Altering water and soil heat regimes with hot water applied for soil disinfection

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Applying hot water for soil disinfection becomes popular in Japan. Hot water application aims to disinfect soil pests with heat of hot water from 75 to 95 °C. Keeping soil temperature over 55 °C for 10 seconds to 4 hours has the effects on disinfecting the soil pests. The amount of hot water application is usually decided by farmer’ s experiences. Excess amount of hot water applied would result in ground water pollution and high fuel costs for a water boilers. The main objective of this study was to find out the unique differences between changes in the volumetric water content and the soil temperature in soil applied hot and tap water. In addition, because previous studies about temperature dependency of soil physic parameters were under around 60 °C, we figured out the temperature dependencies of the dielectric permittivity and thermal property.
We measured the changes in the volumetric water content and the soil temperature in upland soil treated hot and tap water. The amount of both treated water was 185 L m^{-2}. The hot and tap water were prepared as 95 °C with a water boiler and 25 °C, respectively. The volumetric water content was estimated by dielectric permittivity measured with TDR (Time Domain Reflectometry) sensor and the soil temperature was measured with the type-T thermocouple at 5, 10, 20, 40, 60, 80, and 100 cm deep from the soil surface, respectively. Temperature dependencies of the thermal diffusivity and the dielectrics permittivity were revealed. The thermal diffusivity and the dielectric permittivity of Kanto loamy soil were measured from 30 to 90 °C every 10 °C with the cylinder method and TDR, respectively.
The volumetric water content increased from soil surface to deeper soil with hot water application. The volumetric water content in soil in tap water treatment was higher 0.15 m^3 m^{-3} than it in hot water treatment from 5 to 20 cm depth during each water application. Soil temperature from 5 to 40cm was kept over 55 oC more than 4 hours, especially, soil temperature above 10 cm soil depth was raised over 80 oC for a few hours. The dielectric permittivity at 55 and 70 °C in high water content is smaller 15 and 30 % than it at 25 °C. We observed those differences between the volumetric water content in each treatment, because the temperature dependency of the dielectric conductivity.
Temperature dependences of dielectric permittivity of Kanto loamy soil were different at each water content. Especially, it was stronger at high water content. We observed that traveling time of waveform for calculating dielectric permittivity changed shorter with rising soil temperature. Temperature dependence of thermal diffusivity of Kanto loamy soil was strongest at relative water content is around 0.3. We thought that temperature dependency was enhanced by exiting the water vapor.

Keywords: Hot water soil disinfection, Water infiltration, Thermal property, TDR

Newly Developed XRF (X-Ray Fluorescence Spectrometer) Reference Standard Material Targets Low-High Content of Heavy Metals Analysis

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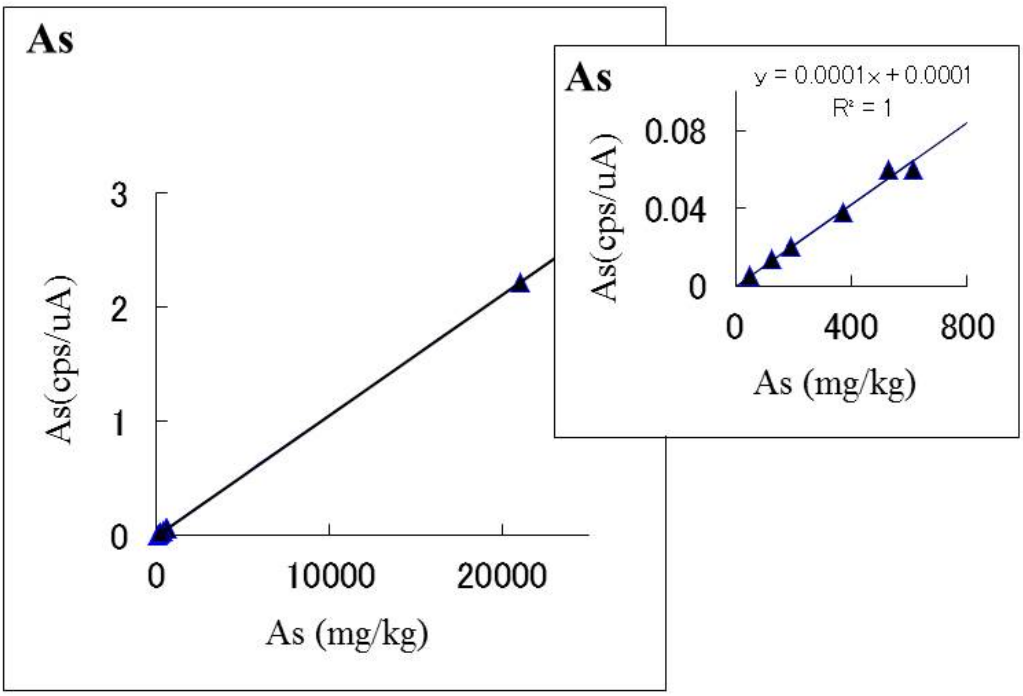
This research describes, in detail, the properties and application of newly developed eight Reference Standard Soils (ME1 Group) for XRF analysis including, experimental design, and the element analysis methods used to provide certified, reference, and information mass fraction values for 63 to 208 trace element constituents. The accuracy and detection limit of the analysis of heavy metals are affected by instrument, method and data processing error. XRF analysis of heavy metal is one of the time and cost savings process compare to conventional ICP-MS. The total number of portable XRF has been over 45000 all over the world at the stage of year 2010. Soil Standard has been used worldwide for the determination of major, minor, and trace element content of soils and similar materials. For precise results by XRF analysis high quality soil sample for calibration line preparation is mandatory. We succeeded to develop Reference Standard Materials for the determination of heavy metals in highly contaminated soil from the trace amount to high content (1 ppm –20000 ppm) by extending calibration line. Emphasis is placed on determination of priority pollutant elements (e.g., Cu, Zn, As, Cd, Pb). No chemicals are added to prepare Reference Soil. These New Reference materials provide the highly precise XRF results equivalent to ICP-MS data that cover the element mass fraction ranges that would be expected in typical soil samples analyzed by environmental research sections.

Keywords: Reference Standard Soils, XRF, Heavy Metals, High Concentration



Semiannually alternating exchange of intermediate waters east of the Philippines

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Intermediate water exchange in the northwest tropical Pacific is explored with the temperature, salinity, and current measurements of a mooring system deployed at 8˚N, 127.05˚E during 2010–2014. For the first time, prominent semiannual variability (SAV; with the maximum power at ~ 187 days) of subthermocline meridional flow along the Mindanao coast is revealed. A significant correlation between meridional flow and salinity is found at intermediate depths. This provides direct evidence for the alternating transports of South Pacific and North Pacific Intermediate Waters by northward and southward undercurrents, respectively. Further analysis with an eddy-resolving ocean general circulation model demonstrates that the SAV is generated locally near the western boundary, manifesting as large-scale subthermocline recirculation and leading to alternating northward and southward flows near the Mindanao coast, which plays an efficient role in the intermediate water exchange of the northwest tropical Pacific. Mechanisms underlying the observed SAV are discussed

Keywords: Strong semiannual variability, Significant correlation between current and salinity, Semiannually reversing water exchange

Numerical Analysis of Mass and Energy Transport in Subsurface and at the Soil-atmosphere Interface using HYDRUS

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It is broadly accepted that mass and energy fluxes in the subsurface in general, and in arid and semi-arid regions in particular, are closely coupled and cannot be evaluated without considering their mutual interactions. While the subsurface processes are commonly implemented in existing models, which often consider both isothermally and thermally induced water and vapor flow, the effects of slope inclination, slope azimuth, variable surface albedo and plant shading on incoming radiation and spatially variable surface mass and energy balance, and consequently soil moisture distribution, are rarely considered. These factors have been recently implemented into the HYDRUS model. In this presentation, the effect of soil heterogeneity and surface roughness on mass and energy fluxes in the subsurface and at the soil-atmosphere interface is evaluated numerically with the HYDRUS model. Additionally, we will demonstrate the use of the HYDRUS model to simulate processes relevant to the ground source heat pump systems.

Keywords: HYDRUS, Soil-atmospheric interface

Underground temperature change in the alluvial fan of the Nagara River, central Japan

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Generally, the underground temperature is constant except near-surface. The temperature in the near-surface (e.g. above 10 m depth) is annually changed due to the effect of seasonal change of ground surface temperature. As the thermal conductivity of rocks and soils are quite low, this seasonal change of ground temperature cannot reach below a certain depth. This depth is dependent on not only the thermal conductivity of rocks or soils but also the groundwater flow in a vertical direction. The constant temperature in a certain depth is almost consistent with the average of ground surface temperature. Low temperature geothermal uses such as ground-coupled heat pumps and groundwater heat pumps apply the temperature difference between surface and underground to the thermal energy use. As the underground temperature is constant, the underground becomes a heat source in winter and a heat sink in summer. Alluvial fans are recharge areas of groundwater and that rapid groundwater flow are expected. In this study, we clarify the distribution of the underground temperature in an alluvial fan to understand the potential of low temperature geothermal energy.

Study area is an alluvial fan of the Nagara River, central Japan. This alluvial fan is located in the marginal area of the Nobi plain. The underground of this alluvial fan mostly consists of sands and gravels and often intercalate thin fine sand and silt layers. The aquifers are divided by these sand and silt layers. The underground temperature of this area had been measured from May 2013 to May 2014 and from April 2016 to February 2017. The temperature is measured in boreholes with the length of 30 m. The measurement is performed once a month by a thermistor thermometer with the interval of 1 m depth. Ground temperature change in each depth of each well is well fitted by a sine curve. Average temperature, phase difference and amplitude of the temperature change in each depth of each well are calculated from the fitted sine curves. The results of underground temperature measurements show that the temperature profiles of most wells can be divided into two zones; the shallower apparent thermal conductive zone and the deeper thermal convective zone. The former is characterized by the decrease of amplitude toward downward, while the latter is almost constant temperature in the zone.

The thermal diffusivity is calculated from the temperature profiles of the shallower apparent thermal conductive zone. The distribution of the calculated thermal diffusivity is characterized by the lower values in the middle part of the fan and the higher in the marginal part. The thermal diffusivity cannot be calculated near the apex of the fan due to almost no shallower apparent thermal conductive zone. The values between the middle and marginal parts are greatly different. This suggests that the difference of the value results not from the thermal property of the formations but from the vertical velocity of the groundwater flow. The ground surface in the middle part is mostly covered by a silt layer and this would prevent water infiltration from the surface.

The temperature distribution in the deeper thermal convective zone is as follow. Phase difference of ground temperature against the river temperature basically increases from north to south in the southern side of the river. Although some wells far from the river seem to be out of sequence, the travel times of the groundwater from the river to these wells would be more than 1 year. The value of the phase differences of these wells should be added 1 or 2 years. The phase differences in the northern side of the river show different and complicated characteristics relative to the southern side. This suggests that the groundwater flow along the old river channels and from the tributary river plays an important role in the underground temperature distribution of the northern side. The distribution of the annual average temperature shows

that the wells near the river are lower temperature. The average temperature of the river water is lower than the average air temperature of study area. These lines of evidence suggest that the area near the river is the recharge area.
For the low temperature geothermal use, the natural change of the underground temperature is important for the efficiency of the heat pumps. The area where the phase difference is 6 months is the best, because the efficiency of the heat pumps becomes higher when the temperature of the heat source is lower during cooing and higher during heating. The potential study of the low temperature geothermal uses should contain the annual temperature change in the alluvial fans.

Keywords: underground temperature change, alluvial fan, Nagara River

Transport in strongly heterogeneous porous formations: Anomalous transport and validity of the First-Order solution

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Transport of a nonreactive solute in natural aquifer is deeply influenced by the spatial distribution of the hydraulic conductivity *K*, in particular when in presence of strongly heterogeneous aquifers. We analyze here a few features of transport in such formations by recent theoretical advancements as well as accurate three-dimensional numerical simulations. We examine the impact of permeability structures on the Breakthrough Curve (BTC) of solute, at a distance *x* from the injection plane, under mean uniform flow of mean velocity *U*. The hydraulic conductivity *K* is modeled as a space random function, resulting in spatially variable velocity and concentration fields. The theoretical and numerical results permit to test and discuss a series of transport features which occur in strongly heterogeneous aquifers, like for instance the BTC tailing, connectivity and the occurrence of anomalous transport. The validity of the classic first order solution, formally valid for small variability of *K*, is also tested through a series of three-dimensional numerical simulations. It is seen that the first order solution is quite robust in predicting the BTC, providing a simple and effective solution to be employed in applications.

Keywords: Subsurface contamination, Breakthrough Curve, Stochastic subsurface hydrology

Numerical Evaluation on Subsurface water distribution from Ring Emitter Irrigation

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Water scarcity causes the utilization of arid land not maximal in supporting agricultural production in Indonesia. It requires an effort to use water as efficiently as possible to improve and maintain the stability of land productivity. One option to improve the water use efficiency is to use subsurface irrigation systems. Ring irrigation is one of subsurface irrigation techniques based on indigenous materials and skills, in which a ring-shaped emitter covered by textile is placed in the root zone. Investigating soil water dynamic in the root zone under such irrigation is essential in order to understand the combined effects of practices and management. The laboratory experiments were conducted to evaluate soil water content at different irrigation water pressure values (10 and 1 cmH_2O) in coarse sand and finer-texture silt. The experimental data were used to calibrate the HYDRUS 2D/3D. Simulation results were in good agreement with the observed data. This study demonstrated that HYDRUS 2D/3D is an effective tool to predict soil water dynamics under the ring emitter irrigation for coarse and fine soils, therefore HYDRUS 2D/3D can be further used to optimize emitter design and operation.

Sensible Heat Balance Determines Subsurface Evaporation or Freezing and Thawing Rates

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Recent advancements in fine-scale measurements of soil thermal properties provide new opportunities to observe heat transfer associated with soil-water evaporation in the upper centimeters of the vadose zone and with soil freezing and thawing in the soil profile. Heat-pulse sensors provide all of the necessary measurements required for sensible heat balance determinations. The residual from a sensible heat balance (i.e., the net sensible heat flux minus the change in heat storage) is attributed to latent heat from water evaporation/condensation in unfrozen soil or to latent heat from freezing/thawing in partially frozen soil. Evaporation estimates from the sensible heat balance provide depth and time patterns consistent with observed soil-water depletion patterns. Sensible heat balance is particularly useful for quantifying the initial soil freezing rates. Implementation of fine-scale measurement techniques for the soil sensible heat balance provides a new opportunity to improve the understanding of soil-water evaporation and soil freezing.

Keywords: Sensible heat balance, Subsurface evaporation, Soil freezing and thawing

Two-dimensional hydraulic analysis of water flow over and through an anisotropic soil layer

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In this study, we focus on the hydraulic analysis of a 2-D water flow on a pervious ground down a hillslope. Different from the past, we not only consider the soil layer as a porous medium with an anisotropic permeability, but also consider the vertical component of the flow velocity, and then compare the results with the relevant literature including Makungo & Odiyo (2011) and Dagadu & Nimbalkar (2012). We divide the flow field into two regions (the water layer and the anisotropic soil layer) and derive horizontal component and vertical component of the flow velocity as well as other physical quantities in the two regions. Herein, by regarding the soil layer as an anisotropic and permeable porous medium, we adopt the Song’ s (1993) laminar model based on Biot’ s poroelastic theory for the momentum equations of the anisotropic soil layer, and the Navier-Stokes equations for the water layer. When considering the anisotropy of permeability in the soil layer, the hydraulic conductivity becomes a tensor, and the momentum equations of the flow in the soil layer should be derived in a new way. Finally, with appropriate boundary conditions and the velocity type set by Desseaux (1999), we derive the horizontal, vertical velocity and (pore) water pressure distributions by taking the Differential Transform Method (DTM) proposed by Arikoglu & Ozkol (2006).

Keywords: subsurface flow, anisotropic, vertical velocity

Gas transport in partially saturated packings of angular and rounded sands: Experiments and theoretical applications

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Gaseous transport in porous media is mainly controlled by pore space geometrical and morphological characteristics, such as pore throat-size distribution and pore connectivity. In this study, we address predicting gas diffusion and permeability in packings of angular and rounded sand grains. Two average sizes of grain i.e., 0.3 and 0.5 mm were used to pack sands in a column of 6 cm height and 4.9 cm diameter. Angular sand grains were packed loosely, while rounded ones tightly to obtain a total porosity of about 0.4 in all samples. Water contents, gas diffusion, and gas permeability were measured at different suction heads. An X-ray computed tomography method was also applied to scan the pore network under fully dry conditions and to capture pore coordination number distribution. By analyzing the measured water retention curve, we found the pore space fractal dimension D ranged between 0.98 and 1.8, while typically $2 < D < 3$ in natural porous media. This shows that the pore throat-size distribution of these packs is narrower than that in typical natural porous media. Experimental results indicated that both gas diffusion and permeability as a function of air-filled porosity (ε) showed linear behavior at higher suction heads, while deviated substantially from linear scaling at lower suctions. Accordingly, the effective-medium approximation and the universal power law of percolation were invoked at higher and lower air-filled porosity ε values, respectively. The crossover between the two occurs at some intermediate air-filled porosity ε_x. We found that at higher air-filled porosities, the main factor controlling diffusion and permeability is the average pore coordination number (Z), while at lower ε values, near a percolation threshold, effects of both tortuosity and connectivity are nontrivial. Comparing the theory with the diffusion and permeability experiments showed that the determined value of Z ranged between 2.8 and 5.3, not greatly different from X-ray computed tomography results. The obtained results clearly indicate that the effect of the pore throat-size distribution on gas diffuion and permebaility was minimal in these sand packs.

Keywords: Coordination number, Gas diffusion, Gas permeability, Pore throat-size distribution, Grain shape

Experimental study on the seismic responses of dip slope using shaking table.

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Limit Equilibrium Method has been widely adopted in slope stability analysis. The Pseudo-Static Method is applied in order to take seismic loads into account, using Peak Ground Acceleration (PGA) as the main factor regardless of the influences of earthquake characteristics such as shape of waves, time lapse and frequency. Since the existence of layer surface in bedded vein could become the weakest part of a dip slope, and in most of the cases, a nearly vertical brittle texture in the sand rock onto the sliding surface induced by tectonic stress and cracks in rock due to the tension forces can be found. It needs further investigation to conclude the components of dip slopes and its characteristics of textures. Therefore, the aim of this study is to explore the relevant causes to dip slope sliding by conducting a series of experiment with physical models on a SDOF shaking table. It is expected the influences of lithological characters, geological structures and seismic loads on dip slope failures can be studied.

Keywords: Shaking table test, Dip slope, Physical model, Seismic response

Global land surface climate analysis based on the calculation of a modified Bowen ratio

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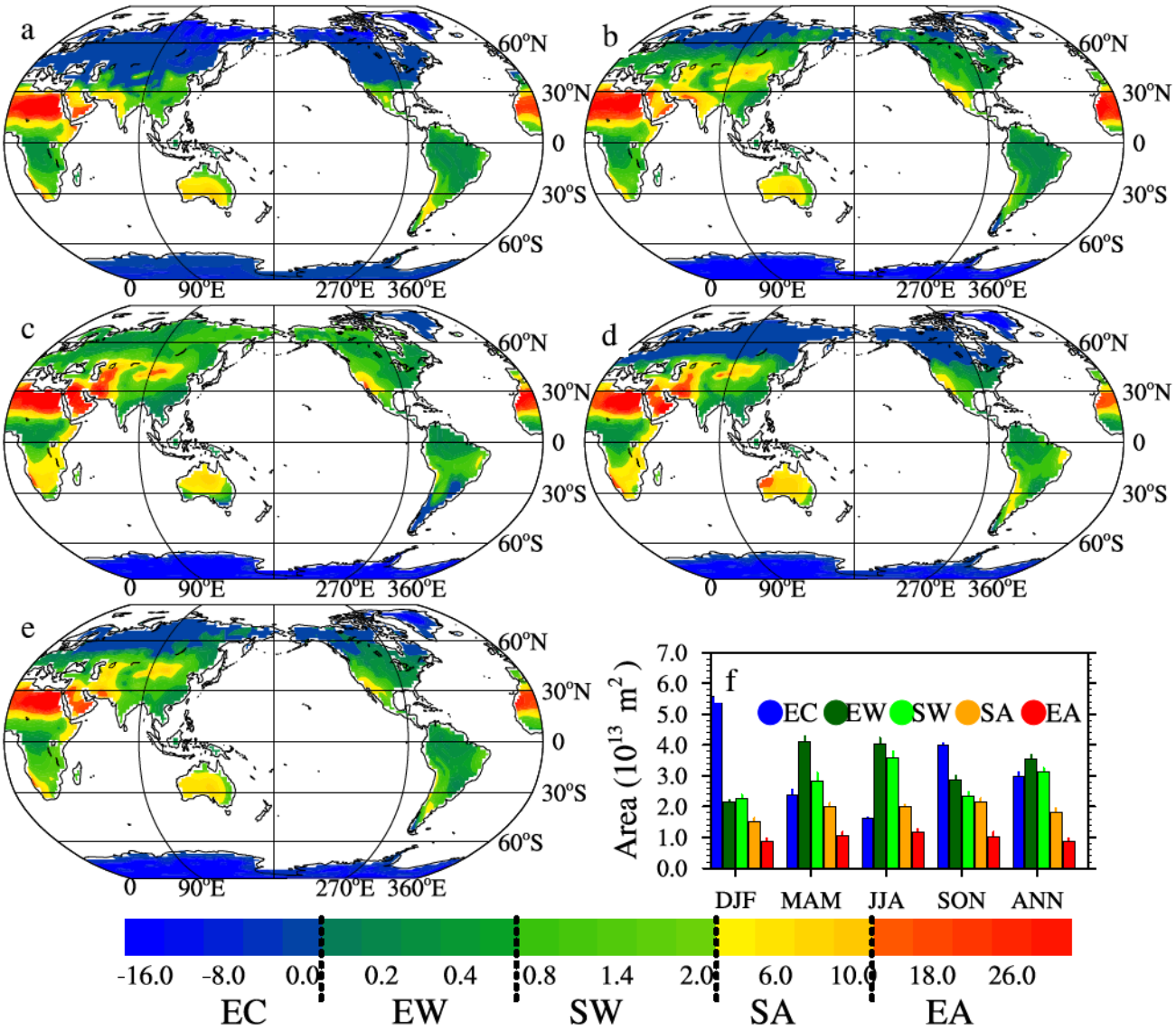
A modified Bowen ratio (BRm), the sign of which was determined by the direction of the surface sensible heat flux, was used to represent the major divisions in climate across the globe and the usefulness of this approach was evaluated. Five reanalysis datasets and the results of one off-line land surface model were investigated. We divided the global continents into five major BRm zones using the climatological means of the sensible and latent heat fluxes during the period 1980-2010: extremely cold, extremely wet, semi-wet, semi-arid and extremely arid. These zones had BRm ranges of (-infinit, 0), (0, 0.5), (0.5, 2), (2, 10) and (10, +infinit), respectively. The climatological mean distribution of the Bowen ratio zones corresponded well with the Köppen-like climate classification, and it reflected well the seasonal variation for each subdivisions of climate classification. The features of climate change over the mean climatological BRm zones were also investigated. In addition to giving a map-like classification of climate, the BRm also reflects temporal variations in different climatic zones based on land surface processes. An investigation of the coverage of the BRm zones showed that the extremely wet and extremely arid regions expanded, whereas a reduction in area was seen for the semi-wet and semi-arid regions in the boreal spring during the time period 1980-2010. This indicates that the arid regions may have become drier and the wet regions wetter over this period of time.

Keywords: Climate classification, surface turbulent heat fluxes, climate change



Investigating lead amounts in shooting range soil partitioned by particle size

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1. Gifu University, 2. Chonnam National University

Soil contamination by lead in shooting ranges has been a critical issue because lead concentrations in soils are often higher than 100 times the concentration of the environmental quality standard in Japan. Tajimi city shooting range is one of the closed shooting range due to the heavy lead contamination. Lead content in soils higher than 10,000 mg kg^{-1} were reported at multiple locations in the shooting range. Phytoremediation and immobilization has been studied for lead contamination in the shooting ranges. However, the phytoremediation could not remove lead efficiently, and immobilization remains the land re-use problem. In order to find the effective way to remove lead and to utilize the land, it is necessary to build deep understanding of the lead behavior in the contaminated soil. Mizutani et al. (2016) reported that lead contents and leached lead quantity depend on the soil particle size. This is explained by that soil has large surface area and number of adsorption units in small particle fractions. In this study, we also investigated lead contents and leached lead quantities in/from contaminated soil partitioned by soil particle size. The soil was sampled from Tajimi city shooting range and it is heavily contaminated, i.e., the lead content is close to 100,000 mg kg^{-1}.

The soil was divided into six fractions by dry sieving with multiple screen sizes. The sieving was performed with a shaker for 30 minutes. The fractions were smaller than 0.045 mm (A), 0.045~0.074 mm (B), 0.074~0.25 mm (C), 0.25~0.5 mm (D), 0.5~2.0 mm (E), and 2.0~4.75 mm (F). For the lead content exam, 2 mL 12.0M HCl and 5 mL 12.0M HNO_3 were added into 0.25 g soils, and the samples were digested by the microwave sample preparation system. After the digestion, the sample were diluted by pure water and centrifuged. The supernatant was passed through 0.45 μm membrane filter. For the leaching quantity exam, soil and pure water were mixed at 1:10 ratio and equilibrated for 24 h on a shaker. After the equilibration, the samples were centrifuged, and EC and pH of the supernatants were measured. The supernatants were passed through 0.45 μm membrane filter. Lead concentration in each sample was measured by ICP-AES.

There is no clear relationship between pH and particle size but EC decreased as particle size increased. The lead contents in each fraction were 45,000-87,000 mg kg^{-1}. The large particle size fractions showed high lead contents, e.g., lead content in 2.0~4.75 mm fraction was 1.9 times larger than that in the fraction less than 0.045 mm. It was expected that the small particles show larger lead contents than those for the large particles. The preceding study reported lead content in that manner. The possible reason is an existence of lead ball and its fragments. Many lead balls were found in the 2.0~4.75 mm fraction. Its fragment cannot be visually observed but probably they exist in the other fractions. The number of the lead ball fragment must decrease as the particle size decrease and, thus, decrease of lead content can be explained. In case we eliminated the visually detectable lead balls in 2.0~4.75 mm fraction, the lead content decreased dynamically from 86,000 mg kg^{-1} to 18,000 mg kg^{-1}. The leached lead quantity in each fraction distributed between 0.9 and 4.3 mg L^{-1}. The small fractions show large leached quantity. This result is also opposite to the preceding study. The existence of lead ball and its fragment can be a possible reason again since the density of lead is higher than that of soil and variety of soil bulk density can affect the leaching quantity. In order to build better understanding of the results, further examinations such as cation exchange capacity, anion exchange capacity, specific surface area, soil particle density are

required.

Keywords: Shooting range, lead, soil contamination

Productivity of Moso Bamboo (*Phyllostachys pubescens*) Forest in Central Taiwan and its Potential to Act as a Significant Carbon Sink

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Bamboo is one of the important forests in subtropical and tropical area. In Taiwan, bamboo forests possess about 7.2% of total forest area. Recently, the aggressive expansion of Moso bamboo (*Phyllostachys pubescens*) forest to surrounding ecosystems has been noticed in eastern Asian countries. The carbon balance including aboveground and belowground carbon stock might be influenced greatly by the vegetation replacements. Moso bamboo has an “off-year” and “on-year” growth phenomenon that would cause significant difference of net primary productivity (NPP) and net ecosystem productivity (NEP) between the two years. So far, few studies have investigated carbon cycling with the consideration of the impact of biennial cycle in Moso bamboo forests. Heterotrophic respiration is a pivotal factor to determine a forest ecosystem as a carbon sink or carbon source. Therefore, the aims of this study were to clarify the characteristic of carbon cycle in a pure Moso bamboo plantation, situated in a montane cloud forest zone of central Taiwan. To these ends, this study 1) examined the aboveground and belowground biomass, 2) estimated the NPP and NEP in the Moso bamboo forest with the long-term data (2012-2015) and 3) compared the results of NPP and NEP in this study with other forests in Taiwan and in the worldwide scale. The NPP and NEP of Moso bamboo forest were 8.95 and 4.17 was Mg C ha^{-1} yr^{-1}, respectively. Comparison of NPP in this study with other forest types showed that the NPP in this study was comparable with that of tropical forests with high annual temperature. The NEP in this study was similar to that of temperate humid forests showing world-largest class NEP. The results revealed that Moso bamboo forest as a potential role of carbon sink in forests ecosystem.

Keywords: bamboo forest, carbon sink, NPP, NEP

Effects of glucose addition on FDA activity and soil hydraulic properties

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Organic matter addition to soil will be a beneficial strategy as it can enhance carbon sequestration in soil and improve soil structure through soil aggregation. However, our understanding on effects of organic matter addition to soil on hydraulic properties has been limited. For example, glucose is known to promote soil aggregation, increasing hydraulic conductivity; however, it could cause biological clogging through increased microbial activity and this could reduce the conductivity. In this study, we examined effects of glucose -liable organic matter- on FDA activity and hydraulic properties. The silt loam soil amended with glucose solution (termed glucose soil; 10mg C g^{-1} soil + 1.25mg N g^{-1} soil) or distilled water (termed control) was incubated at 25℃. After 4, 7, 15 and 33 day incubation, we measured saturated hydraulic conductivity using constant head method and FDA activity. In addition, using 4 and 7 day incubated soils unsaturated conductivity and soil water retention curves were measured by combining simplified evaporation method with dew point method. The functions of soil water retention and hydraulic conductivity curves were determined with van Genuchten and bimodal models. Saturated conductivity for control was significantly higher than that for glucose soil while FDA activity for glucose was significantly higher than that for control on day 4. This negative correlation between the conductivity and FDA activity could be attributed to biological clogging effects. However, this trend was not observed on day 7, 15 and 33. In addition, as the order of the conductivity did not differ between the treatments, for saturated soils, biological clogging effect on the hydraulic conductivity seemed to be small. On the other hand, there was a clear effect of glucose addition on soil water retention curves; the curve for glucose soil showed dual-porosity structure while that for control did not. From their functions, it was suggested that glucose addition increased micro-pore of which diameter is smaller than 10 μm. Since glucose soil with newly formed micro-pore retained water more strongly in the range of 1,000 to 10,000cm than control soil did, unsaturated hydraulic conductivity for glucose soil was lower than that for control. This micro-pore formation can be explained by the association between clay and extracellular polysaccharide substances produced by microbes which was enhanced through glucose addition. In conclusion, in this study it was revealed that glucose addition on the soil enhanced micro-aggregation, but it reduced unsaturated hydraulic conductivity.

Keywords: Soil, FDA activity, Soil water retention characteristics, Hydraulic condcutivity

Geoelectrical mapping of the Soil and Groundwater Contaminated Site: Case Study from Taiwan

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Many site investigations have found that DNAPL is able to penetrate the low permeable layer such as clay or silt-caly layer in subsurface environment. The cumulated DNAPL within the low permeable Layer will gradually diffuse to the high permeable layer to affect he accuracy of investigation and remedial design. As to the deeper zone affected by the penetration of DNAPL, the conventional sampling design investigating only the first unconfined aquifer is no longer suitable for DNAPL investigation. Precisely define the boundary and the distribution of high and low permeable layer is the key to conduct a successful DNAPL investigation. Point information derived from the conventional bore-hole sampling is difficult to be used for locating the DNAPL pollution due to the uncertainty of DNAPL migration and the soluble-phase distribution of the DNAPL partitioned into ground water between the low and high permeable layer. Recently, non-invaded technologies such as geophysical technology have been introduced to provide the plane and space information of pollution in subsurface by integrating few bore-hole dates. The most common used geophysical technologies are ground-penetrating radar method (GPR) and electrical resistivity tomography (ERT). Both methods have their limitations on the pollution investigation when there are interferences exist such as building structure or heavy pavement. A new geophysical technology, geophysical well logging has been developed to overcome above limitations. The information of multi-wells logging could be used to interpret the permeability of subsurface, the dominate flow path and the hot-spot for evaluating the distribution of pollution and the efficiency of remediation in different time sequences. This study would first discuss how DNAPL and its soluble-phase components invade into the low permeable layer based on the field observation. Then, the importance of geophysical technology is introduced with comparing to the limitations of bore-hole investigation. Last, the case studies on using geophysical technologies including geophysical well logging are introduced to snapshot the complex profile of DNAPL distribution for improving future application.

Keywords: DNAPL, Electrical resistivity tomography, Soil and groundwater contamination

Injection of Carbon dioxide included micro-nano bubble water into late Pleistocene sediments and its chemical reaction

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The distributed CO2 storage, which is neutralizing CO2 and sediment in the shallow aquifer, is small-scale storage and is located around emission areas. Carbon dioxide (CO2) included micro-nano bubbles is one approach in neutralizing CO2 and sediments by increasing CO2 volume per unit volume of water and accelerating the chemical reaction.However, the thorough investigation on the behavior of micro-nano bubble water in sediments has yet not been ventured. In order to design underground treatment for CO2 gas in the subsurface, it is required to elucidate the behavior of CO2 included micro-nano bubbles such as trapping, advection and so on. In this study, the in-situ test was carried out by injecting CO2 included micro-nano bubble water into the injection wellwhile simultaneously sampling and analyzing the underground water quality from the viewpoint of the neutralizing CO2 and sediments. Additionally, the electrical resistivity tomography test was tried to monitor the moving micro-nano bubble water between wells.

Keywords: micro-nano bubble, CO2

Nano Bubble Transport in Saturated Porous Media: Effects of Chemical Properties in Nano Bubble Water

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Nano-bubbles (NBs) have a considerable potential for the remediation of soil and groundwater contaminated by organic compounds, especially when used in conjunction with bioremediation technologies. Understanding the transport mechanisms of NBs in soils is essential to optimize NB-based remediation techniques. In this study, transport experiments in a column packed with glass beads (size fraction of 0.1 mm) were conducted, where NBs created by oxygen gas were injected to the column. The NBs concentration in the effluent was quantified using a resonant mass measurement technique (Archimedes, Malvern Instruments) which can separately count bubbles and particles in water. Effects of chemical properties of the NBs water (i.e., pH and ionic strength) on NB transport in the porous media were investigated. The results showed that attachment of NBs was enhanced under higher ionic strength and lower pH conditions. Around 70% of the NBs applied to the column were retained at pH 5 conditions, while almost of all NBs were released at pH 11 conditions.

Keywords: Nano bubbles, Transport, Porous media, pH, Ionic strength

Numerical Modeling of Variable-Density Flow and Mass Transport in the Unsaturated-Saturated Aquifer under Ambient Groundwater Flow Conditions

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Groundwater contamination problems associated with variable-density flow and mass transport in the unsaturated-saturated aquifer commonly exist in the natural environment. Systematic understanding of the mechanism of density-induced mixing processes is vital for predicting the fate and transport of pollutants in the aquifer and protecting the groundwater resources. Liu et al. (2015) numerically investigated the transport process of solute through the unsaturated-saturated aquifer system, with a focus on the impacts of the hydraulic parameters of the unsaturated soil on the process. However, Liu et al. (2015) assumed no groundwater flow condition which may not be the case in the real world situation. Therefore, this study investigated the influence of ambient groundwater flow conditions on the mass transport in the unsaturated-saturated aquifer by a 2-D numerical groundwater modeling. Sensitivity analysis was conducted to examine the influence of the groundwater flow velocity, the unsaturated zone properties, the soil hydraulic parameters, and the mass input rate on the modeling results.

Keywords: Variable-density flow and mass transport, Unsaturated-saturated aquifer, Ambient groundwater flow conditions, Numerical modelling

Effect of Linear Macropore Installation in Subtropical Soil to Reduce Surface Flow at Sugarcane Field

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Linear macropores were installed at subtropical red soil to reduce surface flow at sugarcane field. Examined fields were located at Ishigakijima Island. The fields were suffering from heavy rain which is increasing these days because of climate change. Surface flow causes soil erosion which declines sugarcane productivity. Also soil particles were directly delivered into sea with coral reef. Soil particles would shade the sun and also nutrient rich water damage the coral reef. Therefore, reducing surface flow with soil particles is crucial for protecting subtropical natural environment. We previously installed artificial macropores with bamboo fiber into the fields to enhance vertical infiltration and reduce surface runoff. Result showed that installation of macropore to tillage field reduced the surface flow while enhancing vertical infiltration. Therefore in this research, for easily installation of macropore, we installed another artificial macropore, namely ” linear macropore” for which macropores were created by subsoiler and filled with sugarcane leaves. Fibrous materials were filled to reinforce the structure. Soil moisture, precipitation, surface flow depth and SS concentration were measured for, 1.conventional tillage, 2.linear macropores with fibrous materials, 3.linear macropores without fibrous materials and 4. Non-tillage field, respectively. Result showed that the amounts of surface runoff were lower at the field of linear macropores with fibrous materials and the amounts of sediment runoff were lower under the non-tillage management. Empty linear macropores showed higher runoff and sediment loss. This result shows that linear macropores with fibrous materials reduce surface flow while enhancing vertical infiltration and non-tillage shows some surface flow but reduces sediment flow by reducing impact of rainfall with residue mulching. Surface runoff increased for empty linear macropore management probably because of clogging.

Keywords: red-soil runoff, macropore, non-tillage, sugarcane

Experimental and numerical evaluation of LTNE in saturated porous media under forced convection

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Convective-dispersion equation is formulated over a representative elementary volume (REV) in porous media, and local thermal equilibrium (LTE) is assumed so that the temperature of the solid and fluid phases are equal in the REV. In fact, however, the temperature of solid and fluid phases in the REV under forced convection are not the same all the time, and local thermal non-equilibrium (LTNE) occurred. Although previous research indicates that LTNE may have significant effects on heat transport simulation in porous media under forced convection, very few experimental studies on LTNE have been conducted. In this study, to investigate the effects of particle size and thermal properties of porous media on LTNE under forced convection, one-dimensional heat transport experiment using a column filled with uniform porous media consisting of glass spheres with a diameter of 3, 5 mm or polyoxymethylene (POM) with a diameter of 5 mm were conducted. Hot water was injected into the column at a constant flow rate during an experimental run for different four flow rates, and the temperature time series within the column were measured. To evaluate LTNE, separate measurements of the solid and fluid temperature were required. To meet this requirement, a thermocouple probe was designed to measure the temperature at the center of a particle (solid temperature) and fluid apart from particle surfaces (fluid temperature) separately. Obtained temperature time series of the solid and fluid phases were normalized by the initial and final temperatures, and a normalized-temperature difference (NTD) between the solid and fluid phases were calculated for the evaluation of LTNE. To validate the experimental results, numerical simulations using two-phase model considering LTNE were performed. When three parameters (Darcy flux, hydrodynamic thermal dispersion coefficient, and particle-to-fluid heat transfer coefficient) in the two-phase model were appropriately applied, the numerical solution could reproduce the experimental data for glass spheres of 5 mm and a Darcy flux of 0.0277 cm s^{-1}. Sensitivity analysis was performed to investigate the effects of the particle size and thermal properties on LTNE. The comparisons between the results of the heat transport experiments and sensitivity analysis revealed that the particle size and fluid velocity were dominant factors affecting LTNE rather than the thermal conductivity of solid.

Keywords: Porous Media, Local Thermal Non-Equilibrium, Forced Convective Heat Transport

Cadmium, lead, zinc and arsenic partitioning in earth surface materials in soils from Kamegai mine tailing, Toyama Prefecture in Japan

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Mining extraction and processing generate large volumes of metal- rich waste tailings. This waste is considered be a principal cause of soil contamination in mining areas (Rashed, 2010; Pe-Leve Santos et al., 2014). Once these toxic metals are introduced into soils, they can be transported deeply into the soil and into groundwater, threatening environmental health. The objectives of this research were to analyze the concentration of several heavy metals (Zn, Pb, As and Cd) in soils from a Kamegai mining waste area, determining the chemical partitioning of those heavy metals using the sequential extraction procedure. It can help to understand the mobility of heavy metals and predict their effect.

Thirty-four soil samples were collected for geochemical and rock magnetic analyses from the Kamegai mine tailing. Also in-field magnetic susceptibility measurements of the soil surface were done at locations where soils samples were collected.The 2mm sieved samples were analyzed to determine the metal concentration by the chemical fractionation of Cd, Pb, Zn and As by the modified sequential extraction procedure. Sequential extraction showed that most of the As, Zn and Pb was associated with the poorly crystalized iron oxide, while Cd was associated with the carbonate fraction in samples. The partitioning of Pb and Zn in the iron oxide is more labile the As at weak acid (pH 5) solution, probably due to the pH dependent surface charge behavior of the iron oxide as indicated by the laboratory and modeling studies. The in-field magnetic susceptibility of topsoil was clearly correlated with Fe, Zn, Pb and As concentrations.

Keywords: Heavy metals, Mining area, Speciation

The effect of entrapped air on water flow in the slope during a pipe clogging event

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Introduction

Soil pipes, continuous macropores parallel to the slope, are often observed at hillslope. Recent field studies revealed that in hillslope, soil pipes usually enhance the drainage from the hillslope during a rainfall event and may keep the slope stable. However, once the pipe outlet is suddenly, clogged soil pipe loses the drainage function, which is considered as one of the causes of the slope failure. Laboratory experiments reproducing the pipe clogging during rainfall have been conducted. These studies showed different types of water pressure rise in the slope during the pipe clogging event; one showed sudden pressure jump, but the other showed gradual increase in water pressure. However, the mechanisms are still unclear.

This study examined the water dynamics in the slope during the sudden pipe clogging. We focused on the effect of the air in the soil pipe on water pressure rise around the soil pipe.

Materials and Methods

An acrylic plastic pipe, 7 mm inner diameter, 10 mm outer diameter, and 50 cm long, was used as an artificial soil pipe. Drain hole with 3 mm diameter were evenly opened on the pipe wall at a density of 1.3 holes cm^{-2}. Soil pipe was covered by nylon mesh to prevent sediment inflow. Soil pipe was connected to a pressure transducer through flexible PVC tube to measure air pressure in the soil pipe. Two-needles electrodes were set inside the soil pipe to detect liquid water in the soil pipe.

Acrylic plastic rectangle box, 60 cm long, 4 cm wide and 35 cm high, was used. Downslope boundary of this box was set to the seepage face. Toyoura sand with 3% mass water content was packed to the box with a dry bulk density of 1.43 g cm^{-3} to a thickness of 30 cm. Artificial soil pipe was buried at 2.5 cm above the base of the soil box, and protruded by 1 cm from the downslope boundary. After packing the soil, soil box was tilted up to 20 degrees. Rainfall simulator was used for water supply and rainfall intensity was kept at a rate of 200 mm h^{-1}. After steady-state flow was attained, we fitted the ball valve at the pipe outlet. The valve closed suddenly to simulate the sudden pipe clogging. During the experiments, soil water pressure around the soil pipe and outflow rate were measured at every 10 seconds.

Two soil pipe conditions were set. One is the OpenPipe condition, where soil pipe was connected to atmosphere only at the pipe outlet. The other is the OpenMacropore condition, where pipe was connected to the atmosphere through the flexible PVC tube, which represents the vertical macropores open to the soil surface, as well as at the pipe outlet.

Results and Discussion

At steady-state water flow, open soil pipe showed lower groundwater table compared to that without the soil pipe. Soil pipe drained much water from the soil slope.

After the pipe clogging, OpenPipe and OpenMacropore condition showed quite different water and air dynamics in the slope. In OpenPipe experiment, air pressure in the soil pipe showed sudden jump at the pipe clogging, and all the tensiometers around the soil pipe also showed sudden water pressure jump. After steady-state flow, groundwater table became similar to that without the soil pipe. Air in the soil pipe was entrapped suddenly due to the pipe clogging, and the entrapped air prevented water intrusion from the surrounding soil though it had positive water pressure. In OpenMacropore condition, water pressure

only at the lower part of the slope rose gradually after the pipe clogging, and electrode sensors showed an increase in water level in the lower part of the soil pipe. At steady-state flow, nearly horizontal groundwater table was formed at the lower part of the slope. This suggested that high permeability of the soil pipe made smaller hydraulic gradient in the lower part of the slope.

Keywords: Soil pipes, pipe clogging, entrapped air, slope failure

Soil ice content determination using heating TDR method

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Frost heaving is a major problem in cold regions. Soil ice content is an important property to understand/predict the frost heaving. However, it has been difficult to measure the soil ice content, in particular, in frozen soils at temperature between 0 and −5 ˚C. Therefore, it is required to develop a method to measure soil ice contents with high accuracy. The objectives of this study are i) to develop heating TDR method for soil ice content measurement, ii) to determine the best heat application i.e., heat intensity and heating stop temperature, and iii) to evaluate the accuracy of the method.
The heating TDR method first measures liquid water content in frozen soil, melts ice around the TDR probe by an embedded heater, and measures total water contents. Soil ice content is determined by subtracting the liquid water content from the total water content. In this study, we used sand and Andisol to test the method. Thermal conductivity of the two soils was measured with dual probe heat pulse technique. Three heat intensities, 15 W m^{-1}, 30 W m^{-1}, 80 W m^{-1}, and three temperatures which the heating stop, 1˚C, 2˚C, and 10˚C, were tested to determine the best heat application. Accuracy of the method was evaluated with the determined best heat application and the soils at various volumetric water contents. The soils were first frozen at -15˚C for 6 hours in a constant temperature chamber and temperature was raised to -2˚C when the measurement was performed. The liquid water content, total water content, and ice content determined with the heating TDR method were compared to those determined by the gravimetric method or a model to evaluate the accuracy.
Thermal conductivity of the sand wassix times larger than that of Andisol when volumetric water content is 0.30 m^3 m^{-3}. It indicates that larger heat amount is required to melt sufficient volume of Andisol than that for sand. The best heat application was 30 W m^{-1} heat intensity and 1˚C heating stop temperature for sand, and 15 W m^{-1} heat intensity and 2˚C heating stop temperature for Andisol. The accuracies of the method with the best heat application were ±0.07 m^3 m^{-3} for sand and ±0.05 m^3 m^{-3} for Andisol, respectively. The accuracy decreased when the measurement was repeated because of water transfer due to heat application. However, the accuracies of the first measurements were better than that reported for other methods and there has been no method which efficiently determines soil ice content at temperature between 0 and −5 ˚C. Therefore, the heating TDR method is a beneficial for many studies related to frozen soils at temperature close to 0 ˚C which soil ice content dynamically changes.

Keywords: soil ice content, Time Domain Reflectometry, Frost heaving

Estimate the influence of three different forests litter decomposition on soil CO_2 efflux in central Taiwan

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Soil respiration is one of the most important source of natural carbon emission, and therefore influence the atmospheric amount of carbon. As the soils of different vegetation cover emit different amounts of carbon, this research set three different adjacent measurement plots including a mixed broadleaved trees stand, a Japanese cedar stand and a Bamboos stand, located in FengHuang mountain, Xitou, central Taiwan.The main aim of this study was to determine the link between the litter decomposition of different vegetation types and their soil respiration. We used EGM-4 (Environmental Gas Monitor, PP systems) to observe soil respiration using three different treatments: (1) including litter and living roots, (2) without litter, and (3) without litter nor living roots. Besides, we placed 60 litter bags on the ground of each different vegetation plots to observe and compare the decomposition rate of their leaves. The results showed that the soil respiration rate of the mixed broadleaved stand was superior to the other stands. The relationship between soil temperature and the soil respiration of different treatments showed a significantly strong correlation for the broadleaved and bamboo stands (r^2 = 0.42~0.72), and the Q_{10} values of different treatments were in the same range (1.65~2.45). The litter decomposition rate was slower for the cedar stand, probably due to the higher acidity of that stand soil, influencing the micro-organisms activity. This study has already been hold for one year and will last at least three years, in order to better understand the carbon cycles of those three kinds of vegetation.

Keywords: Soil respiration, Litter decomposition

Gas and water transport in landfill final cover soils during precipitation

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It has been reported that landfill sites are significant sources of greenhouse gases. A part of gases produced in the landfill waste layer are emitted to the atmosphere through the landfill final cover soil. Therefore, it is important to understand how gases move through the final cover soil in order to accurately estimate the greenhouse gases emission from the landfill site. High intensity precipitation events likely induce a gas eruption due to a soil-gas compression following water infiltration. Gas compression also rises soil air pressure and thus reduces water infiltration rates, which restricts amount of leachate from the landfill sites. However, the effects of precipitation on gas and water transport in the final cover soils are not fully understood.
In this study, one-dimensional column transport experiments were conducted to examine the effects of intensity of precipitation, dry bulk density of the cover soil, and gas production rate on gas eruption and rainwater infiltration. A disturbed soil sample (sandy loam) used as a landfill final cover soil was collected. A 5% methane gas or a 5% oxygen gas was injected to the soil column (dia. 10 cm, height 30.5 cm) packed with variable dry bulk densities (1.4, 1.5, 1.6 g / cm^3) from the bottom with variable gas fluxes. Precipitations of variable intensities were applied from the top of the column. Oxygen concentrations inside the column and an outlet chamber placed at the top of the column were measured continuously. Methane concentrations inside the column was measured before and after the precipitation while the methane concentration in the outlet chamber was measured periodically during the precipitation. Soil gas pressure, water contents and temperature inside the column were also monitored during the experiment.

Keywords: landfill, gas eruption, soil, infiltration, precipitaiton, methane

Accounting for Temperature Dependence in Numerical Analysis of Elasto-Plastic Deformation of Saturated and Unsaturated Soils

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As utilization of renewable geothermal heat energy is increasing recently, it is important to have a tool that can assess the influence of disturbing the subsurface thermal regime on the mechanical behavior of the ground. Many previous studies on saturated soils had shown that while there is reduction in consolidation yield stress and shear strengths with increasing temperature, the strengths at the critical state were almost independent of temperature. Our previous study based on the triaxial compression tests for unsaturated soils (DL clay) showed the similar temperature effect as saturated soils. In this study, we have developed a tool that can numerically simulate elasto-plastic behavior of saturated and unsaturated soils under different temperatures based on the finite element method. The effect of temperature on the mechanical behavior of the soil was modeled by formulating an intercept of a normal consolidation line (NCL) as a function of temperature. We additionally adopted a concept of the shear band to modify plastic volumetric strains of dense specimens. The developed model was evaluated by analyzing our experimental data. The analysis domain was 2.5 cm ×5 cm, assuming the axial symmetry of the specimen. Shearing process was simulated by applying a constant strain rate at the top of the soil specimen. Simulated results showed that, for loose specimens, while the initial increase in the shear strength became smaller with increasing temperature, the strengths at the critical state were almost independent of temperature. Temperature effects on the volume change were relatively small. As for dense specimens, the simulated results showed that the peak strength and the volume expansion became smaller with increasing temperature. The strength at the critical state was again independent of temperature as similar as the loose specimens. The simulated results were in good agreement with experimental data.

Soil carbon accumulation process as affected by infiltration pattern.

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Soils are largest terrestrial carbon storage body, however, these days this fertile zone is suffering from soil erosion, permeability descent and thus carbon loss. Therefore, we introduced artificial macropore to enhance vertical infiltration along with organic carbon accumulation. At the same time, non-structural flow, fingering infiltration, was also examined. Toyoura standard sand was packed in a Hele-Shaw cell and artificial macropore made of glass fiber was installed. 100mL of Benzoic acid (500mg/L) with nutrient (N:P:K=6:10:5) was applied with 60mm/h rainfall intensity. Hele-Shaw cells were incubated with 30 °C with RH60%, which were sampled at 1,3,6 days after the rainfall.
Results showed that bypass flow with spot at the bottom was observed for artificial macropore, while wetted vertical downward belt was observed for finger flow. Benzoic acid was observed at the surface for most of the experiments even after 6 days, and there were not clear difference in Benzoic acid contents between surface and lower part. However, water contents were higher at lower part of the cell, which meant macropores were beneficial for vertical infiltration along with evaporation suppression.
Multiple regression analysis for upper and lower part showed that water content contribution, rather than EC, was significant for Benzoic acid concentration. Partial regression coefficient showed negative for upper part of the cell, thus higher the water contents, lower the Benzoic acid concentration. On the other hand, the coefficient showed positive for lower part of the cell, thus higher the water contents, higher the Benzoic acid concentration.
Overall, Benzoic acid showed higher concentration and higher degradation trend at the surface, while degradation resistance was observed at the lower part of the cell. Macropore infiltration showed bypass flow with spot at the lower part, therefore, we estimated that macropore had advantages for organic carbon accumulation with enhanced infiltration.

Keywords: macropore, infiltration, carbon storage

Geostatistical spatial interpolation of soil water retention curve using PTFs based on particle size distribution

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Predicting soil water retention curves (SWRC) or their model parameters at any unsampled locations using a geostatistical spatial interpolation technique requires a number of high quality retention data. Obtaining SWRC is, however, generally tedious, time consuming, and sometimes expensive. Therefore, pedotransfer functions (PTF), which allow one to predict soil hydraulic properties, such as SWRC, from easily measured soil properties, have been developed. In this study a geostatistical spatial interpolation technique was coupled with the PTF to predict water retention curves at given unsampled locations from available particle size distribution (PSD) data. Two PTFs are used in this study, one is the Arya and Paris (AP) model which predicts water retention curves from PSD and dry bulk densities, the other is based on the *k* -nearest neighbor (k-NN) algorithm which is a nonparametric method used in data mining. There are two approaches considered: (1) First, SWRC are predicted from PSD at given observed locations using one of the PTFs. SWRC are then predicted at given unsampled locations through the geostatistical spatial interpolation technique. This approach is referred to as the PTF-first and Interpolation-later approach or the PI approach. (2) First, PSD and the bulk densities are predicted at given unsampled locations using the geostatistical spatial interpolation technique. Then, SWRC are predicted at the unsampled locations by the PTFs from the interpolated PSD and bulk densities. This approach is then referred to as the Interpolation-first and PTF-later approach or the IP approach. Current study compares the performance of these two approaches to predict SWRC at any given unsampled location. The data used in this study were obtained from the Las Cruces trench site database, which contains water retention data for 447 soil samples. The dataset was then split into two sets, prediction and validation sets. This allows for the computation of prediction errors (root mean squared error or RMSE and mean absolute error or MAE). The results used AP model show that the performances of the PI and IP approaches were comparable. On the other hand, the results based on k-NN show that the PI aprroache outperformed the IP approach.

Spreading of Antarctic Intermediate Water in the Philippine Sea

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The Antarctic Intermediate Water (AAIW) is carried by the New Guinea Coastal Undercurrent (NGCUC) to the Philippine Sea (PS), then carried by the Mindanao Undercurrent (MUC) northward. In this study, the AAIW presents two divided parts using a stricter definition. The outshore part of AAIW locates between 400-650db, and reaches 10˚N northmost. The inshore part locates below 800db, and it extends about 15˚N. The two parts are connected by an anticyclonic gyre at about 1.5-3˚N, 127.2-128.6˚E. The wavelet spectrum of the AAIW volume indicate that the significant periods of outshore part and inshore part are 2.3 years and 3.9 years, respectively. We speculate the relationship between ENSO and the two parts of AAIW, but need deeper research about the dynamics in the future.

Keywords: the Antarctic Intermediate Water, the Mindanao Undercurrent