Japan Geoscience Union Meeting 2014
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AHW28-P01 Room:Poster Time:April 30 18:15-19:30

Applicability of EUROSEM for surface runoff in forested slope plain

IKEDA, Hideshi[1*] ; WAKAMATSU, Takashi[1] ; NAKAYA, Ko[1] ; ABE, Seiya[1]

[1]Central Research Institute of Electric Power Industry

Sediment yield in agricultural area has been environmental and economic problems in many countries. In order to restrain sediment yield and to conserve water resource, scientific watershed managements are required in many watersheds. In USDA (United State Department of Agriculture), USLE model (Universal Soil Loss Equation) was developed and applied to many sites. USLE model is empirical model, and requires long term observation data. Then, physical based models, such as WEPP (Water Erosion Prediction Project) and EUROSEM (EUROpean Soil Erosion Model), were developed and applied to watersheds where long-term observation had not been conducted.

In some Japanese forest, forest management, such as thinning, has not been conducted fitly in these years. In poorly managed forest area, sediment yield with surface runoff has occurred and supplied suspended solids into stream, reservoir and coastal area. However, in forested watersheds, application of these models has not been conducted frequently, and it is required to validate and apply these models based on observation of meteorology, forestry, pedology and hydrology.

EUROSEM model is one of the useful tools for evaluation of sediment yield in forested area. In this study, hydrological applicability of EUROSEM is discussed. EUROSEM is a prediction model for sediment yield, which was developed by European Union in 1990s. It consists of hydrological and sediment sub-models, those are physical-based process models in non-steady state. EUROSEM has been applied to agricultural areas in Europe and China, for example in watershed of Three Gorge dam, Yangtze River. On the other hand, it is not applied to Japanese forest area frequently, where sediment yield is reported recently.

In Central Research Institute of Electric Power Industry (CRIEPI), we have been conducting observation for sediment yield since June 2010 in Akagi testing center, located in north Kanto plain. The observation system consists of 3 sites, one open field and two forest stands. For open field, precipitation was observed using Laser Precipitation Monitor (LPM,THEIS, FRG) consequently. For in two forest stands, vegetation, meteorology and hydrology survey were conducted. In vegetation survey, canopy analyzing and forest floor survey were conducted in every months. In meteorology survey, precipitation was observed using LPM consequently. In hydrology survey, surface runoff was observed in experimental area with 2m length and 0.5m width using tipping gauge continuously. Soil moisture and temperature were observed in every 10 minutes in experimental area.

In these two forest stands, EUROSEM hydrological sub - model was applied in 35 storm events, and siumlated surface runoff was validated based on observed data. EUROSEM hydrological sub model was applied to 10 storm events in previous study and appeared to simulate surface runoff for storm events with rainfall intensity between 2.0 - 5.0mm / 10mim. In this study, surface runoff was simulated well in storm events with rainfall intensity larger than 5.0mm/10min using infiltration rates lower than those in laboratory experiments.

Keywords: Forest, Surface Runoff, Sediment Yoelds, Prediction Method, EUROSEM, Storm - Runoff

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AHW28-P02 Room:Poster Time:April 30 18:15-19:30

Distribution of trace elements in 3 small rivers and the surrounding geology in the North Osaka prefecture, Japan

EVEN, Emilie[1*] ; NOJIMA, Aki[1] ; MASUDA, Harue[1]

[1]Department of Geosciences, Osaka City University, Japan

The Rivers Yono, Ibaraki and Minoh, that are tributaries of the River Yodo in the northern part of the Osaka prefecture, Japan, flow across the Paleozoic-Mesozoic sedimentary formations and the Ibaraki granitic complex. Waters from these rivers have been used for domestic purposes and some trace metals have been reported in concentrations above the environmental standard limits. Previous studies have shown that the sedimentary rocks were the sources of trace metals, especially arsenic, whereas the granitic sequence of quartz diorite, granodiorite and adamellite is believed to be the source of rare earth elements (REEs). In addition to track back of the origin of these trace elements, the transportation phases and the geochemical budget of trace metals along the river flow are examined as a first step to set up a simple transportation model. Here are presented first results.

Results showed that the geochemical patterns of riverbed sediments matched the distribution of the source rocks. The geochemistry of trace elements in river water is likely controlled by the weathering of riverbed sediments. River sediments from sandstone and quartz diorite contained high amount of trace elements and yielded high concentrations of trace metals in river water but low concentrations of REEs. Comparatively, river sediments originated from adamellite contain lower amounts of trace elements but river waters flowing across this formation showed to have the highest concentrations of REEs. O/H isotopic ratio in river water pointed at the meteoritic origin of the water in the upper reaches of rivers and the contribution of groundwater in the lower reaches. The fractionation of trace elements regarding the different size pools of total concentration, 0.45μm and 0.22μm filtration showed that most of the trace elements were transported within the $<$0.22μm phase. Temperature of river water seems to influence the concentrations of elements, as concentrations increased with increasing temperature throughout the year. The role of organic matter (likely as colloidal carriers) is limited since an inverse relationship was observed. Water mixing calculation with major and trace elements yielded accurate geochemical budget model ($<$5% error), where as redox sensitive species induce large errors of $>$15%, even on few meters distance along the flow path.

Keywords: Rare Earth Elements, River Water, Source rock, Trace Metals, Transportation

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AHW28-P03 Room:Poster Time:April 30 18:15-19:30

Seasonal variation in oxygen stable isotopic ratio and nitrate concentration in a mountain agricultural watershed

ARITOMI, Daiki[1*] ; ONODERA, Shin-ichi[1] ; SAITO, Mitsuyo[2] ; MARUYAMA, Yutaka[1] ; JIN, Guangzhe[1] ; ONISHI, Koki[3]

[1]Hiroshima University, [2]Okayama University, [3]Fukken Co., Ltd.

We aimed to examine the groundwater flow and seasonal variation of NO3–N in coastal aquifer of a granite catchment considering the contribution of bedrock groundwater and denitrification processes.

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AHW28-P04 Room:Poster Time:April 30 18:15-19:30

An Overview of Recent Hydrological Models for Estimating Phosphorus flux

SHIMIZU, Yuta[1*] ; ONODERA, Shin-ichi[2] ; SAITO, Mitsuyo[3]

[1]NARO/WARC JSPS-PD, [2]Graduate School of Integrated Arts and Sciences, Hiroshima University, [3]Graduate School of Environmental and Life Science, Okayama University

Phosphorus which derived from forest, agricultural area and urban is discharged to river stream via surface runoff and drainages. There is a time lag from ”inflowing to river channel” to ”outflowing to coastal area” because most of transported phosphorus is retained in river channel due to physical, chemical and biological processes. Previous studies about material balance in watersheds show that total amount of phosphorus emission is not correspond to total amount of discharged phosphorus. This is because of phosphorus retention in watersheds. So it is necessary to understand about phosphorus retention processes for estimation of phosphorus transportation. In recent years, distributed hydrological models are used to estimate phosphorus transportation. Most of these models are developed in western countries, and have been improved its accuracy of estimation of sediment and water quality. The objective of this study is to review phosphorus retention process in watersheds and model description for understanding model limitation for phosphorus transportation.

Keywords: Hydrological Model, Phosphorus, Material transport, Watershed

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AHW28-P05 Room:Poster Time:April 30 18:15-19:30

Water pollution and arsenic behavior in the Red River, North of Vietnam

INOUE, Ryo[1*]

[1]graduate school of science,Osaka City

Water pollution and arsenic behavior in the Red River, northern Vietnam.

Inoue,R1.Shinntani,T1.Masuda,H1.Yonezawa,G1.Truong Xuanluang2.Hang Do Thi2.
(1 Osaka City University, 2 Hanoi University of Mining Geology)

The Red River, flowing through the northern part of Vietnam, is originated in Yunnan, China and running parallel to the Hoang Lien Son mountain range. Arsenic pollution of groundwater has been a serious problem in rural area located on the Red River delta. The sources of arsenic must be carried to the aquifer through the river, although transportation processes are not well understood. In this study, arsenic transportation process through Red River was studied from the analytical results of river water, suspended particles, river-bed sediments which were collected in the Vietnam territory. In addition, general situation and the cause of the river water pollution was considered.

Total dissolved ions of river water sample is 5.0meq/L in Lao Cai located at the upper most stream in Vietnam, 2.4meq/L in Bao Ha and 2.1meq/L in Yen Bai at middle-stream, and 3.4meq/L in Hanoi at downstream. Low concentration of dissolved solids between Lao Cai and Hanoi is due to the inflow of the surface water from Hoang Lien Son mountain range. Such an inflow is clear from the lower oxygen and hydrogen isotope ratio of river water than those of main channel waters. δ18O: -9.9∼-10.0 ‰ and δ2H: -69 ‰ in Lao Cai. δ18O: -12.9∼-13.0 ‰ and δ2H: -91∼-92 ‰ in the branch channel in Hoang Lien Son mountain range, and δ18O:-11.6∼-11.9 ‰ and δ2H:-82∼-84 ‰ in Bao Ha and Yen Bai at middle-stream. Branch channel water in Hoang Lien Son mountain range diluted the dissolved salts and pollutants such as As and Pb. Arsenic is transported as dissolved components (∼60%) and adsorbed components (∼40%) in the river.

Arsenic concentration has clearly positive correlation to the XRD intensity of smectite. Weak positive correlation between arsenic and kaolinite was also found. However, there is no relationships between arsenic and iron, indicating that the arsenic doesn ' t behave with iron oxyhydroxides in the river. And, smectite found only in suspended particles sample of Red River main channel water, thus, the arsenic is transported with clay minerals in the Red River.

Keywords: arsenic, Red River, Vietnam, Isotope

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Estimation of water balance in a coastal agricultural catchment using SWAT and HYDRUS Model.

JIN, Guangzhe[1*] ; SHIMIZU, Yuta[2] ; ONODERA, Shin-ichi[1] ; SAITO, Mitsuyo[3] ; MATSUMORI, Kenji[2]

[1]Hiroshima University Graduate School of Integrated Arts and Sciences, [2]National Agriculture and Food Research Organization, Western Region Agricultural Research Center, [3]Graduate School of Environmental and Life Science, Okayama University

Quantify the rate of ground water recharge and clarify the water balance in watersheds is basic and important for efficient ground water resource management. It is particularly important in regions with little rain which face with the risk of water shortage. However, the rate of aquifer recharge is one of the most difficult factors to evaluate. Especially, the former method of groundwater recharge estimation, are normally subject to large uncertainties and easily to cause errors. Recently, there are several attempting for estimation of groundwater recharge using distributed hydrological models in the world.

The Soil and Water Assessment Tool (SWAT) Model is one of a physically based and quasi-distributed continuous time hydrological model used to estimate water budget in previous researches around the world. SWAT Model has been implemented for watershed hydrology related issues such as estimation of surface water flow and groundwater recharge rate. We could more specific testify the groundwater flux combined SWAT Model with HYDRUS Model which is a software package for simulating water, heat, and solute movement in two- and three-dimensional variably saturated media. The objective of this research is to estimate water balance and to clarify the groundwater recharge parameter in an agricultural catchment in the Seto Inland Sea, using the SWAT Model, and to estimate the groundwater flow using the HYDRUS Model.

The study site is located on the southern part of Ikuchi Island, which is one of the islands in central Seto Inland Sea. The orange groves cover approximately 50% of the total catchment area. Due to the small annual precipitation (approx.1000mm/y) with large inter-annual variation, Ikuchi Island is facing a risk of water shortage in the serious dry year.

As input to SWAT Model, topographic data (10 m grid), soil map (1/25000), land use map (1/25000) and weather information were used to build and calculate the SWAT Model. Evaporation was estimated by the Penman-Monteith method. Simulation time periods is 2000-2013, including warm up period of 2000-2003 and calibration period of 2003-2004. The calibration was conducted using the Sequential Uncertainty Fitting (SUFI2). The reproducibility of daily discharge in calibration period by the model was found to be acceptable (NSE=0.69, RSR=0.56, PBIAS%=18, R^2=0.75). Amount of groundwater recharge is accounted as the water discharge into aquifer except the flows which are eventually discharged from aquifer, such as return flows into river and amount of water moving into the vadose zone.

The result shows spatial difference in groundwater recharge rate. About 10 times higher groundwater recharge rate was found in middle and downstream areas. While middle and downstream area are indicated the main groundwater recharge area, upstream is small recharge rate due to steep slope. Groundwater recharge shows smaller volume than river discharge, it comprise about 17% of total precipitation in annual average consideration. From the comparison of water balance calculation, it is found that both of river discharge and groundwater recharge fluctuated in high precipitation year of 2011 (1,527mm), low precipitation year of 2005 (781mm) compared to average balance. In high precipitation year, groundwater recharge rate increased about 6 times than in low precipitation year, the increasing of river discharge is at about 2.5 times.

Consequently, it was confirmed that spatial and temporal variation of groundwater recharge rate in long term. And we could estimate the long term water balance base on these information. However, it is noted that this result may include some uncertainty and chance to improve. Seat model could not reflect the groundwater flow, simulated with HYDRUS Model on the groundwater flow could provide us with the groundwater data. In the presentation, more detailed data cover long time periods and results testifying groundwater level variation with HYDRUS Model will be displayed.

Keywords: Ikuchi Island, SWAT Model, HYDRUS Model, groundwater recharge rate, water balance

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AHW28-P07 Room:Poster Time:April 30 18:15-19:30

Seasonal variation in nutrient dynamics in the tidal zone of Yamato river

ONODERA, Shin-ichi[1*] ; SAITO, Mitsuyo[2] ; SHIMIZU, Yuta[3] ; MARUYAMA, Yutaka[1] ; MIYAOKA, Kunihide[4] ; JIN, Guangzhe[1] ; ARITOMI, Daiki[1]

[1]Hiroshima University, [2]Okayama University, [3]NORO, [4]Mie University

In coastal megacities, sever groundwater depression and water pollution occurred. These impacts affected to river environment change. Especially, the river mouth area has been deposited the polluted matters. These areas have characteristics of water level fluctuation which causes river water-groundwater interaction and the associated change in dynamics of nutrients. However, these effects on the nutrient transport in tidal reaches and nutrient load to the sea have not been fully evaluated in previous studies. Therefore, we aimed to clarify the nutrient dynamics with the river water-groundwater interaction in the tidal river of Osaka metropolitan city. We conducted the field survey from the river mouth to the 7km upstream area of Yamato River, which has a length of 68km and a watershed area of 1070 km2. In addition, model simulations were also conducted. Spatial variations in radon (222Rn) concentrations and the difference of hydraulic potential between river waters and the pore waters suggest that the groundwater discharges to the river channel in the upstream area. In contrast, river water seeped into the groundwater in the river mouth area. It may be caused by the lowering of groundwater level associated with the excess abstraction of groundwater in the urban area. The spatial and temporal variations in nutrient concentrations indicate that nitrate-nitrogen (NO3-N) concentrations changed temporally and it negative correlated with dissolved organic nitrogen (DON) concentrations. Inorganic phosphorous (PO4-P) concentrations showed the increasing trend with the increase of the river water level. Based on the mass balance, nutrient reproduction from the river bed was suggested in tidal reach during a summer, especially phosphorus was large.

Keywords: seasonal variation, nutrient dynamics, tidal river, polution, phosphorus

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AHW28-P08 Room:Poster Time:April 30 18:15-19:30

Examination on the classification and ecological index of ponds based on the stability of stratification

OKUBO, Kenji[1*] ; SAITO, Mitsuyo[1] ; TAKAGI, Shinya[1] ; ONODERA, Shin-ichi[2] ; MARUYAMA, Yutaka[2] ; JIN, Guangzhe[2] ; ARITOMI, Daiki[2] ; SHIMIZU, Yuta[3]

[1]Okayama Univ., [2]Hiroshima Univ., [3]JSPS PD, NARO/WARC

We aimed to examine on the classification and ecological index of the small ponds based on the stability of stratification. The seasonal variation of the stratification was examined using the monitoring data of water temperature in multiple depths in the 4 different ponds located on an island which is highly influenced by agricultural activity. DO, fluorescence, nutrients data were used for the evaluation of ecosystem condition.

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Rock magnetic profiles of sediment cores in Hachirogata : effect of a land reclamation

OTA, Yuki[1*] ; SATO, Takaharu[1] ; ONODERA, Shin-ichi[1] ; JIN, Guangzhe[1] ; SAITO, Mitsuyo[2] ; HAYAKAWA, Atsushi[3]

[1]Graduate School of Integrated and Arts Sciences, Hiroshima University, [2]Graduate School of Environmental and Life Science, Okayama University, [3]Faculty of Bioresource Sciences, Akita Prefectural University

We examined the influence of land reclamation on rock magnetic profiles in Lake Hachirogata. In this lake, all flowing rivers exist on an east side and a large reclamation land touch at west and north sides. Two sediment core samples were collected at the eastern central (HL-1) and northwestern bankside (HL-2) sites in this lake in September 2013, using the 1m piston core sampler (7-8 cm diameter). HL-1 was 77cm and HL-2 was 78cm.

Keywords: Lake Hachirogata, sediment, rock magnetism, land reclamation

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Spatial distribution of radon (222-Rn) and radium (226-Ra, 228Ra) in the coastal seawater of Seto Inland Sea and its con

SAITO, Mitsuyo[1*] ; ONODERA, Shin-ichi[2] ; OHTA, Tomoko[3] ; GUO, Xinyu[4] ; TAKEOKA, Hidetaka[4] ; ONISHI, Hidejiro[4] ; KUBOTA, Takumi[5]

[1]Okayama Univ., [2]Hiroshima Univ., [3]Hokkaido Univ., [4]CMES, Ehime Univ., [5]KURRI, Kyoto Univ.

Previous studies have revealed that submarine groundwater discharge (SGD) is one of the important pathways for nutrients and the other dissolved materials from terrestrial area to the marine environment. For the evaluation of the effect of SGD, the timescale of nutrient transport in the coastal area derived by SGD such as residence time is important as well as nutrient flux by SGD. Radioactive isotopes of radon (222-Rn) and radium (226-Rn, 228-Ra) are one of the useful tracers for the evaluation of SGD and residence time of water mass in the coastal area. The objective of the study is to examine the spatial variation of 222-Rn and 226-Rn, 228-Ra in the coastal seawater of the central part of Seto Inland Sea and its controlling factors. The study area is southwestern part of the Hiuchi-Nada with the area of approximately 30 km $\times$ 13 km. Relatively high concentrations of 222-Rn, 226-Rn and 228-Ra were detected in the southern part of the study area. These results suggest the effect of SGD from seafloor.

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Arsenic distribution in porewater and coexisting sediments of Kumano Basin, Nankai Trough

YOSHINISHI, Haruka[1*]

[1]Osaka City University

Arsenic contamination of groundwater is a serious problem in the world, especially in the deltas along large rivers originated from Himalayas such as Bangladesh and West Bengal, India. Sulfide minerals including pyrite in shales is one of the candidates of source minerals causing arsenic contamination. However, the mechanism of arsenic concentration in sedimentary rocks has not been well understood. In this study, arsenic behavior in the porewater and host sediments was determined to understand the fixing process of arsenic during early stage of diagenesis in modern marine sediments.

Porewaters and squeezed cakes were sampled at three sites (C0002, C0021, C0022) in the Nankai trough by IODP, Expedition 338. The sediments from Site C0002 is composed hemipelagic mud of distal turbidites, those from Site C0021 of mass transport deposits (MTDs), Site C0022 is dilled at right above the megasplay fault, and highly fractured zone, likely related to the megasplay faulting was found at 100 mbsf (meters below seafloor).

Arsenic concentration of the porewaters at Site C0002 was constant 0-1.1μM at 200-300 mbsf, and it increased with depth to 3μM in 300-400mbsf. The highest concentration (3μM) was recorded at 400 mbsf, and the concentration decreased below that depth. In C0021, arsenic concentration of the porewaters is 0.2μM on an average at 0-160 mbsf and give no relationship to the depths. It increased quickly to 1.2μM down to 200 mbsf. In C0022, arsenic concentration is 0.3μM on average at 0-100mbsf. The highest concentration (1.5μM) was observed at 130-160mbsf, and then drastically decreased to 200 mbsf. Arsenic concentration became constant below that depth.

Arsenic concentration of sediments is 40-120μM at 300-500 mbsf in Site C0002, 40-90μM at 100-150mbsf in Site C0022. The arsenic concentration is varied without relationship to the depth.

Mineral composition determined by XRD showed that the all sediments analyzed were dominated by quartz, feldspars, micas, calcites, smectite, and chlorite/ kaolinite. Hornblende and pyrite were occasionally observed.

Compared to the major chemical composition determined onboard, arsenic concentration of porewater correlated to pH, Fe, Pb, and Mn. It is suggested that the arsenic was accumulated in the sediments via coprecipitation with iron hydroxides/oxides at the sea floor, similar to many trace heavy metals, and was released intio the porewater by desorption under reducing environment, or by decomposition of iron hydroxides/oxides. After that, arsenic may be fixed into pyrite with depth, however, the fixing mechanism of arsenic in the deep is not clear at present.

Keywords: Arcenic, Nankai Trough, IODP

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Research on dissolved inorganic phosphorus concentrations forming process in a forested mountainous stream

TAKEDA, Manami[1*] ; OHTE, Nobuhito[1] ; EGUSA, Tomohiro[1] ; SUZUKI, Masakazu[1]

[1]Department of Forest Science Graduate School of Agricultural and Life Sciences

Since the ecosystems of river, lake, and ocean are supported by P supply from terrestrial area, it is important to understand the mechanisms behind the P discharge from the catchments through the aquatic system. It has generally been considered that loss of P from a forested area through a headwater stream is small, because it is preserved tightly within forested ecosystem. It has previously been reported that heavy rainfalls lead to a large P loss from forested catchments, and major fractions of exported P is particulate form absorbed onto soil particles. Therefore, many studies have focused on particulate P load during high flow condition. However, it has been still poorly understood about the controlling mechanisms of sources and transport of dissolved inorganic phosphorus (DIP), which is directly available for organisms. In order to explain the controlling mechanisms of DIP discharge, we conducted field investigations on the DIP dynamics through the elemental hydrological processes in the hill slopes of a headwater catchment, and illustrated the spatial distribution of DIP concentrations of the stream network in meso-scale catchment.

The study site was Fukuroyamasawa experimental watershed located in The University of Tokyo Chiba Forest and Inokawa watershed including Fukuroyamasawa. The size of Fukuroyamasawa is 1 ha, and that of the Inokawa watershed is 503 ha. Through fall water, stem flow water, litter layer infiltration water, soil water, groundwater and stream water were sampled once every two weeks from August 2013 to November 2013. Rainwater was collected at the meteorological station located near by Fukuroyamasawa. In Inokawa watershed, flow observation and stream water sampling at the point with various watershed area on low-flow period in September 2013 and December 2013. The samples were filtered by 0.45 micrometer membrane filters immediately after the sampling. Then DIP was analyzed using molybdenum blue (ascorbic acid) absorptiometry.

The average DIP concentration of rainwater was 0.2 micromol / L during the observation period. That of through fall, stem flow and litter layer infiltration water were 0.9, 1.7 and 10.9 micromol / L respectively. DIP concentration felt remarkably with soil layer passage, and the average DIP concentration of soil water, groundwater and steram water was 0.6 micromol /L. DIP concentration in Inokawa stream water ranged from minimum limit of determination, 0.1 micromol /L, or less to 9.2 micromol / L. When we investigated the relation between DIP concentration and a contributory area, DIP concentration differed in about 2 km2 or less, and it increased at the larger than 2 km2 as the contributory area became large. There was a strong positive correlation between DIP concentration and EC.

In Fukuroyamasawa, it was shown that DIP added during canopy passage was almost absorbed in the soil layer at particles, and was removed from the water, and hardly contributing to the outflow to a mountain stream. EC is an index for underwater dissolved matter concentration, and it turns out that the amount of the dissolved matter concentration of mineral origin is shown at Inokawa watershed. Therefore, the relationship of DIP concentration and EC has suggested that mountain stream underwater DIP mainly originates in bedrock weathering, and that the spatial distribution of DIP concentration is determined with the contribution of a groundwater course which passes bedrock.

Keywords: Dissolved Inorganic Phosphorus (DIP), forested mountainous stream, spatial distribution, catchment area

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Mixing of river water as deduced from major component concentration, Sr and S isotopic ratios in Tama River, Akita.

WAKASA, Sachi[1*] ; ISHIYAMA, Daizo[2] ; MATSUBAYA, Osamu[3] ; SATO, Hinako[2] ; SHIN, Kicheol[4] ; NAKANO, Takanori[4]

[1]Center for Geo-Environmental Science, Akita Unisity, [2]Faculty of International Resource Sciences, Akita University, [3]Emeritus professor, Akita University, [4]Research Institute for Humanity and Nature

The acidic high temperature hot spring discharged from the Tamagawa hot spring (Ohbuki) into the Tama River system through the Shibukuro creek is still acidic downstream. The acidity of the Ohbuki hot spring water is neutralized using limestone before it discharges into the Shibukuro creek. In this study, geochemical signatures of mixing between Tama River and its tributaries were deduced from concentration of major chemical components, Sr and S isotopic ratios. The Ohbuki hot spring water has high concentration of chloride and sulfate. The δ^{34}S of sulfate is the highest (δ^{34}S = 31.8 ‰) in the watershed. Due to the neutralization, the concentration of calcium, strontium and strontium isotopic ratio increases (^{87}Sr/^{86}Sr = 0.7068). The mixing rate of water flowing out from the neutralization facility is about 20% and 8% before and after the confluence of Shibukuro and Tama Rivers, respectively. The concentration of the major chemical components decreases gradually downstream and is almost similar to other tributaries in the Tama and Omono Rivers system. The pH of the water also decreases from 3 to neutral (about 7). The strontium isotopic ratios of 0.7040, 0.7068 and 0.7049-0.7062 for the Ohbuki, the neutralization facility and tributaries of the Tama River respectively, reflect the geology of the catchment area. A two component mixing phenomena is observed in the Tama River and its tributaries based on the major chemical components. However, the two component mixing relationship is not clearly distinct with the Sr isotope ratios. The δ^{34}S of sulfate in the Ohbuki thermal water (+31.8 ‰) and Tawa River (+6.6 – +8.8 ‰) near the confluence of the Tama and Omono Rivers supported the two component mixing relationship observed from the major chemical component. The results observed in this study are used to interpret the mixing mechanisms operating between the Tama River and its tributaries.

Keywords: Mixing of river water, Akita, Concentration of major chemical components, Strontium isotopic ratio, Sulfur isotopic ratio

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Feature of distribution of radioactive cesium in irrigation canal

KUBOTA, Tomijiro[1*] ; TARUYA, Hiroyuki[1] ; TANAKA, Yoshikazu[1] ; HAMADA, Koji[1]

[1]National Institute for Rural Engineering, NARO

The purpose of this study is to clarify distributive characteristics of a radioactive cesium in the irrigation canal by examining the radioactive cesium contained in the bottom sediment along the canal from its intake to the downstream. One of the millrace located in Fukushima Prefecture was selected as a case for investigation, and the distribution of the amount of the sedimentation, the concentration of radioactive cesium in the bottom sediment, and the air dose rate were examined. The sandy deposit was seen in the upstream of the canal, and those concentration of radioactivities Cs were comparatively low with 1-5kBq kg^{-1}. On the other hand, relatively high concentration of radioactivity Cs was seen in the downstream of canal, and was within 3-28kBqkg^{-1}. The air dose rate in the waterway were relatively low because of the influence of ponding, relatively high air dose rate were seen in the place where the depositional surface had been exposed.

Keywords: radioactive cesium, irrigation canal, sediment, air dose rate

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Current status of the groundwater use in an island of the Seto Inland Sea: a case study of Ikuchijima-island

TANIGUCHI, Tomomasa[1*] ; ONODERA, Shin-ichi[2] ; TAKAHASHI, Hidehiro[3] ; SAITO, Mitsuyo[4] ; SHIMIZU, Yuta[5]

[1]Faculty of Humanities, Law and Economics, Mie University, [2]Graduate School of Integrated and Arts Sciences, Hiroshima University, [3]NARO Western Region Agricultural Research Center, [4]Graduate School of Environmental and Life Science, Okayama University, [5]NARO Western Region Agricultural Research Center, JSPS PD

The study is aimed to examine the current status of the groundwater use in an island of the Seto Inland Sea, southern Japan. This area is characterized by high risk of drought with low annual rainfall and limited water resource. We conducted face-to-face surveys in the form of a multiple-choice questionnaire in two areas (districts of Miyabara and Hayashi) with different main resource of agricultural water in Ikuchijima-island, Onomichi-City. Citrus farms such as orange, lemon etc. are widely cultivated in both areas.

The rate of households having domestic well is about 74% in Miyabara district, and is about 62% in Hayashi district. The main purposes of groundwater use are watering in garden and car wash in both areas. About 20% of respondents answered that groundwater resource is not enough for the agricultural use in the dry season. It indicates the groundwater is regarded as one of the important water resource in the island. Averaged daily domestic use of groundwater per household are estimated to be 361L/day and 271L/day in Miyabara and Hayashi, respectively.

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