

## The Effect of Artificial Macropores on the Amount of Organic Matters in Soils and Plant Biomass

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Artificial macropores with fibrous material were installed in degraded red yellow soils to enhance vertical infiltration along with organic matter and nutrients. They enhanced vertical infiltration without cultivation which could cause small particle loss from the surface soils. Macropore and no macropore plots were prepared and total carbon in 10, 30, 50 cm depth were measured every half year. Infiltrated soil water was sampled through capillary force soil water sampler to measure total organic carbon and ion concentration. Results showed that soil total carbon in macropore plot increased in spring while it decreased in fall. Control plot showed few fluctuations. Total carbon concentration in soil water also showed higher trend in macropore plot, thus the TC fluctuation in soils could be caused by infiltrated soil water conducted by artificial macropores. Ion concentration was also measured to find that nitrate nitrogen was higher in summer season in macropore plot, which would be a source for biological decomposition of organic matter and also for nutrient for plant growth. Resulted plant biomass in macropore plot was two times larger than that in control plot. Additionally, plant species number observed at the macropore plot was 12, while it was 8 in control plot. This vegetation would be possible organic matter source for future soils. Finally, carbon increment in poor nutrient soils after macropore installation was calculated as 0.0036 g-C g-soil-1 yr-1 (20.4 t-C ha-1 yr-1), which was very successful. The study had successfully showed that relatively simple technique of artificial macropore with fibrous material could increase the organic matter in soils and recover the vegetation in ill-drained soils.

キーワード: マクロポア, 浸透, 炭素固定

Keywords: macropore, infiltration, carbon sequestration

## 自然由来汚染土壌における鉛の長期的溶出特性評価 Characterization of Long-Term Leaching Properties of Lead from Naturally Contaminated Soils

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Recent amendment of the Soil Contamination Countermeasures Act in Japan requires countermeasures to the soils including naturally occurring heavy metals, i.e., the soils even if they are naturally contaminated. Among a variety of toxic heavy metals, Lead remains a top priority for study, because it is one of the most common contaminants not only in Japan, but worldwide.

To characterize the long-term leaching properties of lead from naturally contaminated soils, six samples taken from the surroundings of different, abandoned metal mines were collected and tested. Chemical compositions, mineral compositions, cation exchange capacity, total organic carbon, total and leaching concentrations, existing form and sequential leaching concentrations of lead were systematically analyzed and examined.

The results of this study demonstrated that 1) X-ray fluorescence analysis cannot obtain comparative value of total concentration of lead for naturally contaminated soils compared with the standard test method based on acid extraction. 2) Leaching concentration does not depend on total concentration. Soil samples containing low total concentrations that are below environmental standard may have high leaching concentrations. 3) Leaching concentration is not stable during sequential and/or long-term leaching. Leaching concentration that meets environmental standard at a time may fail to meet environmental standard someday even under similar pH conditions. 4) Leaching properties of lead from naturally contaminated soils are fundamentally controlled by its existing form. 5) Compared with removing toxic heavy metals, immobilization and/or solidification together with risk-based management of naturally contaminated soils could be more cost-effective and practical.

キーワード: 自然由来, 重金属類, 鉛, 長期溶出特性, 逐次溶出試験

Keywords: Naturally Occurring, Heavy Metals, Lead, Long-Term Leaching Properties, Sequential Leaching Test

## 土壌パイプが降雨流出過程に及ぼす影響 Soil pipe effect on rainfall-runoff process

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### Introduction

At hillslope, soil pipes are often formed by activity of soil fauna and plant roots as well as internal erosion. Many researches indicated that soil pipes parallel to the slope bed greatly influenced hillslope hydrological phenomena. In order to understand hillslope soil water dynamics, it is important to understand and model role of the soil pipes. For this reason, quantitative discussion of the effect of soil pipes on rainfall-runoff process is needed. Several model experiments and numerical analyses using soil box with artificial soil pipes indicated that soil pipes changed groundwater table profile. However, since most previous researches handled the steady-state condition, understanding of soil pipe effect on transient water dynamics during a rainfall event is still limited.

Our research objective is to clarify the effect of soil pipes on unsteady soil water dynamics under rainfall.

### Experiment and numerical analysis

We packed toyoura sand homogeneously to form a soil box of 60 cm long, 30 cm high and 4 cm thick, with an outlet at the downstream end. As the artificial soil pipe, perforated acrylic pipes with the inside diameter of 7 mm were buried. The artificial soil pipes had many drain holes of 3 mm in diameter at the lateral side to pass soil water between soil matrix and pipe. The pipes were covered by nylon mesh to prevent inflow of sand particles. Soil pipes were buried at 2.5 cm above the impermeable bed. Soil pipes are commonly considered to be discontinuous in the soil, so we set three soil-pipe conditions, i.e. no pipe, continuous pipe and discontinuous pipes. Rainfall simulator was set above the soil surface to add the rainwater to the soil. At first, constant rainfall was added to attain steady state percolation through the soil. Then, rainfall intensity had risen for a while, and then returned to be the same intensity at the beginning of the rainfall. This procedure gave a pulse-like change in rainfall intensity. During the experiment, we measured rainfall intensity and discharge from an outlet by the tipping bucket. Also, soil water pressure at twelve observation points was monitored using tensiometers.

In the numerical analysis, we tried to reproduce the experiment using HYDRUS-2D software. Soil pipe was modeled as virtual soil matrix with high hydraulic conductivity and low air-entry value. Soil hydraulic function was described by the van Genuchten-Mualem model. Applied rainfall was expressed by the flux boundary and downstream outlet was assigned as seepage face boundary.

Keywords: soil pipes, rainfall-runoff process

## 海成帯水層の温度変化が地下水質に与える影響 Effects of temperature change in a marine subsurface aquifer on groundwater quality

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Ground Source Heat Pump (GSHP) systems are getting increasingly used worldwide. GSHP systems utilize the groundwater temperature via heat exchange for cooling or heating of buildings, and GSHP is generally recognized as a renewable and sustainable energy system. For example, applying GSHP instead of conventional heating/cooling systems makes it possible to reduce CO<sub>2</sub> emissions to the atmosphere, save energy, and restrain urban heat island phenomena. On the other hand, GSHP systems dispose heat or cold to the subsurface, which causes subsurface temperature change and, consequently, may cause changes in chemical composition of the groundwater (possible groundwater contamination) as well as a disturbance of the subsurface microbial ecosystem. However, the effect of temperature change on the subsurface environment is not well understood. Therefore, we conducted a long-term thermal loading and natural cooling test and investigated the temperature change effects on groundwater quality. The experimental site is located in Saitama University, Japan. The experimental system was installed with a U-tube as the heat exchanger. Four groundwater monitoring wells were installed for an upper (marine) and a lower (non-marine) aquifer at 1m (W1), 2m (W2), 5m (W5) and 10m (W10) distance from the U-tube heat exchanger. Thermal loading into the subsurface was applied for totally 13 months by circulating 40 °C water inside the U-tube heat exchanger. Results showed groundwater temperature at W1 increased about 8 °C (from 17 °C to 25 °C) for the first 6 months and then stayed almost constant. In the upper aquifer, concentrations of boron, DOC, and several other chemical components increased together with the increase in subsurface temperature. In the lower aquifer, a similar effect of temperature could only be observed for one chemical while data were not sufficient for other chemical compounds. After thermal loading, the effect of natural cooling on groundwater quality was investigated for 14 months. At the end of the thermal cooling period, the subsurface temperature and the concentrations of components that had increased during thermal loading all decreased to approximately the initial values observed before heating had started. For these components, an approximate linear relationship between change in chemical concentration and change in subsurface temperature was observed.

キーワード: 地中熱利用ヒートポンプ, 熱負荷, 温度変化, 地下水質, 海成帯水層, 自然冷却

Keywords: Ground Source Heat Pump(GSHP), thermal loading, temperature change, groundwater quality, marine aquifer, natural cooling

## 室内拡散試験を選択及び設計するための理論と技術的判断基準 Theoretical and Technical Criteria for Selecting and Designing Laboratory Diffusion Tests

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Mass transport in geo-environments is primarily controlled by advection, dispersion and sorption if no chemical and/or bio-chemical reactions and chain decay are involved. When permeability is low and/or hydraulic gradient is extremely small, mass transport in a geological stratum such as a clay layer will be controlled by diffusion and sorption.

To properly select a test method, and to effectively perform a laboratory diffusion test, theoretical solutions to both through and in-diffusions are overviewed. Based on discussion of analytical technologies for different kinds of chemicals, such as contaminants and/or nutrients associated with bio-remediation of volatile organic compounds (VOCs), this presentation illustrates how to selection a test method, how to shorten required testing time, how to determine sampling interval and how to interpret experimental data.

キーワード: 室内拡散試験, 透過型拡散試験, 浸入型拡散試験, 理論解, 分析精度

Keywords: laboratory diffusion tests, through-diffusion, in-diffusion, theoretical solution, analytical precision

## 撥水性発現に関する各要素の検討 Consideration of various factors on the expression of Soil Water Repellency

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**Soil water repellency (SWR)** is a phenomenon that exhibits soil hydrophobicity mainly related to the presence of organic matter coating in soil grains. Agricultural farm manure, organic fertilizer, different vegetation type as well as microbial activity in the soil could be the reasons to develop hydrophobicity of soil. Importance of SWR studies is to understand the nonuniformed infiltration, surface run-off and soil erosion etc. The objectives of this study are (i) to investigate the difference of SWR measurement in the field and laboratory condition and (ii) to identify the relationship between the SWR and soil physical and chemical properties. Two sites were selected; greenhouse vegetable farm at Mizuho-farm, Miki city, Hyogo prefecture in Japan and pasture land at Tihoi farm, Waikato in New Zealand. Field measurement and soil sampling in Mizuho-farm were carried out on December 2013 and October 2014. Sampling in Tihoi farm was carried out on February 2014 and December 2014. At the Mizuho-farm, two greenhouses were selected (No. 7 and No. 21) and field water drop penetration time (WDPT) were carried out using transect walk, grid locations (10 m x 3.0 m area), auger samples for depth profile and random points measurements. In addition to correlate the biomass production to SWR, biomass percentage were estimated using quadrat (0.3 m x 0.3 m) method.

Similar to that, WDPT were measured at Tihoi-farm on selected transect lines along the sloping land (ridge and furrow) and most top of the pasture land. At the same time, surface soil samples and core samples were selected to measure laboratory WDPT and soil physio-chemical properties for Japan and New Zealand sites. Results were analyzed to compare field and laboratory WDPT measurements and effect of physio-chemical properties on degree of SWR.

Keywords: Soil Water Repellency, water repellency parameters, soil organic carbon, mass transport

## マグネシウム試薬の種類によるヒ素除去性能の違いについて Difference in Arsenic Removal Performance among Types of Magnesium Reagents

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発展途上国の一部の地域では、ヒ素によって汚染された地下水を飲料水として直接利用しているため、健康被害が懸念されている。それゆえ、健康リスク低減のために、効果的かつ安価な‘ヒ素除去剤’の開発及び供給が切望されている。ヒ素除去剤（ヒ素吸着剤または凝集剤）を開発するためには、ヒ素除去に密接に関連する成分に着目した系統的な試験を実施し、そして試験で得られた基礎的データを蓄積・公開する必要がある。本研究では、ヒ素除去に有効な成分の一つとして、マグネシウムに焦点を当てた。ヒ素除去試験は模擬ヒ素汚染水を用いて行われた。6種類のマグネシウム試薬（塩化マグネシウム、硫酸マグネシウム、酸化マグネシウム、水酸化マグネシウム、軽質と重質の炭酸マグネシウム）が試験され、それらのヒ素除去性能は、試薬添加量と試薬中のマグネシウム含有量に基づいて評価された。

キーワード: ヒ素除去, マグネシウム塩, ヒ素汚染水, ヒ素除去率, ヒ素除去効率

Keywords: arsenic removal, magnesium salts, arsenic contaminated water, arsenic removal ratio, arsenic removal efficiency

## Application of Time Lapse Electrical Resistivity Tomography to the Soil and Groundwater Contaminated Site: Case Studies

### Application of Time Lapse Electrical Resistivity Tomography to the Soil and Groundwater Contaminated Site: Case Studies

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Electrical Resistivity Tomography (ERT) is a useful geophysical tool for investigation of the soil and groundwater site. It could be applied in estimating the groundwater flow direction and contaminants space distribution. With these applications, we could establish monitoring or sampling wells in potential pollution areas. ERT survey could delineate the contaminated areas with high concentrations in relatively simple geological sites. Even in the seriously DNAPL leakage cases, it is possible to directly detect the DNAPL pool. However, when the site condition is complex (e.g. the electrical characteristic of contaminants and geological materials is similar), it is difficult to distinguish the differences between contaminants and geological materials in electrical resistivity profiles. Therefore, the Time Lapse-ERT (TL-ERT) can be applied to monitor the distribution of electrical characteristic changes underground and to indirectly indicate the flow direction of contamination. Furthermore, the TL-ERT is also an efficient approach to evaluate remediation effectiveness in remediation or post-remediation sites. When the lapse of time is short, TL-ERT is similar to real-time monitoring. It is more efficient to estimate the transportation direction of pollutant or medicament by using TL-ERT combined with Cross-Hole Electrical Resistivity Tomography (CHERT). It can not only get high resolution electrical resistivity images but also increases the benefit of new monitoring wells.

キーワード: NAPL, ERT, Time Lapse, Geophysical survey, Pollution, Resistivity imaging  
Keywords: NAPL, ERT, Time Lapse, Geophysical survey, Pollution, Resistivity imaging



## HYDRUS-2Dを用いた人工マクロポアによる降雨浸透促進効果の評価 Assessment of enhanced infiltration by artificial macropore with HYDRUS-2D

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土壌は植物や大気など地球全体において最大の炭素貯留体である。しかしながら、近年、気候変動や不十分な管理の影響によって、土は水の貯留層や栽培地としての機能することができない。今研究では、耕耘を行わず、雨水の浸透を促進することを目的として土壌中に人工マクロポアを導入した。劣化し、有機物の乏しい土壌では、激しい降雨によりその表層にクラストが発生する場合がある。この状況では土壌表層の土壌構造は降雨の浸透に大きく影響を与える。人工マクロポアとは土壌構造を人為的に再現することで、土壌表層における降雨の浸透を促進する働きを持つ。今実験では HYDRUS-2D を用いて人工マクロポア技術を再現することを目的としている。人工マクロポアは土壌表層に開いた孔隙から土壌表層の表面流を流入させる効果がある。しかし、HYDRUS-2D では土壌表層の表面流を計算することはできない。そこで、表面流を計算するために、計算領域内に飽和含水率と透水係数が高く設定された仮想空間を設定した。そして、シミュレーションの予測値と実際の実験値を比較した。その結果、仮想大気を設定することで人工マクロポアへの降雨の流入を正確に表現することができた。以上のことから、仮想大気を用いて HYDRUS-2D 上での人工マクロポアの浸透促進を再現が可能であるとわかった。

## FTIR スペクトル分析による劣化土壌中の有機物測定 Measuring Fresh and Old Organic Matter Contents in Degraded Soils using FTIR spectroscopy.

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土壌は陸域で最大の炭素プールであり、また、水貯留や植物の培地としての重要な機能も持つ。しかし現在、気候変動による土壌消失や農地管理の変化が、土壌有機物の減少を引き起こしている。現在の研究で我々は浸透促進によって表層の有機物を土壌中に引き込むことに成功しており、植物生育を促している。この際に、新鮮有機物の寄与と既存の有機物を区別出来たならば、浸透促進効果の測定において有益である。そこで本研究では、フーリエ変換型赤外分光光度計 (FT-IR) が土壌中の有機物に適用できるか検討を行った。

豊浦標準砂とベントナイトをベース材料とし、炭素重量でそれぞれ土壌中の有機物に見立てたセルロースとフミン酸を0~5%の割合で混合した。測定には拡散反射法を用い、ピーク面積から定量を試みた。得られた赤外スペクトルより、 $3450\text{cm}^{-1}$ 、 $2900\text{cm}^{-1}$  がセルロースと、 $2600\text{cm}^{-1}$  がフミン酸との相関を持つ吸収強度であるとわかった。最後にセルロースとフミン酸の両方を混合した試料から、セルロースとフミン酸それぞれの量が測定を試みた。セルロースは、フミン酸の量にかかわらず、濃度が2%以下のとき精度よく定量出来た。一方で、フミン酸は濃度3%以上のときに精度よく定量出来た。

キーワード: FTIR スペクトル, 土壌有機物, 土壌炭素

Keywords: FTIR spectrums, soil organic matter, soil carbon

## A Case Study of Combining Geophysical Prospecting Techniques at a DNAPLs Contaminated Site

### A Case Study of Combining Geophysical Prospecting Techniques at a DNAPLs Contaminated Site

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Since 2008, site remediation was being conducted on both soils and groundwater which are impacted by dense non-aqueous phase liquid plumes (DNAPLs), in an old waste dump site of abandoned factory located in Hsinchu, Taiwan. This included continuous pumping and treatment on contaminated groundwater from wells. The DNAPLs existed for a long time and no records of previous operation were available. Therefore, significant quantity of DNAPLs remained in the subsurface and infiltrated downwards from the topsoil to lower bedding of fine sand embedded with gravel and siltstone.

In this study, we presented the investigation outcomes of electrical resistivity tomography (ERT) and ground-penetrating radar (GPR) at the DNAPLs-impacted site. Evaluation of RIP technique deployment in detecting buried DNAPLs and assessment of remediation efforts are also discussed. Results indicated zones with anomalously high resistivity to be associated with contaminated DNAPLs presence. Resistivity maps clearly outlined the subsurface distribution and the possible migration path of DNAPLs.

キーワード: Dnapls, electrical resistivity tomography (ERT), ground-penetrating radar (GPR)  
Keywords: Dnapls, electrical resistivity tomography (ERT), ground-penetrating radar (GPR)

## Application of Surgical Remediation to Complex Contaminated Sites in Taiwan Application of Surgical Remediation to Complex Contaminated Sites in Taiwan

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Because of geological heterogeneity, it is easily to misestimate the distribution of pollutants and to predict the transportation of pollutants difficultly during the investigation and remediation of groundwater contamination. Furthermore, the injection of gas and remediation reagents or biological species cannot effectively transport to pollutant area of complex geology, especially in low-permeability strata. Therefore, it is necessary to develop Surgical Remediation(SR) for some geological heterogeneity complex sites. The SR is to applying high resolution of investigation techniques to get more underground characteristic, such as 3D pollutant distribution, geological distribution and biochemical information, and to using better remediation transportation techniques to overcome geological heterogeneity. For example, remediation reagents can be spread more widely to remediate pollutants in low-permeability strata.

A geological complex contaminated site in Taiwan, interbedded with sand and silty clay and its permeability reached 2<sup>-3</sup> orders of magnitudes, was studied in this research. The groundwater is highly contaminated with 1,2-Dichloroethane and Vinyl Chloride. (Many of them reached tens of ppm.) The pollutants have distributed over high-permeability strata (sand) and low-permeability strata (silty clay). We introduce the concept of SR, using Multi-Depth Pollutant Sampling Analysis, Multi-Depth Radon Analysis, Bacteria Flora Analysis, Multi-Depth Slug Tests, Well Log Analysis and Multi-Depth Flow Velocity and Direction of Single Well Test, to evaluate the 3D hydrogeology characteristic and the space-time variation of pollutants. We design appropriate injection pressure and flow according to hydraulic conductivity value range, pollution concentrations, and polluted depth and apply Double Packer Injection (DPI) to utilize multi-depth method injecting remediation reagents (Japan Patented Biosimulation Reagents, EDC?, which can degrade high-concentration chlorinated contaminants effectively was chosen.) into the specific deep strata, and use the automated monitoring system developed by ourselves to confirm the interrelationship between the pressure of each injection depth and flow changes. The injection parameters are modified accordingly and instantly. Finally, we use the groundwater flow direction and perpendicular direction to evaluate the overall mass flux variation, and combine with novel geophysical, Cross-Hole Electrical Resistivity Tomography (CHERT), to directly or indirectly evaluate remediation reagents variation during transportation and the space-time improvement performance. This research proves that SR can be effectively investigated underground characteristic, and remediation reagents can be efficiently transported within high-permeability strata and low-permeability strata to fit in with the expected direction, and pollution concentrations can be reduced significantly in few months to conform to the Control Standard.

キーワード: Geological heterogeneity, Surgical remediation, Double Packer Injection, Automated Monitoring Systems, Cross-Hole Electrical Resistivity Tomography

Keywords: Geological heterogeneity, Surgical remediation, Double Packer Injection, Automated Monitoring Systems, Cross-Hole Electrical Resistivity Tomography

## 多孔質体における溶質輸送係数の温度依存性に関する研究 Temperature Dependency on Solute Transport Parameters in Porous Media at Saturated Condition

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Widespread use of ground source heat pump systems may disturb thermal condition of soils, and potentially causes changes in subsurface mass transport. Therefore, understanding temperature dependency of the solute transport characteristics is essential to accurately assess environmental risks due to perturbation of subsurface temperature. In this study, one-dimensional solute transport experiments were conducted in repacked columns under temperature control (10 °C to 40 °C) to investigate effects of temperature on solute transport parameters. Toyoura sand and glass beads were used in the experiments. In the transport experiments, 0.01M KCl solution was injected to the core sample with 5-cm diameter and 5-cm height from the bottom end. The concentrations of the electrolyte at the effluent were measured using electrical conductivity, and used for calculating solute dispersion coefficient. The solute diffusion experiments were also performed under different temperature conditions to obtain temperature effect of solute diffusion coefficient. The results showed hydraulic conductivity and solute diffusion coefficient for both materials increased with increasing temperature due to lower viscosity of water at higher temperature. Toyoura sand showed that solute dispersion coefficient at 25 °C was highest followed by 40 °C, and 10 °C, indicating effects of temperature on solute diffusivity and viscosity of water affected solute dispersion characteristics. For glass beads with larger size fraction, temperature dependency on solute dispersion coefficient was insignificant.

キーワード: 溶質分散係数, 溶質拡散係数, 透水係数, 温度依存性

Keywords: solute dispersion coefficient, solute diffusion coefficient, hydraulic conductivity, thermal dependency

## スリランカ廃棄物処分場における埋設廃棄物の締固め特性 Compaction properties for municipal solid waste at open dumping sites located in Sri Lanka

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Due to rapid urbanization, generation of municipal solid waste is increasing in developing countries. However, most of the waste disposal site in developing countries is an unsanitary open dumping causing serious social and environmental problems such as subsidence and collapse of waste slopes at disposal sites. Sri Lanka is one of countries facing the waste disposal problems (Sato, et al., 2012), and most of collected waste is dumped at the disposal sites without any engineering consideration such as ground settlement and slope stability. Several studies have been done to investigate geotechnical properties for municipal solid waste samples (e.g., Chen et al., 2009; Reddy et al., 2009), however effects of climate condition and age of waste on geotechnical properties are not well understood.

In this study, to investigate effects of climatic conditions and age of waste fill on compaction properties of buried municipal solid waste. Boring core and box samples of buried municipal solid waste and its subgrade taken from two open dumping sites under different climatic conditions in Sri Lanka: Udapalatha (Average temperature is 17.5 ? 25.0 degree, annual rainfall is greater than 2,500 mm) abandoned open dumping site in the wet zone and Hambantota (Average temperature is 26.3 ? 28.1 degree, annual rainfall is less than 800 mm) open dumping site under operation in the dry zone. The age of collected ranged less than 3 years after dumping for new dumped zones and between 4 and 11 years for old dumped zones. Furthermore, intact boring core and box samples of subgrade were taken from a point at which no waste dumping. Basic physicals and chemical properties such as moisture content, specific gravity (Gs), Atterberg limits, particle size distribution, waste composition, pH and EC, ignition loss were measured in the laboratory. Standard proctor tests were carried out to determine the maximum dry bulk densities and optimum water contents for waste and subgrade samples.

Results show that Gs values for waste samples in both wet and dry zones were less than intact soil, in addition less than 2.50 for waste samples in the wet zone. Based on the waste compositions for two sites in wet and dry zone, for every waste samples, residue content below 4.75mm were rich, and the residue content for dry zone exceed 60%, the waste samples in the wet zone had more various kinds of wastes. The maximum dry densities ( $\rho_{dmax}$ ) for dry zone were around 1.5 times higher than those of wet zone. *In-situ* dry bulk densities ( $\rho_{in-situ}$ ) were around 80 % compared to  $\rho_{dmax}$  for both samples in wet and dry zones. Both  $\rho_{dmax}$  and  $\rho_{in-situ}$  gave good linear relations to residue content below 2.00mm and loss on ignition. Therefore, the residue content and loss on ignitions seem to be good indices to identify the compaction properties for dumped waste materials.

Keywords: Municipal solid waste, Maximum dry bulk density

## Compressibility for industrial waste materials with various mixing proportions and settlement analysis

### Compressibility for industrial waste materials with various mixing proportions and settlement analysis

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Solid waste materials are highly heterogeneous depending on various waste compositions, making it difficult to understand their engineering characteristics. The purpose of study is to find out effects of waste compositions and mixing proportions on the optimization of the dry density of solid waste materials. In this study, totally 6 different waste materials, un-burnable domestic waste, un-burnable industrial waste, incineration ash, crushed concrete, organic sludge and inorganic sludge, were used as tested materials. The purpose of study is to find out effects of waste composition and mixing proportions on the compaction and to optimize the maximum dry bulk density of the waste samples to reduce the landfilling space requirement with least settlement of the final landfills. Standard compaction/proctor test results showed that maximum dry bulk densities of the incineration ash (1.53-1.74 g/cm<sup>3</sup>) and crushed concrete (1.37-1.52 g/cm<sup>3</sup>) were higher than the inorganic sludge (0.76 g/cm<sup>3</sup>) and organic sludge (0.90 g/cm<sup>3</sup>) respectively. The maximum dry bulk density for the mixed sample with ratio of 2:6:2 and 2:2:6 (1.65g/cm<sup>3</sup>) dry mass basis were 2.17 times greater than that of inorganic sludge. Consolidation properties determined with modified oedometer apparatus with 10cm diameter and 10cm height to incorporate the coarser fractions of the waste materials, showed that compression index (Cc) of the sludge was 0.21 which reduced significantly 0.04 and 0.02 in that of 1:1:1 and 5:2:3 mixed samples respectively. A simple settlement analysis was carried out using measured consolidation parameters, assuming 10-m thick of waste layer below 3-m soil capping. Three different waste layers, only sludge, two mixed samples of concrete and sludge, three mixed samples (sludge, crushed concrete and incineration ash), were tested in the analysis. Results showed that the final settlement for the three mixed samples was 8 times lower than that of the sludge sample.

キーワード: Solid waste, Sludge, Compaction, Consolidation, Compressibility, Settlement  
Keywords: Solid waste, Sludge, Compaction, Consolidation, Compressibility, Settlement