3rd IWA Specialized International Conference
Ecotechnologies for Wastewater Treatment 2016 (ecoSTP16)
Cambridge, UK, 27-30 Jun 2016

The effects of biodiscs rotation in a new Rotating Bed Biofilm Reactor for the removal of Hydrogen Sulphide

Francesco Spennati*, Simone Rossi*, Cesira Giordano**, Claudia Vannini**,
Daniele Bacchi***,Gualtiero Mori****, Giulio Munz*.

*University of Florence, Department of Civil and Environmental Engineering, Florence, Italy; francesco.spennati@unifi.it;
** University of Pisa, Lungarno A. Pacinotti 43, 56126, Pisa, Italy;
*** ITALPROGETTI spa - Montopoli in Val d'Arno, Pisa, Italy;
****CER2CO - Consorzio Cuoiodepur Spa , San Romano - San Miniato, Pisa, Italy

INTRODUCTION

The prototype was implemented as pretreatment before chemical scrubbers in the actual gas treatment train of a tannery wastewater treatment plant (Cuoiodepur, Pisa - Italy). The RBBR treated an average of 8000 m^3 h^{-1} of gaseous effluent (20% of the total gaseous flow rate treated in the plant) with variable hydrogen sulphide concentrations (10-400 mg S m^{-3}) in the influent. The prototype was able to remove up to 20 Kg d^{-1} of H_2S, and about 80% of the total load, allowing to save a corresponding dosing of chemicals (NaOH) of about 600 Kg d^{-1}. A characterization of the biomass in the biodiscs was performed through bio-molecular analysis. Among the different operating conditions tested, the biodiscs rotation frequency was demonstrated to be a fundamental parameter for biofilm thickness, pH in the solution and solids retention time control and, thus, to optimise hydrogen sulphide removal as well as mitigation of pressure head loss increase.

MATERIALS AND METHODS

The prototype

The prototype had a cylindrical shape and the reaction volume was divided into four sectors, each one consisting of two rotating biodiscs with a diameter of 2.38 m and a disc thickness of 32 cm; in the last sector there was only one biodisc with a disc thickness of 64 cm. Within each sector a septum, with an height of 50 cm, was installed in order to hydraulically separate each zone from the other and to maintain a 40 cm water depth, so that the discs were partially submerged in water. The biodiscs were filled with polyurethane foam (PUF) with a specific surface of 600 m^2 m^{-3}, a density of 35 kg m^{-3} and a porosity equal to 390 pores m^{-1}, the gas flow crossed each zone (in series treatment), while the liquid flow is independent for every sector, allowing to maintain different process and washing conditions in each sector (figure 1,2,3 and 4).

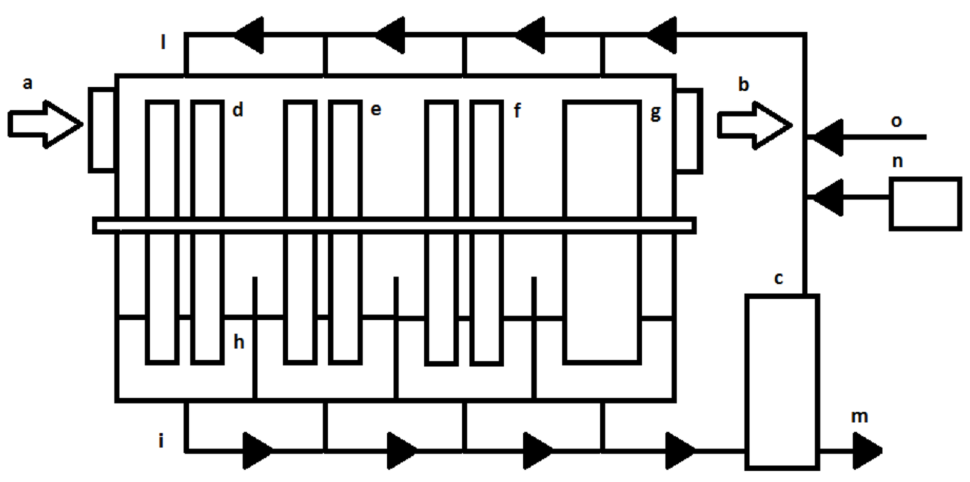

Figure 1. The prototype scheme: a) inlet gas stream, b) outlet gas steam, c) recirculation water tank, d) first sector biodiscs, e) second sector biodiscs, f) third sector biodiscs, g) fourth sector biodiscs, h) water level, i&l) recirculation water flow, m) discharge water, n) nutrients, o) make up water

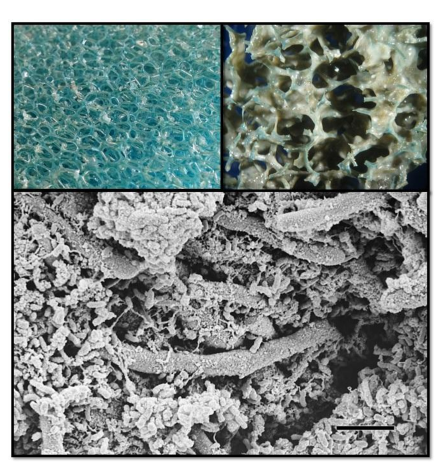

Figure 2. In high part of the picture there was a clean PUF in the left, a colonized PUF in the right; a SEM picture in the bottom (5 μm).

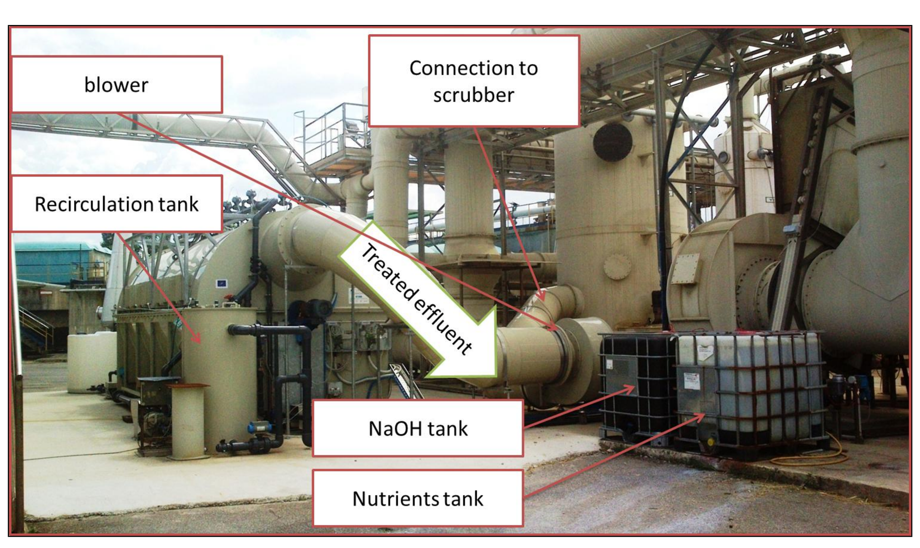

Figure 3. The prototype frontal view.

Figure 4. The prototype installation in the Air treatment plant.

Experimental setup and operating conditions

The start up phase lasted 30 days and the inoculum was made by primary and biological sludge of Cuoiodepur WWTP. The prototype was implemented and fed with 20% of the polluted stream. The reactor was operated with an empty bed retention time of 3-6 s. The influent concentrations of H_2S were within the range of 10-400 mg S m^{-3}. After the start up phase, the removal efficiency was 80% and the EC reached peaks of 90 g H_2S m^{-3} h^{-1}.

Temperature: The prototype was used in two different seasons.
Recirculation flow rate: The flow rate was varied (3-10 m^3 h^{-1}).
pH setpoint: The pH setpoint was gradually varied from 3 to 6.5.
Empty bed contact time: 3-6 seconds
Biodiscs rotation: Gap time tested: 1, 5, 15, 60, 90, 180, 240, 720 and 1440 minutes.
The rotation time tested: 1, 5 and 15 minutes.
The velocity range: 0.1 - 3 rpm.

Process and biomass monitoring

The monitoring of the prototype included the analysis of biological, chemical and physical parameters. Probes were installed to measure: pH, suspended solids (with a Turbidity Analyzer Hach Solitax, specifically calibrated), dissolved solids and the volumetric gas flow rate. A Gas Chromatograph (Agilent 7890B) equipped with Flame Photometric Detector was installed to measure the influent and effluent H_2S concentrations. In the recirculation liquid the following parameters were measured (water samples were taken three times for a week): Chemical Oxygen Demand (COD), soluble Chemical Oxygen Demand (sCOD), Total Organic Carbon (TOC), total sulphur, ammonium and phosphate. The Total Suspend solids (TSS) were determined by drying at 105 ° C (24 h) and the Volatile Suspended Solids (VSS) were measured by ignition at 570 ° C (0.5 h). Biofilm supports and recirculation water were regularly sampled for the characterization of biomass. The prototype microbial community was then studied through isolation attempts and molecular techniques. An investigation based on the gene coding for 16S rRNA was performed. Sequence polymorphisms were investigated through Terminal-Restriction Fragment Length Polymorphism (T-RFLP). Next Generation Sequencing (NGS) was also performed, in order to explore the entire microbial community, while for a direct estimation of bacterial presence in the samples, Fluorescence In Situ Hybridization (FISH) was carried out. A media containing thiosulfate and minerals was used for isolation attempts of Sulfur-Oxidizing Bacteria (SOB) .

Acknowledgement: The authors thank the EU LIFE+ Program (Biosur project ENV/IT/075),
Miur (FIR RBFR13V3CH) and the EU Marie Curie Irses Program (Carbala Project PIRSES-GA-2011-295176).

BIOSUR ROTATING BIOREACTORS FOR SUSTAINABLE HYDROGEN SULPHIDE REMOVAL
European Commission Programme LIFE+ Environmental Policy and Governance | Contract LIFE 11 ENV/IT/075

BIOSUR is a project co-financed by the European Commission under the LIFE+ Programme and involves the application of an innovative technology for the treatment and control of odorous emissions.

Biological systems represent, as static biotrickling filter (BTF), are a possible alternative to the conventional chemical scrubber to reduce the operation cost and potentially eliminate the need for chemicals. The main critical point is the high head loss when operating at high load, become clogged.

In the context of the UE LIFE+ Project BIOSUR (Rotating Bioreactors for sustainable hydrogen sulphide Removal), a full scale prototype of a Rotating Bed Biofilm Reactor was designed and constructed with the aim of using the biodiscs rotation as innovative strategy for the removal the excess biomass, thanks to the shear stress between biodiscs and water in the bottom part of the MBBTF. The prototype was the first full scale moving bed BTF applied to gaseous effluent treatment operated worldwide.

RESULTS AND DISCUSSION

The EC was maximum at pH 3 and was almost halved at pH 6.5. At higher pH, increased oscillations in the pH values were recorded and biodiscs rotations caused a temporary sharp decrease of pH till 2, due to the sponge effect of polyurethane foam (figure 5, 6 and 7). The EC also decreased with rotation times greater than 30 minutes, due to biomass washout. The sampled recirculation water during the gap times had very low turbidity and suspended solids, while during the rotations, both the turbidity and the related suspended solids increased, as it can be noticed from Figure 1.2. Members of the genus *Acidithiobacillus* were by far the prevalent bacterial component and probably the major responsible for H_2S removal in the described system and the most resistant to pH oscillations. The preliminary biological results essentially concurred with the experimental results: the relative abundance of *Acidithiobacillus* decreased from 90.5% to 45.9% when pH increased from 3 to 6 and from 89.9% to 51.6% when gap time between a rotation and the following one decreased from 90 to 5 minutes (with rotation time of 5 minutes for both cases). The accumulation and the removal of the biomass was easily regulated by low-speed rotation, so the overall pressure drop was very low (always less than 4 mbar).

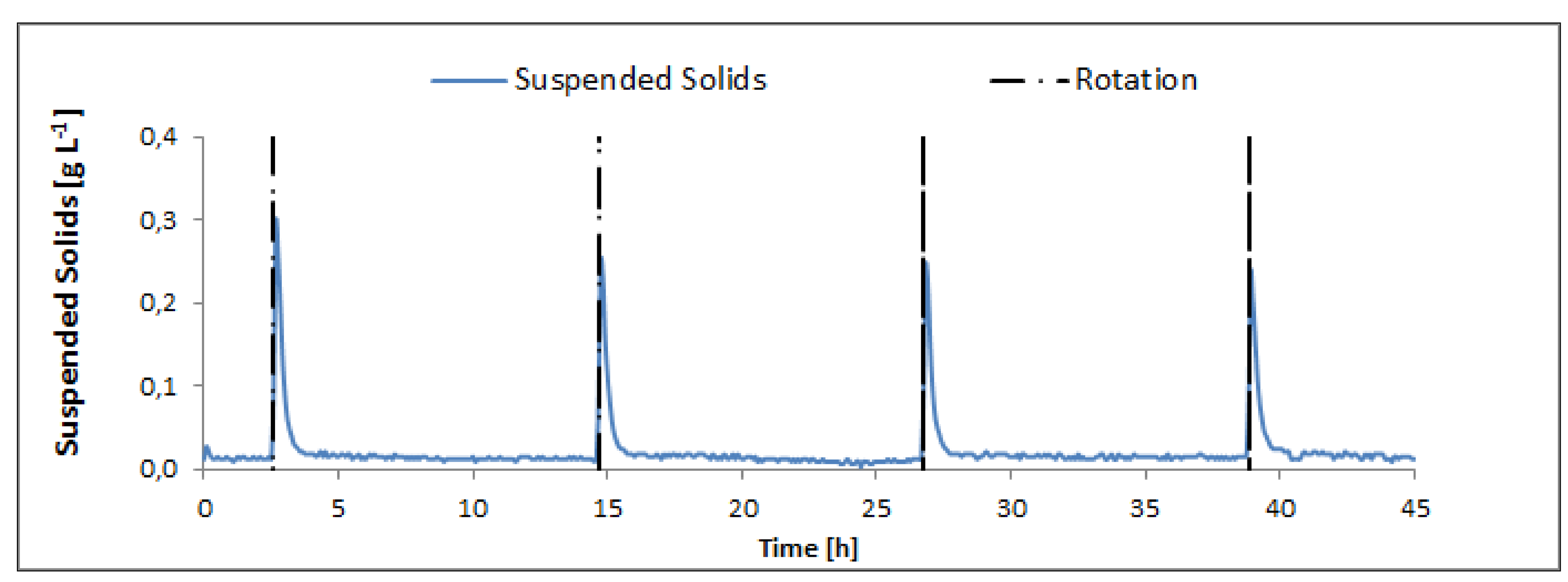

Figure 5. Effects of biodiscs rotations on the Suspended Solids.

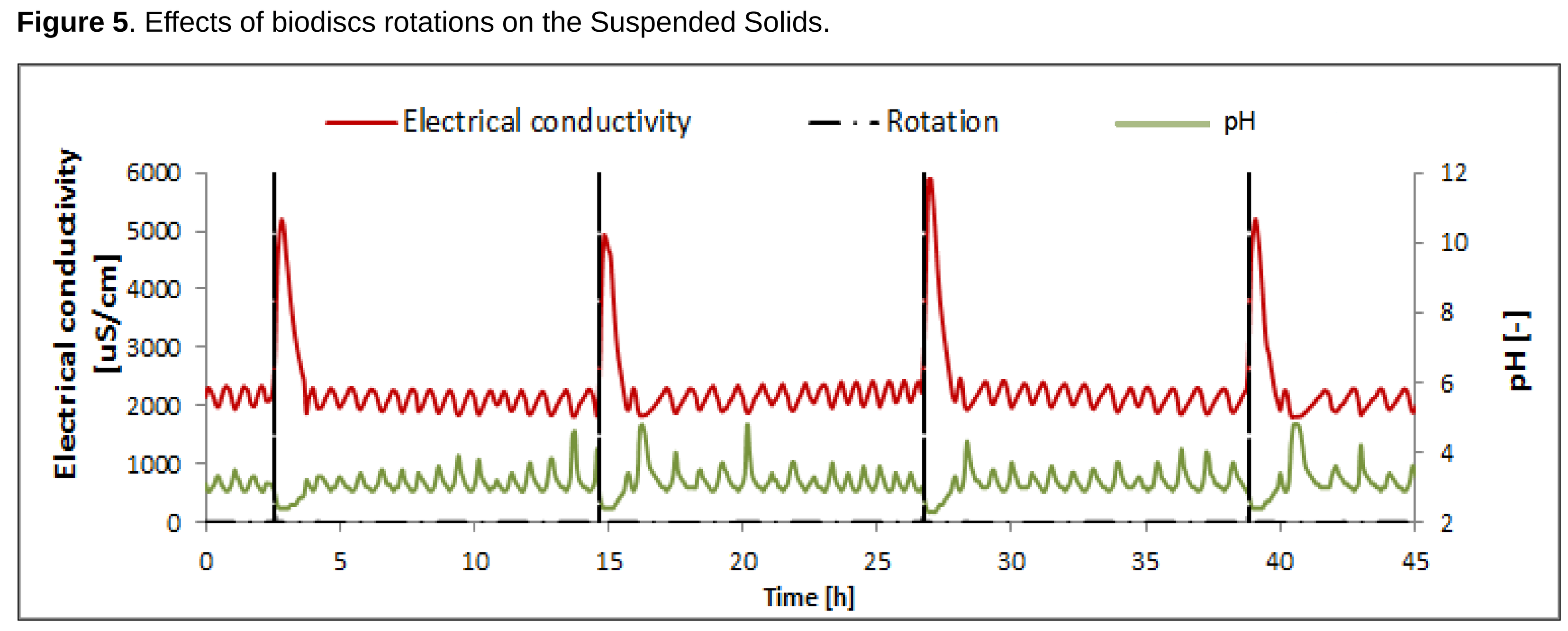

Figure 6. Effects of biodiscs rotations on pH and electrical conductivity.

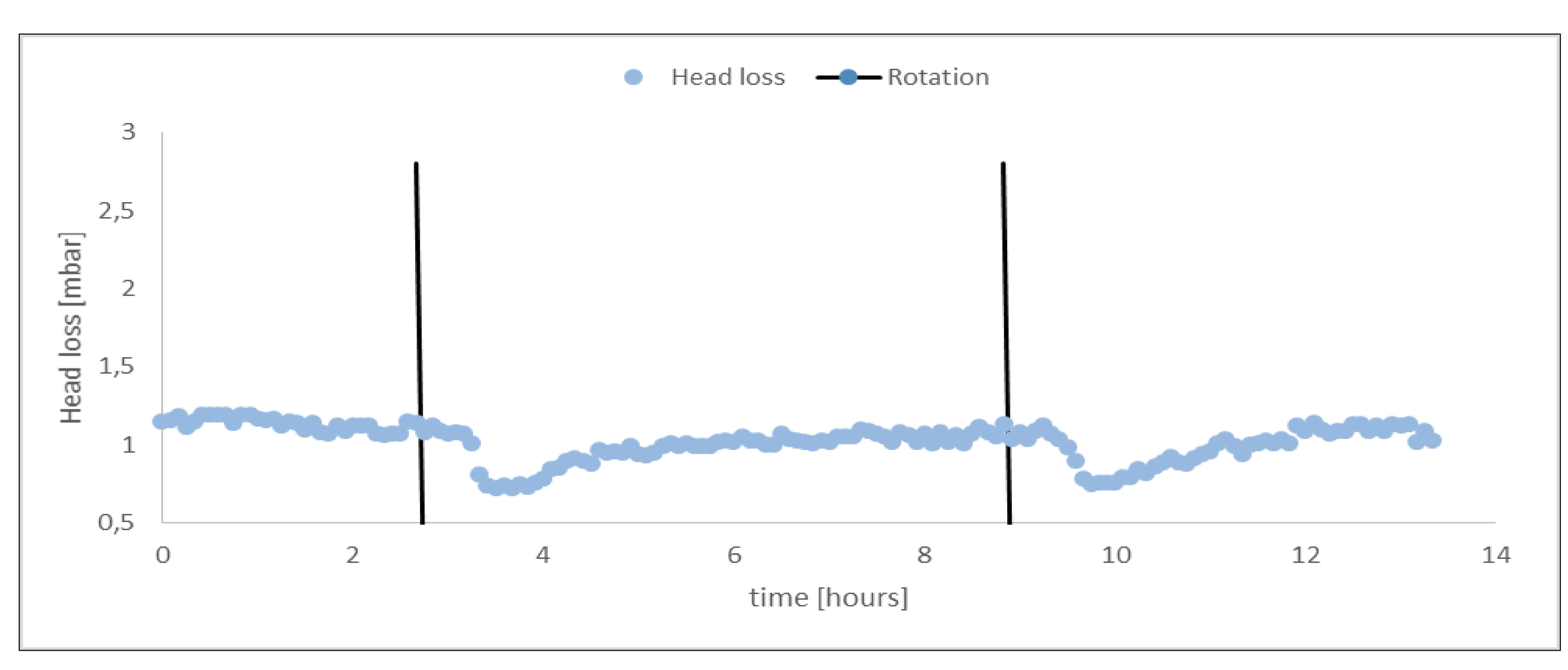

Figure 7. Effects of biodiscs rotations on head loss

www.biosurproject.eu/