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Centrifuge Model Test of Groundwater Pollution Due to Construction of Pile Foundations in Waste Disposal Site

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Investigation of the contaminant leakage from a post-closure offshore landfill site using centrifuge model tests is presented. The leakage assessment is mainly focused on the disturbance caused to the natural clay barrier of the landfill site by construction of massive deep-foundation structures such as piles, and the lifetime impact due to such structures. The study shows that the nondisplacement-type pile installation causes very minimal disturbance to the NC clay ground, even though field conditions are critical, and there is no possibility of triggering subsurface pollution from the landfill site under normal conditions of soil-structure interaction.

INTRODUCTION

Offshore waste disposal has been a common practice for solid waste management in a developed country like Japan. While using an offshore site for waste disposal, the naturally existing thick clay deposit over the area has been used as a barrier for protection of groundwater contamination. In the post-closure stage, some of these areas are needed to be used for construction of modern city infrastructures. Suspicion exists that the possible disturbances to the naturally existing soil barriers by constructing massive deep-foundation structures may trigger subsurface pollution. This research represents a long-term assessment of possible groundwater pollution due to construction of pile foundations, and the threat posed by its lifetime existence in such waste disposal sites, using normally consolidated kaolin clay in centrifuge. An application of centrifuge technology for this purpose is advantageous, since the real ground condition can be simulated in a model, and long-term simulation can be performed accelerating the transport processes. Further, any deformation or disturbance caused by pile installation in the ground can be effectively modeled. Soil-structure interaction and its impact in a geoenvironmental examination are a new topic of interest, and the analytical or numerical approach is cumbersome. So far a model incorporating such issues has been very rare.

PHYSICAL MODELING OF CONTAMINANT TRANSPORT

Principles of Contaminant Transport in Clay

Contaminant transport in porous media is classically described by a form of partial differential equation referred to as the advection-dispersion equation (Bear and Verruijt, 1987; Freeze and Cherry, 1979; Ogata, 1970). For 1-dimensional flow in a homogenous, isotropic media, this equation becomes:

$$R_d \frac{\partial C}{\partial t} = D_{hl} \frac{\partial^2 C}{\partial X^2} - V_{\text{int}} \frac{\partial C}{\partial X} \tag{1}$$

where C is the concentration of solute in fluid phase, t and x are time and direction of transport, and D_{hl} is the coefficient of hydrodynamic dispersion in the longitudinal direction. Average interstitial flow velocity (V_{int}) is defined as $V_{\text{int}} = V/n$ ($V =$ Darcy's flow velocity; $n =$ porosity) for a fully saturated condition. R_d is the retardation factor given by the following:

$$R_d = 1 + \frac{\rho_d K_d}{n} \tag{2}$$

where ρ_d is the soil's dry density, and K_d is the distribution coefficient:

$$K_d = \frac{dS}{dC} \tag{3}$$

where dS is the change in sorbed concentration, and dC the change in dissolved concentration. The model ground in the study is made of kaolin clay of low specific surface, which is very low in reactivity. The contaminant source used in the model is sodium chloride, which is also a nonreactive chemical. So chloride sorbed in the clay mineral surface is insignificant and doesn't form any insoluble precipitates. Under these conditions:

$$R_d = 1 \tag{4}$$

As the porous media used in the model is pure clay (kaolin) with very low hydraulic conductivity, the Peclet number (P_L) (Eq. 5) in the model becomes very small (less than 1 under high centrifugal acceleration with hydraulic gradient 1, which is the possible hydraulic gradient in the field):

$$P_L = \frac{d_{50} V_{\text{int}}}{D_m} \tag{5}$$

d_{50} is the mean particle size, and D_m the coefficient of molecular diffusion. Under such a condition, the dispersion of solute in the model clay can be regarded as the molecular diffusion (Perkins,

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