AERATION EFFICIENCY FOR A LEACHATE TREATMENT PLANT

Ioana Corina MOGA[1], Gabriel PETRESCU[2], Bogdan NASARIMBA[3], Diana ROBESCU[4]

In the present paper are presented the results obtained during theoretical and experimental researches related to a MBBR reactor. The tank is used for leachate treatment. The aeration energy costs are significant and the correct selection of the diffusers type is essential. Four types of diffusers/aeration systems were tested in different conditions.

1. Introduction

The Moving Bed Biofilm Reactor (MBBR) technology is a leading-edge biological solution for wastewater treatment based on the aerobic biofilm principle with all of the advantages of activated sludge systems and none of the problems [1]. Moving bed systems comprise all biofilm processes with continuously moving media, maintained by high air or water velocity or mechanical stirring. Biofilm carrier material (media or biomedia) is selected based on size, porosity, density and resistance to erosion. By using a material with a large specific surface area (m^2/m^3) high biological activity can be maintained using a relatively small reactor volume. Small parts made of special materials with density close to the density of the water, are immersed in the bioreactors. The biofilm carriers are kept in suspension and even mixed with the help of air bubbles generated by the aeration system. Worldwide there are several models of biofilm carriers [2]. This type of biofilm support is most effective because it is not clogged and unlike rotary contactors does not require additional energy consumption.

The basis of the MBBR process is the biofilm carrier element that is made from polyethylene. The elements provide a large protected surface area for the biofilm and optimal conditions for the bacteria culture to grow and thrive. The biofilm that is created on each carrier element protects the bacterial cultures from operating excursions to yield a very robust system for those industrial facilities

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[1] PhD, Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania
[2] Eng., SC DFR Systems SRL, Bucharest, Romania
[3] PhD, SC DFR Systems SRL, Bucharest, Romania
[4] Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania

loaded with process fluctuations [3]. The biofilm also provides a more stable "home" for the bacteria to grow, so there is less space required, compared to other biological systems and far less controls. Essentially nutrient levels and DO levels are the only control points for the system. MBBRs can be designed for new facilities to remove biochemical oxygen demand / chemical oxygen demand (BOD/COD) from wastewater streams or for nitrogen removal. Existing activated sludge plants can be upgraded to achieve nitrogen and phosphorus removal or higher BOD/COD capacity (increase of up to 500% has been obtained) [1].

The main purpose of the researches (presented in this article) was to develop a new compact leachate treatment plant. That is why several theoretical studies and experimental researches have been realized. An important stage was the aerated bioreactor designing. Water oxygenation is a mass transfer process of oxygen from gas/air to the liquid mass [4]. It can be used in water treatment in order to remove the organic matter. The oxygen in the air, the ozonized air or directly the pure oxygen can be used in the process [5]. In this case, air is introduced in a bioreactor with the help of a blower.

Diffused air aeration tanks have been used successfully on the majority of WWTPs. In addition, since the aeration system typically represents more than 50% of the total plant energy [6], plant designers and operators can realize substantial savings in overall plant energy costs through the efficiency of the aeration system. In order to improve the oxygen mass transfer mathematical modeling and numerical simulations for the aerated bioreactor have been made. Further more, several laboratory measurements have also been realized.

2. Research stages and methods used

First of all, the aeration system type had to be established. Around the world several aeration methods exists, from which the main procedures are: surface aeration, brush aeration, horizontal rotation, vertical rotation, air diffusing, coarse bubbles, and micro diffusers [3].

Oxygen transfer, the process by which oxygen is transferred from the gaseous to the liquid phase, is a vital part of a number of wastewater treatment processes. The functioning of aerobic processes depends on the availability of sufficient quantities of oxygen. Because of the low solubility of oxygen and the consequent low rate of oxygen transfer, insufficient oxygen to meet the requirements of aerobic waste treatment enters the water through normal surface air-water interface. To transfer the large needed quantities of oxygen, additional interfaces must be formed. Oxygen can be supplied by means of air or pure oxygen bubbles introduced in the water to create additional gas-water interfaces. In wastewater treatment plants, submerged bubbles aeration is most frequently accomplished by dispersing air bubbles into the liquid. The diffused or bubble

aeration process consists of contacting gas bubbles with water for the purpose of transferring gas to the water. The most commonly used diffuser system consists of a matrix of perforated tubes (or membranes) or porous plates arranged near the bottom of the tank to provide maximum gas to water contact [3].

For good performance the rate of supply of dissolved oxygen should be equal to the rate of oxygen consumption exerted by the mixed liquor under any given set of circumstances.

In diffused air systems bubbles are distributed from diffusers at the base of the reactor. Oxygen transfer takes place from the rising bubbles to the mixed liquor to supply the oxygen requirements for the biological process.

For a given volume of water being aerated, aeration devices are evaluated on the basis of the quantity of oxygen transferred per unit of air introduced to the water for equivalent conditions.

A number of equipment and operational parameters interact to influence the efficiency and rate of transfer of oxygen such as: tank dimensions (length, depth and width), aeration size, type, location, and airflow rate [1].

These parameters determine factors such as bubble size and the degree of turbulence. Conditions in the mixed liquor also have an impact on the transfer; for example, temperature, ionic strength, presence of surface-active compounds, and solids concentration. The rate of oxygen transfer (under the conditions prevailing in an aeration basin) is governed by the liquid phase mass transfer coefficient, k_L. Determination of k_L poses experimental problems in that knowledge of the interfacial area for mass transfer, A_t, per unit volume, V, is required. For this reason the rate of transfer for a particular system is usually reflected by the overall mass transfer coefficient, K_{La}; without attempting to separate the factors K_L and A_t/V:

$$K_L a = K_L \frac{A_t}{V} \tag{1}$$

where K_{La} is apparent volumetric oxygen mass transfer coefficient in clean water, h^{-1},

V - water volume in the tank, m^3,

A - interfacial area of mass transfer, m^2.

There are several methods of experimental determination of mass transfer coefficients. The so-called clean water non-steady state method was selected in this study. The unsteady state test or re-aeration of deoxygenated clean water (reoxygenation) is presently the most broadly accepted test procedure [6]. The accepted procedure for determining and evaluation the overall oxygen transfer coefficient (K_{La}) is considered as follows. The test method involves the removal of dissolved oxygen (DO) from a known volume of water by the addition of sodium sulfite followed by reoxygenation to near the saturation level. The DO of the water volume is monitored during the re-aeration period by measuring DO

concentration at several different points. The basic equation describing the rate at which oxygen is absorbed by water is [1]:

$$\frac{dc}{dt} = K_L a (C_{st} - C_t) \tag{2}$$

where dc/dt is transfer rate of oxygen to the water, mg/l,

C - concentration of oxygen in the water at time, t, mg/l,

C_{st} - saturation, or equilibrium, concentration of oxygen in water with respect to air in bubble at mean depth, mg/l,

t - time.

The difference (C_s, - C) between saturation value and actual concentration of oxygen (C) in the body of the liquid phase is usually called oxygen deficit. The oxygen transfer rate is determined by integrating of this equation. From (2), the initial oxygen uptake rate at $C_t = 0$, is:

$$\frac{dc}{dt} = OC = K_L a (C_{st}) \tag{3}$$

where OC is the oxygen transfer capacity of the system, (kg O_2/h).

The fraction of oxygen transferred to the water due to the pass of one-meter cubic of air is expressed as oxygenation efficiency (E) of the diffuser system, which can be written as [3]:

$$E = \frac{OC \cdot H}{I} \tag{4}$$

where H is the liquid depth in the tank, m,

l - the aeration intensity, or volumetric air flux per unit area of tank surface.

If the oxygen concentrations are measured in mg/l, and the time interval to determine K_{La} is expressed in hours, dc/dt in (3) gives the oxygen uptake rate in mg/l at 0 mg/l dissolved oxygen (DO) concentration in the test water. By multiplying this value by the quantity of aerated water, the mass oxygen uptake rate is obtained, and oxygen absorption, (δ), is determined by:

$$\delta = \text{(rate of oxygen uptake by test water/ rate of oxygen input by aerator)} \times 100 \tag{5}$$

The fraction of oxygen transferred from air into water (δ) at the moment when the dissolved oxygen equals to C_t can be found from the following relationship:

$$\delta = \frac{K_{La}(C_{st})V}{I \cdot j \cdot A_T} = \frac{K_{La}(C_{st})H}{I \cdot j} \tag{6}$$

where j is a constant = 298; (the amount of oxygen in g/m^3 of air at $T = 20°C$),

V - the aeration tank liquid volume, m^3,

A_T - the aeration tank surface area, m^2.

The saturation values for oxygen in water at equilibrium at normal atmosphere conditions are available in standard tables [1], [3]. These values must be corrected for actual test pressure conditions, which vary from atmospheric at the water surface to atmospheric plus the depth of water.

3. Results

Numerical simulations (fig. 1) were correlated with the experimental researches. The oxygen profile concentration was determined (fig. 1). During the numerical simulations it was established the fact that the biofilm carriers improve the oxygen mass transfer [7] because the time contact between air bubbles and water mass is increased.
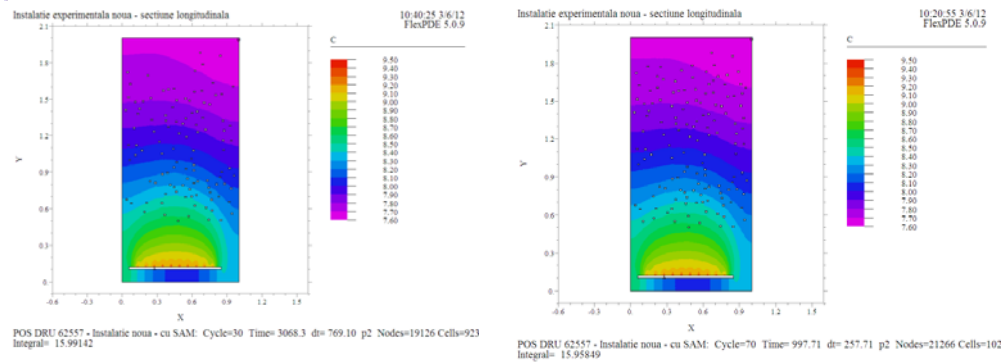

Fig. 1. The oxygen profile concentration for a MBBR tank

The same conclusion was obtained during the experimental researches. A laboratory basin (fig. 2) was used for the determination of the oxygenation curves for different situations. The bioreactor was filled with biofilm carriers in different proportions and the tap water was deoxygenated.

Fig. 2. Experimental MBBR installation

Fig. 3. Biofilm carriers inside the MBBR and a surface aerator/mixer

Two sensors were mounted inside the bioreactor to determine the values for the dissolved oxygen. Four aeration systems (types of diffusers) were tested with and without biofilm carriers inside the tank. The tested aeration systems were: stainless steel pipes with 1 mm orifices, stainless steel pipes with 2 mm orifices, elastomer diffusers and a mixt aeration system (a bottom aeration system combined with a surface mixer/aerator).

Only two oxygenation curves are presented in Figure 4 and Figure 5 (for 30% and 50% biofilm carriers filling and for a constant air flow rate – 75 Nm^3/h. In these cases was tested the classical aeration system realized from stainless steel pipes).
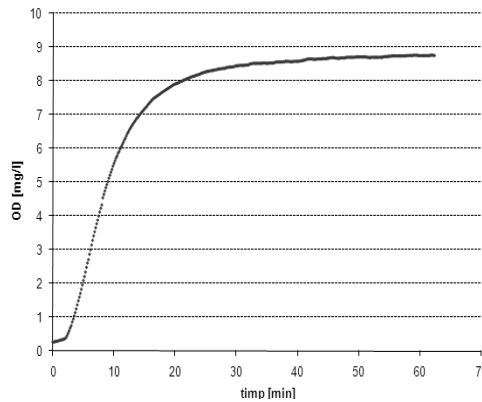
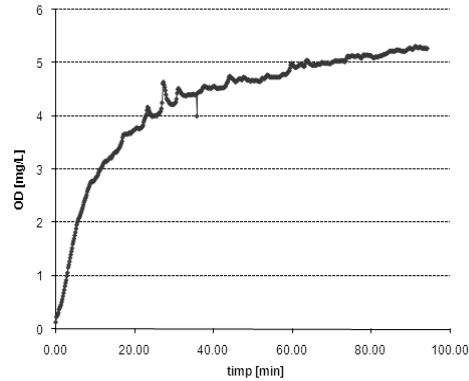|	
Fig. 4. Oxygenation curve for 30% biofilm carrier inside the bioreactor	Fig. 5. Oxygenation curve for 50% biofilm carrier inside the bioreactor

The experimental curves approaches the curve described in the literature [8 - 9]. It is noted that at the measurements beginning, in the first 20 min. the concentration of dissolved oxygen in the water is rising rapidly, and after this period a small increasing is achieved which tend to saturation.

Based on the curve slope between 0.2 and 0.8 of saturation concentration can be determined the value for the global mass transfer coefficient. To conclude on the effectiveness of aeration system the efficiency of each type of aeration system was calculated. The results for the two situations (the tank with or without biofilm carriers) are presented in table 1.

The analysis of the chart shows that the introduction of the biofilm carrier in the bioreactor improves the oxygen mass transfer (the same conclusion resulted from numerical simulations).

Efficiency of the tested aeration systems

Aeration system/Type of diffuser	Reactor without biofilm carrier	Reactor with biofilm carrier (50% filling)
A mixt aeration system (a bottom aeration system combined with a surface mixer/aerator)	7.06	7.48
Elastomer diffusers	5.21	5.73
Stainless steel pipes with 1 mm orifices	2.36	2.42
Stainless steel pipes with 2 mm orifices	1.18	1.24

4. Conclusions

Based on the obtained results, the elastomer diffusers were chosen to be assembled on the leachate treatment plant. A small laboratory treatment plant will be realized and tested in situ. The MBBR technology was chosen for the designing of the leachate treatment plant because this technology provides a compact installation, small footprint, low maintenance of the attached growth system that minimized the operational and maintenance issues associated with trickling filters and rotating biological contactors.

Acknowledgments

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