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Running head: Biotreatment of phenol in a bioreactor

Article type: Application of environmental microbiology in organics-contaminated wastewater treatment

Biotreatment of Phenol-Contaminated Wastewater in a Novel Spiral Bioreactor

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1* Use single-word verbs whenever & wherever possible.

Abstract. A spiral bioreactor inoculated with microorganisms obtained from activated sludge was used to ~~carry out~~ conduct a feasibility study for phenol removal. The reactor was operated continuously ~~under~~ at various phenol loadings ranging from 53 to 201.4 g m^{-3} hr^{-1}, and ~~under~~ at different hydraulic retention time (HRT) in the range of 20–180 min to estimate the performance of the ~~bioreactor~~ device. The R_r indicated ~~Results showed~~ that phenol removal efficiency ranging from 82.9 to 100% can be reached ~~as~~ when [redundant] the ~~spiral bio~~reactor ~~was~~ is operated at a HRT of 1 h and a phenol loading of less than 111.9 g m^{-3} h^{-1}. ~~For~~ At an influent phenol concentration of 201.4 g m^{-3}, the removal efficiency ~~of phenol~~ [redundant] increased from 18.6 % to 76.9 % with ~~the~~ an increase of HRT (20–120 min). ~~The~~ For the treatment of phenol in the reactor, the maximum degradation rate (V_m) was 1.82 mg l^{-1} min^{-1}; [semi-colon] ~~maximum degradation rate (V_m) and half saturation constant (K_s) for treatment of phenol in the spiral bioreactor were 1.82 mg l^{-1} min^{-1} and 34.95 mg l^{-1},respectively.~~ the half-saturation constant (K_s), 34.95 mg l^{-1}. ~~Besides~~, Moreover a first-order model with a rate constant of 0.1178 min^{-1} was established for predicting substrate conversion. ~~The~~ This model is ~~able to give a good approximation of~~ capable of accurately approximating the experimental data.

Keywords: biodegradation; kinetics; phenol; spiral bioreactor

2* "Besides" is a colloquialism best avoided in formal academic writing.

3* All keywords should appear in the Abstract. The circled words do not occur here.

1* Even better than has been found toxic would be is toxic — unless you need to hedge.
2* "Research" is an uncountable noun. Do not attempt to make it plural. However, you actually mean "researchers" here. Pardon me!

1. Introduction

Phenolic compounds and their derivatives are the major pollutants discharged from many industrial processes, including refining petroleum, synthesizing resins, preparing photographic chemicals ~~preparation~~, and manufacturing explosives ~~explosives manufacture~~ (Sittig, 1997; Alemzadeh *et al.*, 2002; Nuhoglu *et al.*, 2005; Jiang *et al.*, 2006; Mohanty *et al.*, 2008). Among these pollutants ~~them~~ [hyphen], phenol, a water-soluble and highly mobile chemical that can cause severe odor and taste problems, [has early been shown to be found] toxic to many [reduce verbosity] marine biochemical functions and fish life, even at low concentrations (Sufit, 1978).

In the recent years, researchers have made great efforts to develop more efficient [diction] and cost-effective control technologies for phenol treatment. Biological treatment is a more preferable alternative to traditional physical and chemical control methods due to its low cost, reliable operational stability, and pollution destruction efficiency. Although While phenol is considered to be inhibitory at high concentration (Yoong *et al.*, 1997), biological [redundant] treatment techniques are widely used for treatment of wastewater or soil containing moderate amount of phenol levels (5–500 mg l^{-1}) (Patterson, 1985; Bandhyopadhyay *et al.*, 2001).

Immobilized-cell technology is a recent advancement in biotechnology [comma], which allows ing for compacting and maintaining a large amount number of cells in biotreatment systems for remediating contaminants. Besides Moreover [no space], down stream separation and processing costs could can be eliminated by immobilizing the microbes. In 1992, Lakhwala et al. developed a spiral bioreactor that could minimize channeling effects and maximize the microbe-contaminants interaction was developed to remove organic compounds and reactor achieved excellent performance. (1992). Being capable of minimizing channeling effects and maximizing the interaction of microbial contaminants, their [syntax] [diction] excellent performance was obtained (Lakhwala *et al.*, 1992). [faulty coordination (non-parallel)] Furthermore [comma], this reactor shows good potential for both kinetic and studies as well as for scaling scale up/down studies of multiphase processes because it is easily reproducible [comma] and its hydrodynamics activities approach

3* Reserve usage of "while" for its temporal [time] sense.
4* Use "number of" with countable nouns; "amount of" with uncountable.
5* "Besides" is a colloquialism best avoided in formal academic writing.

1* Verify the spelling: Rues/Rus/Ruse. Compare Line 25, p. 12.

the plug-flow operation (Kallinikos and Papayannakos, 2007). Rues and coworkers (1995) using a spiral bioreactor for removal and recovery of metals from aqueous wastes and found that the spiral bioreactor was efficient in binding metal ions from the waste stream. Close to 90% recovery by acid wash can be achieved in the pH range of 2.0 to 2.5. Apart from aqueous waste treatments, the spiral also had been used to treat gaseous wastes. For instance, Shim and coworkers (1995) used a fixed-film spiral bioreactor containing immobilized activated sludge microorganisms to degrade ethanol vapors in the range of 600 to 7000 ppmv and a maximum elimination capacity of 185 g ethanol h^{-1} m^{-3} of reactor volume was observed. Guo *et al.* (2001) used a spiral-wound fibrous bed bioreactor to co-metabolic degrading trichloroethylene (TCE) by P*seudomonas putida* F1 and found that 98.5% TCE could be removed over 4 hours. However, it should be note that this bioreactor was mainly operated under batch conditions.

The aim of this research was to evaluate the capacity of a mixed culture to grow and degrade phenol in a spiral bioreactor operated under different hydraulic retention time and various organic loading. Besides, a mathematic model capable of predicting phenol removal efficiency and the time needed to obtain certain conversion was successfully developed. The result obtained in present work could be a useful reference for engineered biotreatment processes.

2. Materials and Methods

2.1. MICROORGANISM AND GROWTH MEDIUM

A mixed culture obtained from a wastewater treatment plan in central Taiwan was acclimated in a bioreactor fed with phenol as sole carbon source. After acclimation and incubation for a period of time, the cultures were prepared as seed

2* Use the next-smaller font size for all except the first character in each sub-header at this level. Presumably, this should be 11pt.

1* (1) What is a "moderate amount"? This phrase is too general in a context which should be specific. How much? (2) Which medium was the phenol added to? You have listed 12 mediums in Lines 2–5 on this page. Merely add "s" if you mean more than one medium. If you mean something else, let us discuss how to word it.

[Avoid redundancy]

cultures for the spiral bioreactor. The mineral medium(s) used in the present work were as follows: K_2HPO_4, 4.27 g l^{-1}; KH_2PO_4, 3.48 g l^{-1}; $(NH_4)_2SO_4$, 0.34 g l^{-1}; $MgSO_4 \cdot 7H_2O$, 0.46 g l^{-1}; $FeSO_4$, 0.001 g l^{-1}; $CaCl_2 \cdot 2H_2O$, 0.018 g l^{-1}; $CuCl_2 \cdot 2H_2O$, 0.01mg l^{-1}; $CoCl_2 \cdot 6H_2O$ 0.2 mg l^{-1}; $ZnSO_4 \cdot 7H_2O$, 0.1 mg l^{-1}; $MnCl_2 \cdot 4H_2O$, 0.03 mg l^{-1}; Na_2MoO_4 $2H_2O$, 0.03 mg l^{-1}; and $NiCl_2 \cdot 6H_2O$, 0.02mg l^{-1}. All chemicals used were analytical grade reagent(s).

[12-pt → 11pt ~ no space]

2.2. BIOREACTOR SET UP

[See Note 2, p. 4.]

[comma]

Figure 1 shows the configuration of the spiral bioreactor, constructed. The reactor was made up of seven layers of polypropylene columns with an internal diameter of 120 mm and a height of 22 mm. The overall height and working volume of the spiral reactor are were 230 mm and 1 L, respectively. Each layer of column was packed with spiral-wound bio-support to leave allow a space for liquid to pass through traverse the channel. The bio-support was made consisted of filter sponge attached on to a sheet of plastic [mat] matting. (This form sounds better in this context.)

[diction]

[diction]

The A artificial wastewater was prepared by the addition of adding a moderate amount of phenol in to the mineral salts medium(s); Besides, moreover, 2% CaO_2 was added to the [redundant] wastewater to provide sufficient dissolved O_2 (7–9 mg l^{-1}) for the microbial respiration and metabolic degradation of the phenol. As is shown in Figure 1, the influent enters the center of the lowest layer column of the bioreactor and passes through the spiral channel as shown in more detail in Figure 2. As it flows through the channels, phenol was is oxidized by the microorganisms grew growing on and attached on to the bio-support sheet. After passing through the seven layers of the bioreactor, the treated water leaves the reactor from the top of the bioreactor.

*1

[avoid redundancy]

Experiments were carried out conducted in the continuously operating bioreactor for more than 300 hours. The loading of phenol in the influent was varied from 53 to 201.4 g

1* It is unnecessary to use the full form "spiral bioreactor" so many times — unless another reactor is introduced.
2* Is "Teflon Minivert" a brand name? If so, the capitalization is appropriate; otherwise, revise to lower-case.

m^{-3} h^{-1}, while the different hydraulic retention time (HRT) of the inlet stream was in the range of 20–180 min. The sampling ports were located at the inlet and exit of the spiral bioreactor. A liquid sample of 2 ml was taken from each sampling port using a glass gastight syringe periodically.

2.3. ANALYTICAL METHODS

Liquid samples taken from the bioreactor were filtered by a bio-filter (TITAN-Nylon -0.2 μm) to removal microorganisms and inert materials that may interference the analysis results. Thereafter, a liquid sample of 1 μl was taken from the filtered sample and was then injected into a model GC-14B gas chromatograph (Shimadzu Corp., Japan) equipped with a RTX-1 capillary column (30 m×0.53 mm) and a flame ionization detector by a gastight syringe equipped with a Teflon Mininert valve fitting. Helium (99.98% purity) was used as the carrier gas and nitrogen was used as a makeup gas. Oven temperature was controlled at a constant temperature of 105 °C, while injector temperature and detector temperature were set at 200 °C and 250 °C, respectively. Calibration cure were obtained using identical experimental sample vials.

2.4. KINETIC STUDY

An equation modified from Michaelis-Menten model was used in this study to determine the kinetic parameters for phenol degradation and the degradation rate could be given by:

$$\frac{C_{in}-C_{out}}{t}=\frac{V_m\times\dfrac{C_{in}-C_{out}}{\ln(C_{in}/C_{out})}}{K_S+\dfrac{C_{in}-C_{out}}{\ln(C_{in}/C_{out})}} \quad (1)$$

where C_{in} and C_{out} are the phenol concentrations (g m^{-3}) at the inlet and outlet of the spiral bioreactor, respectively, V_m is the maximum degradation rate (g m^{-3} h^{-1}) and K_s

* Why introduce an acronym if you do not subsequently use it?

is the half-saturation constant (g m^{-3}), t is the hydraulic retention time (h). While C_{in}, C_{out}, and t can be obtained from experiment data, values of V_m and K_s were calculated numerically by fitting the biodegradation data to the solution of Equation (1) through nonlinear parameter regression and a least-square minimization procedure. All of the calculations were done by using Microsoft Excel 2003 Solver.

3. Results and Discussion

3.1. REACTOR PERFORMANCE

Figure 3 illustrates the performance of the bioreactor operated continuously under various experimental conditions. The hydraulic retention time and liquid flow rate were controlled at 60 min and 0.001 m^3 h^{-1}, respectively. High removal efficiency (RE) of 100% can be reached as the phenol loadings (LO) were in the range of 5.3 to 69.9 g m^{-3} h^{-1}, indicating that the spiral bioreactor exhibits an excellent ability for phenol removal under moderate phenol loading conditions. However, the removal efficiency dropped dramatically from 82.9% to 30.9% as the inlet phenol loading was increased from 111.9 to 201.4 g m^{-3} h^{-1}. Besides, for inlet phenol concentrations below 201.4 g m^{-3}, the removal efficiency increased with the increase of hydraulic retention time. Note that the loading (LO) and removal efficiency (RE) are defined as:

$$LO = \frac{Q}{V} \times C_{in} \quad (2)$$

$$RE = \frac{C_{in} - C_{out}}{C_{in}} \times 100\% \quad (3)$$

where Q is the liquid flow rate (m^3 h^{-1}), and V is effective volume (m^3).

* See Note, p. 7. .

3.2. EFFECT OF ORGANIC LOADING ON REMOVAL EFFICIENCY

Figure 4 shows the effect of organic loading on the removal efficiency and elimination capacity (EC) of phenol. Elimination capacity (EC) is defined as:

$$EC = \frac{Q}{V} \times (C_{in} - C_{out}) \quad (4)$$

It is shown in Figure 4, that the removal efficiency is always more than 80% when the residence time is 60 min and the inlet phenol concentration is less than 111.9 g m^{-3}. However, the removal efficiency dropped dramatically as the inlet phenol concentrations were greater than 111.9 g m^{-3}. This phenomenon might be due to that the organic loading was over the maximum tolerable value of the mixed culture and consequently caused the inhibitory effect on culture growth. Hence, the apparent removal efficiency was reduced.

The removal efficiency was in the range of 100 to 47.2% when the spiral bioreactor was operated at an inlet phenol loading of 5.3 to 201.4 g m^{-3} h^{-1} and a HRT of 60 min. As is demonstrated in Figure 4, the elimination capacity of the spiral bioreactor is equal to phenol loading as the loading was less than 69.9 g m^{-3} h^{-1}. Besides, phenol is degraded completely and a removal efficiency of 100% also can be reached at this loading range. Therefore, this bioreactor was performed as a mass transfer limited system while the elimination capacity is in proportion to phenol loading. However, the system turned to be reaction rate limited as the phenol loading was greater than 111.9 g m^{-3} h^{-1}. That is, the inlet loading rate was over the maximum degradation capacity of bioreactor. Hence, the elimination capacity obtained diverged gradually from the 100% degradation line. Furthermore, the removal efficiency dropped to a range of 45 to 50% at a phenol loading of 201.4 g m^{-3} h^{-1}. The maximum

* See Note, p. 7.

elimination capacity of the spiral bioreactor for phenol was approximately 150–155 g m^{-3} h^{-1}.

3.3. EFFECT OF HYDRAULIC RETENTION TIME ON REMOVAL EFFICIENCY

Figure 5 shows the effect of hydraulic retention time on the removal efficiency of the spiral bioreactor. The investigation was carried out at an inlet phenol concentration of 201.4 g m^{-3}, and hydraulic retention time from 20 to 180 min (corresponding liquid volume flow rate from 0.003 to 0.0003 m^3 h^{-1}). As the reactor was operated at a hydraulic retention time from 20 to 60 min, the removal efficiency was only in the range of 18.6 to 46.2%. It is surmised that this result was attribute to the reason that this operation condition could not provide sufficient time for phenol to pass through the biofilm and to react. This speculation could be proofed as the liquid retention time doubled. Removal efficiency increased from 46.2 to 76.9% as the hydraulic retention time was extended from 60 min to 120 min.

However, as can be seen in Figure 5, the removal efficiency increased only slightly when the hydraulic retention time is greater than 120 min. For instance, as the hydraulic retention time increased from 120 min to 180 min, removal efficiency only increased from 76.9% to 82.2%. This indicated that there must be something happened in the bioreactor and limited the removal ability of the bioreactor. After a serious of tests, it is found that this was due to the shortage of dissolved oxygen for aerobic degrading phenol. It is found that the effluent contained only 0.72 mg l^{-1} oxygen whereas the influent contained 7–9 mg l^{-1} oxygen. Hence, for the bioreactor operated at an inlet phenol concentration of 201.4 g m^{-3} and hydraulic retention time of 180 min, dissolved oxygen was the rate-limited factor.

3.4. KINETICS

The kinetic parameters for the mixed-culture degrading phenol in the spiral

* See Note, p. 7. .

bioreactor were 1.82 mg l^{-1} min^{-1} and 34.95 mg l^{-1} for the maximum degradation rate (V_m) and half-saturation constant (K_s), respectively. The low value of half saturation constant indicates that the mixed culture has a high affinity to phenol. That is, the bioreactor could provide a large surface for microbe-contaminants contact and reaction. In addition, it is observed that the maximum degradation rate increased with increasing HRT or decreasing phenol loading.

As can be seen in Figure 5, the data obtained from experiment result seems can be best approximated by an exponential line. Hence, it is suggested that a first-order reaction model may be suitable for describing the kinetic behavior under the given experimental conditions

$$\ln\left(\frac{C_{in}}{C_{out}}\right) = K \cdot t, \qquad (5)$$

Where K is the first-order reaction rate constant (h^{-1}) and can be obtained by direct linear plot of $ln(C_{in}/C_{out})$ versus t and has a value of 0.1178 h^{-1} in this study.

Rearranging Equation (5) after combined it with Equation (3), an equation capable of predicting the removal efficiency of phenol under various HRT may be given as:

$$RE = \left(1 - e^{-Kt}\right) \times 100\% \cdot \qquad (6)$$

The solid line shown in Figure 5 is the result of model predictions. As can be seen in this figure, the stimulated results compared favorably with the experimental data obtained. Therefore, the proposed model could be utilized to predict phenol degradation in the spiral bioreactor successfully.

1* "Such endear" is ungrammatical. Furthermore, any form containing "endear" does not make good sense here. Another word is needed, or the entire sentence should be deleted.

2* See Note, p. 7.

4. Conclusions

The elimination capacity of the reactor and the pollutant loading rate play important roles in the design and operation of a bioreactor. The size of a bioreactor fro the removal of certain pollutants is primarily depend on these two parameters. Such endear is presently is in progress. This study shows that a laboratory-scale spiral bioreactor was effective for removal of phenol from wastewater. The removal efficiency in the bioreactor decreased with an increase in the inlet liquid flow rate or the inlet phenol concentration. Besides, the low value of *Ks* indicated that the spiral bioreactor was capable of providing large surface for phenol and biofilm interaction. Furthermore, the first order model could be utilized to predict phenol removal efficiency in the spiral bioreactor successfully.

Nomenclature

C_{in}	phenol concentrations at the inlet (g m^{-3})
C_{out}	phenol concentrations at the outlet (g m^{-3})
K	first-order reaction rate constant (h^{-1})
K_s	half-saturation constant (g m^{-3})
Q	the liquid flow rate (m^3 h^{-1})
t	hydraulic retention time (h)
V	effective volume (m^3)
V_m	maximum degradation rate (g m^{-3} h^{-1})

Use headline grammar (i.e., omit "the") in lists.

Acknowledgment

The authors wish to express appreciation to Dr. Cheryl J. Rutledge for her editorial assistance.

notice 3 commas

Department of English, Da Yeh University,

1* Why are different-sized fonts used in this list?
2* Remember: It is redundant to say 'A Comparative Study of...' in a title. Avoid this error in your own titles.
3* See Note, p.1.

1* References

Alemzadeh, I., Vossoughi, F. and Houshmandi, M.: 2002, 'Phenol Biodegradation by Rotating Biological Contactor', *Biochem. Eng. J.* **11**, 19–23.

Bandhyopadhyay, K., Das, D., Bhattacharyya, P. and Maiti, B.R.: 2001, 'Reaction Engineering Studies on Biodegradation of Phenol by *Pseudomonas Putida* MTCC 1194 Immobilized on Calcium Alginate', *Biochem. Eng. J.* **8**, 179–186.

Guo, G.L., Tseng, D.H. and Huang, S.L.: 2001, 'Co-Metabolic Degradation of Trichloroethylene by *Pseudomonas Putida* in a Fibrous Bed Bioreactor', *Biotechnol. Lett.* **23**, 1653–1657.

Jiang, Y., Wen, J., Bai, J., Wang, D. and Hu, Z.: 2006, 'Phenol Biodegradation by the Yeast *Candida Tropicalis* in the Presence of *m*-cresol', *Biochem. Eng. J.* **29**, 227–234.

Kallinikos, L.E. and Papayannakos, N.G.: 2007, 'Fluid Dynamic Characteristics of a Structured Bed Spiral Mini-Reactor', *Chem. Eng. Sci.* **62**, 5979–5988.

Lakhwala, S.F., Goldberg, B.S. and Sofer, S.S.: 1992, 'A Comparative Study of Gel Entrapped and Membrane Attached Microbial Reactors for Biodegrading Phenol', *Bioprocess Eng.* **8**, 9–19.

Mohanty, K., Das, D. and Biswas M.N.: 2008, 'Treatment of Phenolic Wastewater in a Novel Multi-Stage External Loop Airlift Reactor using Activated Carbon', *Sep. Purification Technol.* **58**, 311–319.

Nuhoglu, A. and Yalcin, B.: 2005, 'Modelling of Phenol Removal in a Batch Reactor', *Process Biochem.* **40**, 1233–1239.

Patterson, J.W.: 1985, *Industrial Wastewater Treatment Technology*, 2nd Edition, Butterworths, [State?] USA, ___ pp.

Rus, E., Sofer, S. and Lakhwala, F.: 1995, 'A Spiral Bioreactor for Removal and

4* See Note 1, p.4.

Recovery of Metals from Aqueous Wastes', *Bioprocess Eng.* **13**, 13–17.

Shim, J.S., Jung, J.T., Sofer, S. and Lakhwala, F.: 1995, 'Oxidation of Ethanol Vapors in a Spiral Bioreactor', *J. Chem. Technol. Biotechnol.* **64**, 49–54.

Sittig, M.: 1997, *How to Remove Pollutants and Toxic Materials from Air and Water–A Practical Guide*, Noyes Data Corporation, Park Ridge, NJ, USA, pp.

Sufit, D.J.: 1978, 'Some effects of exposing rainbow trout in phenol solution', *J. Fish Biol.* **13**, 7–17.

Yoong, E.T., Lant, P.A. and Greenfield, P.F.: 1997, 'The Influence of High Phenol Concentration on Microbial Growth', *Water Sci. Technol.* **36**, 75–79.

1* Use headline grammar (i.e., omit "the") in captions — except when complete sentences are needed. · A caption should be as brief as possible — not verbose or redundant.

1* Figure captions 3*

Figure 1. Schematic diagram of ~~the novel~~ spiral bioreactor. [See Note, p. 1]

Figure 2. Cross-section of ~~the~~ ~~spiral bioreactor~~ and mechanics of flow ~~in the spiral bioreactor~~. (a: Inside view ~~of the spiral bioreactor~~; b: Wastewater enters ~~bioreactor~~ via ~~the~~ center of ~~the~~ reaction layer ~~for layers~~ 1, 3, 5 and 5; c: Wastewater enters ~~bioreactor~~ via ~~the~~ edge of ~~the~~ reaction layer ~~for layers~~ 2, 4 and 6)

Figure 3. Reactor performance ~~for~~ continuous operation under various experimental conditions. (I: Acclimation period; II: Inlet phenol loads of 5.3–69.9 g m^{-3} h^{-1}, HRT of 60 min, Avg. removal of 100%; III: Inlet phenol loads of 111.9–201.4 g m^{-3} h^{-1}, HRT of 60 min, Avg. removal of 82.9–47.2%; IV: Inlet phenol loads of 201.4 g m^{-3} h^{-1}, HRT of 20, 40, 60, 120, 180 min, Avg. removal of 18.6–82.2%)

2* Figure 4. Effect of organic loading on phenol removal efficiency and elimination capacity (EC) of ~~the spiral~~ bioreactor.

2* Figure 5. Effect of hydraulic retention time on phenol removal efficiency of ~~the spiral~~ ~~bioreactor~~ and simulative result of the mathematic model.

2* In this case, my Note on p.7 is overruled by a prescription under "Figures" in the stylesheet: "... legend (without abbreviations)...."

3* Remember to indicate in the margins: "Insert Figure — about here."

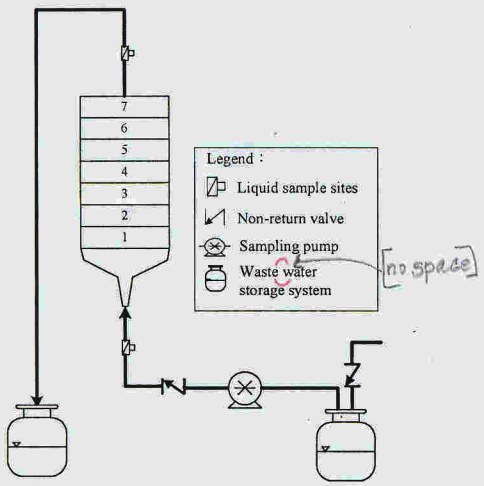

Figure 1.

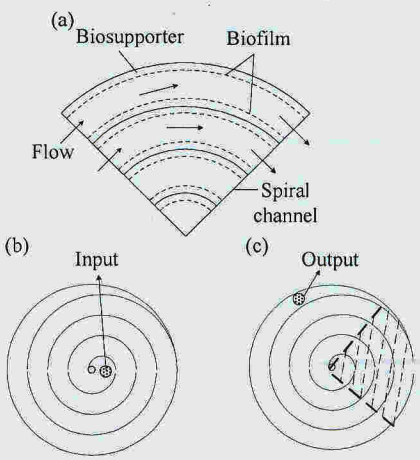

Figure 2.

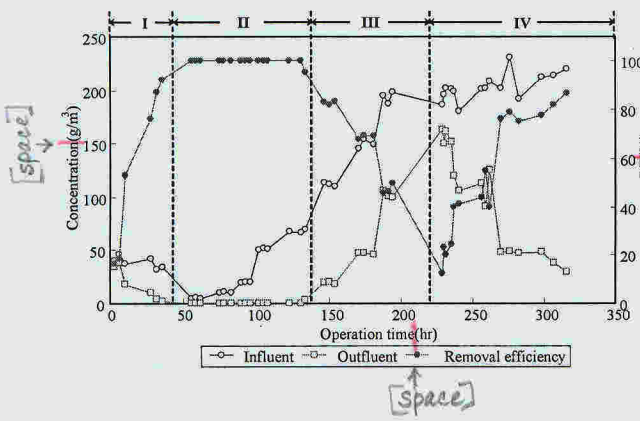

Figure 3.

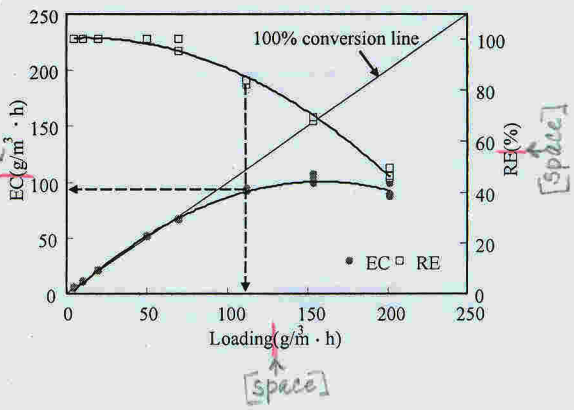

Figure 4.

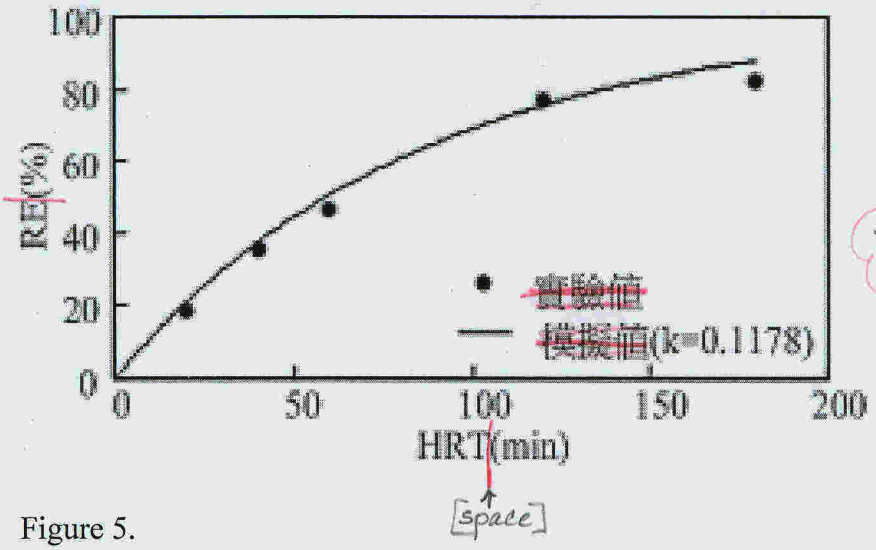

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Figure 5.

May 20, 2008

Dear Editor:

Attached please find the manuscript entitled "**Biotreatment of Phenol Contaminated Wastewater in a Novel Spiral Bioreactor**" submitted for publication in *Water, Air and Soil Pollution.* The aim of this research was to evaluate the capacity of a mixed culture to grow and degrade phenol in a spiral bioreactor operated under different hydraulic retention time and various organic loading. Besides, a mathematical model capable of predicting phenol removal efficiency and the time needed to obtain certain conversion was successfully developed. The result obtained in present work could be a useful reference for engineered biotreatment processes.

The original paper was not published elsewhere. The experiments been properly conducted with controls, replication at procedures. The article also is of international value. The authors all consent to submit the manuscript to the Journal, and all agree to transfer the copyright to the publisher.

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Sincerely,

[redacted]