Applicability of CDE Equation for Simulation of Escherichia coli Bacterial Leaching from a Silty Clay Soil

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ABSTRACT

In this study, the equilibrium equation was used to predict the transfer and absorption of bacteria in the column of soil during leaching time. The coefficient determination for direct modeling through the equilibrium equation was recognized 0.58 respectively. But, in the inverse modeling, bacterial movement in soil was predicted by using equilibrium equation had higher coefficient to amount 0.91 respectively. These results show the high efficiency of model through using the equilibrium equation (CDE) in the inverse method than its direct method in simulating the bacterial movement in the soil treated. The evaluation of model sensitivity was carried out by changing the soil hydraulic parameters in a specific range, it was revealed that the model has been sensitive to some changes of the soil hydraulic parameters and also it undergoes drastic changes when the parameters of the curve simulated by the model change. Finally, the validation of the inverse method using the equilibrium equation was 0.98. Both show the accuracy and correctness of the model.

Key words: Escherichia Coli bacteria, simulation, HYDRUS-1D model.

Introduction

Manure is a valuable biological source and it has some ecologically and environmentally positive and negative effects, and it is much used in agriculture [2]. There are different kinds of poisonous gases, combination of mutation and solution, pathogenic microorganisms, drug-resistant bacteria, protozoa, and viruses in the waste matters of animals. For instance, one can refer to the fecal forms such as salmonella, shigella, escherichia coli, and dangerous protozoa such as cryptosporidium and giardia which are among pathogenic bacteria present in the waste matters of animals [4]. The model HYDRUS-1D is one of the advanced models in relation with the movement of water, minerals, and warmth in soil. This model was developed by Simonk et al. in Russian soil laboratory in the United States of America [1]. Through the use of HYDRUS-1D model, one can simulate the movement of bacteria and bacterial contamination resulting from using manure contaminated by different kinds of pathogens and some strategies can be presented for the correct use of manure and preventing the soil, surface and underground water from being contaminated by manure.

Materials and Methods

The samples of soil under study were put in PVC columns which were 35 centimeters high and 10.5 centimeters in diameter. Then, some weighted hen manure was added to the columns and it was mixed with 5 centimeters of soil. Then, the columns were studied for irrigation for 5 days. After every rinse, the drained water coming out the soil columns was put in sterilized containers. Afterward, the environment of culture was taken out from the incubator and some bacterial colonies were observed [3]. For every column of soil, the software of operation and the density of Escherichia coli bacteria in the drained water during the time have been simulated. The needed main inputs of the model for simulation consist of: information related to time and printing the results, soil hydraulic characteristics, introducing the primary and boundary conditions for the water flow.

Results and Discussion

Sensitivity analysis:
Some of the results obtained from the determination and analyzing the sensitivity of the model have been shown in Fig 1. Model was sensitive to the changes of soil hydraulic parameters (i.e.) and the amount of model predictions changed as the parameters were changed.

Fig. 1: The sensitivity analysis model with the modified data: A (saturated water content (qs) with the use equilibrium equation), B (water retention in soil (n) with the use equilibrium equation).

**Calibration:**

The simulated BTC of E.coli with CDE using direct and invers method vs observed E.coli BTC are shown in Fig 2. There was a weak correlation between the observed BTC and the simulated by the model using the CDE in the direct modeling (Fig 2-A). The value of coefficient 0.58 shows that the equilibrium equation with the direct method was not able to estimate exactly the amount of bacterial movement in soil (Fig 2-A). while the value of coefficient 0.91 with equilibrium equation( in the inverse method shows a high correlation between the measured data and the simulation (Fig 2-B).

The fitted hydraulic parameters with CDE using invers method are shown in Table 1.

![Fig. 2: Simulation of the E.coli bacteria using of equilibrium equations (CDE) treated by hen manure: A) the direct method. B) The inverse method.](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \alpha )</th>
<th>n</th>
<th>( k_s )</th>
</tr>
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<tbody>
<tr>
<td>CDE</td>
<td>0.1068</td>
<td>0.4873</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>(0.0712-0.1068)</td>
<td>(0.344-0.516)</td>
<td>(0.008-0.012)</td>
</tr>
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**Accuracy measures (statistical measures):**

In order to evaluate the accuracy of the model predictions, some statistical measures were calculated using model predictions and measured data. The statistics included correlation coefficient (R²), Mean difference between predicted and observed data (Md), and root mean square error (RMSE) with the following equations. The statistics are shown in Table 2.

![Table 1: Some fitted Hydraulic parameters of the model.](image)

<table>
<thead>
<tr>
<th>Equation</th>
<th>direct method</th>
<th>inverse method</th>
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<tbody>
<tr>
<td></td>
<td>Md</td>
<td>RMSE</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>-12800</td>
<td>42.81</td>
</tr>
</tbody>
</table>
Md values shows model overestimation, while negative Md values shows model underestimation. Md values for equilibrium equation in using direct modeling and inverse modeling had negative amounts.

Less RMSE values shows more accuracy in model prediction. RMSE values for model predictions equilibrium equation in direct method compared with invers method was less. This shows more accuracy invers method than the direct method with using equilibrium equation.

Testing (validation) step:

To check the model performance and to know if the model can be used for the same cases, a validation steps was run using the data obtained from other replications in the same treatment. The results are shown in Fig 3. The testing results showed that model could predict Ecoli leaching with good accuracy both using CDE equations.

Fig. 3: Validation of model predictions using equilibrium equation treated by hen manure.

Conclusion:

Comparing the direct and inverse methods of HYDRUS-1D for predicting Ecoli transport through the soil using CDE equation, the inverse method was more effective than direct method. with the ability of synchronic estimation, estimation of the needed coefficients for the model with the hydraulic characteristics in a specific environment and putting the coefficients in those defined limits the results were by large more precise and had a high correlation with the measured data along with the equilibrium equation compared with the direct method.

References