

- Case Study: V-spring™ bioreactor system treating CS₂-emissions at a fungicide manufacturing plant

I. Introduction of the Site and the System

This fungicide production plant had to be in compliance with regulations of the authorities, which implies a reducing of the CS₂-emissions. Different waste gas abatements techniques were considered like active carbon, incineration and biofiltration. Biotrickling was proposed, because they eliminate many of the drawbacks of classical physical-chemical techniques especially on investment and operating costs.

II. Design Comments

The following design criteria were encountered: An airflow of 8500 m³/h containing carbon disulphide concentrations of 100 - 300 ppm. The acceptance criterium is based on 97% removal of carbon disulphide with an average outlet concentration of less than 10 ppm. The waste gas from this fungicide production plant contains very small amount dust particles of fungicide and also compounds other than CS₂. Therefore different lab-studies and bench-scale studies are performed first to find out whether biological treatment of this waste gas is possible. The restrictions and important process parameters had to be determined. The results shows that dust has to be removed from the airstream and that pretreatment of the waste gas is necessary to remove some of the traces of VOC-pollutants present in the waste gas. A range of compounds other than CS₂ is present at concentrations lower than 1 ppm among a couple of chlorinated compounds, which are though necessary to remove from the waste gas as much as possible.

A biotrickling bioreactor system (V-spring reactor) was designed and built. The system consisted of 2 bioreactors and an upfront scrubber and a control container. Micro-organisms capable of degrading CS₂ at extreme low pH are cultivated and used as inoculum for start-up of the bioreactor system. A CS₂-dosing system is installed to make it possible to cope with irregular productions. During production shutdowns CS₂ can be dosed in small amounts to keep the micro-organisms active and to shorten start-up times at restarts of production.

III. Operation of the System

Start-up:

The bioreactor system is started up using the CS₂-dosing system, which was actually installed to deal with the irregular production. Ambient air with CS₂ is lead through the bioreactor system resulting in growth of the micro-organisms. As soon as the bioreactors were fully-grown the ambient air is shut off and process waste gas from different process units is lead through the bioreactors.

Normal operation:

During normal operation caustic is dosed in the up-front scrubber to remove unwanted compounds. Water and nutrients are dosed discontinuously to the bioreactors and the continuous measurement of the pH and the acid content of the process water in the biotowers controls the system. The production schedule can be discontinuously, which give very discontinuous loadings of CS₂ to the bioreactor. To prevent reduced CS₂-removal efficiencies after resume of the production the CS₂-dosing system is used to keep active the micro-organisms during production stops.

IV. Performance

The removal of CS₂ was at first slow and problems were encountered to obtain a stable operating system. Additional site research is combined with lab-studies to improve the system stability. It was found that the stability problems were related to dust accumulation in the scrubber, waste gas sucking from an unwanted source and sub-optimal pre-treatment in the upfront scrubber. This all resulted in unwanted compound in the waste gas (most likely chlorinated compounds) that caused unstable performance.

After optimisation the system operates according specification (see Table 5). The total CS₂ emission was below 10 ppm at the design inlet CS₂-loadings. It is seen that 12 hours up-front resume of the production the CS₂-dosing system should be started in order to be able to eliminate removal efficiency due to discontinuous production. This will be further optimized to find out minimize CS₂-dosing during production interruptions. The biotrickling system showed to be robust for situations like the power black-out of 8 hours (...) and fresh water interruptions of at least 2 days.

Table 5a: CS₂-removal in the biotrickling reactors measured at different days by Gas Chromatography.

measurement	Inlet CS ₂ conc. (ppm _v)	Outlet CS ₂ conc. (ppm _v)	removal (%)
1	273,0	2,6	99,1
2	315,4	2,0	99,4
3	403,7	9,4	97,7
4	456,7	7,2	98,4
5	456,2	13,3	97,1

V. Table

Table 5b: Case study of biotrickling reactors treating waste gas at a fungicide production plant.

Reactor Type	V-spring™ Bioreactor system	
Owner and location	Fungicide manufacturer	
Manufacturer	BIOWAY bv (Ede, The Netherlands)	
Year of installation	2002	
Type of air stream	waste gas from the process reactors, drying screens and vacuum pumps	
Reactor type	2 V-spring™ bioreactors with upfront scrubber and control container	
Medium type	Permapac™ type V	
Air flow rate	8500 m ³ /h	
Pressure drop	< 100 Pa (< 0,4 inch WK)	
Average bed temperature	20-25 °C	
Contaminants treated	Carbon disulphide (200 ppm) and traces of other VOC (< 5 ppm)	
System controls	Automatic water and nutrient feed by PLC. Alarm generation for different unwanted situations: temperature, water pressure, water flow, air pressure, salt content, liquid levels in recirculation tank and scrubber.	
Design and acceptance criterion	97% removal of carbon disulphide with an average outlet concentration of less than 10 ppm	
Capital Costs	\$1.190.000,- including up-front scrubber/deduster, process control container, installation on site and start-up.	
Approximate operating costs per year	Depreciation (over 20 years)	: \$59500,-
	Interest rate (5%)	: \$35989,-
	Energy (fan: 8500 m ³ /h at 0,5 inch WK and control panel: 2,5 kW at \$0,04/kWh)	: \$ 1398,-

	Water (10 m3/day a \$ 2/m3) : \$ 7300,-
	Nutrients : \$ 5423,-
	Chemicals (NaOH) : \$12500,-
	Operating costs (2 hour per week a \$50,-/hour) : \$ 5200,-
	Media change replacement : \$ 0,-
	Maintenance (1,5% per year of the investments cost) \$17850,- +
	TOTAL: \$145160,-
Treatment costs per 1000 m3 off-gas treated	→ \$ 1,95/1000 m3 off-gas treated
Typical performance	➤ > 97 % carbon disulfide-removal



Figure 4: Bioreactors treating CS₂ from waste gas at a fungicide production plant.