Anaerobic treatment of phenol in a continuous fluidized-bed bioreactor
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ANAEROBIC TREATMENT OF PHENOL IN A CONTINUOUS FLUIDIZED-BED BIORREACTOR

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Abstract

Due to the high growth of population in the last years, industrial and domestic sewage water generation has increased, directly affecting in environment and causing serious contamination incidents.

The use of the fluidized bed biorreactors for the high-loaded organic wastewater anaerobic treatment mean an important advance in the wastewater treatment, although it is not too disseminated in industrial fields. In these systems it is possible to obtain a high active bio-mass concentration (until 40 g/l) inside the reactor with no recirculation necessity of the bio-mass. Fluidization of theses particles is obtained by liquid recirculation, which makes possible to have a good mixture and permits to reduce resistance to the mass transfer between liquid phase and biofilm. Therefore process velocity will be given by microbes-growth kinetic equations.

In this study, was used an anaerobic continuous fluidized-bed bioreactor (RALF) supplied with a synthetic wastewater with a mixture concentration of 500 ppm organic acids a 600 ppm of phenol. Amounts of 85% to 95% of phenol and 90% to 100 % of organics acids were effectively degraded in the RALF, with a hydraulic retention time of 6 hours. Influent and effluent composition was measured by gas chromatography GC-TCD, GD-FID and TOC. Test showed high efficiency in phenol treatment in a RALF, obtained the kinetic constant of phenol degradation of 0.0012 L/mg·day (considering a first order reaction).

Keywords: biodegradation, anaerobic treatment, fluidized-bed bioreactor, phenol.

1. Introduction

In anaerobic digestion most of the organic compounds are degrade by the action of a wide variety of microrganisms (usually bacteriums) in oxygen absence and other oxidant agents.

Biological conversion of the organic matter is carried out in three phases (Figure 1). First one is a hydrolysis step, carried out by hydrolytic microorganisms through an enzymatic way. Then takes part acidogenesys step, in which 'acid-former bacteriums' take part. The last stage is metanogenesys step, which is the velocity limit stage because of its lower degradation velocity, and makes fundamental a kinetic research when designing and doing a scale-change. CH_4 and CO_2 are the most significant products of degradation.

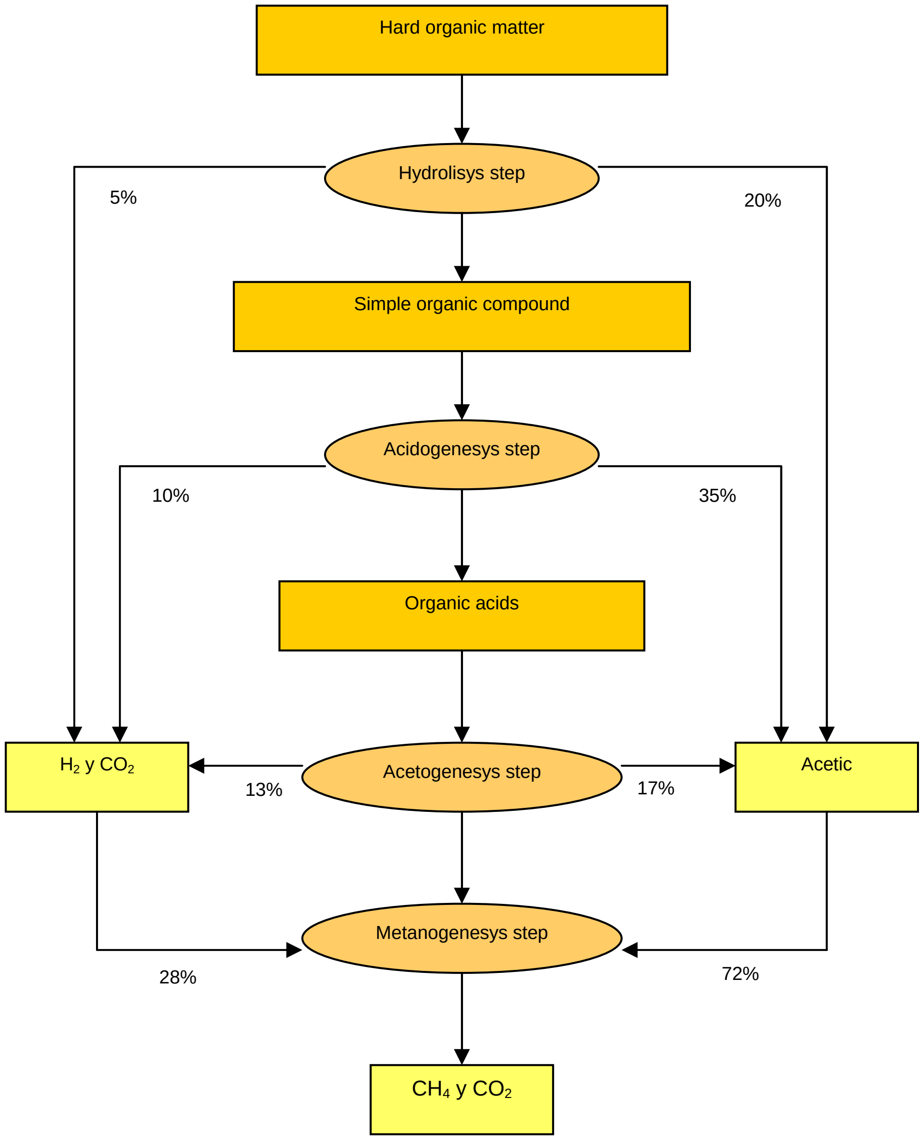

Figure 1: Anaerobic digestion phases (McCarty y Smith, 1986)

Phenol is an aromatic compound that is commonly found in the industrial wastewater from the manufacturing of synthetics chemicals, pesticides, etc. Biodegradation of phenol in wastewater is generally more cost-effective than the treatment processes. In this study, degradation of phenol has been done in a fluidized-bed bioreactor (RALF) by the addition of increasing concentrations next to the feeding point.

So the aim of this work is to analyze the anaerobic degradation in an organic-matter continuous system done in an anaerobic fluid bed reactor. There are three different aspects to take into account:

- Monitoring the anaerobic fluid bed reactor.
- System response when introducing a feeding with increasing amount of phenol (from 5 ppm to 600 ppm).
- Kinetic study of phenol degradation.

2. Materials y methods

A mixture of acetic, propionic and butyric acids (2:1:1 proportion) until 500 ppm in TOC- were used as the only source of carbon to feed the reactor. Macro and micronutrients were supported in relation 100:7:1 in C:N:P, and its composition were based in the use of Evans minimum medium. Next, phenol concentration was increased until 600 ppm. During de continuous period, the reactor was feeded with a synthetic wastewater, varying the TOC concentration from 500 ppm until 1100 ppm with 6 hours of hydraulic retention time.

Fluidized-bed bioreactors consist of a principal body with cylindrical vertical form hermetically closed (Figure 2). Recirculation entrance is located at the bottom and the homogeneous fluidization is obtained because their conic shape. The exit for this recirculation is top-side located. On upper side of the reactor there is an extractor hood which is used to bio-gas evacuation. This kind of reactors used to have a small gas-solid-liquid phases-separator to avoid solid and bio-gas losses.

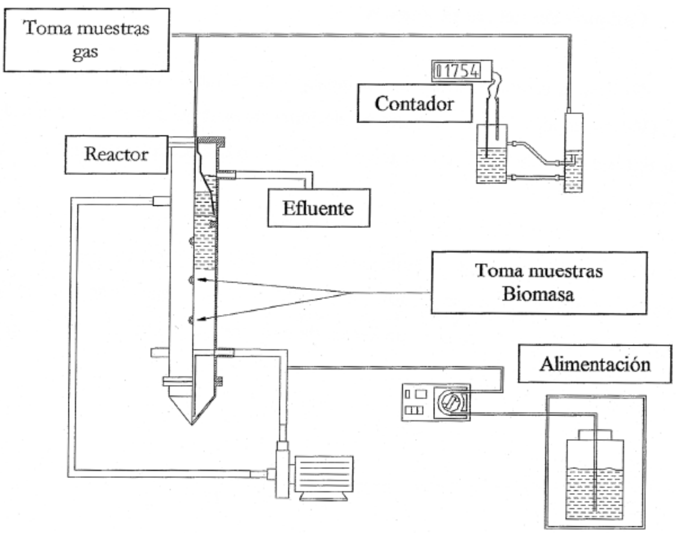

Figure 2: RALF diagram use in the work.

Feeding flow (L/day), gas flow (L/day) and gas composition [CH_4 and CO_2 (mM) was measured by gas chromatography GC-TCD], also influent-effluent composition (acids and phenol) by gas chromatography GD-FID and TOC in a TOC Analyzer.

3. Results

3.1. TOC and DQO evolution

Removal efficiency of acid degradation was about 90% in TOC and DQO, sometimes 100% with 6 hours of hydraulic retention time. In both parameters, the evolution shows three stages corresponding to the start-stage of the reactor, with an increasing performance; a stationary phase, with a stability results between 90% and 100%; and finally, decreasing for the phenol incorporation to the feeding (Figure 3).

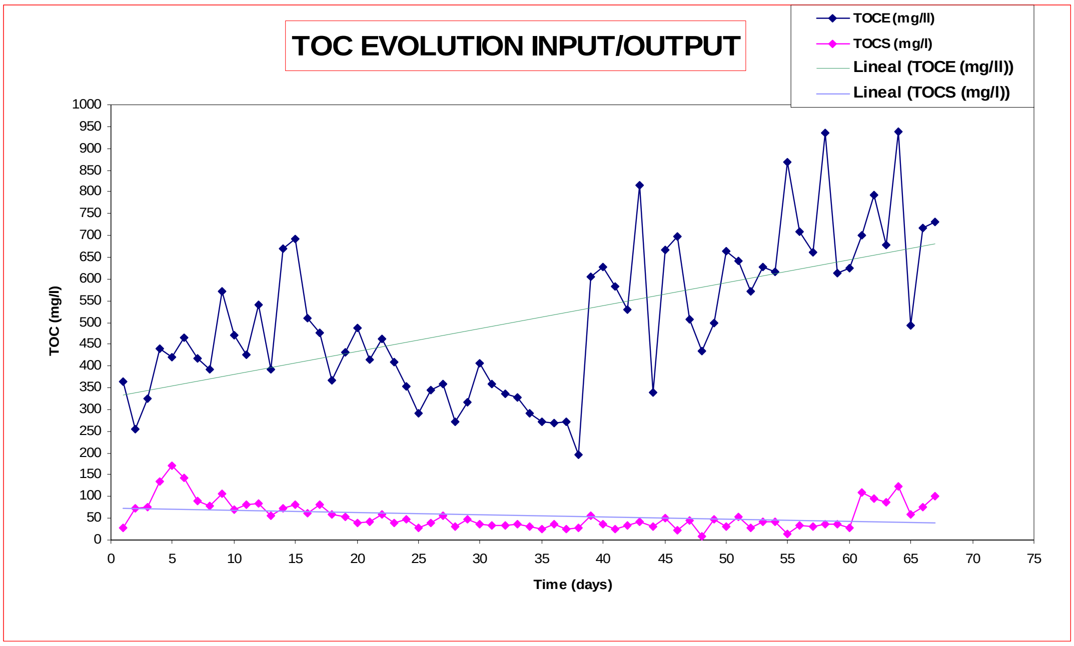

Figure 3: TOC evolution input/output in reactor

As can be showed in the graph attached, degradation efficiency percentage increased, without affecting the measures by phenol addition until concentrations of 600 ppm. A carbon balance was done obtaining input values (TIC+TOC) between 1838 and 5375 mg/day, and output values (TOC+TIC+CH_4+CO_2) from 2529 to 485 mg/day.

3.2. Phenol evolution

Table and figure attached show that percents of final phenol degradation vary from 85% to 95%, getting smaller values when increasing its concentration (Table I and Figure 4). General degradation trend towards 86%, but sometimes it is lower, and other times it can reach 100%.

Table I: Phenol results.

Fecha	$Fenol_E$ (mg/l)	$Fenol_S$ (mg/l)	Carga org. fenol $_E$ (g/día)	Carga org. fenol $_S$ (g/día)	Rendimiento eliminación fenol (g/día)
30-03-06	47,27	5,081	0,175	0,019	89,25
03-04-06	66,639	3,365	0,247	0,012	94,95
04-04-06	48,239	10,101	0,178	0,037	79,06
05-04-06	41,683	5,772	0,154	0,021	86,15
06-04-06	62,224	3,145	0,230	0,012	94,95
12-04-06	115,93	3,262	0,429	0,012	97,19
18-04-06	73,625	4,923	0,272	0,018	93,31
19-04-06	66,989	4,388	0,248	0,016	93,45
20-04-06	121,738	20,813	0,450	0,077	82,90
26-04-06	63,953	3,013	0,237	0,011	95,29
27-04-06	67,441	0	0,250	0,000	100,00
28-04-06	71,846	3,405	0,266	0,013	95,26
11-05-06	139,676	44,945	0,517	0,166	67,82
12-05-06	254,889	32,132	0,943	0,119	87,39
16-05-06	193,6	57,959	0,716	0,214	70,06
18-05-06	135,448	10,329	0,501	0,038	92,37
19-05-06	128,6	28,69	0,476	0,106	77,69
22-05-06	574,875	78,016	2,127	0,289	86,43
24-05-06	185,159	47,161	0,685	0,174	74,53
26-05-06	272,582	62,041	1,009	0,230	77,24
29-05-06	497,362	79,044	1,840	0,292	84,11
30-05-06	398,62	54,396	1,475	0,201	86,35

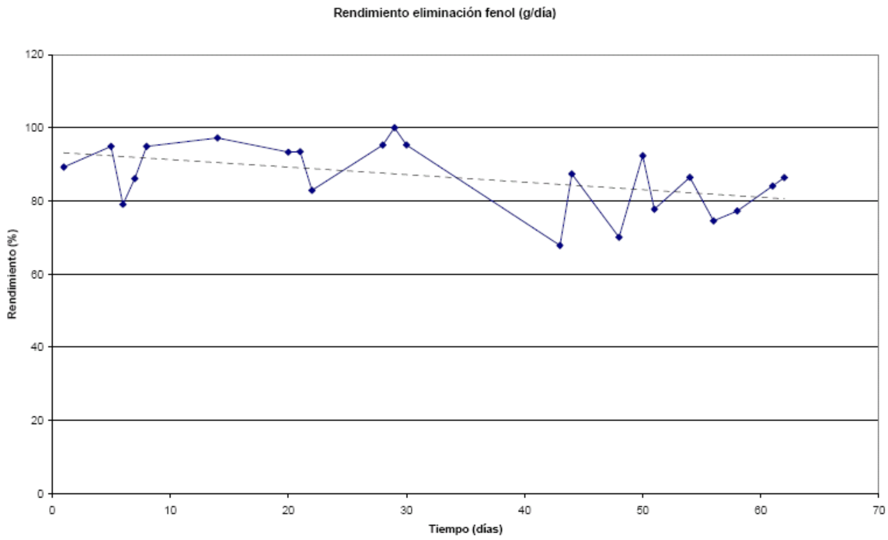

Figure 4: Phenol evolution input/output in

A first order cinematic constant has been supposed on phenol degradation reaction in order to obtain q (phenol specific consumption velocity) and K (kinetic Constant) through the following equation [1]:

$$q = \frac{Q(S_0 - S)}{X \cdot V} = K \cdot S \qquad \textbf{[1]}$$

A result obtaining of kinetic constant is 0.0012 L/mg·day, as can be showed in the Figure 5.

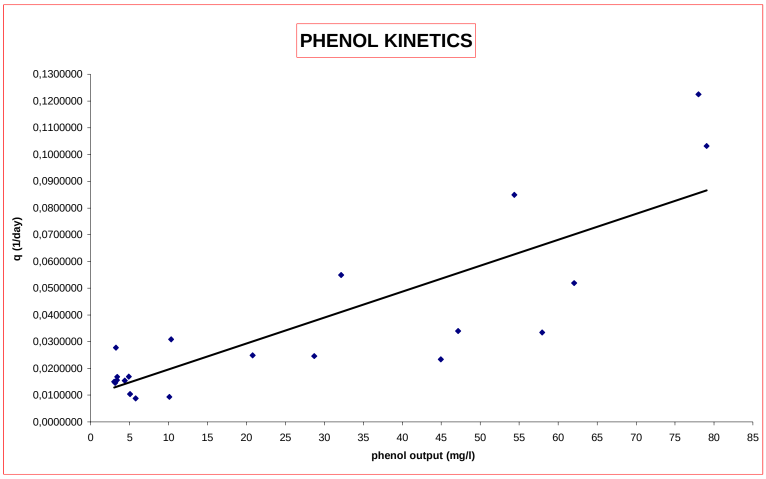

Figure 5: Kinetic constant of phenol degradation

3.3 <u>Acids evolution</u>

Generally, acid degradation has been complete in the most of case except in specific situations.

4. Conclusions

1. Fluidized-bed biorreactor shows high efficiency in phenol treatment, reaching removal efficiency until 100% sometimes, instead they usually vary from 85% to 95% (so high values considering 6 hours of time retention and a no-adapted sludge).
2. Illustration of kinetic reaction fits to a straight line, which shows the reaction occurs in a low-amount-zone of substrates, considering a first order reaction with K=0.0012 L/mg·day.

5. References

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