Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

AGE04-01 Room:102B Time:May 20 14:15-14:30

Temperature effects on the solute diffusion process in kaolin clay

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Widespread, below-ground constructions of waste storage, geothermal energy, and infra-structure facilities such as nuclear waste deposits, ground source heat pump systems, and underground subways have lead to local subsurface temperature anomalies.Soil temperature markedly affects solute transport and retardation processes in sediments, including diffusion, adsorption, and desorption. In this study, the effect of temperature on solute diffusion was investigated. The diffusion of KCl in water-saturated kaolin clay with different void ratios was measured at three different temperatures (6,15, and 40 degree Celcius) using a newly-developed specified volume diffusion apparatus (SVD). The diffusion processes of both Cl^- ion and K^+ ion in kaolin clay as a function of void ratio and temperature will be discussed in detail, and proxy-functions for predicting the influence of temperature and compaction on the solute diffusion coefficient in kaolin clay will be presented.

Keywords: solute diffusion, temperature, kaolin clay, compaction

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Numerical simulation of heat exchange process during thermal response test.

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Ground source heat pump systems (GSHP) use ground or groundwater as a heat source. They can achieve much higher coefficient of performance (COP) than conventional air source heat pump systems because the temperature of the ground is generally much more stable than that of the air. GSHP has been receiving great interests among countries in North America and Western Europe, as well as some developed countries in Asia because it can potentially reduce energy consumption and greenhouse gas emission. While GSHP can inject heat from the buildings to the ground for cooling during the summer, it can pump heat stored in the ground for heating during the winter.

A reliable simulation tool is needed to evaluate GSHP performance and to assess environment impact. In this study, we used FlexPDE software to simulate heat exchange and transfer processes during thermal response test (TRT) in the ground using a vertical-loop closed GSHP system. FlexPDE allows one to solve multi-physics partial differential equations in multi-dimensions based on finite element solutions. To simulate GSHP processes, 3D conduction and 1D convection of heat transport model was used as fluid flow inside U-tube of GSHP can be considered one dimensional.

This simulation study shows that, while initial heat exchange process is strongly affected by layering, the effect diminishes as time elapsed. This confirms the applicability of the infinite line source model to analyze TRT data.

Keywords: Thermal response test, Ground source heat pump, Numerical simulation

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AGE04-03 Room:102B Time:May 20 14:45-15:00

Changes in subsurface temperature and groundwater quality induced by in-situ long-term thermal loading test

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Ground source heat pump (GSHP) systems have gradually become popular for space cooling and heating in recent years. The GSHP systems discharge waste heat into subsurface environment for cooling or taking up heat of groundwater for heating, inducing the thermal disturbance. The thermal disturbance might affect the subsurface environment including groundwater quality. However the influences of GSHP systems on the subsurface environment have not been well understood and studied. In this study, the changes in subsurface temperature and groundwater quality by operating the GSHP system over a long time period were monitored and discussed.

The GSHP system was installed with 50 m length U-tube as a heat exchanger at the campus of Saitama University. Four groundwater monitoring wells were installed for the upper (GL-16.25 m to 17.80 m) and lower (GL-38.70 m to 40.15 m) aquifers at 1 m (W1), 2 m, 5 m and 10 m distance from the U-tube heat exchanger. At each monitoring well, resistance-type temperature detectors were placed at 10 depths with 5 m interval. For in-situ thermal loading test, 40 C hot water has been circulating inside the U-tube since August 2012. The groundwater have been continuously sampled from all monitoring wells for every 1-2 weeks, and chemical properties (pH, EC, DO, ORP, dissolved gases, dissolved organic carbon, dissolved inorganic ions and heavy metals) were measured.

The subsurface temperature has increased from 15-18 C to 22-24 C at the monitoring well ”W1” by the thermal loading test for 5 months. For the groundwater from upper aquifer, some heavy metals such as Li and B clearly increased at the monitoring well ”W1” with the temperature rise, while for the groundwater from lower aquifer, there were no specific variations.

Keywords: thermal loading test, subsurface temperature, groundwater quality, heavy metals

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AGE04-04 Room:102B Time:May 20 15:00-15:15

Mechanism of water pressure propagation in the hillslope aquifer

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In hillslope hydrology, saturated lateral flow along soil-bedrock interface greatly contributes to the increase in rainfall runoff volume[1)]. van Meerveld and McDonnell (2006) reported interesting phenomena that during rainfall, groundwater level at the upslope wells responded earlier than that sited downslope, and traveling velocity of peak water level between the wells was about ten times as fast as pore water velocity[2)]. Various theories have been proposed to explain rapid water movement in soil and quick runoff response (macropores and soil pipes, translatory or piston flow, groundwater ridge and so on). However, difference between traveling velocity of peak water level and pore water velocity is not clarified sufficiently. The objective of this study is to clarify the mechanism of the peak water level traveling through the slant aquifer by the model experiment and numerical analysis.

We packed toyoura sand homogeneously to form a model slope of 210 cm long, 100 cm high and 5 cm wide, with a reservoir at the upslope boundary, and an outlet at the downslope end. Nine tensiometers were inserted to monitor reservoir water level and groundwater level. Tipping bucket was used to measure flow rate from the outlet. First, we kept reservoir water level constant in order to make steady state water flow in the slope. Then, we added water to the reservoir to simulate groundwater level fluctuation. In the numerical analysis, we tried to reproduce the model experiment using HYDRUS-2D, which simulated two dimensional water movement through soil in the model slope and reservoir. Reservoir water level was controlled by the water flux boundary condition (BC) at the top of the reservoir. Downslope outlet was assigned as seepage face BC, and the other boundary surrounding the model slope was no flux BC. Soil hydraulic function was described by the van Genuchten-Mualem model.

As soon as reservoir water level rose, all the tensiometers and flow rate at downslope outlet responded simultaneously. This result means that fluctuation of groundwater level in part may influence groundwater level of whole aquifer. Groundwater level peak occurred at upslope and transferred to downslope, and maximum discharge was observed just after the groundwater level peak at the vicinity of the downslope outlet was detected. Traveling velocity of peak water level was 5-35 times as fast as pore water velocity. As packed toyoura sand was a homogeneous medium, translatory flow could explain the difference between traveling and pore water velocity. Numerical simulation quantitatively reproduced amplitude of the groundwater level fluctuation, but time required to transfer the fluctuation toward downslope part was overestimated. In conclusion, translatory flow might play an important role in the rapid traveling of peak water level. Quantitative discussion of traveling of peak water level in aquifer is important to understand quick runoff from hillslope at the rainfall event.

References 1) van Meerveld and McDonnell. 2006. *Water Resour. Res.* 42 W02410, 2) van Meerveld and McDonnell. 2006. *Water Resour. Res.* 42 W02411

Keywords: groundwater level, traveling velocity

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AGE04-05 Room:102B Time:May 20 15:15-15:45

Geostatistical Modeling of the Spatial Distribution of Soil Arsenic around a Smelter: From Sampling to Remediation

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For almost 100 years, the Asarco Company operated a copper smelter in Tacoma, Washington State. Air pollution from the smelter settled on the surface soil over more than 1,000 square miles of the Puget Sound basin. As part of the Tacoma Smelter Plume project, there have been a number of studies looking at soil arsenic contamination, leading to the collection of more than 5,000 soil samples over the years. In 2009, the State of Washington received a settlement from Asarco, including a lump sum to pay for partial cleanup. The present study aimed to pool all of the sampling results to create a model that can be used to further prioritize areas for additional sampling and remediation since not enough money is available to clean all parcels.

A simulation-based approach was first developed to: 1) incorporate wind rose information, elevation, proximity to the smelter and field measurements in the geostatistical mapping of arsenic concentration estimates at the residential parcel level, and 2) compute the probability of exceeding specific arsenic levels at the parcel and block-group levels. Results indicate higher arsenic concentrations on undeveloped parcels, closer to the smelter and along the prevailing wind directions. The simulation-based approach also allowed the computation for each block-group of the expected number of parcels where a given arsenic concentration threshold is exceeded with a minimum probability. This information will be used to select widely contaminated block-groups where all parcels will be systematically sampled and the ones exceeding a target threshold (e.g. 90 or 100 ppm) will be remediated.

A design simulation study was conducted to compare the power of different composite sampling design options when deciding whether the average arsenic concentration within a residential parcel exceeds or not decision criteria of 90 or 100 ppm. The expected rates of false positives and false negatives were computed for six different sampling design options that included: composite samples at 4:1, 6:1, 8:1, 10:1, and 12:1, as well as an MIS design at 30:1 for comparison purposes. Based on the power curves and field practicability/cost issues, the 8:1 composites were selected by the local agency.

Keywords: sampling design, remediation, interpolation, pollution, soil arsenic

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AGE04-06 Room:102B Time:May 20 16:15-16:30

Effects of Mineral and Organic Compositions on Dissolution of Lead from Naturally Polluted Soils

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A recent amendment to the Japanese Soil Contamination Countermeasures Act requires the treatment of soils including those naturally polluted by heavy metals. Naturally polluted soils have great variety, and contain different kinds of chemical, mineral and organic compositions. Dissolution and/or leaching of heavy metals from naturally polluted soils can be significantly affected by their compositions, because both clay minerals and organic matters have strong adsorptivity. The knowledge about the effects of mineral and organic compositions on dissolution of heavy metals from naturally polluted soils is of fundamental necessity for the design of remediating naturally polluted sites.

In this study, more than 10 types of naturally polluted soil samples containing the heavy metal of Lead (Pb) were collected from abundant metal mine areas. A series of tests including X-ray Fluorescence Analysis (XRF), X-ray diffraction analysis (XRD), organic matter analysis, standard dissolution tests and sequential leaching tests were performed to exam the effects of mineral and organic compositions on dissolution of Pb from the naturally polluted soils. In addition, an artificially polluted soil by mixing a commercially available natural soil with Pb(NO3)2 was also prepared and similar analyses were carried out for a comparison. This presentation illustrates the details of the above experimental study, indicates the difficulties with clean-up of naturally polluted sites and proposes a methodology for assessing the applicability of remediation techniques.

Keywords: Natural pollution, Heavy metals, Mineral, Organic matter, Dissolution, Sequential leaching

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AGE04-07 Room:102B Time:May 20 16:30-16:45

Immobilization of Phosphorus and Heavy Metals in Swine Manure Using Activated Red Mud

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Swine manure contains large amounts of water-soluble pollutants such as phosphorus and heavy metals. When it is applied to land, theses pollutants may pose serious threat to soil and groundwater quality through running off. In this study, an immobilization material was prepared from red mud (RM) and used to immobilize the pollutants in swine manure. It was found that phosphorus and heavy metals were effectively immobilized by the prepared immobilization material and the efficiency increased with the increase in activation temperature and the RM dosage. Leaching experiments showed that the immobilization efficiency of phosphorus, copper, zinc, and arsenic reached 84%, 65%, 47%, and 89% respectively as the swine manure was amended with 10% RM. Sequential extraction experiments suggested that the mechanism for immobilization reaction was mainly co-precipitation that transformed labile phosphorus and heavy metals into stable forms.

Keywords: Phosphorus, Heavy Metals, Immobilization, Swine Manure, Activated Red Mud

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AGE04-08 Room:102B Time:May 20 16:45-17:00

Radioactive fallout removal from the surface soils by enhancing vertical transport.

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Fukushima nuclear power plant damaged by the East Japan Great Earthquake caused radioactive fallout around the Tohoku region. Because radioactive fallout was positively charged, it was reported to being adsorbed to soil surface. Surface soil scraper and deep plowing would be, therefore, effective for the removal of radioactive materials. However, these techniques were available for flat and wide land like school yard or farm land. Field survey revealed that correlation between EC and radioactive dosage were significant, which meant radioactive fallout did not immediately adsorb to soil surface but stayed as exchangeable ion for a while and was transported with surface water.

Thus we applied artificial macropores to effectively remove radioactive fallout from the surface soil. Artificial macropore filled with bamboo fiber was made in soils (Field: d=1cm length=50cm, Lab: d=0.6cm, length=20cm). Zeolite was placed at the bottom of the macrpores (Field: 5cm, Lab: 3cm) to absorb transported Cesium. Four treatment was prepared such as macropore, macropore with ammonium sulfate, no macropore and no macropore with ammonium sulfate. 400mm artificial rainfall was applied in one month.

Results showed artificial macropore effectively transported radioactive Cesium to deeper profile while ammonium sulfate enhanced the amount of Cesium delivered to the deeper profile. No radioactive Cesium was observed from the drainage water.

Field experiment showed significant reduction in macropore plots than no-macropore plots, however, it is not significant for ammonium sulfate plots.

Keywords: radioactive fallout, infiltration, macropore

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AGE04-09 Room:102B Time:May 20 17:00-17:15

Surface heterogeneity and flux measurement height in large eddy simulations

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Source/sink heterogeneity of a surface is a critical issue for micrometeological measurement methods of turbulent surface fluxes because the surface is heterogeneous in nature which is different from the assumption of horizontal homogeneity by most methods. This affects methods such as the eddy-covariance technique where fluxes are measured in situ from a mast and the source area (i.e. footprint) of the measurements lies upwind from the mast. If the horizontal scale of the heterogeneity is very small compared to the measurement height, effects of surface heterogeneity will be averaged out above a blending height, which would be below the measurement height. Moreover, if the spatial scale of the surface patches is so large compared to the measurement height that the turbulent flux footprint of the measurements will cover only one patch, the area within the footprint will be homogeneous. Hence, we will evaluate the impact of the scale of horizontal homogeneity on the turbulent flux for varying measurement heights. To obtain detailed turbulence information in the atmospheric boundary layer, large eddy simulations (LES) are applied. In addition, a Lagrangian stochastic (LS) model is applied for particle simulations in order to interpret source areas. Neutral and cyclic boundary conditions are set for LES model. Simulations are based on an ideal chess board surface with alternating surface exchange: particles are released from alternating squares and the source height is on the surface (0 m). Each simulated surface has a different, but homogeneous, roughness. This study reveals important information on the relationship between measurement height and horizontal homogeneity of the surface as well as the effects of surface roughness to the blending height. The results of the study can be used in the design of future flux measurement systems, and in the interpretation of results from the existing systems.

Keywords: Large eddy simulation, Lagrangian stochastic model, Blending height

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Surface water's quality and definition of risk areas in Agueda's transboundary watershed

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This paper focuses on the environmental characterization of Agueda watershed. The Agueda project is an ongoing work in the framework of the POCTEP program, Portugal and Spain. The main core of the present work is the development of a methodology to be used as a generic and flexible tool for a dynamic risk analysis, allowing the definition of leverage strategies e.g. to land management in this transboundary region.

This work started with the assessment of the quality of surface water. A sampling campaign was conducted between October and December of 2011. Fifteen surface water samples were collected along the tributary rivers and twenty three more along the main river bodies. The following chemical parameters were analyzed: Biochemical Oxygen Demand (BOD), Dissolved Oxygen Concentration (DO), Ntotal; pH, Temperature and Electric Conductivity were analyzed. The dissolved oxygen concentration (DO) and the biochemical oxygen demand (BOD) were used as indicators of environmental pollution. A coupled hydrodynamic and water dispersion model implemented in QUAL2kw software was used to simulate the distribution of these parameters along the river. The simulation results are consistent with field observations and demonstrate that the model has been correctly calibrated

The second part of our work is the mapping of vulnerability across the Agueda watershed. The DRASTIC Pesticide index was used. The DRASTIC is a parametric method (developed by US EPA) for evaluating the intrinsic vulnerability of groundwater systems on a regional scale. It takes into account the inherent geological, hydrological and hydrogeological characteristics of an area, but is independent of the nature of human activities. The parameters included in the method are depth to water (D); net recharge (R), aquifer media (A), soil material (S), topography (T), impact of vadose zone (I) and hydraulic conductivity (C) of the aquifer. Higher DRASTIC scores implies higher likelihood of contamination. The DRASTIC method includes two versions: the generic DRASTIC and the pesticides DRASTIC where the seven parameters' weights are reassigned in order to reflect the relevance of anthropic activities.

A Geographical Information System (GIS) was built to overlap the maps of vulnerability classes and surface water quality's parameters. The joint visualization allows the identification of regions of, high-high, High-low, low-high and low-low, vulnerability-risk.

The high-high areas are located mainly in the central zone which is the tertiary aquifer and the largest urban area. Feasibility studies of different treatment schemes and the development of specific monitoring activities must be addressed in future work.

Keywords: Watershed, DRASTIC Pesticide, QUAL2kw simulation, risk regions