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# Modeling Penetrating Unconfined Bed Pressure Flow Influences on Deposition of Methylomonas in Lateritic and Silty Formation

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**Abstract**

This paper evaluates pressures of flow influences on Methylomonas observed through formation characteristic to penetrating unconfined bed. The study was able to investigate change in Methylomonas concentration with respect to time and depth at shallow phreatic zone. These conditions imply that these microbes are found to migrate at every stratum within short period of time in the coastal location. Thus at shallow depth, the rate of migration were influenced by high degree of porous formation deposited in the study area. Such condition has established fast migration with high concentration of Methylomonas in the study location. These conditions were experienced on physical process, while on ground water exploration; it resulted to abortive well due to pollution from deposition of Methylomonas. Monitoring and evaluation were the best option in order to determine the transport process and rate of concentration. Mathematical modeling methods were found appropriate thus; it was applied by developing the model and simulating it. Theoretical values were generated and compared with other measured value from column experiment. Both values developed favuorable fits to validate the model. The study is imperative because the rate of migration including stratum that deposits highest level of Methylomonas concentration has been observed. Experts will definitely apply these conceptual applications to monitor the migration rate of Methylomonas in the study location.

***Keywords:*** Methylomonas deposition; Modeling Penetrating; Silty Formation; Unconfined Pressure Flow.

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## 1. Introduction

Over the last few decades, the deterioration of both groundwater quality and quantity has become a global phenomenon, which will further intensify the demand for drinking Water increases [1]. Numerous severe cases of groundwater contamination with reference to storm water infiltration have been documented worldwide [2, 3, 4]. Few studies have also been documented nationally on groundwater with reference to major ions, trace elements and bacteriology [5, 6, 7. However literature is silent on the impact of storm water infiltration into groundwater. In recent years attention on the increasing ionic concentration of traces metals in groundwater as result of storm water infiltration has been studied by various workers [8, 9, 10, 11, 12, 13, 14]. These have been attributed to human interference, proliferation of industries and recent agriculture practices in urban areas where storm water flow recharges the aquifer system and thus degrading the water quality. It is often difficult to determine the exact source of major ions pollutants [13] because there are many potential sources of groundwater contamination including urban storm water runoff. Storm water infiltration in urban areas is cause of concern with regard to the risk of groundwater pollution [7, 14]. Storm water infiltration has been shown to affect groundwater quality and quantity [3, 8]. Contaminants present in urban storm water include volatile organic compound, pesticides, nutrients, and trace elements [3]. This can originate at the land surface or in the atmosphere [2]. Some constituents either volatize during storage or sorbs to the particulate matter [11, 15] and are not transported to the water table; however, are more persistent, and may threaten groundwater quality. In a vast majority of developing countries, fast growing populations combined with poor living conditions in rural areas have forced many people to migrate to cities in search of better living conditions. This has led to a dramatic expansion of most of the major cities throughout developing countries, mainly via the uncontrolled growth of slums or squatter settlements on their fringes [15, 16, 17, 18]. Nitrogen is one of the most abundant elements in the Earth's biosphere and one of the six elements (C, H, O, N, P, and S) that are the major constituents of living tissue. Nitrogen gas ($N_2$) comprises approximately 78% of the Earth's atmosphere, but this is largely unavailable as a nitrogen source for most living organisms. Consequently, nitrogen availability in all ecosystems is largely dependent on inputs of biologically available nitrogen from external sources or internal cycling of nitrogenous compounds into biologically available forms. Nitrogen often limits biological production in estuaries, oceans, and many terrestrial systems [13 15, 17, 19] and can be limiting in lakes, streams and wetlands.

## 2. Materials and Methods

Standard laboratory experiment where performed to monitor the rate of Methylomonas concentration using column experiment at different soil formation. The soil depositions of the strata were collected in sequence based on the structural deposition at different locations. These samples were collected at different locations generating variation at different depth. It produced different migration of Methylomonas concentrations through pressure flow at different strata. The experimental result was applied to compare with the theoretical values to determine the validation of the model.

### *2.1 Governing Equations*

Deterministic modeling techniques were used by applying analytical solution. The governing equations for the study are expressed in Equation 1:

$$\overline{V}\frac{\partial c^2}{\partial t^2} = \overline{K}h_{(x)}\frac{\partial c}{\partial Z} - \frac{Q}{n_e}\frac{\partial c}{\partial Z} \tag{1}$$

**Nomenclature**

| | | | |
|---|---|---|---|
| C | = | Methylomonas Concentration | [ML-$^3$] |
| H($_x$) | = | Aquifer thickness | [L] |
| $\overline{K}$ | = | Homogenous permeability | [LT-$^1$] |
| Q | = | Rate of flow | [LT-$^1$] |
| Ne | = | Porosity | [-] |
| T | = | Time | [T] |
| Z | = | Variation Depth | [L] |

Substituting $C = TZ$

$$\overline{V}\,ZT^{11} = \overline{K}h_{(x)}Z^1T - \frac{Q}{n_e}Z^1T$$

Dividing by T,Z, we have

$$\overline{V}\frac{T^{11}}{T} = \overline{K}h_{(x)}\frac{Z^1}{Z} - \frac{Q}{n_e}\frac{Z^1}{Z} \tag{2}$$

$$\overline{V}T^{11} = \overline{K}h_{(x)}Z^1 - \frac{Q}{n_e}Z^1 = \beta^2 \tag{3}$$

$$\overline{V}\frac{T^1}{T} = \beta^2 \tag{4}$$

$$\overline{K}h_{(x)}\frac{Z^1}{Z} = \beta^2 \tag{5}$$

$$-\frac{Q}{n_e}\frac{Z^1}{Z} = \beta^2 \tag{6}$$

This implies that equation (5) and (6) can be expressed as:

$$\left[\overline{K}h_{(x)} - \frac{Q}{n_e}\right]\frac{Z^1}{Z} = \beta^2 \tag{7}$$

$$\overline{V}\frac{T^{11}}{T}\frac{dc}{dt} = \beta^2 \tag{8}$$

$$\overline{V}\frac{d^2}{dt^2} = \beta^2 \tag{9}$$

$$\overline{K}h_{(x)}\frac{dc}{dz} = \beta^2 \tag{10}$$

$$\frac{Q}{n_e}\frac{dc}{dz} = \beta^2 \tag{11}$$

$$d^2z = \left[\frac{\beta^2}{\overline{V}}\right] = dz \tag{12}$$

$$\int d^2 - \int\frac{\beta^2}{\overline{V}}dz \tag{13}$$

$$dz = \frac{\beta^2}{\overline{V}}z + C_1 \tag{14}$$

$$\int dz = \int\frac{\beta^2}{\overline{V}}z\ dz + C_1\int dz \tag{15}$$

$$z = \frac{\beta^2}{\overline{V}}\frac{z^2}{2} + C_1 + C_2 \tag{16}$$

$$z = \frac{\beta^2}{\overline{V}}\frac{z^2}{2}\ C_1z + C_2 \tag{17}$$

$$z = 0$$

$$\boxed{z = \frac{\beta^2}{2\overline{V}}z^2 + C_1z + C_2} \tag{18}$$

Auxiliary Equation becomes:

$$\Rightarrow \frac{\beta^2}{2\overline{V}} z^2 + C_z + C_2 = 0 \quad (19)$$

Applying quadratic expression we have

$$M = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad (20)$$

$$M_{1,2} \; \frac{-C_1 \sqrt{C^2 - 4\frac{(\beta^2)}{4\overline{V}} C_2}}{\frac{\beta^2}{\overline{V}}} \quad (21)$$

$$M_1 = \frac{-C_1 + \sqrt{C^2 - 2C_2 \frac{\beta^2}{2\overline{V}}}}{\frac{\beta^2}{\overline{V}}} \quad (22)$$

$$M_2 = \frac{-C_1 - \sqrt{C_1^2 - 2C_2 \frac{\beta^2}{\overline{V}}}}{\frac{\beta^2}{\overline{V}}} \quad (23)$$

Assuming this discriminate is a complex root; therefore, equation (22) and (23) can be expressed as:

$$\boxed{C = [T, Z] = D_1 \, Cos \, M_1 t + D_2 \, Sin \, M_2 z} \quad (24)$$

But if $t = \frac{d}{v}$

$$\boxed{C = [T, Z] = D_1 \, Cos \, M_1 \frac{d}{V} + D_2 \, Sin \, M_2 \frac{d}{V}} \quad (25)$$

And Z = $V.T$

$$C = [T, Z] = D_1 \, Cos \, M_1 V.t + D_2 \, Sin \, M_2 V.t \quad (26)$$

## 3. Results and Discussions

Results on the concentration of Methylomonas at different soil depths and time are presented in Tables 1 to 4.

**Table 1:** Theoretical values of Methylomonas concentration at different depths

| Depth [m] | Methylomonas Concentration (Mg/L) |
|---|---|
| 3 | 7.34E-03 |
| 6 | 0.0132 |
| 9 | 0.034 |
| 12 | 0.045 |
| 15 | 0.042 |
| 18 | 0.046 |
| 21 | 0.054 |
| 24 | 0.053 |
| 27 | 0.073 |
| 30 | 0.082 |

**Table 2:** Theoretical values of Methylomonas concentration at different depth

| Time per day | Methylomonas Concentration (Mg/L) |
|---|---|
| 10 | 0.47 |
| 20 | 0.84 |
| 30 | 1.34 |
| 40 | 1.56 |
| 50 | 2.19 |
| 60 | 2.66 |
| 70 | 2.88 |
| 80 | 3.43 |
| 90 | 3.82 |
| 100 | 4.24 |

**Table 3:** Comparison of Theoretical and Measured Values of Methylomonas Concentration at different Depth

| Depth [m] | Methylomonas Theoretical Values (Mg/L) | Methylomonas Measured Values (Mg/L) |
|---|---|---|
| **3** | **7.11E-03** | **6.00E-03** |
| **6** | **0.0142** | **0.012** |
| **9** | **0.021** | **0.018** |
| **12** | **0.028** | **0.024** |
| **15** | **0.035** | **0.03** |
| **18** | **0.042** | **0.036** |
| **21** | **0.049** | **0.042** |
| **24** | **0.056** | **0.048** |
| **27** | **0.064** | **0.054** |
| **30** | **0.071** | **0.06** |

**Table 4:** Comparison of Theoretical and Measured Values of Methylomonas Concentration at different Time

| Time per day | Methylomonas Theoretical Values (Mg/L) | Methylomonas Measured Values (Mg/L) |
|---|---|---|
| 10 | **0.41** | **0.4** |
| 20 | **0.83** | **0.81** |
| 30 | **1.25** | **1.22** |
| 40 | **1.67** | **1.63** |
| 50 | **2.09** | **2.04** |
| 60 | **2.51** | **2.45** |
| 70 | **2.92** | **2.88** |
| 80 | **3.34** | **3.27** |
| 90 | **3.76** | **3.68** |
| 100 | **4.18** | **4.09** |

The study on the migration of Methylomonas in coastal area has been expressed in the system through the following graphical representation in Figures 1 to 4.

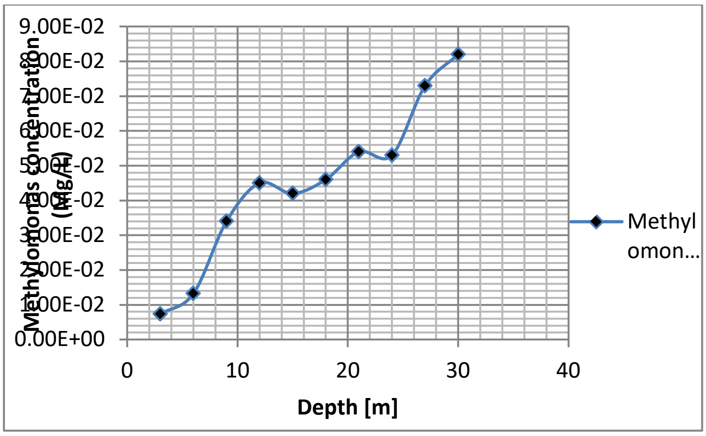


**Figure 1:** Theoretical values of Methylomonas concentration at different depth

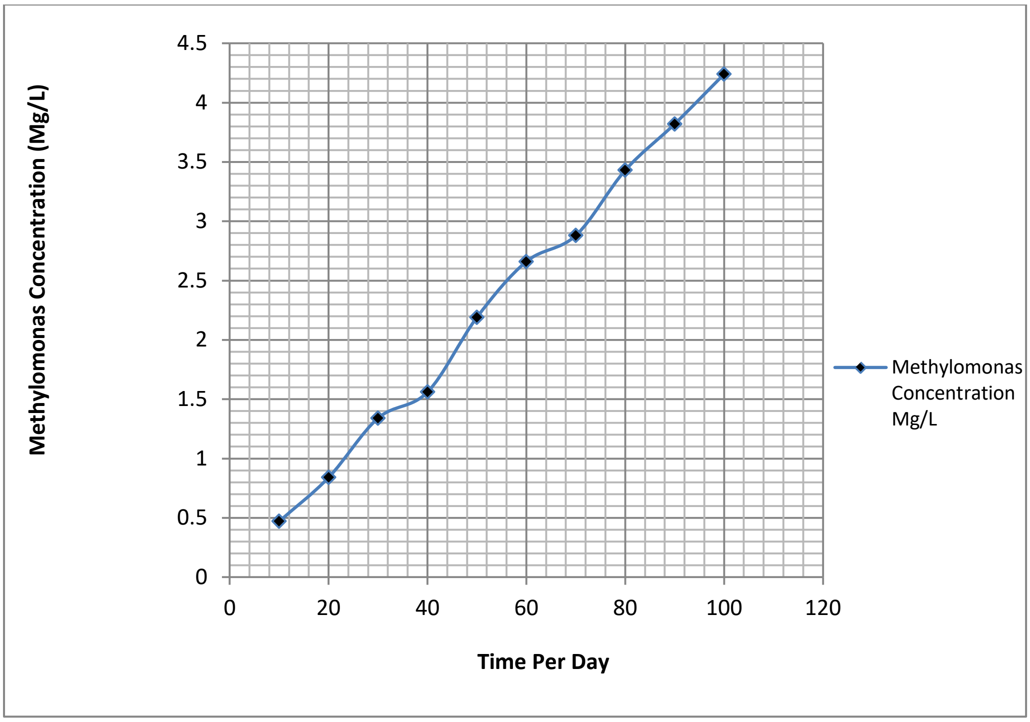


**Figure 2:** Theoretical values of Methylomonas concentration at different Time

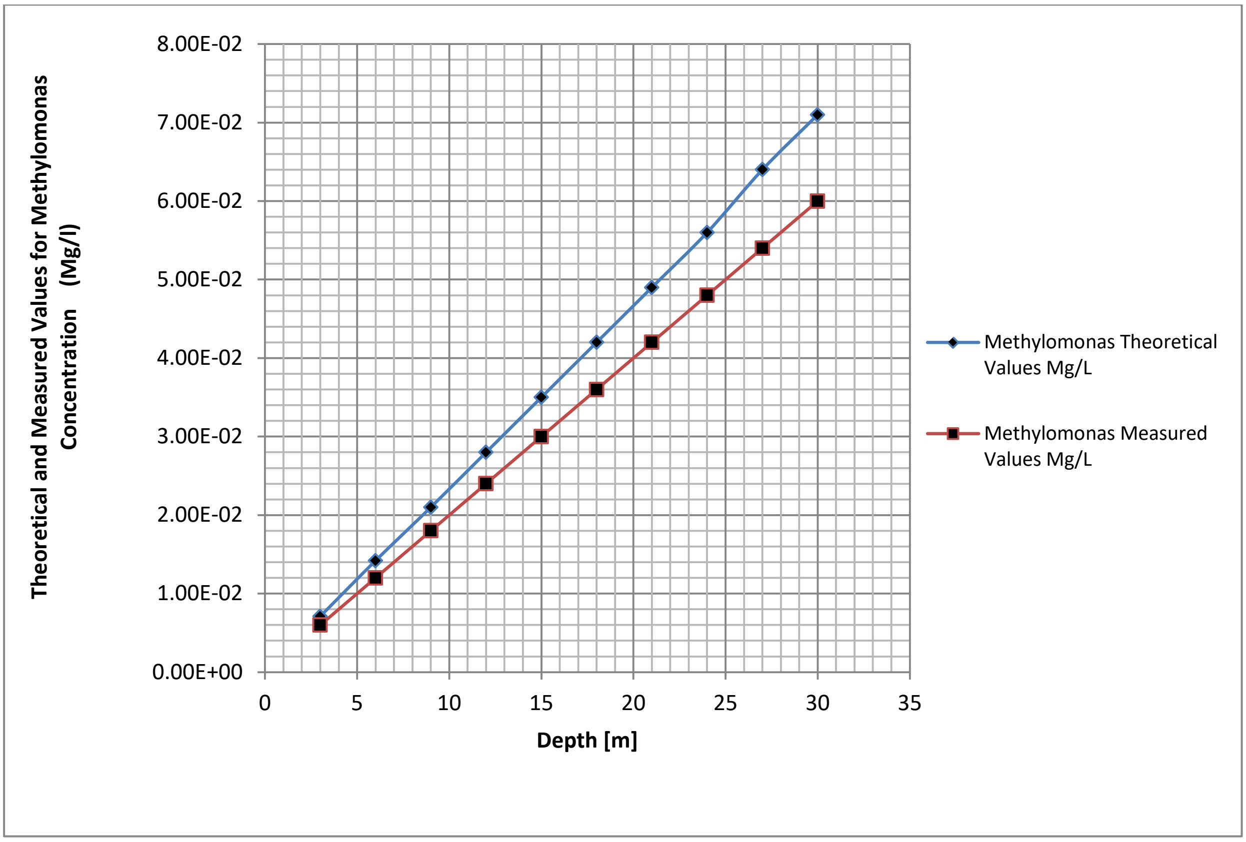


**Figure 3:** Comparison of Theoretical and Measured Values of Methylomonas Concentration at Different Depth

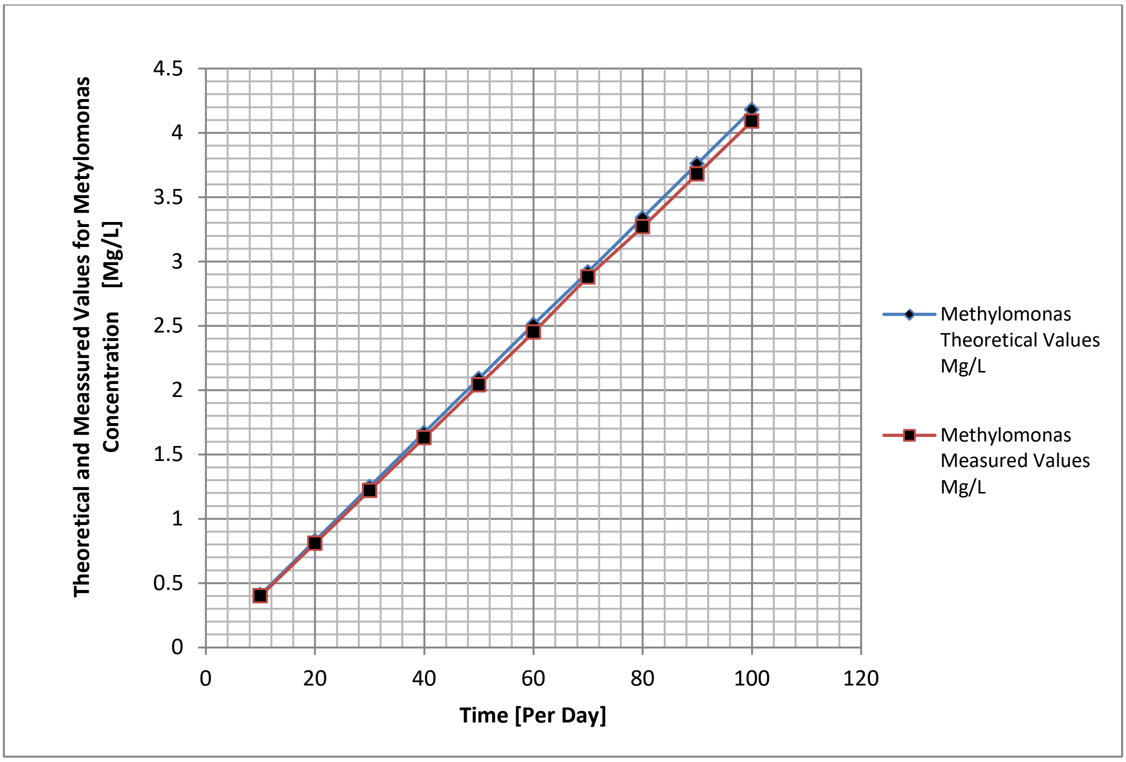


**Figure 4:** Comparison of Theoretical and Measured Values of Methylomonas Concentration at Different Time

Figure 1 expressed the transport system in fluctuation through exponential phase from the lowest at 3m to the highest at 30m. Figure 2 express the system in terms of time which developed slight fluctuation from the lowest at 10 days and the optimum at 100 days. Figure 3 developed the comparison between the theoretical and measured values, both parameters express exponential phase with best fits from the lowest at 3m and optimum at 30m. However, Figure 4 maintained a linear increase from the lowest at 10 days and the highest at 100 days thus express best fit. Moreover, rapid migration was observed from the lowest at 3m to the optimum at 30m. The behaviour of microbes was base on the structural setting of the strata and the rate of porosity from the transition zone to silty formation as observed. Such condition developed fracture at the porous sand stone and the migration of these microbes were influenced by these condition as rapid concentration are observed at 30m at the period of 100 days. The theoretical values were compared with measured values and both parameters developed favuorable fits validating the model.

## 5. Conclusions

Ground water is a valuable resource and most people around the world rely on its abstract exploration and exploitation for water supply. The study observed a serious (heavy) ground water pollution which would be a threat to most coastal area in deltaic location. The deposition of the Methylomonas was observed to be predominant on the structural setting of the formation. High degree of porosity through saturation of lateritic soil transiting through a porous sand stone to silty formation pressured rapid migration of Methylomonas deposition to Phreatic environment. The rate of pollution source was observed through a physical process in ground water exploration in the study area. To solve these problems, mathematical modeling techniques were found appropriate in other to monitor and evaluate the deposition and concentration level of the microbes. The developed governing equation produced a model to predict the deposition of the microbes in the study location. The developed model was simulated, theoretical values were generated and measured values were compared with the theoretical values. Both parameters generated favuorable fits, thus validating the model. Experts would find this model as a useful tool in monitoring and evaluating the deposition of Methylomonas in coastal environment. Methylomonas has constantly caused lots of ill health and deaths in the deltaic environment, as a result of high deposition of the contaminants in the study environment.

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