

A critical review of the article Li, S. *et al.* (2023) Mathematical modelling of the biofiltration treating mixtures of toluene and N-propanol in biofilm and gas phase

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Latest publications

- Guerrero Chávez, N., González Gómez, G., Camarillo Gómez, K.A., (2023). Biofiltros como alternativa para el control de aire contaminado. En *Artículos del Congreso Internacional de Investigación Academia Journals Celaya 2023*, Tomo 6, Ingenierías, (pp. 160-164). Celaya, Gto. Academia Journals. <https://www.academiajournals.com/s/Tomo-06-Ingenierias-Articulos-Academia-Journals-Celaya-2023.pdf>
- Maeda, X., Orozco, H., Ruiz, C.A., Maeda, A., Guerrero, N. (2020). General considerations for the design of a laboratory bench to evaluate the performance of an internal combustion engine. *Pistas Educativas*, 42 (137), pp. 371-378. <https://pistaseducativas.celaya.tecnm.mx/index.php/pistas/article/view/2287/1834>
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Latest publications

- Valadez-Delapaz, N.P., Tapia-Esquivias, M., Gonzalez-Gomez G. y Malagon-Soldara S.M. (2021). Montecarlo simulation in COVID-19 infection scenarios to forecast industrial labor suspensions in Mexico, *2021 Congreso Colombiano y Conferencia Internacional de Calidad de Aire y Salud Pública (CASAP)*, Bogota, Colombia, pp. 1-5, DOI: 10.1109/CASAP54985.2021.9703440.

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Latest publications

- Pérez-Soto, G.I., Camarillo-Gómez, K.A., Rodríguez-Reséndiz, J., Manríquez-Padilla, C.G., (2024). Novel technique to increase the effective workspace of a soft robot. *Micromachines*, 15(2), 197. DOI: 10.3390/mi15020197
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The article under review explores a mathematical model used with a mixture of volatile organic compounds (VOC) in the biofilm and gaseous phase to investigate various aspects of the biofiltration process. The homotopy perturbation method is used to observe the solution of the model, which is compared to solutions by numerical methods (Li *et al.*, 2023).

The homotopy perturbation method is relatively new for solving non-linear differential equations (Filobello-Nino *et al.*, 2014). It has been evaluated in previous studies, such as the 2015 study by Sivakumar *et al.*, for the solution of a biofilter based on mass transfer. In 2020, Dharmalingam *et al.* used the method to solve a mathematical model of a bacteria- and fungi-based biofilter. In 2021, Joy Salomi *et al.* studied the solution of non-linear equations in synthesizing n-aminopiperidine.

This document aims to analyze the accuracy of the homotopy perturbation method in solving non-linear differential equations and compare it with the previously mentioned works. Li *et al.* presented a mathematical model of the gas phase and the biofilm for the biofiltration of toluene and n-propanol in their research in 2023. The homotopy perturbation technique is used to solve non-linear partial differential equations. The proposed solution is validated by comparing it with numerical simulations in MATLAB®.

The biofilter used for the research consists of an acrylic tube with an internal diameter of 19.4 cm and a height of 94 cm. Three sampling points are used to collect bed material for analysis. The effective volume of the biofilter is 12.6 l with a total packing height of 42.5 cm. A humidifier maintains an adequate humidity level and an airflow of between 5 and 10 l/min.

The mathematical model of the biofilter performance proposed is based on the mathematical model of Dixit *et al.* in 2011, which includes the microbial kinetics for mixtures of toluene and n-propanol. The proposed model considers the phenomena of convection, absorption, diffusion, and biodegradation. To describe the microbial kinetics, Monod kinetics is used with the inclusion of cross-inhibition effects of the substrate-contaminant mixture.

Four second-order partial differential equations are established: two for the biofilm phase, which describe the diffusion of the compound and the microbial kinetics through the biofilm; one for toluene, and one for n-propanol; and two for the gas part, which describes the concentration of toluene and n-propanol in the gas inside the biofilter. The equations are then converted to dimensionless units.

The homotopy perturbation method is used to solve the model, which reduces the non-linear differential equation to a series of linear differential equations. It is studied under two scenarios: one in a transient state and another in a steady state. In the first one, two scenarios are assumed, one where the microbial kinetics are saturated and another where they are not. For the steady state, it is assumed that there is no net growth or decay in the biofilm for a specific concentration.

A comparison is made in the elimination of toluene and n-propanol in the biofilm phase to observe if there is any difference in the degradation of each contaminant. Finally, the solution of the non-linear partial differential equations by the homotopy perturbation method is compared with numerical simulations performed in MATLAB® to validate the accuracy of the solution.

In conclusion, with the different simulations and parameter variations, it has been demonstrated that, for the biofilm phase, by increasing the value of the parameter that represents the influence of n-propanol on the biodegradation of toluene (α), the concentration of toluene (S_r) increases.

In addition, if the parameter value that depends on the inlet concentration of toluene (β) is increased, the concentration of toluene in the system also increases. It has also been observed that the concentration of toluene increases by decreasing the parameter value that depends on the biomass thickness (ϕ). Likewise, the concentration of n-propanol increases if β_I is increased and ϕ_I is decreased.

It was observed in the gas phase that increasing α , β , and A while decreasing ϕ and A_I leads to a rise in the concentration of toluene. Similarly, the concentration of n-propanol rises when increasing β_I and A , and decreasing ϕ_I and A_2 .

A comparison of the concentration profiles between toluene and n-propanol led to the conclusion that high loads of n-propanol can inhibit toluene degradation; meanwhile, high loads of toluene do not negatively affect the decomposition of n-propanol.

Furthermore, the solutions using the homotopy perturbation method were identical to those obtained using the numerical solution, so using the homotopy perturbation method as a solution to non-linear partial differential equations is valid.

The results of Li *et al.* in 2023 were almost identical to the simulations and experimental data presented by Sivakumar *et al.* in 2015. That is, both present a mathematical biofilter model based on mass transfer and parameter estimation using the homotopy perturbation method, which was then solved by the finite element method. The results presented were almost identical to the simulations and experimental data.

In 2020, Dharmalingam *et al.* developed a model of a biofilter based on bacteria and fungi. Their study aimed to determine the accuracy level of solving non-linear differential equations using the homotopy perturbation method. Also, when the authors compared their results with those obtained by numerical methods, they found almost identical values, demonstrating that the solution method is ideal for non-linear differential equations.

In 2021, Salomi *et al.* studied the solution of non-linear equations using the homotopy perturbation method in the synthesis of n-aminopiperidine. The accuracy level of this work agreed with those works mentioned above. Although the research of Li *et al.* in 2023 proved that the homotopy perturbation method successfully solved non-linear partial differential equations, some areas of opportunity in the presented article can be pointed out. Mainly, the references used to cite relevant and omitted information in the analyzed article have no correspondence or do not exist in the references mentioned. In conclusion, the solution of the mathematical model of biofilter using the homotopy perturbation method presented high accuracy with the numerical solutions performed previously.

Finally, the works compared with the Li *et al.* in 2023 have not the same mathematical model, but the same solution method; all of them reported results very similar to those of reference, demonstrating that the new homotopy perturbation method turns out to be promising for the solution to non-linear equations by its level of accuracy in the results obtained.

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