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Model prediction of contaminant transport in porous soil

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General Note
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ABSTRACT

The general objective of the study was prediction of contaminant transport in porous soil. Standard laboratory experiment where performed to monitor the movement of nitrate transport in porous soil and to predict the concentration of pollutants at different depth at time interval of 3days, 9days, 15days, 21days and 27days respectively. Soil samples were collected at different depth and this was carried out for a period of five months. The concentration of contaminants increases with increased in days of sample collection. Therefore, to investigate the flow of the contaminant in porous soil, the model developed shows the simulation values that were compared with experimental values. Results shows that they were in good agreement with R^2 ranging from 0.807 to 0.81.The developed model will be a useful tool in monitoring flow of contaminant transport in a porous soil.

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Keywords: Model, Porous soil, Nitrate transport, Soil samples.

1. INTRODUCTION

If untreated waste flowing into the septic tank does not receive adequate treatment, it simply moves into the groundwater unnoticed thus causing problem on public health [1], [2]. Leaking septic tanks will cause untreated sewage to short-circuit to the groundwater leading to pollution and possible outbreak of epidemics. Moreover, raw sewage can escape from leaking septic tanks and pollute surface waters such as ponds, streams, springs, lakes and even swimming pools. Several studies have found the presence of Hepatitis A, Shigella spp, E coli O157, Giardia and Cryptosporidium resulting from fecal contamination [3], [4],[5],[6]. Nevertheless, displacement studies would not be left behind because, this is actually what gave the insight of contaminant transport processes like; diffusion, dispersion, sorption, retardation and transformation [7],[8],[9]. Therefore, the results from these models will give an insight into the extent to which groundwater has been polluted by contaminant. Therefore, the main objective of this study was to predict contaminant transport in a porous soil.

2. MODEL DERIVATION

From the below governing equation

$$\frac{\partial c}{\partial t} = \frac{D}{R}\frac{\partial^2 C}{\partial Z^2} - \frac{V}{R}\frac{\partial C}{\partial Z} - \frac{KC^n}{R}\, mt^{m-1} \tag{1a}$$

Let $\frac{KC^n}{R}\, mt^{m-1} = \beta$ (1b)

The expression can be written as

$$\frac{\partial c}{\partial t} = \frac{D}{R}\frac{\partial^2 C}{\partial Z^2} - \frac{V}{R}\frac{\partial C}{\partial Z} = \beta \tag{1c}$$

Let $C = TZ$

Applying Bernoullis method of separation of variables

$$\frac{T^I}{T} = \frac{D}{R}X^{II} - \frac{V}{R}X^I - \beta = \gamma^2 \tag{2}$$

$$\frac{T^I}{T} = \gamma^2 \tag{3}$$

$$\frac{D}{R}X^{II} - \frac{V}{R}X^I - \beta - \gamma^2 = 0 \tag{4}$$

From equation (3) $T = ae^{\gamma 2t}$ (5)

Also from equation (4) the auxiliary equation yields

$$\frac{D}{R}m^2 - \frac{V}{R} - \beta - \gamma^2 = 0 \tag{6}$$

$$M = \frac{V}{R}\,\frac{\pm\sqrt{\frac{V^2}{R} + 4\frac{D}{R}\beta\gamma^2}}{2\frac{D}{R}} \tag{7}$$

$$X = ACosMz + BSinMz \tag{8}$$

Combining eq (5) and (8) we have

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$C(z,t) = ae\gamma^2[ACosMz + BSinMz]$ (9)

Subject equation (9) into boundary condition

At t=0, z=0 and $C=C_0$ yield ;

$0 = aA$

ie $C[z,t] = C_0 e^{\gamma^{2t}}[ACosMz + BSinMz]$ (10)

$\frac{\partial C}{\partial z} = C_0 e^{\gamma^{2t}}[-AmSinMz + BMCosmz]$ (11)

at $Z = 0, \frac{\partial C}{\partial Z} = 0$ (12)

$0 = C_0 e^{\gamma^{2t}} [CosMz]$ (13)

at $x = L, \frac{\partial C}{\partial Z} = 0$ (14)

$Yields$

$0 = C_0 e^{\gamma^{2t}}[-AmSinML]$ (15)

$C_0 e^{\gamma^{2t}} \neq 0$ (16)

$AmSinmL = 0$ (17)

$ML = n\pi$, (n= 1,2 3,) (18)

$M = \frac{n\pi}{L}$ (19)

$C(z,t) = C_0 e^{\gamma^{2t}} \left[Cos \frac{n\pi z}{L}\right]$ (20)

Where Z = vertical depth of transport flow

t = time of sampling (days)

L = length of transport flow (m)

$C_0 = initial\ concentration$ (mg/l)

3. MATERIALS AND METHOD

Standard laboratory experiment were performed to monitor the movement of nitrate transport in porous soil and to predict the concentration of pollutants at different depth at time interval of 3days, 9days, 15days, 21days and 27days respectively. Soil samples were collected at different depths of 0.5m,1m, 1.5m, 2m, 2.5m, 3m, 3.5, 4m, 4.5m, and 5m. This was carried out for a period of five months. Thereafter, the experimental results were compared with the predicted values for model validation.

4. RESULTS AND DISCUSSION

The results are presented both in tables and graphical representation for nitrate concentration in porous soil. Figures 1-5 shows the experimental (Ce) and predicted (Cp) transport of contaminants at different depths in 3, 9, 15, 21, and 27days. The R^2 values ranges from 0.807 to 0.811 respectively. Tables 1-5 show an indication of positive agreement between experimental and predicted model. Most of the experimental data gave higher values than the predicted values [10]. From fig.1, the concentration was at the peak of 0.5m to a minimum point of 5 m. The experimental and predicted results give the best fits as shown in fig.1. Also in figures 2, 3, 4

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and 5, their concentration increases as the day increases. The concentration of the contaminant at day 3 had small values when compared with the other figures. In summary, the concentration of the contaminants increases with increased in days of sample collection as shown in below figures except in fig.4 were the concentration values decreased little on day 21 at the depth of 0.5m. This effect could be attributed to non- uniformity of the particle sizes of soil and soil porosity.

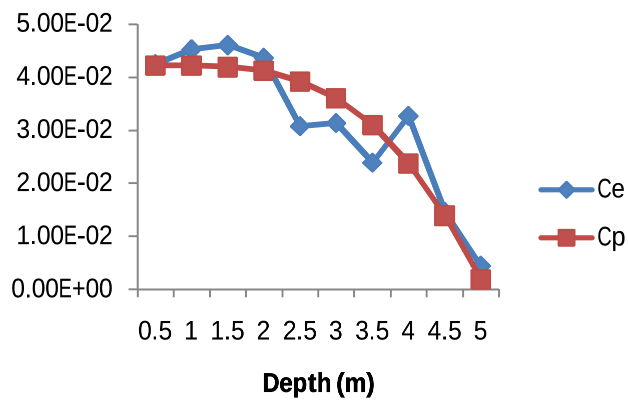

Figure 1 Predicted and Experimental values of nitrate concentration at different depth in 3days

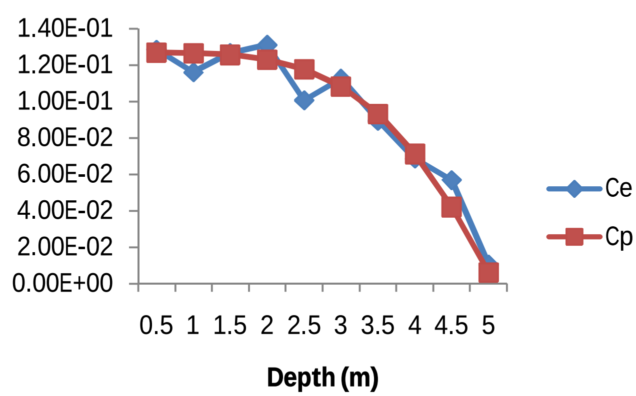

Figure 2 Predicted and Experimental values of nitrate concentration at different depth in 9days

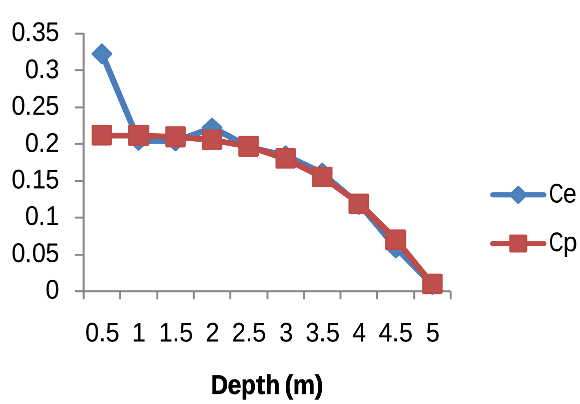

Figure 3 Predicted and Experimental values of nitrate concentration at different depth in 15 days

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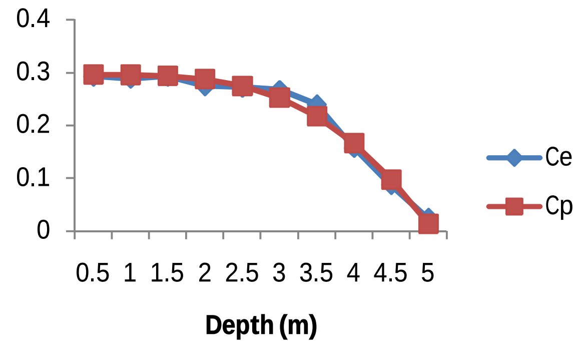

Figure 4 Predicted and Experimental values of nitrate concentration at different depth in 21 days

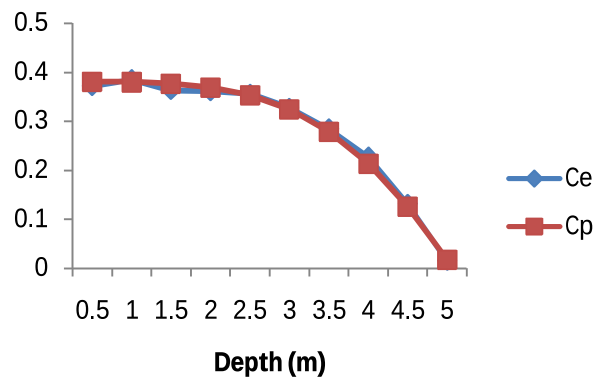

Figure 5 Predicted and Experimental values of nitrate concentration at different depth in 27days

Table 1 Predicted and Experimental Values of Nitrate Concentration at Different Depth in 3days

Depth(m)	Predicted concentration (mg/l)	Experimental concentration (mg/l)
0.5	4.22E-02	4.25E-02
1.0	4.22E-02	4.53E-02
1.5	4.19E-02	4.61E-02
2.0	4.12E-02	4.37E-02
2.5	3.92E-02	3.08E-02
3.0	3.61E-02	3.14E-01
3.5	3.10E.02	2.39E-02
4.0	2.37E-02	3.27E-02
4.5	1.39E-02	1.46E-02
5.0	1.-90E-3	4.40E-03

Table 2 Predicted and Experimental values of nitrate concentration at different depth in 9 days

Depth (m)	Predicted concentration (mg/l)	Experimental concentration (mg/l)
0.5	1.27E-01	1.29E-01

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1.0	1.27E-01	1.16E-01
1.5	1.26E-01	1.27E-01
2.0	1.23E-01	1.31E-01
2.5	1.18E-01	1.01E-01
3.0	1.08E-01	1.13E-01
3.5	9.31E.02	8.94E-02
4.0	7.11E-02	6.86E-02
4.5	4.19E-02	5.68E-02
5.0	5.90E-02	1.01E-03

Table 3 Predicted and Experimental values of nitrate concentration at different depth in 15 days

Depth (m)	Predicted concentration (mg/l)	Experimental concentration (mg/l)
0.5	2.11E-01	3.22E-01
1.0	2.11E-01	2.04E-01
1.5	2.09E-01	2.04E-01
2.0	2.05E-01	2.22E-01
2.5	1.96E-01	1.96E-01
3.0	1.80E-01	1.84E-01
3.5	1.55E.01	1.61E-01
4.0	1.19E-01	1.18E-01
4.5	6.98E-02	5.86E-02
5.0	9.90E-03	9.30E-03

Table 4 Predicted and Experimental values of nitrate concentration at different depth in 21 days

Depth(m)	Predicted concentration (mg/l)	Experimental concentration (mg/l)
0.5	2.96E-01	2.93E-01
1.0	2.95E-01	2.88E-01
1.5	2.93E-01	2.93E-01
2.0	2.87E-01	2.74E-01
2.5	2.75E-01	2.72E-01
3.0	2.53E-01	2.67E-01
3.5	2.17E.01	2.39E-01
4.0	1.66E-01	1.57E-01
4.5	9.78E-02	8.74E-02
5.0	1.39E-02	2.46E-02

Table 5 Predicted and Experimental values of nitrate concentration at different depth in 27 days

Depth(m)	Predicted concentration (mg/l)	Experimental concentration (mg/l)
0.5	3.80E-01	3.37E-01
1.0	3.80E-01	3.85E-01
1.5	3.77E-01	3.64E-01

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2.0	3.69E-01	3.61E-01
2.5	3.53E-01	3.56E-01
3.0	3.25E-01	3.28E-01
3.5	2.79E.01	2.85E-01
4.0	2.13E-01	2.27E-01
4.5	1.26E-01	1.31E-01
5.0	1.79E-02	1.58E-02

5. CONCLUSION

The flow of contaminants in a porous soil was carefully investigated using standard laboratory procedures. The developed model was calibrated using the result obtained from the laboratory experiment. The model developed generated simulation values from high values to low concentration. The flow of the contaminant in the porous soil decreases with increased in depth of the soil. Also, the concentration of the contaminants increases with increased in days of sample collection as shown in tables 1-5 except table 4 where the concentration values decreased a little, on day 21 at a depth of 0.5m. The experimental and predicted values express the best fits and their R^2 ranged from 0.807 to 0.811. Therefore, the developed model will be a useful tool in monitoring flow of contaminant transport in a porous soil.

Author's contribution

Authors EAC and AJC designed the study, wrote the protocol and edited the manuscript. Author EAC managed the literature searches, statistical analyses of the study, wrote the first draft of the manuscript and editing of the manuscript. Both authors read and approved the final manuscript.

Conflicts of Interests

Declared none

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