A MODIFIED AIRLIFT REACTOR FOR TREATMENT OF LEMON INDUSTRY WASTEWATER

A reactor for treatment of lemon industry

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Abstract

A modified airlift reactor of 10 m^3 with a height to diameter ratio of 10, has been developed for the treatment of wastewater from the lemon processing industry. The aim of this work is to evaluate reactor performance. We worked in a continuous system with activated sludge, using the microorganisms present in the wastewater and testing the most important parameters of the process (HRT, SRT, F/M, VRC, K_{La}) .

An outflow settler tube incorporated to the reactor design allowed a 25% higher sludge concentration with 200 to 500 Lh^{-1} flow rates and a 10 to 15% higher sludge concentration with or 600 to 800 Lh^{-1} flow .

Volumetric removal capacity of the suspended solid was more than 6 kg BOD_5/m^3 x d with fewer than 17h hydraulic retention time.

Maximum BOD_5 removal was 92% with a 200 Lh^{-1} flow.

The reactor had good mixing performance and volumetric mass transfer coefficient. Foam was easily eliminated due to the new reactor design.

Keywords: airlift reactor; wastewater; lemon industry, BOD, suspended solids.

Nomenclature

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Oxygen transfer plays an important role in the aerobic treatment of wastewater; the energy requirement for optimal oxygen transfer in the activated sludge process is around 70% of the total operating cost of the wastewater treatment plant. Consequently, mixing and gas holdup are fundamental factors to be considered when designing and running an aerobic reactor. Hsium and Wu (1995) studied liquid mixing in airlift reactors with different column diameters.

The lemon industry produces juice, essential oil and dehydrated peel and generates a large volume of liquid effluents (340 L/lemon tn) with a total BOD_5 of about 6000 mg/L.

Bibliographic information on aerobic treatment of these effluents has not been found. We consider it is important to work in the design of a treatment process suitable to the particular characteristics of the lemon processing industry.

Based on bibliographical and our laboratory data, a pilot plant scale reactor was designed to minimize power consumption and maximize kg BOD_5 degraded /m^3 .d. The system includes a modified airlift reactor with an overflow outlet tube that also works as a settler to diminish biomass leakage, thus keeping a higher microorganism concentration, and a secondary settler to separate sludge from liquid.

The purpose of this work is to evaluate reactor performance in wastewater treatment at a lemon processing plant. Work was carried out in a continuous system with sludge activated at different retention times and the most important variables were optimized.

Material and methods

This work was carried out at Citromax saci, a lemon processing plant in Tucumán, Argentina.

The schematic diagram of the airlift reactor is shown in Fig.1, It is 1m in diameter and 12 m high, with an inner pipe 75 cm in diameter. There are two ports for pH and DO sensors. Air was sparged into the bottom of the reactor through four diffusors made with a neoprene membrane. The bioreactor was topped by a 2m high disengaging cap of 1.50 m internal diameter.

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Average wastewater composition for the experiment was COD 6850mg/L; BOD_5 5970 mg/L; pH 3.2; SS 3,75mg/ml; acidez 0.4mg/ml; DO 1mg/L.

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Other parameters were calculated as follows:

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where C was the bulk concentration of dissolved oxygen and Cs was the saturated concentration of dissolved oxygen.

The value of K_La was determined from the slope of the linear regression with

$$\ln \left(1 - \frac{C - Co}{Cs - Co} \right)$$ referred to "t".

Co is the initial concentration of dissolved oxygen.

Results and discussion

High AFR values improve contact between the solid and gaseous phases; these effects are fundamental to achieve an efficient oxidation of the organic matter in the bioreactor because oxigen is needed by aerobic microorganisms as an electronic acceptor. AFR influence on oxygen concentration in the reactor is seen in Fig 2. As airing increases so do shear forces and they may jeopardize cell integrity, but this effect is much lower than when the mixing is performed with a mechanical shaker.

The values of K_{La} and mixing time with reference to superficial air velocity for the proposed reactor are shown in figure 3. The data obtained on K_{La} are higher than the results published by Deckwer (1975). Mixing time decreased and mass transfer coefficient was higher with increasing superficial air velocity.

HRT is one of the most important variables influencing residual BOD because when reactor feedflow increases so does F/M ratio while removed BOD % decreases. Fig. 4 shows HRT variables of BOD removal% at Usg of 5 cm s^{-1} . At HRT of 2 d, BOD residual % is less than 10%.

Gas holdup data of the reactor increases with AFR occupying 16.28 % of reactor volume with an AFR of 5 m^3 air.m^{-3}.h^{-1}. BOD_5 maximum removal percentage (92%) was obtained with a 200 Lh^{-1} flow rate. With an 800 Lh^{-1} flow, equivalent to a hydraulic retention time of 0.50 h, the percentage decreased to 50%. The highest removed BOD_5 value was 6.14 Kg. m^{-3}.d^{-1} with an HRT of 0.58 d. Lower values were reported in the treatment of city effluents with airlift reactors (Roessink and Eikelboom, 1997).

Control runs for the various operational parameters of the reactor working with wastewater from a lemon proccesing plant are shown in table 1. As reactor feedflow increases, the F/M ratio and residual BOD grow proportionally while VRC rises up to a 700 L/h flow and then it begins to decrease.

Sludge retention times were always higher than hydraulic retention ones due to the reactor settler. This is because of a 5% to 25% higher variation between reactor VSS and the VSS in the liquid coming out of it, depending on feedflow.

At flow rates over 600 L/h settling problems appeared: SVI values were higher than 500 mg/l, and VSS diminished in the reactor.

When compared with the conventional airlift reactor, the proposed reactor with a settling outflow pipe, reached a sludge concentration 25% higher at flow rates between 200 and 500 Lh^{-1} and a concentration 10 to 15% higher at flow rates between 600 and 800 Lh^{-1}.

Mass transfer between phases gradually improved when increasing Usg, resulting in the decrease of residual BOD_5.

Fig 5 shows that BOD in the reactor decreases when Usg increases and that that reduction depends on HRT.

Biomass average produced per kg of removed BOD_5 was 0.52 kk^{-1}.

There were no foam problems in the reactor and the addition of antifoam compounds was not necessary since the air and foam outflow system worked successfully.

It may be concluded that the modified airlift reactor works efficiently in the citrus industry residual water treatment . The settler outflow tube added to the reactor obtained a higher microorganism concentration than did the conventional airlift and no bacterial recycling was necessary. The principal process variables were thus considerably improved.

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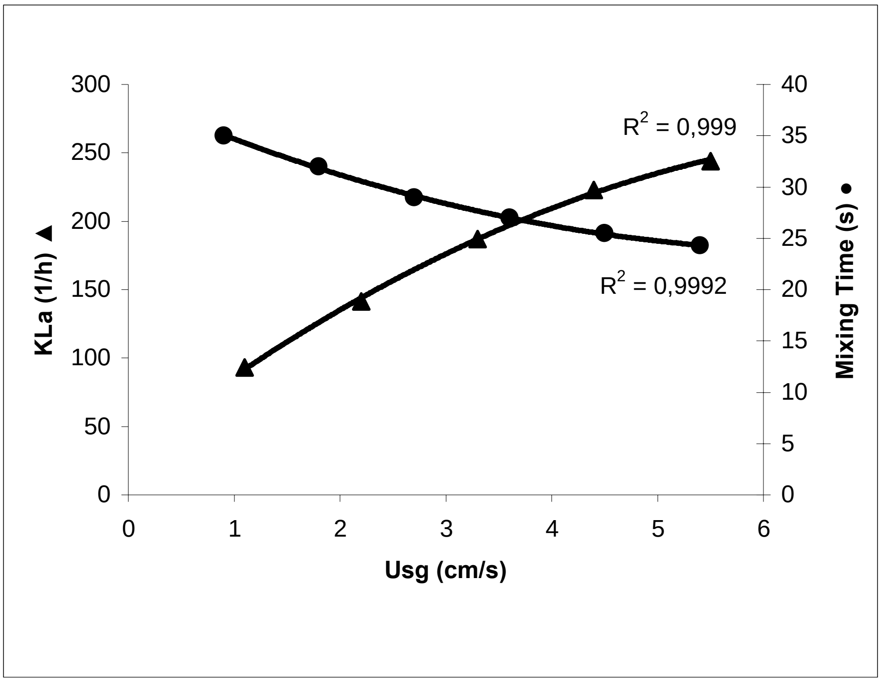


300
250
200
150
100
50
0
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
R2 = 0,999
R2 = 0,9992
KLa (1/h)
Mixing Time (s)
Usg (cm/s)

Fig. 3

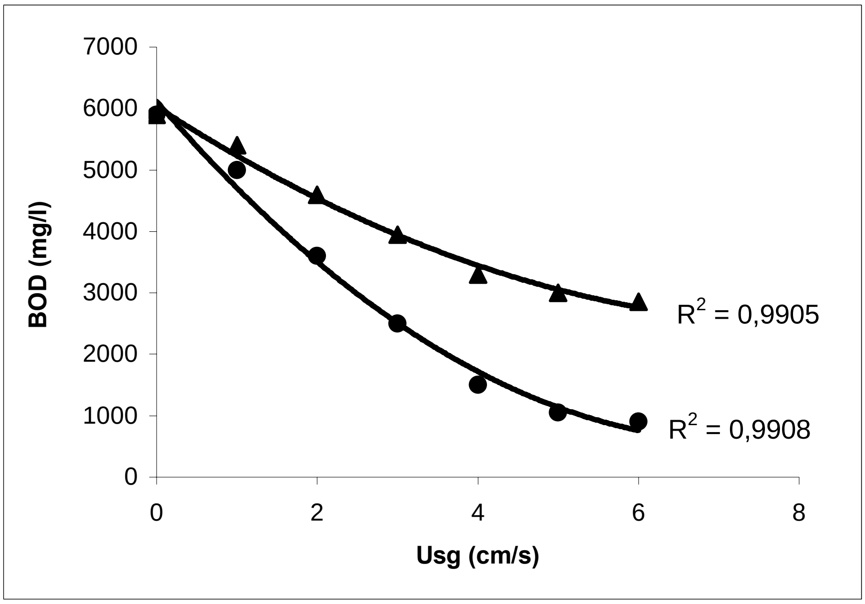
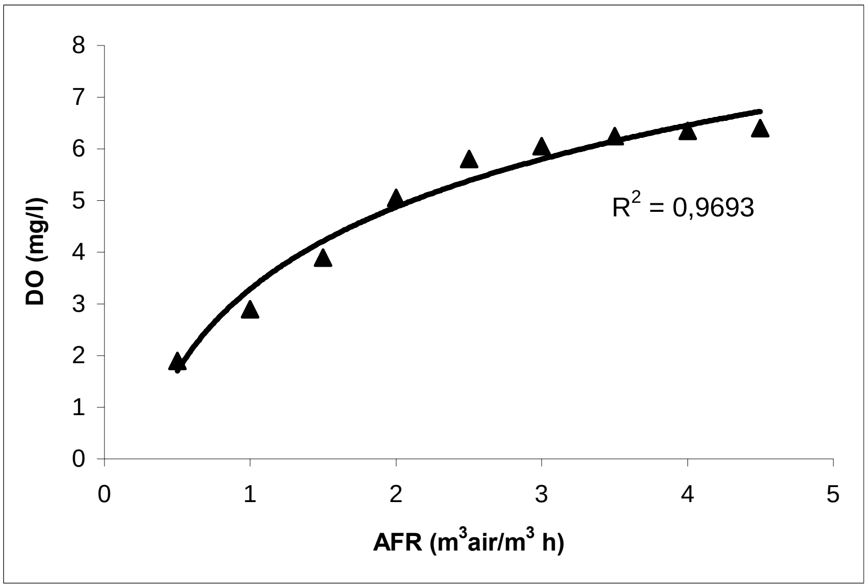

7000
6000
5000
4000
3000
2000
1000
0
BOD (mg/l)
0
2
4
6
8
Usg (cm/s)
R^2 = 0,9905
R^2 = 0,9908

Fig. 5



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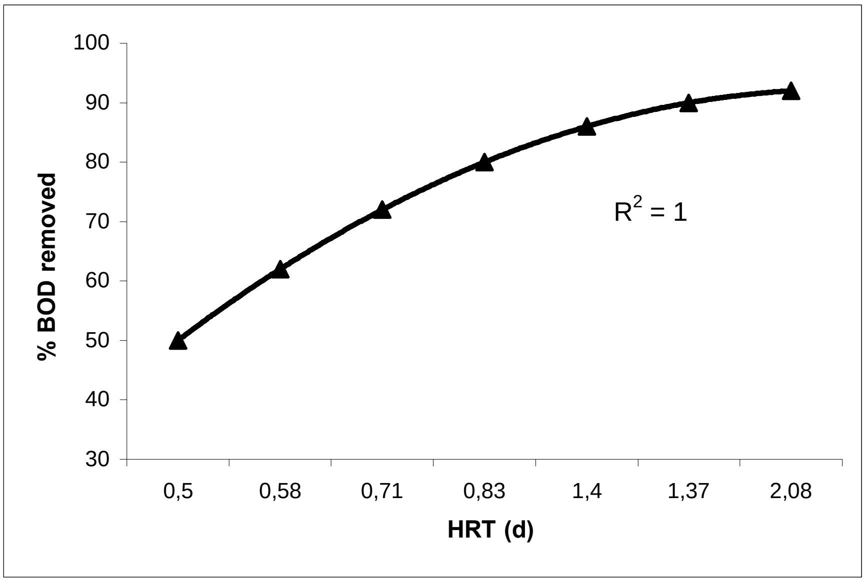
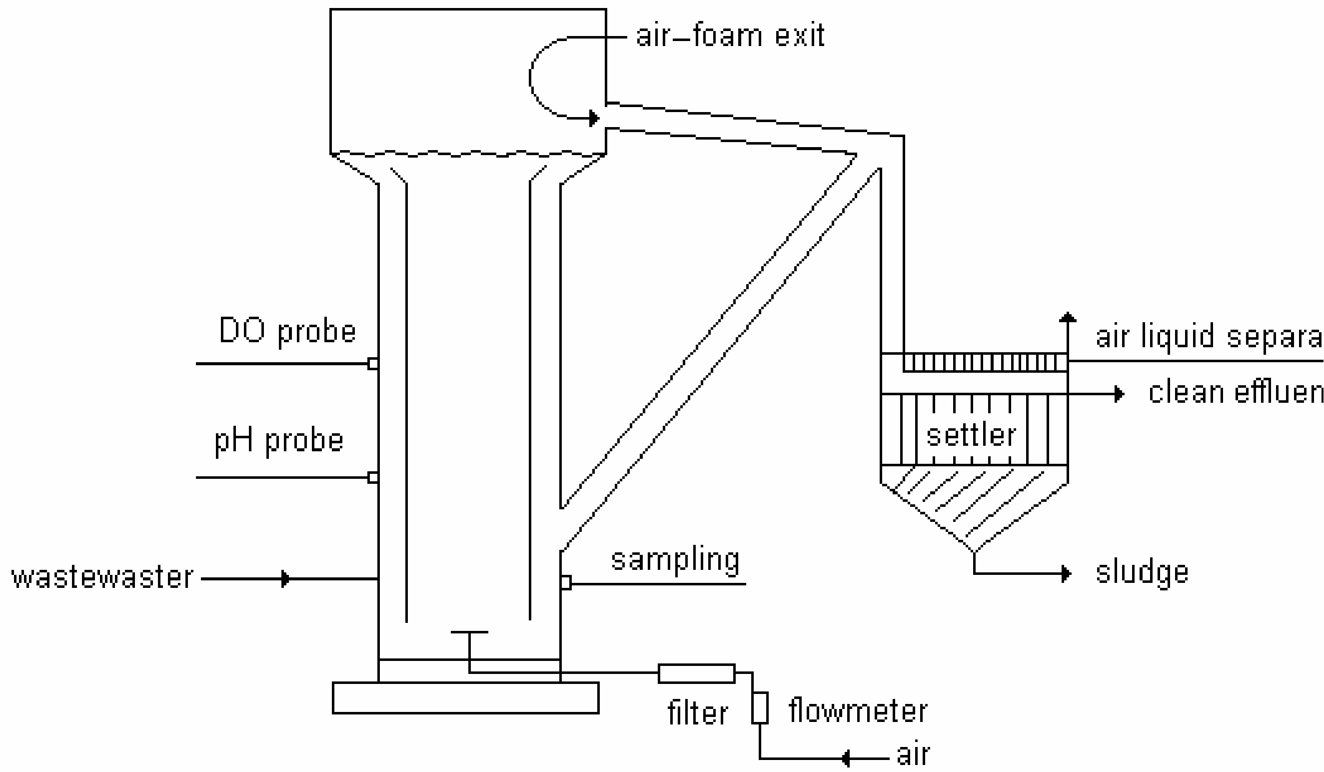

100
90
80
70
60
50
40
30
% BOD removed
R2 = 1
0,5
0,58
0,71
0,83
1,4
1,37
2,08
HRT (d)

Fig. 4


air–foam exit
DO probe
pH probe
wastewaster
sampling
air liquid separa
clean effluen
settler
sludge
filter
flowmeter
air