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Velocity dynamics effect on partial deposition of lead of heterogeneous coarse formation applying predictive model

Abstract

This paper monitors partial deposition of lead through the influences from velocity dynamics in heterogeneous coarse depositions. The study examine rate of deposition at different strata under the influences of heterogeneous coarse in the study location, the transport of lead in coarse formation developed variation of concentration through heterogeneity of velocity of fluid dynamics in the study area, the system were develop by considering the migration rate of the contaminant at various depth, the developed system generated the governing equation to produced the derived model at different phase, the derived solution generated model at different phase base on the behaviour of velocity dynamics in the study area, the study is imperative because the derived model will definitely monitor the rate of partial deposition of lead in the study location.

Keywords: velocity dynamics, partial deposition, lead, heterogeneous, coarse formation

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Introduction

A large design of deep geological repository for high level radioactive wastes (HLW) are based application of multi-barrier approach with segregation of the waste from the environment. The multi-barrier notion includes the natural geological barrier such as (host rock), engineered barriers includes compacted sand-Bentonite mixtures (placed around waste containers or apply as buffer and sealing elements) and metal canister. It has observed that Compacted Bentonite-based materials are important materials for this purpose where develop low permeability, generating high swelling and high radionuclide retardation capacities.[1–4] Engineered barriers are frequently consisting of compacted bricks. These are where bricks are placed around waste container are used to form sealing buffers, it has been observed that the so-called technological voids found to be between the bricks themselves or between bricks, canisters and the host rock are unavoidable. As an example, 10mm thick gaps between Bentonite blocks and canister and 25 thick mm gaps between the Bentonite blocks and the host rock have been considered in the basic design of Finland.[5] These technological voids appeared to be equal to 6.6 % of the volume of the gallery in the FEBEX mock-up test.[6] Once placed in the galleries, engineered barriers are progressively hydrated by pore water infiltrating from the host-rock. This water infiltration is strongly dependent on the initial state of the compacted material water content, suction and density, e.g.,.[7,8] Indeed, it has been shown that water transfer in unsaturated swelling compacted Bentonite or sand Bentonite mixtures is strongly dependent on the imposed boundary conditions in terms of volume change. As shown in Yahia,[9] Komine et al.[10,11] and Ye et al.,[12] the degree of swelling allowed significantly affects the amount of infiltrated water, with much water absorbed when swelling is allowed and a minimum amount of water absorbed when swelling is prevented. Volume change conditions also appeared to have, through microstructure changes, significant influence on the hydraulic conductivity. In this regard, the degree of swelling allowed by the technological voids described above has a significant influence on the hydro-mechanical behaviour of the compacted Bentonite and their effects need to be better understood. Swelling results in a decrease in dry density that may lead to a degradation of the hydro-mechanical performance of engineered barriers.[12,13] As a result, the safety function expected in the design may no longer be properly ensured. Therefore, a better understanding of the effects of the technological voids is essential in assessing the overall performance of the repository.

Theoretical background

The deposition of velocity on fluid flow was express on the effect reflected on partial deposition of lead in heterogeneous coarse formation, these parameter determine lead deposition in every structure stratum, the study monitored the behaviour base on the velocity of flow dynamics in heterogeneous coarse deposition, such condition were found to influences the deposition rate of lead in the study area, heterogeneity of coarse deposition express the structure intercedes of coarse deposition thus the dynamics of flow in the deposited strata, in such geological setting the formation predominate the flows thus the depositions of substances such as lead, this condition implies that lead partial deposition were observed to express it rate of migration base on the influences from the dynamics from velocity of flow and heterogeneity from coarse soil,. Predicting partial deposition of such substances in soils, the migration rate of the substance were observed base on the rate of concentration from the lithology of the formation, these relationship express the variable significant influences in the dynamics of velocity on partial deposition of lead. The system were developed considering these variables that should play significant role in the deposition of lead, formation characteristic under the influences structural stratification of the formation were thoroughly integrated in the system, the significant role of the degree of porosity and permeability express the imperative role in the system, the developed system generated the governing equation that determine the velocity dynamics on partial deposition of lead in heterogeneous coarse deposition. The governing equation are derived to generate the reflection of velocity dynamics in partial deposition of the substances in heterogeneous coarse formation, the derived solution are express below considering various condition that may pressure the substance to generate slight variation of lead concentration in heterogeneous coarse formation.

Developed governing equation

$$\bar{V}\frac{\partial q}{\partial t} = \frac{\varphi}{ne}\frac{\partial q}{\partial z} - Kx\frac{\partial q}{\partial z} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The expression here is the is the governing equation that will evaluate the velocity dynamics on partial deposition of lead, the developed equation are generated base on the significant parameters in the system that monitor the deposition of lead in heterogeneous formation, lots of variation on the concentration of lead with respect to change in depth has been observed in the study area. The rate of lead concentration has develop lots of variations influenced by heterogeneity from coarse uniformity coefficient, therefore the developed governing equation considered this condition to developed the expression in 1.

Nomenclature

Q = Aquifer height [L]

$\bar{V}$ = Homogeneous velocity [LT^{-1}]

K$_x$ = Permeability coefficient [LT^{-1}]

φ = Flow rate [LT^{-1}]

Ne = Porosity [-]

T = Time [T]

Z = Depth [L]

$$\frac{\partial q}{\partial t} = S^1C(t) - C(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\frac{\partial q}{\partial z} = S^1C(z) - C(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\frac{\partial q}{\partial z} = S^1C(z) - C(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Substituting equation (2), (3) and (4) into equation (1) yields:

$$S^1C(t) - \bar{V}\left[\bar{V}S^1C(t) - C(o)\right] + \frac{\varphi}{ne} + Kx\left[S^1C(x) - C(o)\right] \ldots.(5)$$

$$S^1C(t) - \bar{V}\left[\bar{V}S^1C(t) - \frac{\varphi}{ne}SC(x) + KxS^1C(x)\right] \quad \ldots\ldots\ldots\ldots.. (6)$$

$$C(t) = {}^{1}\!/_{S}\left[\bar{V}S^1C(t) - \frac{\varphi}{ne}S^1C(x) + KxS^1C(x)\right] \quad \ldots\ldots\ldots\ldots.(7)$$

$$C(t) = {}^{1}\!/_{S^1}\left[\bar{V}S^1C(t) - \frac{\varphi}{ne}S^1C(x) + KxC(x)\right] \quad \ldots\ldots\ldots\ldots.(8)$$

$$C(t) = \frac{\bar{V} - \frac{\varphi}{ne} + Kx}{S^1} \quad \ldots\ldots\ldots\ldots\ldots\ldots.(9)$$

$$C(t) = C(t) - \bar{V} + \frac{\varphi}{ne}V + Kx \quad \ldots\ldots\ldots\ldots\ldots\ldots.(10)$$

$$C(t) = S^1C(t) = \bar{V}\,C(t) + \frac{\varphi}{ne} + KxC^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

$$C(o) = \left[\bar{V}C(t) + \frac{\varphi}{ne} + Kx\right]C(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots.(12)$$

$$S^1C(t) = \left[\bar{V} - \frac{\varphi}{ne} + Kx\right]C(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots.(13)$$

$$C(t) = \frac{S^1C(t)}{\bar{V} + \frac{\varphi}{ne} + Kx} \quad \ldots\ldots\ldots\ldots\ldots. (14)$$

$$C(t) = \frac{S^1(t)}{\bar{V} + \frac{\varphi}{ne} + Kx} \quad \ldots\ldots\ldots\ldots\ldots\ldots.(15)$$

Looking at directions of fluid flow in soil, there should be the tendency where the deposition should be thorough evaluated; this implies that in 15, the stages of the derived solution should monitor the condition of fluid dynamics under the influences of deposited hydraulic conductivity pressured by heterogeneous coarse depositions. It develop velocity dynamics to generates some of the major factors that should determined the rate of partial depositions of lead in any formation, therefore the expressed solution monitor the ability of the developed model to monitor the behaviour of lead concentration partially through the determined parameters , the deposition of the expressed model at these phase of the derived solution assess the parameters and express its relationships with the time of velocity flow dynamics in such conditions.

Furthermore, considering the boundary condition, we have at

$$t = 0 \;\; C^1(o) = C(o) = 0$$

$$C(t) = \left[\bar{V}S^1\;C(t) - \frac{\varphi}{ne}C(x) + Kx\;C(x)\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots(16)$$

$$\frac{0}{\bar{V} - \frac{\varphi}{ne} - Kx} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots. (17)$$

Considering the following boundary condition in the equation

$$C(t) - Co - \bar{V}S^1\;C(t) - \bar{V}Co - S^1(t) + \frac{\varphi}{ne}C(x) + \frac{\varphi}{ne}Co\;S^1C(x)$$
$$+ Kx\,S^1(x) + Kx\,Co + S^1(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(18)$$

$$C(t) = \bar{V}\,C(t) = SC(t)\;Co - \bar{V} + \frac{\varphi}{ne} + Kx\,Co \quad \ldots\ldots\ldots\ldots\ldots(19)$$

Considering the denominator in the equation, we have

$$C(t) = \left[\bar{V} + \frac{\varphi}{ne} + Kx\right]Co \quad \ldots\ldots\ldots\ldots\ldots\ldots.(20)$$

Considering $\frac{\varphi}{ne} = \frac{1}{\bar{V}}$

$$C(t) = \left| \frac{1}{\bar{V}} + \bar{V} + Kx \right| Co \qquad \ldots\ldots\ldots\ldots\ldots\ldots (21)$$

$$C(t) = \left| \frac{1 + V^2 + VKx}{\bar{V}} \right| Co \qquad \ldots\ldots\ldots\ldots\ldots\ldots (22)$$

$$C(t) = \left| \left(1 + V^2 + VKx\right) \frac{1}{V} \right| Co \qquad \ldots\ldots\ldots\ldots\ldots\ldots (23)$$

$$C(t) = \left| \left(1 + V^2 + VK\right) \frac{\varphi}{ne} \right| Co \qquad \ldots\ldots\ldots\ldots\ldots\ldots (24)$$

$$C(t) = \lambda \qquad \ldots\ldots\ldots\ldots\ldots (25)$$

$$\lambda = \left| \left(1 + V^2 + VK\right) \frac{\varphi}{ne} \right| Co \qquad \ldots\ldots\ldots\ldots\ldots (26)$$

$$\lambda = \left| \frac{\varphi}{ne} + \frac{\varphi}{ne}V^2 + \frac{\varphi}{ne}VKx \right| Co \qquad \ldots\ldots\ldots\ldots\ldots\ldots (27)$$

$$\frac{\varphi}{ne}V^2 + \frac{\varphi}{ne}KxV_{Co} + \left[\frac{\varphi}{ne}Co - \lambda \right] = 0 \qquad \ldots\ldots\ldots\ldots\ldots (28)$$

Applying quadratic expression to equation (28), we have

$$V^2 + \frac{\varphi}{ne}Kx + \left[\frac{\varphi}{ne} - \lambda \right] = 0$$

Where a= $\frac{\varphi}{ne}V^2$, b= $\frac{\varphi}{ne}KxVCo$ and c= $\frac{\varphi}{ne}\lambda$

$$V = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (29)$$

$$V = \frac{-\frac{\varphi}{ne}KxVCo\sqrt{\frac{\varphi}{ne}KxVCo^2 - 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \qquad \ldots\ldots\ldots\ldots\ldots (30)$$

$$V_1 = \frac{-\frac{\varphi}{ne}KxVCo + \sqrt{\frac{\varphi}{ne}KxVCo^2 - 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \qquad \ldots\ldots\ldots\ldots (31)$$

$$\varphi\Lambda_2 = \frac{-\frac{\varphi}{ne}KxVCo - \sqrt{\frac{\varphi}{ne}KxV\,Co^2 - 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \qquad \ldots\ldots\ldots\ldots (32)$$

Since we have $A\ell^{st} + B\ell^{st}$, it implies that

$$qt = A\exp\frac{\frac{\varphi}{ne}KxVCo + \sqrt{\frac{\varphi}{ne}KxVCo^2 - 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \qquad \ldots\ldots\ldots (33)$$

If A=B=1

$$q(t) = \exp\left[-\frac{\frac{\varphi}{ne}KxVCo + \sqrt{\frac{\varphi}{ne}KxVCo^2 - 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} t \right] + \ell^{\left[-\frac{\frac{\varphi}{ne}KxV\,Co + \sqrt{\frac{\varphi}{ne}KxV\,Co^2 + 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \right] t} \qquad \ldots\ldots\ldots\ldots\ldots (34)$$

The behaviour of these system are to express various parameters that transmits fluid in different formations, looking at this condition it has to evaluated from the derived solution, the variations on hydraulic conduction determine the rate velocity of flow dynamics, these condition influences the heterogeneity in partial depositions of lead, the derived expression monitor the velocity dynamics pressured by formation characteristics, these affect the rates of lead concentration as the contaminant migrates to different soil formations. These developments were considered in the derived solution base on the heterogeneity of the structured strata under the influences of geological settings. The derived model at these phase monitored the behaviour of the substances through the effect from these parameters between 16-34. Application of the derived expression are base on the relationship establish in their various functions, these condition provided a platform for parameters to institute their various functions in the storage of fluid dynamics base on heterogeneous setting, the application of quadratic method were to integrate various parameters base on their relationship to evaluate their functions, because theses will always pressure the deposition of fluid variation influencing partial depositions of lead substances in coarse formation. The expressed solution at this stage implies that the relation between those parameters shows the rate of integrated influences despite their variations in depositions.

Applying inverse Laplace of the equation yield

$$q(t) = \left[t + \frac{\varphi}{ne}KxVCo \right] Co \left[-\frac{\frac{\varphi}{ne}KxVCo + \sqrt{\frac{\varphi}{ne}KxVCo^2 + 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \right] t$$

$$\left[\left[-\frac{\frac{\varphi}{ne}KxVCo\sqrt{\frac{\varphi}{ne}KxVCo^2 + 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \right] \right] t - \left[\frac{\frac{\varphi}{ne}KxVCo - \sqrt{\frac{\varphi}{ne}KxVCo^2 + 4\frac{\varphi}{ne}V\frac{\varphi}{ne}\lambda}}{2\frac{\varphi}{ne}V} \right] t \qquad \ldots\ldots\ldots\ldots (35)$$

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$$qt = \left[\frac{\varphi}{ne} KxVCo \Big/ t^{2} \qquad Co \right] \left[- \frac{\frac{\varphi}{ne} KxVCo + \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 \frac{\varphi}{ne} V} \right]$$

$$\left[\left[- \frac{\frac{\varphi}{ne} VKxCo \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 \frac{\varphi}{ne} V} \right] \right] \ell^{\left[- \frac{\frac{\varphi}{ne} KxVCo \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda \varphi \Lambda V \beta}}{2 \frac{\varphi}{ne} V} \right] t}$$

$$- \left[- \frac{\frac{\varphi}{ne} KxVCo \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 \frac{\varphi}{ne} V} \right] t \qquad \ldots\ldots\ldots\ldots\ldots..(36)$$

At this point $Co = \varphi t \neq 0$

for equation (34) at $t = 0$ $C(o) = Co$, we have

$$Co = \left[\frac{\varphi}{ne} KxVCo + \frac{\varphi}{ne} V + \frac{\varphi}{ne} x \right] Co \left[1 + 1 + 1 \right] = 0$$

$$= \left[\frac{\varphi}{ne} KxVCo + \frac{\varphi}{ne} V + \frac{\varphi}{ne} \lambda \right]$$

Hence $\frac{\varphi}{ne} KxV + \frac{\varphi}{ne} V + \frac{\varphi}{ne} \lambda = 0$

Equation (37) can be written as:

$$qx = Co \left[t + 2 \right] \left[- \frac{\frac{\varphi}{ne} KxVCo + \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 \frac{\varphi}{ne} V} \right] t$$

$$\left[\frac{\frac{\varphi}{ne} KxVCo \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 \frac{\varphi}{ne} V} \right] t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (37)$$

If $t = \frac{d}{v}$

$$C(z) = Co \left[\frac{d}{v} + 2 \right] \left[\frac{\frac{\varphi}{ne} KxVCo \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 V \varphi \Lambda} \right] \frac{d}{v}$$

$$\left[\frac{\frac{\varphi}{ne} KxVCo \sqrt{\frac{\varphi}{ne} KxVCo^{2} - 4 \frac{\varphi}{ne} V \frac{\varphi}{ne} \lambda}}{2 V \varphi \Lambda} \right] \frac{d}{v} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (38)$$

Partial deposition of lead through velocity dynamics has been expressed though these derived solutions, the study monitored the system were the formation deposit lead substances in partial conditions, such condition were observed in the study location to determined their influences in n variation of lead concentration, permeability and soil porosity were significant parameters that varies, these variables were integrated to monitor the substances in the study location, these expression monitored the variation of effect from these influential parameters, the establishment of these parameters through their relationship has shows there different significant in the derived model expression.

Conclusion

The study of velocity of flow dynamics on partial deposition of lead has been expressed, the study were carried out to monitor it in heterogeneous in coarse deposition, significant parameters determined that deposition the rate of the substances were considered in the derived solution, the deposition of lead in coarse formation were monitored considering the geological setting reflecting on the velocity dynamics that migrate it at different formation, porosity and permeability in the in coarse formation were observed in different dimension through the derived solution, the system monitor the substances at different phase base on the heterogeneity of the formation. The study is imperative because the cause of partial deposition of the contaminant has been determined in the study location.

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Conflict of interest

The author declares no conflict of interest.

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