High throughput biofiltration for odour control at water purification plant

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ABSTRACT

A high throughput trickling biofilter for odour control was designed basing on the principles of biotrickling filter technology developed in Moscow Bakh Institute of Biochemistry. All the necessary blocks except a fan: temperature and humidity control unit, a biofilter bed, an irrigation system, a control block and display unit are combined within one compact biofiltration module – a standard container 6000x2400x2400 mm. The plant is thermo-insulated that enables outdoor installation. The biofilter is easily scaled up by adding extra filtration beds. A typical biofiltration module rated for 5,000-10,000 m^3/h has a contact time of 3-6 s (biofilter bed total volume – 10.5 m^3) and a maximum footprint of 14.5 m^2. After extensive pilot plant studies the first 5000 m^3/h trickling biofilter easily scalable to 20000 m^3/h was installed at Moscow Water Works in spring 2007 to control odour emissions - hydrogen sulfide, mercaptanes and other malodorous volatile organic compounds in up to 60 mg/m^3 concentration. The performance results of the industrial biofilter are discussed.

1 INTRODUCTION

Biofiltration – is an established technique to control odours (Devinny *et al.*, 1999). Various types of biofilters have been suggested and successfully applied varying from the most simple open air units with soil/compost beds (www.bohnbiofilter.com) to sophisticated fully automated enclosed plants using proprietary artificial media and enabling full process control (Popov and Zhukov, 2005). The area of odour control is rather competitive and only most economic solutions have a chance of surviving on the market. Moreover deodouration is regarded less technically challenging than VOC control enabling simple biofiltration plants to perform quite satisfactory and comply with existing legislation and end-user expectations.

Trickling bed biofilters offer a number of advantages over conventional biological methods to treat off-gases. In some cases the contact time between the VOC laden air and the biocatalyst in trickling bed biofilters may be reduced to below 10 s range (Gabriel and Deshusses, 2003) thus minimizing the overall system footprint, dimensions and power requirements. For a number of years we are perfecting the design of the trickling biofilters (Zhukov *et al*., 1998; Popov and Bezborodov, 1999) and explore their potential in various applications: e.g. water soluble VOCs used in flexographic printing (Popov *et al*., 2004) , chlorinated compounds (Popov *et al*., 2005), formaldehyde (Popov *et al*., 2000), BTEX (Bezborodov *et al*., 1998), etc. Here we report an All-in-One high-throughput biotrickling filter for odour control applications and present its preliminary performance characteristics at Moscow Water Works.

2 MATERIALS AND METHODS

2.1 Microorganisms

As a base of the microbiological consortium used to populate the carrier in the biofilter the thionic bacterium *Thiobacillus novellas* has been used which efficiently degraded hydrogen sulfide. It was complimented by other strains from the in-house collection capable to utilise mercaptanes and volatile compounds present in the emissions of the water purification plants. All the strains used have been tested in a specialised certified laboratory properly authorised to perform such studies and were proved to be non-pathogenic, non-virulent and non-toxic for mammals.

2.2 Carrier

An inert polymer carrier with open-pore foam-like structure was used to immobilize the microbial consortium.

2.3 Analytical methods and monitoring

Biofilter performance was monitored organoleptically and instrumentally. The personnel present on site evaluated the intensity of the smell at the outlet of the biofilter. The inlet and outlet concentrations of H_2S (main source of the obnoxious odour) were routinely measured on-site electrochemically by a portable electrochemical analyzer Colion-1. The electrochemical cell analyzer was from time to time calibrated against a standard laboratory calorimetric procedure for quantifying SH-compounds. Prior to standard laboratory assay the SH-containing compounds were trapped by passing the predetermined volume of the air through the cartridges filled with glass spheres covered with solution of lead or mercury acetate.

The assay of the gas mixtures was performed via GC/MS with Shimadzu GC-2010 instrument equipped with GCMS-QP2010 Thermal Desorber (Markes International Ltd., UK) and capillary columns. The sample for GC/MS was obtained by adsorbing the volatiles by aspirating the controlled volume of air through a Tenax© column.

3 RESULTS AND DISCUSSION

3.1 Construction of the Biofilter

To make biofilter more user-friendly and versatile a novel layout of the plant was used. An All-in-One principle was followed. All the main functional units of the plant: inlet air distribution and conditioning system; biofilter bed; irrigation and pH-control system; air transport system and droplet remover; control unit; etc. are enclosed within a standard 20-feet container (6000x2400x24000 mm) (Figure 1).

The plant is properly thermo-insulated that enables outdoor installation. This is most important for the regions with a severe climate to which Russia evidently belongs to. When not in operation the plant can run in a stand-by mode maintaining its internal temperature regimes and thus precluding freezing or overheating.

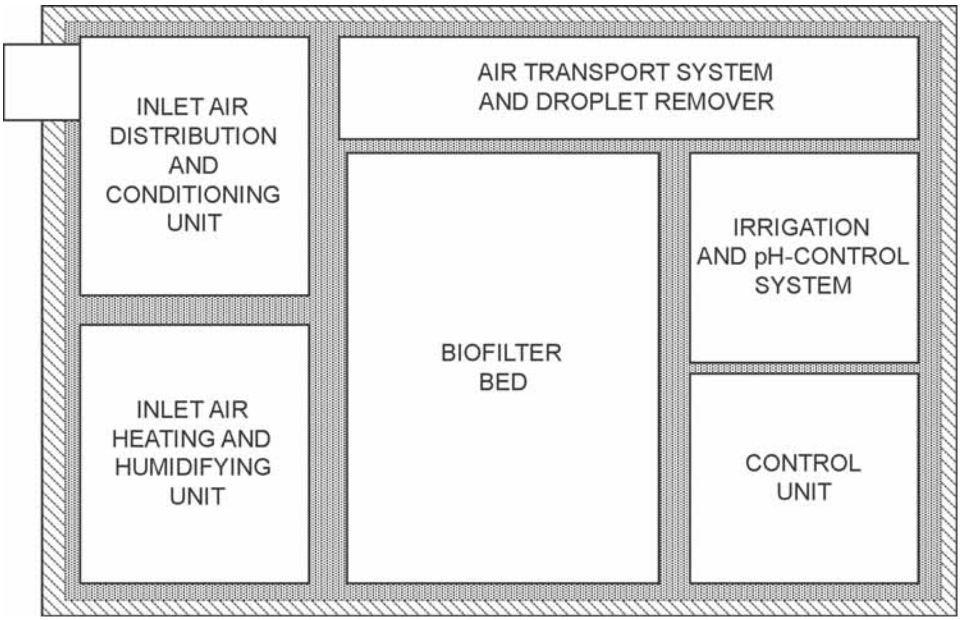

Figure 1. Schematic outline of the All-in-One biotrickling filter.

The plant is very simple to start and operate. It requires just proper tap water and power supply and connection to the on-site existing drainage/sewage system. The air ducts are easily fitted to the inlet flange of the system. The system can be regarded of the type «install-and-run».

The main parameters of the plant are shown in Table 1, while its general view and location on site appear in Figure 2.

Table 1.
Parameters of the biofiltration plant.

Parameter and unit	Value
Nominal air flow, m^3/h	4,000 – 11,000
EBRT, s	3-10
Optimal inlet concentrations of volatiles, mg/m^3	< 250
Pressure drop, Pa	350 – 1,250
Installed power, kWt	< 18,5
Irrigation flow, m^3/h	< 12,5
Maximal air linear velocity, m/s	< 0,70
Consumption of tap water (including evaporation), l/h	< 110
Power consumption for outdoor installation (summer / winter), kWt*h	< 3.5 / 15.5
Temperature of the incoming air, °C	0 – 50
Allowed ambient temperature, °C	(-20) – (+40)
Dimensions (HxLxW), mm	2,475x6,300x2,400
Operating foot-print, m^2	14,5
Dry weight, kg	< 3,700
Wet weight (operating), kg	< 10,500

The compact arrangement of all the components of the biofilter within one unit provides a number of technological advantages: easy transportation, erection and mounting; easy interfacing with the infrastructure existing on site (power, water, sewage, etc.); easy maintenance and service. The plant can be easily scaled up by adding either additional filtration beds or by adding extra complete units.

3.2 Operation of the biofilter

Main operation facilities of the sewage department of the Moscow Water Works are located rather close to the housing area. It is not feasible to relocate them, thus management of Moscow Water is looking for efficient and cost-effective technology that will enable to secure that neighbouring households do not complain about the irritating odours. An extensive programme of testing and pilot runs was launched that enabled Moscow Water to select a trickling biofilter technology as the best available technology to control odours. The final phase of tests with a full-scale biofiltration plant, Figure 2, is currently in progress.

Figure 2. Biofilter at the premises of Moscow Water Works.

The biofilter was mounted close to the workshop for the residue sedimenting and dewatering that produces concentrated malodourous emissions. More than 70 components that varied in concentration quite considerably over time were identified in the emission by GC/MS technique. The dominant one was methane (1500-1600 mg/m^3), while hydrogen sulfide – the major irritating pollutant was present in 12-16 mg/ m^3 concentration with peaks up to 60-90 mg/ m^3.

The profile of the inlet and outlet H_2S concentrations measured on-line with electrochemical sensor is presented in Figure 3. The results of the start-up and several months monitoring confirmed reliability of the technology. After about one month acclimation period the plant reached its target performance efficiency and is able to remove >98-99 % of the hydrogen sulfide coping with the spike emissions of about 30-80 mg/m^3.

The instrumental GC – GC/MS assays showed that such pollutants as mercaptanes, amines, limonene, aromatic compounds were degraded with the efficiency of >99 % and could not be determined at the biofilter outlet (Table 3). Thioglycolic acid – one of the major pollutants with an average concentration of 5.5-6.0 mg/ m^3 and peaks up to 10 mg/ m^3 was usually degraded with efficiency of 80-99 %. Considerable depletion of the methane content - 40-70 % was also noted.

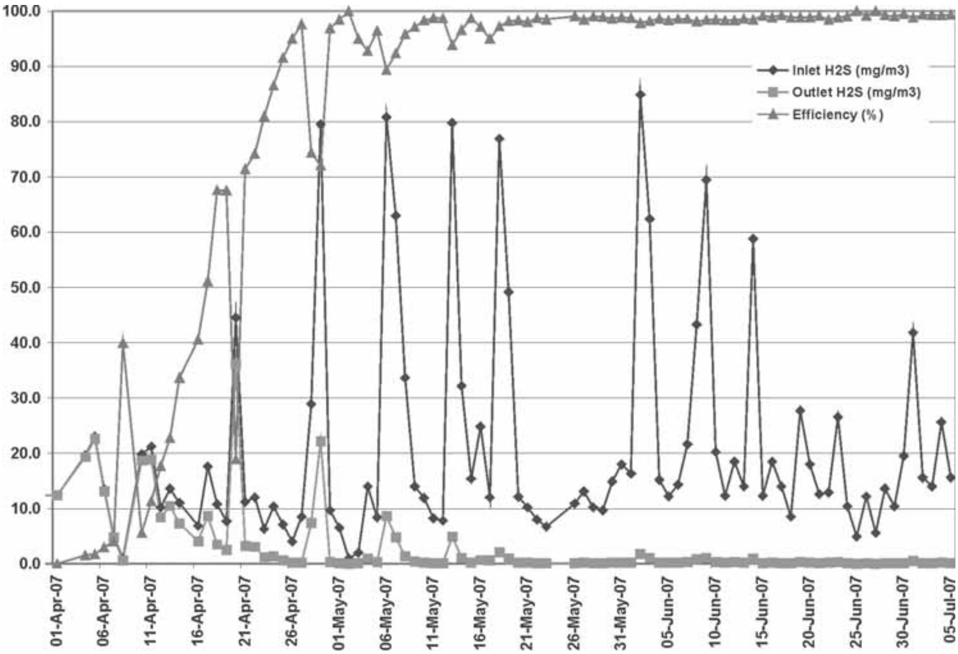

Figure 3. Start-up and performance of the trickling biofilter for odour control operating at Moscow Water Works. EBRT = 6 s.

The long-term (up to one year period) monitoring of the biotrickling filter plant is required to draw sound conclusions on the efficiency and the running costs. However already preliminary results show that the new All-in-One biotrickling filter could provide a viable solution to odour control at municipal water treatment plants.

Table 2.
Efficiency of VOC degradation in the biofilter.

Compound	Retention time, min	Peak area, Inlet	arb.un. Outlet	Conversion, %
1. Methane	00:55	11226.2	2557.85	77
2. Isobutyl amine	01:09	72.32	–	>99
3. Ethyl sulfide	01:43	5.89	–	>99
4. Thioacetic acid	01:57	211.80	47.54	78
5. Thioglycolic acid	02:19	86.32	–	>99
6. Dioxane	02:37	22.84	–	>99
7. Toluene	02:47	32.53	–	>99
8. Ethylene diamine	02:53	27.11	–	>99
9. Methyl mercaptane	02:59	21.65	–	>99
10. Butyric acid	03:54	6.67	–	>99
11. Dibutyl amine	05:27	8.50	–	>99
12. Ethanol amine	05:38	11.24	–	>99
13. Limonene	08:26	13.19	–	>99
14. Dibutyl sulfide	08:50	3.61	–	>99

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