RESEARCHES RELATED TO THE BIOLOGICAL STAGE FROM WASTEWATER TREATMENT PLANTS

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ABSTRACT. – Researches related to the biological stage from wastewater treatment plants. In the present study a model for the oxygen concentration profiles in a mobile bed biofilm reactor (MBBR) is proposed. 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 water density, 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. Water oxygenation is a mass transfer process of oxygen from gas/air to the liquid mass. It can be used in wastewater treatment in order to remove the organic matter, in the biological stage. The functioning of aerobic processes depends on the availability of sufficient quantities of oxygen. In wastewater treatment plants, submerged bubbles aeration is most frequently accomplished by dispersing air bubbles in the liquid. The main purpose of this study is to determine the concentration of dissolved oxygen using mathematical modeling and numerical simulations. The aim of the study is to find the optimum dimension and position of the aeration pipes for maintaining the oxygen concentration in the limits indicated in the literature. Experimental determinations (measurements of the DO concentration) have also been realized. The oxygen profile concentration, in a MBBR reactor, was determined.

Keywords: aeration system, dissolved oxygen, MBBR, wastewater treatment.

1. INTRODUCTION

The growing production of domestic and industrial landfill leachates often involve a combination of wastes in the world causes serious disposal problems. Solid waste landfill sites are often defined as hazardous and heavily polluted wastewaters with considerable variations in both composition and volumetric flow.

The discharge of landfill leachate can membrane lead to serious environmental problems, since the leachate contains a large amount of organic matter in (both biodegradable and non-biodegradable carbon), ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salts. The leachate is characterized

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by a high COD and BOD level. The organic matter contained by the leachates can be removed by biological treatment. Off all biological treatments, the one that uses moving bed systemas is most efficient.

2. BIOLOGICAL WASTEWATER TREATMENT

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. This type of support is most effective because it is not clogged and unlike rotary contactors do not require additional energy consumption. Worldwide there are several models of biofilm carriers (Fig. 1).

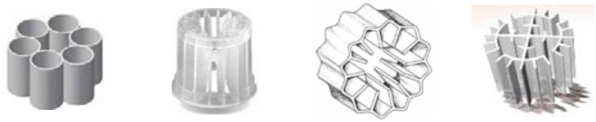

Fig. 1. ***Biofilm carriers***

Water oxygenation is a mass transfer process of oxygen from gas/air to the liquid mass. 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. In this case, air is introduced in a bioreactor with the help of a blower. The main purpose of this study is to determine the concentration of dissolved oxygen using mathematical modeling and numerical simulations. In the second stage, several experiments are realized and the aeration system efficiency is determined.

3. NUMERICAL SIMULATIONS FOR A MBBR

Few of the results obtained from numerical simulations are presented in Fig. 2 - 5. Several cases were considered: section through the classical bioreactor without biofilm carriers (Fig. 2) and mobile bed biofilm reactor with 1 - 3 air diffusers (Fig. 3 - 5).

For the realization of the numerical simulations Flex PDE software and the dispersion equation (simplified form) were used. Experimental researches were made in a bioreactor with 2 m length and height and 1 m width.

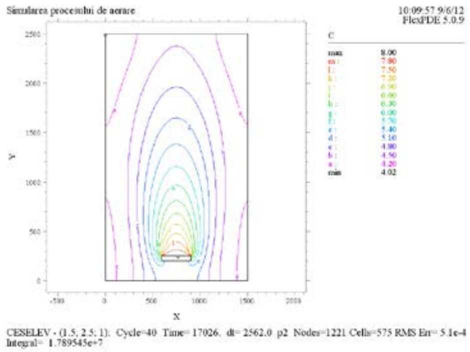

Fig. 2. ***Aerobic bioreactor with 1 diffuser***

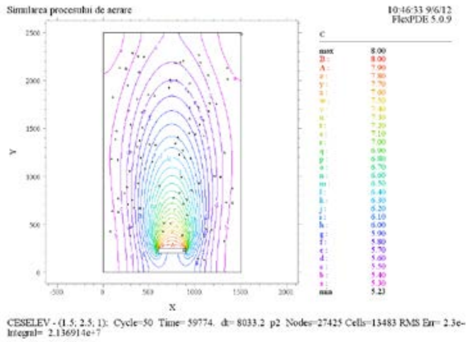

Fig. 3. ***MBBR with 1 diffuser***

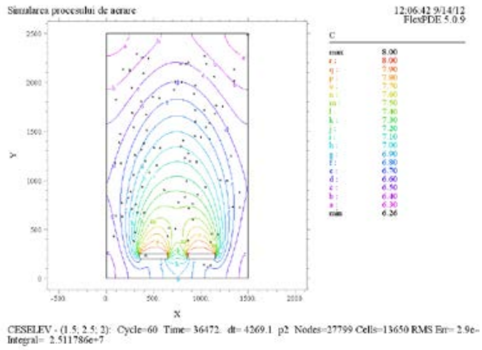

Fig. 4. ***MBBR with 2 diffusers***

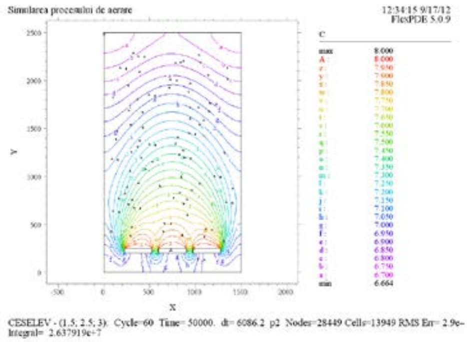

Fig. 5. ***MBBR with 3 diffusers***

Analyzing fig. 2 - 5 it can easily be observed that biofilm carriers help the oxygenation process. Resulting air bubbles rise to the surface and in their way up they meet the biofilm carriers. Bubbles, due to their interactions with the bio-media, divide and by-pass the biofilm carriers. The time contact between air and wastewater increases and that is why a better oxygen mass transfer is obtained. In the case where biofilm carriers were not considered to be introduced inside the bioreactor, the minimum value for DO concentration (conforming to the simulation results) is 4.02 mg/l, and in the other cases (Fig. 3 - 4) the minimum value for DO is 5.23 mg/l. It is clearly the fact that biofilm carriers inside a bioreactor improve the oxygen mass transfer. In the following section, experimental reaches are presented from which the same conclusion can be obtained.

4. EXPERIMENTAL RESULTS

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.

Air diffusing is a rather new approach to the issue of oxygen transfer in wastewater treatment plants (WWTPs) process. In this technology air is first compressed in compressors and then transferred in pipes to a distribution system at bottom of the aeration basin. Air is then introduced to the liquid transferring oxygen on its way to the surface of the basin. Two main technologies are used – coarse bubbles and micro diffusers. 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, sufficient oxygen to meet the requirements of aerobic waste treatment does not enter water through normal surface air-water interface. To transfer the large quantities of oxygen that are needed, additional interfaces must be formed. Oxygen can be supplied by means of air or pure oxygen bubbles introduced to the water to create additional gas-water interfaces. In wastewater treatment plants, submerged bubbles aeration is most frequently accomplished by dispersing air bubbles in the liquid. 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.

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.

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 At/V:

$$K_L a = K_L \frac{A_t}{V} \tag{3}$$

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].

$$a = \frac{A_t}{V} \tag{4}$$

where a is the interfacial area per unit volume, [m^2/m^3].

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. 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:

$$\frac{dc}{dt} = K_L a\left(C_{st} - C_t\right) \tag{5}$$

where: d_c/d_t 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 eq. (5), the initial oxygen uptake rate at $C_t = 0$, is:

$$\frac{dc}{dt} = OC = K_L a\left(C_{st}\right) \tag{6}$$

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:

$$E = \frac{OC \cdot H}{I} \tag{7}$$

where: H is the liquid depth in the tank, [m]; l − the aeration intensity, or volumetric air flux per unit area of tank surface.

The transitory regime was used for determinations – the variation of DO concentration. The principle method is to measure the modification of DO concentration in time, from 0 mg/l to the saturation concentration. Zero oxygen concentration was achieved by adding excess of sodium sulphite in the presence of cobalt ions. In this way, the initial DO in the water was consumed. Excess sodium sulfide, up to 10-20% is consumed by introducing air into wastewater mass and the moment when DO reach 0 mg/l is considered the measurements' baseline.

A constant air flow, which was introduced by the aeration system $Q_{air} = 50\ m^3/h$, was established. Two measuring points inside the bioreactor were established. The two sensors were placed at different immersion depths as follows: first sensor was located in the center of the basin at a distance of 0.5 m from the slab foundation (bioreactor base) and the second at 0.3 m. Tap water was introduced inside the bioreactor and no biofilm carries was introduced. After this stage, the bioreactor was allowed to operate 2 hours in order to reached a permanent hydraulic regime. Then, the process of decreasing DO concentration to 0 mg/l, by adding sodium sulphite and catalyst, began. Dissolved oxygen concentration was determined at intervals of 20 seconds to 40 minutes. Experimental results (variation of dissolved oxygen concentration in time) are presented in Fig. 6.

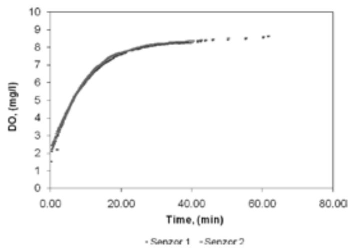

Fig. 6. ***DO variation during the first set of measurements***

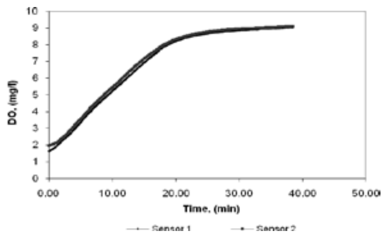

Fig. 7. ***DO variation during the second set of measurements***

From the analysis of graphs obtained (presented in fig. 6), it is observed that similar values were registered by the 2 sensors. It specifies that the sensors were placed at different depths and different locations of the basin. After about 25 minutes a value of oxygen concentration of 8 mg/l has been reached. The experimental curve approaches the curve described in the literature (American Water Works Association, 2000), (Robescu Di. *et al.*, 2011). It is noted that at the measurements beginning, in the first 20 minutes the concentration of dissolved oxygen in the water is rising rapidly, and after this period a small increasing is achieved which tend to saturation. Curve slope between 0.2 and 0.8 of saturation concentration gives us an idea on global mass transfer coefficient.

For the next set of measurements, the air flow was modified. The air flow rate injected by the aeration system was $Q_{air} = 100\ m^3/h$. The measuring points were the same as in the previous case. This set of measurements was performed under the same conditions as the first, the same steps were followed.

The filling ratio ranges from 30–70% of the total reactor volume. It is recommended that the filling fractions should be below 70% so as to be able to move the carriers freely. Some studies recommended that the surface area of the biofilm carriers should be calculated based on the internal (protected) surface because microscopy has shown no sign of biofilm growth on the outside of the smooth plastic elements due to the erosion of biofilm caused by the frequent collision between the particles.

In our case the bioreactor was 50% filled with biomedia. In this case only one sensor was used to measure the dissolved oxygen levels, because it was not known whether the interaction between biofilm carriers and the sensor will affect the measuring equipment. Measurements were performed for an air flow of 75 m^3/h. Fig. 8 shows the curve of dissolved oxygen.

To conclude on the effectiveness of aeration system the chart shown in fig. 9 was made. The analysis of the chart shows that the introduction of the biofilm carrier in the bioreactor improves the mass transfer (same conclusion resulted from numerical simulations).

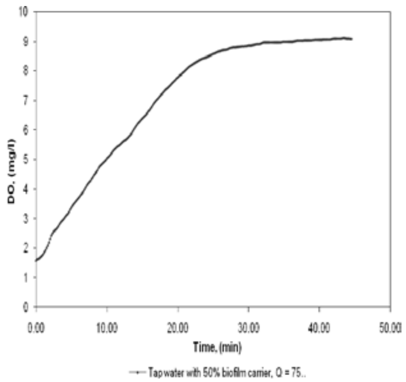

Fig. 8. ***DO variation during the third set of measurements***

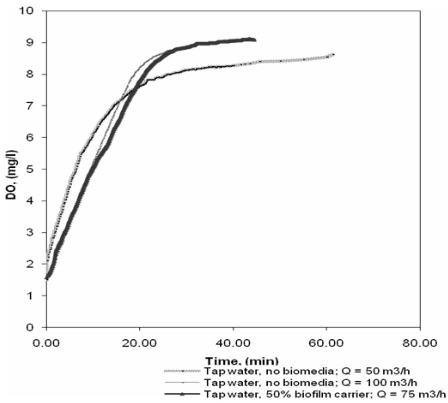

Fig. 9. ***DO variation – comparative graphic***

The graphic obtained for the case of biofilm carrier and an air flow of 75 m^3/h is similar to the case without biomedia, but with a greater air flow - 100 m^3/h. These results show that the introduction of biomedia in the bioreactor increases the time contact between air bubbles and water and so the mass transfer of oxygen is more efficient.

5. CONCLUSIONS

The advantages of using mobile media are: minimum footprint, fully automatic operation, modular construction, technology with fixed biofilm, guaranteed biofilm carrier to 20 years; adaptability shock load; produces very little sludge; low investment; minimal labor force; rapid installation and easy, steady performance; meets EU standards; reduced operating costs; organic load can be increased by 500% for the same volume of the bioreactor; can be used in almost all type of tanks (shape and size); efficient method for upgrading existing wastewater treatment plants from various sources (food, pulp/paper, pharmaceuticals, textiles, beer, refineries).

In conclusion, because this technology meets these requirements and the numerous benefits listed above, we recommend its use in wastewater treatment processes. The MBBR technology is very usefull for leachate treatment. The documentary researches in this area are still in progress. Researchers seek new technological solutions and new mathematical instruments for modeling and simulation.

Numerical simulations performed during the researches led to important results which could not be obtained in other way. Mathematical models that were the basis for numerical simulations can be used in other situations, for other geometries of basins or other aeration system configurations.

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