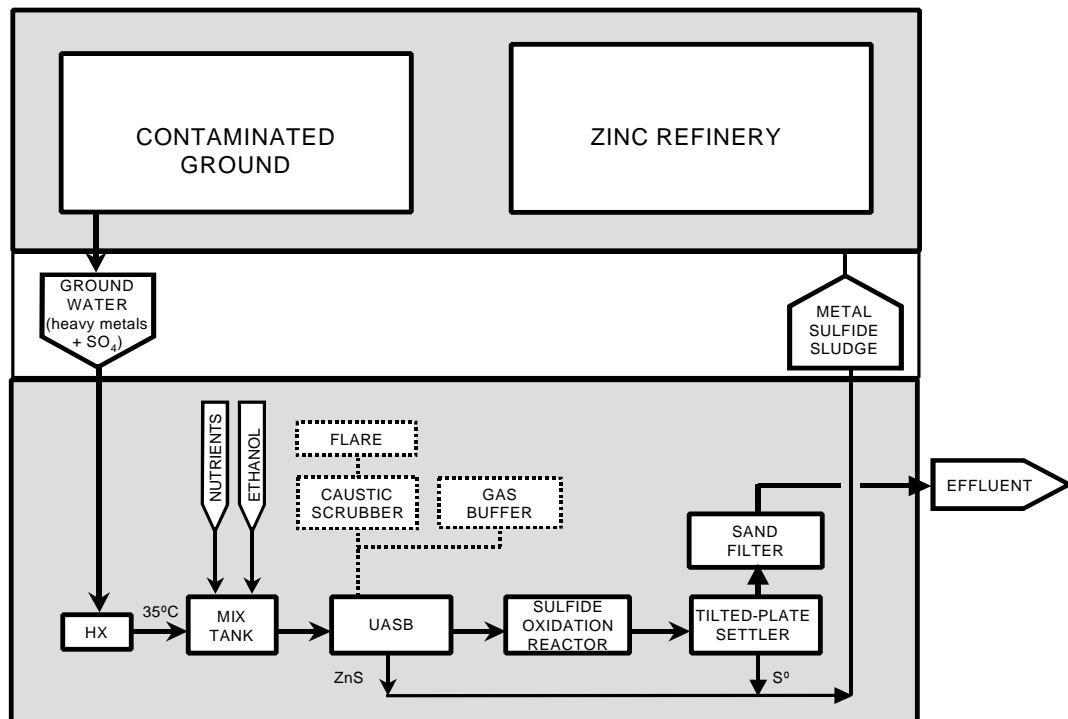
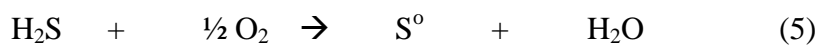
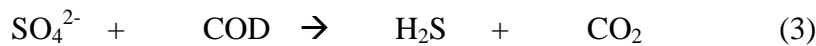


Figure 4: Process flow diagram of effluent treatment plant at zinc refinery

The elemental sulfur produced is subsequently settled in a tilted-plate separator. Continuous sand filters remove fine solids ensuring the effluent water quality complies with the set standard for surface body discharge. Both the anaerobic sludge of the anaerobic reactor (mainly consisting of ZnS) and the elemental sulphur sludge from the tilted-plate separator are fed back to the roasters of the zinc refinery. In 1999 a new effluent treatment plant was installed at the same zinc refinery, treating sulfate containing process water in which hydrogen (instead of ethanol) is used as essential electron donor for biological sulfate reduction. Instead of an anaerobic UASB for sulfate reduction a gaslift loop reactor type was used. The produced ZnS is recycled for the production of zinc and sulfuric acid (H₂SO₄).

Results

Table 4 presents the design and achieved discharge limits of the metal and sulfide effluent treatment plant. All main solid waste streams are recovered in the refinery.

Table 4: Design and operational data of metal and sulfate removal plant at a zinc refinery

Parameter	Unit	Influent	Effluent
Flow	m ³ /h	400	
Zinc	mg/l	50	< 0.15
Cadmium	mg/l	1	< 0.001
Sulfate	mg/l	1000	< 200

CONCLUSIONS

1. Rather than being regarded as an end-of-pipe solution, effluent treatment, comprising anaerobic treatment, is successfully applied as an integral part of various industrial production processes.
2. Anaerobic treatment produces valuable energy, enables the recovery of resources and minimizes the amount of waste products.
3. Anaerobic treatment has been successfully applied for effective removal of organic compounds (COD) as well as inorganic compounds (metals and sulfates).

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