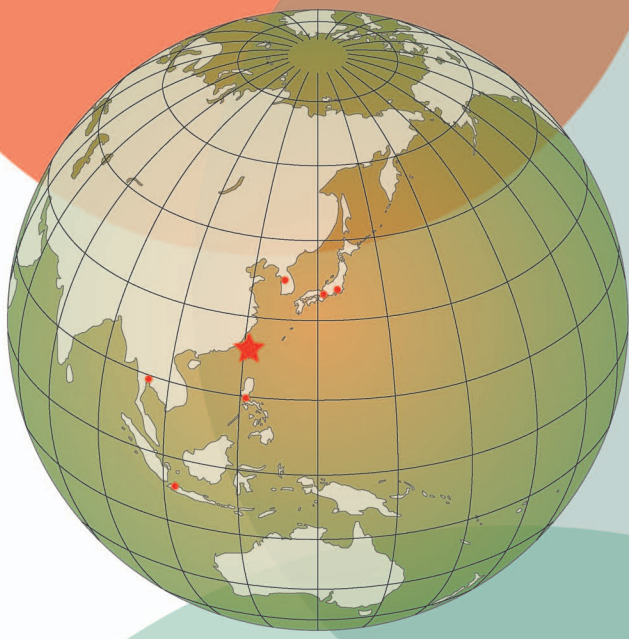
The 3rd International Symposium

Human Impacts on Urban Subsurface Environment



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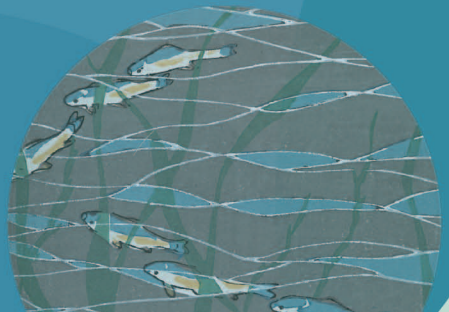

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Human impacts on Urban Subsurface Environment

Makoto TANIGUCHI*

*Research Institute for Humanity and Nature, Kyoto, Japan
makoto@chikyu.ac.jp

Change in reliable water resources between groundwater and surface water occurred in many Asian cities depending on the development stage of urbanization and life style. Although the subsurface water is connected with surface water in hydrological cycle, both waters were treated separately for both natural and social sciences. In RIHN's project of "Human impacts on subsurface environment", intensive field observations and data collections had been made in the basins including Tokyo, Osaka, Bangkok, Jakarta, Manila, Seoul, and Taipei, to evaluate the relationship between development stage of the city and various subsurface environments in Asia beyond the boundaries between surface - subsurface environment and land - ocean. As a factor of separating water, energy and material at the earth surface into above and below the surface, land use/cover changes at three ages (1940's, 1970's and 2000's) in Asian 7 cities have been analyzed based on GIS with 0.5 km grid. Urbanization causes the decease in groundwater recharge rate (due to decrease in permeable layer) and increase in thermal energy transport (due to heat island effect) into the subsurface environment. In this project, subsurface environmental problems such as land subsidence, groundwater contamination, and subsurface thermal anomaly were analysed with two categories of integrated indicators. One is the "natural capacity for the resilience", and another is the "changing society and environment". There is a limitation as natural capacity in each city for the use of groundwater which is an alternative, an adaptation, and resilience to the changing climate and society. In this project, the importance of integrated treatments beyond the boundaries between surface/subsurface and land/ocean is shown for better understanding and management of environment with wise use of subsurface environment for future in Asian cities.

Keywords: subsurface environment, urbanization, pollution, natural capacity, resilience, integrated indicators, beyond boundaries

Long-term urban economic development and water demand in Asian megacities

Tomoyo TOYOTA* and Shinji KANEKO**

*Research Institute for Humanity and Nature, Kyoto, Japan
toyota@chikyu.ac.jp
**Hiroshima University, Hiroshima, Japan
kshinji@hiroshima-u.ac.jp

Income can be used as a measure of various different aspects of socioeconomic changes in the long run. Much of studies in social science applied this empirical evidence to elucidate causal relationships of socioeconomic changes at national scale both for a country study and international comparison. However, few of those studies have reported at city scale due mainly to data availability. The study first tries to estimate long-term income changes for seven Asian megacities during the period between 1900 and 2000, based on national income records developed by Madison (2001, 2003) with adjustment using available local data. Then following the Petty-Clark's Law on macro industrial transformation patters derived from national data of the world, we estimates long term shares of primary, secondary and tertiary industries to GRDP (Gloss Regional Domestic Products) for seven megacities. Furthermore, using those estimated indicators on income and industrial structure, the water demand of residential sector, commercial sector and industrial sector in the cities are also estimated. The study examines the validity of the estimated indicators with available corresponding data from various local sources. Finally, simple comparative analysis is performed to compare the relationship between long-term urban development and water demand in seven Asian megacities.

Keywords: long-term income growth, urban development, industrial transformation, urban water demand

Urbanization and sewerage system development: lessons and challenges in Asian megacities

Tsuyoshi IMAI*, Chen JIN**, Tomoyo TOYOTA***, C. VITOONPANYAKIJ****, S. KESSOMBOON****, P. BANJONGPROO**** and Shinji KANEKO*****

*Yamaguchi University, Yamaguchi Japan
imai@yamaguchi-u.ac.jp
**Beijing Normal University, Beijing, China
chenjin@ires.cn
***Research Institute for Humanity and Nature, Kyoto, Japan
toyota@chikyu.ac.jp
****Bangkok Metropolitan Administration
*****Hiroshima University, Hiroshima, Japan
kshinji@hiroshima-u.ac.jp

Urbanization threatens environmental qualities and urban ecosystems in cities particularly in Asian megacities with rapid expansion and intensification of population and economic activities. With population growth and industrial transformation from manufacturing to service industry, water consumption in residential and commercial sectors is increased; accordingly waste water discharge is increased. In this context, public service of waste water treatment such as sewerage system becomes critically important to manage the water quality in city. Yet, common challenges for megacities in developing countries are typically financial and technical limitations to cope with the rapidly increasing needs to develop public sewerage system. Beijing and Bangkok are now rapidly increasing the coverage rate of waste water treatments from residential and commercial sectors with partly help from international donor agencies including JICA and JBIC. It can be proposed interesting comparisons of development histories of sewerage system in two cities in terms of rain falls (combined or separate sewer systems), treatment technologies, financial and technical assistants from Japan, institutional settings between national and city governments. The paper tries to compare commonalities and differences of sewerage system development experiences between two capital megacities in Asia, namely Beijing and Bangkok in reference to that of Tokyo. The lessons and challenges derived from comparison would be useful information to other followers as growing megacities in Asia such as Jakarta, Manila and Ho Chi Ming.

Keywords: Sewerage development, historical evaluation, Asian megacities, Bangkok, Beijing

The Effects of Urbanization on Shallow Aquifer Recharge in Asian Megacities: An Application of the SWAT Model to Bangkok

Katsuya Tanaka* and Shinji Kaneko**

* Associate Professor, Shiga University, Shiga, Japan
katsuyat@gmail.com
** Professor, Hiroshima University, Hiroshima, Japan
kshinji@hiroshima-u.ac.jp

Urbanization (areal expansion of cities) is one of the most influential modern geomorphic processes, and it affects groundwater systems, especially shallow aquifers significantly. This study examines the impacts of rapid urbanization (areal expansion of cities) on shallow aquifer recharge in Bangkok, Thailand. To achieve this objective, the Soil and Water Assessment Tool (SWAT) model is used to link land use change and resulting water movements on and beneath the land surface. Historical land use patterns are obtained from Bangkok land use map in 1960 and 2000, digitized by the Research Institute for Humanity and Nature. The map is obtained from the soil map of the world developed by the FAO/UNESCO.

The parameters of the SWAT model are calibrated at the stream gage near Chao Phraya estuary using data from 1998 to 1999, and then validated using data from 2000 to 2001. Applying validated parameters and climatic conditions in 2000, shallow aquifer dynamics are compared between land uses in 1960 and 2000. Our results show that the amount of water stored in the shallow aquifer is significantly reduced from 1960 to 2000. This is primarily due to increased pavement areas and extraction of groundwater such as pumping for meeting industrial and household water demands.

Keywords: urban development; groundwater; shallow aquifer; SWAT; Thailand

Impacts of flooding and land subsidence in KAMANAVA, Metro Manila

Karen Ann B. JAGO-ON and Shinji KANEKO*

*Hiroshima University, Hiroshima, Japan

karenjagoon@hiroshima-u.ac.jp

The dense population in the northern part of Metro Manila, Philippines which is composed of the cities of **Ka**lookan, **Ma**labon, **Na**votas and **Va**lenzuela (or KAMANAVA area) has habitually suffered from floods due to heavy rainfall, poor drainage systems and high tide in Manila Bay. Previous studies have shown that flooding is aggravated by land subsidence which is mainly caused by excessive groundwater withdrawal. Low-level regular flooding occurs many times a month especially during high tide, while heavy flooding usually happens when heavy rainfall coincides with high tides. Frequent flooding has brought huge economic losses to communities and disruption of commercial, industrial and social activities in the area.

The first part of this presentation describes flooding characteristics in KAMANAVA and investigates the economic costs incurred by communities through an interview survey conducted among households and companies in the four cities. This also includes identifying the coping mechanisms of residents to reduce flood effects. With the threat of climate change and impacts of land subsidence and urbanization, long-term policy measures are recommended to regulate groundwater abstraction, reduce subsidence rates and eventually lower the risk of flooding. However, regular flooding is a continuous threat which needs to be addressed immediately. The second part explores resettlement of affected communities as a possible immediate measure to reduce land subsidence and flood impacts.

Keywords: land subsidence, flooding, economic cost, resettlement

Asian Urbanization and its Environments

Gayl D. NESS

*University of Michigan, Michigan, USA
gaylness@umich.eu

RIHN's Human Impacts on Urban Subsurface Environments projects has made substantial progress. It is especially effective in seeing the unseen and gaining a better understanding of that unseen environment. The Asian cities on which the project focuses represent one of the most dramatic human social movements in our time. In the span of a mere century the Asian urban population will expand from 200 million to 3.2 billion. Moreover that urban population lives in a high risk environment, whose vulnerability increases with global warming. As many observers, the struggle for sustainability will be won or lost in the world's urban areas, and the Asian urban environment will play a highly critical role in this struggle. We suggest that the project's excellent work on the unseen environment now needs to make links to th**e** many other urban environments to promote the development of sustain able cities. Here we suggest a modeling exercise that will focus attention on linking the many urban environments to work toward sustain able cities.

Urban Development and Water Environment Changes in Asia

Akihisa YOSHIKOSHI*

*Ritsumeikan University,Kyoto,JAPAN
ayt03221@lt.ritsumei.ac.jp

Since their growth into modern cities, Asian megacities have seen a change in their water environment due to such undertakings as the reclamation of their regional streams, rivers, lakes and ponds, and commencement of large-scale groundwater withdrawal projects. As a result, so-called water environment issues, i.e. lower groundwater levels, salinization of groundwater and land subsidence, emerged in many megacities. A time-series analysis of the process of their emergence reveals that the earlier a city developed, the earlier water environment issues emerged. Accordingly, one can well expect that a city that is currently demonstrating remarkable growth might see in the near future an emergence of water environment issues similar to those in other cities that developed in earlier days. If effective steps are taken now, before it is too late, the water environment issues to emerge in Asian megacities in the future may turn out to be different from those in the past.

In this research, cities that have followed different paths of development are examined: Tokyo, Osaka, Seoul, Taipei, Bangkok, Jakarta and Manila. These megacities are the research subjects in "Human Impacts on Urban Subsurface Environments," a research project at the Research Institute for Humanity and Nature that the author is also involved with.

In this research, the urban development processes in the Asian megacities and resulting changes in their water environment were discussed, and the water environment issues that have emerged as a consequence were sorted out. As a result, it has been brought to light that the cities that developed early also saw water environment issues emerge early, but a good part of them are now in the process of being solved. This research stopped short of examining any specific actions taken to address those issues, but a remaining challenge is to apply in an effective fashion the approaches and experience of those cities to other megacities.

As a city develops, changes occur to its water environment, such as a decrease in the area of its waters. Such changes would result in reduced groundwater recharge or might also diminish water retention and other functions served by the surface ground, possibly making it vulnerable to floods. It is a very important task to assess what changes in water environment lead to water environment issues to what extent, but there is still very little understanding of these questions. Presumably, a challenge remains for us to answer them in the future by studying a particular megacity.

Keywords: urban development, water issue, water environment change, Asian megacity

Numerical Simulations of Recent Urban Warming in Five Asian Mega-Cities

Toshiaki ICHINOSE*

*National Institute for Environmental Studies, Tsukuba, Japan /
Nagoya University, Nagoya, Japan
toshiaki@nies.go.jp

The author applied a mesoscale climate model, CSU-MM (Pielke, 1974; Ichinose *et al.*, 1999) to land use data of five Asian meda-cities in two stages, which was established by the RIHN project, and performed numerical simulations (dx=dy=2km; dt=15sec) of urban warming related to recent urbanization. Target date is typical fine and calm day in the hottest season. The end of March was assumed for cases of Bangkok and Manila, and the end of July was for cases of Seoul, Taipei and Jakarta.

In comparison of computed surface air temperatures, Seoul showed the largest warming of 1 to 1.5 deg C in afternoon to dawn. However, difference of 2 to 3 deg C was given in the case of northern suburb of Bangkok where showed drastic land use change from paddy field to urban area in the leeward of the city center.

In cases of skin temperature, daily maximum temperature of every 3 hours appeared at noon, while at 3PM in cases of surface air temperature. In general, larger difference (around 1 deg C) between two stages appeared at dawn. In Bangkok, presence of sea breeze probably brings a little decrease of skin temperature at the city center during two stages. Extension of urban area to the leeward may enhance the wind speed of sea breeze passing through the city center and this enhances heat exchange between ground surface and atmosphere. The largest warming of skin temperature also appeared in the leeward of the city center and it exceeded 13 deg C at noon.

Keywords: urban warming, numerical simulation, land use, mesoscale model

Urban Heat Islands and the Change of Urban Climate in Taipei

Yingjiu BAI*

*Tohoku University of Community Service and Science, Sakata, Japan

bai@koeki-u.ac.jp

As economic development, urbanization and population growth continue in Asian megacity, the urban heat island ("UHI") phenomenon has often been attributed to causing severe environmental problems in large cities, such as energy shortage, air pollution, and deterioration of living conditions. However, UHI researches in large cities in tropical and subtropical regions are rare. The needs to document and predict UHI in tropical and subtropical regions, in order to find effective methods to mitigate the impact of UHI are acute.

This study has two main purposes; the first is to clarify the relationship between the change of urban climate and urban development in Taipei, and the second is to characterize the UHI in low latitude region.

This study examined Taipei City has been urbanized rapidly from 1967 and urban warming appeared from 1985. The effects of urbanization on local weather and climate change resulted in a remarkable increase in mean temperature and minimum temperature. However, urbanization resulted in little change in maximum temperature in Taipei City**.**

The results of field observations in 2008 clearly indicated that (1) the inner city and the satellite cities where neighbour inner city were high-temperature regions, and the distribution of the high-temperature region was related to the residential density;（2）the temperature difference in winter was over 2°C during nighttime between the inner city and the suburb; (3) the UHI reached its greatest intensity on cloudless nights before sunrise, and the maximum UHI intensity in winter reached around 4.1°C; and (4) the temperature difference between the inner city and the satellite cities where neighbour inner city was little during nighttime.

Keywords: Taipei, urban heat island (UHI), the effects of urbanization, the change of urban climate

Comparative analysis of land use distributions and changes in Asian mega cities

Akio YAMASHITA*

*Rakuno Gakuen University, Hokkaido, Japan

akio@rakuno.ac.jp

Distribution of land use and its chronological changes are the mirrors that directly reflect the present situation and changes in the natural and socioeconomic environments in the region concerned, and they serve as indexes to measure the effects of people's activities on the ground. As such, analysis of land use is the basis for academic fields that approach the relationship between human activities and nature from a spatial perspective, such as geography.

Most of the megacities in Asia are located on low-laying areas alongside the downstream of large rivers; the population has rapidly increased and these cities have changed significantly in the past period of 50 to 100 years. Accompanying these changes, problems in water resources, urban heat island effects, and underground environment issues symbolized by land subsidence have occurred. However, the present stage of progress and maturity as a city differs among cities, and as a result, the overt and latent characteristics noted in the above-mentioned urban environment issues also vary.

In this study, therefore, land use mesh maps were made to be used as indexes to compare megacities in Asia on the progress of urbanization and industrialization and accompanying various urban environmental problems. In this study, we examined seven cities in three periods: Tokyo, Osaka, Seoul, Taipei, Manila, Bangkok, and Jakarta. The purpose of this study is to comparatively analyze spatial characteristics of land use distribution in respective cities in respective periods, and their chronological changes.

As a result, we were able to analyze and interpret the land use distribution patterns and changes in the past century in seven cities in Asia. The method of this study is considered to be versatile for preparing the same standard land use maps, targeting a relatively wide range, such as metropolitan areas, and using overseas maps and old-edition maps. In other words, this method is suitable for a relative study that compares the past and present, and overseas cities and cities in Japan.

Keywords: land use, topographic map, urbanization, geographic information system

The Roles of Government in Groundwater Management
-Institutional Responses to Land Subsidence Problem in Asian Mega City-

Takahiro ENDO*

*Research Institute for Humanity and Nature, Kyoto, Japan
endo@chikyu.ac.jp

Land subsidence is a problem that appears repeatedly in Asian mega-cities such as Tokyo, Osaka, Bangkok and Jakarta with some temporal gaps. The main cause is regarded as excessive groundwater pumping for industrial uses. It is afraid that people will face higher flood risk because these cities are located at low flat plain in coastal area. Negative impacts on existing infrastructure are also worried. How to prevent and stop land subsidence is a major groundwater problem in Asian Mega-Cities.

The purpose of this paper is to compare land subsidence policies between Osaka and Bangkok and deduce some lessons from them. Land subsidence can be regarded as an example of social dilemma. Stopping land subsidence benefits all the residents who face high flood risk. Intuitively, it seems that people connected by a common benefit will automatically realize these benefits by mutual cooperation. But this is not always the case. Rather, it would be fallacious to say that individuals who share a common benefit automatically promote it. When an individual contributes to the common benefit, they get only a small portion of the benefit their contribution makes. The rest will spill over to other individuals because the benefit is in common. If they find what they get is insufficient and the contribution does not give a return, they will not make any contribution. In such a situation, they have an incentive to be a free-rider who just expects contributions from others. Where the free-rider prevails, a common benefit will not be sufficiently provided. This can be expressed as “everybody’s business is nobody’s business” situation and is well-known as collective action problem to social scientists.

Governmental intervention is an effective way to solve this situation, because government can force groundwater users to change its behavior. This is the reason why government intervention took place in Osaka and Bangkok in solving land subsidence problem. The policy option government took in those cities is various. It included designation of critical area, permitted system of groundwater pumping, enforcement of technical standards, construction of waterworks and groundwater charge system. Among these options, the most effective solution was construction of waterworks. It is because groundwater users had no choice but to keep abstraction without alternative water supply.

Keywords: land subsidence, social dilemma, waterworks, groundwater charge system

Chemical and physical evidences in the groundwater aquifer caused by the groundwater over-pumping and their countermeasures in the major Asian coastal cities.

Jun SHIMADA

Graduate school of Science and Technology, Kumamoto University, Japan
jshimada@sci.kumamoto-u.ac.jp

Economic growth of urban area induces the huge water demand for the city production and this situation creates the groundwater related disasters in many Asian cities. This situation has started from 1960's at Osaka and then Tokyo and Nagoya area in 1970's. After this, many coastal cities in South East Asia had experienced similar problems later 1980's to 2000's; such as Taipei, Shang-hai, Bangkok, Jakarta, etc. This was caused by over-pumping of groundwater in the urban area and the related local city governments had tried to make countermeasures to protect the groundwater disasters by the groundwater regulation with the help of their national government. In the case of Japan, it has good success and the dropped groundwater level has clearly recovered because of the humid temperate hydrological condition of Japanese island. Similar recovery has confirmed in Taipei and Bangkok, but it has not succeeded at Jakarta. Although the coastal Asia has the potentiality of some amount of groundwater recharge, to success the groundwater regulation, we need both the infrastructure of surface water supply at the groundwater regulation area and the legal background support for the groundwater regulation.

At the planning stage of the present project, we believe that those groundwater over-pumping situations must create the forced groundwater flow in the particular aquifer and this should contain the precise time series information along the groundwater flow line in the aquifer, as the paleo-hydrology information in the aquifer. For this purpose, we have developed the young age tracer of groundwater such as CFCs and ^{85}Kr. The sampling and analytical methods for these new age tracers has almost completed and confirmed its accuracy. However, we have confirmed that it could not use CFCs tracer in the urban aquifers, because of man made local CFCs contamination noise. However, those CFCs contents can be useful to understand the induced vertical groundwater flow through different aquifers caused by the depressed groundwater potential under the city area. This kind of situation has been confirmed at Tokyo, Bangkok and Jakarta area and the vertical induced flow are much more than the lateral groundwater flow along the aquifer.

Key words: over-pumping, induced groundwater flow, groundwater regulation, CFCs,

A Method for Groundwater Dating using Anthropogenic Radionuclide of ^{85}Kr

N. MOMOSHIMA[a], F. INOUE[b], S. SUGIHARA[a], T. OHTA[c], Y. MAHARA[c], J. SHIMADA[d], R. IKAWA[e], M. TANIGUCHI[f]

[a]Radioisotope Center, Kyushu University, Fukuoka, Japan, [b]Graduate School of Science, Kyushu University, Fukuoka, Japan, [c]Research Reactor Institute, Kyoto University, Osaka, Japan, [d]Faculty of Science, Kumamoto University, Kumamoto, Japan, [e]Groundwater Research Group, Geological Survey of Japan, Ibaraki, Japan, [f]Research Institute for Humanity and Nature, Kyoto, Japan

momoshima.noriyuki.551@m.kyushu-u.ac.jp

The ^{85}Kr (10.8y) would be an alternative dating tracer for groundwater to tritium (12.34y) which was released to environment from nuclear detonations in 1950s and early 1960s but recent concentrations have significantly decreased. An increasing trend of ^{85}Kr concentration in the atmosphere and a conservative nature of Kr (1.14ppm) after dissolved in groundwater enable us to use ^{85}Kr as a tracer for groundwater. We developed a new groundwater dating method using ^{85}Kr.

Kr with other gases dissolved in groundwater is recovered with a Kr extraction system which is equipped with an external inflow type hollow fiber membrane and a dry vacuum pump. The extraction efficiency of Kr was confirmed to be about 99% using water equilibrated with known concentrations of Kr in air. Kr and other gases extracted from groundwater are compressed in a cylinder using a dry compressor pump connected to the vacuum pump in tandem to a maximum pressure of 0.5 M Pa and brought back to the laboratory. The extracted gas in the cylinder is at first passed through a CH_4 oxidation system and a CO_2 elimination system, and was transferred to a rubber balloon. The Kr mostly O_2 and N_2 in the balloon was collected in activated charcoal at liquid N_2 temperature and a large portion of O_2 and N_2 was removed from the activated charcoal flowing He gas at dry ice temperature. The remaining gases in the trap were transferred to a small activated charcoal trap which was connected to a gas chromatograph. Separation of Kr and other gases was carried out using a MS5A column with He carrier and Kr separated was introduced to a Kr recovery system confirming isolation of Kr with a TCD. Kr isolated was adsorbed on silica gel in a quarts vial cooled with liquid N_2 and p-xylene base scintillator was poured into the vial from a scintillator reservoir in the Kr recovery system. Recovery evaluated using Kr in air was 60-90%. The activity was measured with a low background liquid scintillation counter with a counting efficiency of 70% for beta ray of ^{85}Kr. Specific activity of ^{85}Kr/Kr was calculated by the ^{85}Kr activity and the amount of Kr detected with the TCD.

Homogeneity of atmospheric ^{85}Kr concentration in the general environment except near nuclear fuel reprocessing plants was observed and a comparison of a known historical change of atmospheric ^{85}Kr/Kr with ^{85}Kr/K observed makes possible to determine the age of groundwater

Keywords: ^{85}Kr, groundwater dating, hollow fiber membrane, liquid scintillation counting

Disturbance of Groundwater Flow System due to Excessive Pumping in the Bangkok Metropolitan Area, Thailand

Tsutomu YAMANAKA* and Makoto MIKITA†

*Terrestrial Environment Research Center, University of Tsukuba, Tsukuba, Japan
tyam@suiri.tsukuba.ac.jp
†Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Japan
mikita@suiri.tsukuba.ac.jp

Excessive groundwater pumping from deep wells since 1950s in the Bangkok metropolitan area (BMA), Thailand, has induced remarkable piezometric drawdown and land subsidence. Yamanaka et al. (2009) investigated the disturbance of the groundwater flow system due to the pumping using water isotope and conservative anion as tracers, and revealed that major productive aquifers are partially replenished by downward leakage across confining layers, especially within the BMA. However, quantitative aspects of such phenomena are not yet fully clarified. In this study, we aim to evaluate quantitatively an enhancement of confined groundwater recharge and its renewal by numerical experiments using a three-dimensional groundwater flow model.

The constructed model reproduced well observed piezometric-level variations. Outputs from the model clearly showed that recharge of confined groundwater under natural conditions (e.g., without pumping) had occurred only at suburban hilly areas, while it was enhanced due to pumping not only at the suburban areas but also within BMA. The enhanced recharge was more remarkable at locations where Bangkok clay is relatively thin. In addition, response of the recharge flux to the temporal variation of groundwater pumping was faster within BMA and slower at suburban areas. In 2001 when the groundwater pumping rate was the maximum, total recharge flux at land surface within the model-domain became approximately 13 times larger than that under natural conditions. As a result, mean turnover time for the whole groundwater-flow-system reduced from more than 50,000 years to less than 5,000 years. For shallow aquifers the fraction of the water renewed by enhanced recharge since the beginning of groundwater pumping reached to more than 80% at recharge zones situated in hilly suburban areas, but was less than 20% in urban areas. These results suggest that renewal rate of groundwater is not very high because of large storage capacity and the current water quality field is strongly affected by processes of deltaic plain formation.

Keywords: confined groundwater, groundwater use, groundwater flow model, numerical experiment, groundwater recharge

The process of changing groundwater age in Jakarta area

Makoto KAGABU*

*Graduate School of Science and Technology, Kumamoto University, Japan
m.kagabu@es.sci.kumamoto-u.ac.jp

Apparent groundwater age (residence time) in Jakarta area by using ^{14}C method was performed two times; in 1985 by Gehy and Söfner (1989) and in 2008 by RIHN project. Although the age-distribution tendency in 2008 was the same as in 1985, all of the groundwaters were relatively younger. This observation was particularly apparent under the urban area, where the age of the groundwater was approximately 10,000 to 15,000 yr younger than that measured in 1985.

We assumed three possible reasons for the decrease in the age of the groundwater below the urban area are: (1) modern seawater intrusion into the groundwater, (2) older groundwater mixing with younger, shallower groundwater, and (3) increase in the rate of groundwater circulation. These reasons are related to excessive groundwater pumping below the urban area.

To verify the process of changing groundwater age, the groundwater flux in the aquifer under the DKI Jakarta was calculated by using groundwater flow simulation method (Groundwater Vistas 5, Scientific Software Group, USA).

The vertical groundwater flux from shallow aquifer showed main flux after 1980 among 5 fluxes (from east and west side, from seaside, from upstream, from bottom layer and from top layer). The groundwater shortage by pumping was compensated by this flux reached about 50 % in 2007. This result implies that the reason (2) (mentioned above) has big contribution to the decrease in the age of groundwater. The vertical groundwater flux also showed the expanding of groundwater catchment area caused by excessive groundwater pumping.

In my presentation, the situation of future groundwater potential from two scenarios (save or neglect the excessive groundwater pumping) will be also shown.

Keywords: groundwater age, groundwater flow simulation, excessive groundwater pumping, Jakarta

Groundwater quality degradation based on stable isotope and nitrate content in Jakarta Basin

Robert DELINOM[1], Makoto KAGABU[2], Yu UMEZAWA[3], Takahiro HOSONO[2], Rachmat FAJAR LUBIS[1], Sudar YANTO[1], Makoto TANIGUCHI[4]

[1] Research Center for Geotechnology , Indonesian Institute of Sciences

[2] Kumamoto Univeristy

[3] Hiroshima University

[4] Research Institute for Humanity and Nature

rm.delinom@geotek.or.id

Nowadays, more than 13 millions people live in Jakarta Area and it will increase in the near future. This population pressure increases the groundwater abstraction in the area and can cause groundwater, either quality or quantity, problems. The quality decreasing is marked by the appearance of some pollutants, such as nitrate pollutant which is produced by human activity, i.e. domestic waste, garbage leaching, and fertilizer over used.

The analysis result of nitrate (NO_3) content in groundwater was varied from 0.00 to 79,737 mg/l. The high content of nitrate were found in dug well of unconfined aquifer, while in the groundwater of confined aquifer the nitrate content is relatively low (< 4 mg/l). It is concluded that the presentation of those pollutant is caused by poor sanitation system and the presentation of nitrate pollutant is very much connected with un-control groundwater abstraction either for domestic or industry use. Stable isotope analysis was executed in order to recognize the origin of the nitrate pollutant

Keywords: Groundwater, stable isotope, nitrate, pollutant, Jakarta groundwater basin

Review of Groundwater Management and Land Subsidence in Bangkok

Oranuj LORPHENSRI, Anirut LADAWADEE

*Department of Groundwater Resources,
Ministry of Natural Resources and Environment, Thailand
oranujl@hotmail.com

The history of groundwater use in Bangkok started in 1907. Since then, groundwater is the important source of public water supply concurrent with surface water. Both public and private sectors had freely developed groundwater for several decades before consequent affect revealed. Due to the past uncontrolled over pumping of groundwater, certain aquifers and overlying clay layer are under substantial stress, leading to serious land subsidence which at its most severe amounts to 10 cm/year (1978-1981). In certain places, with combined surface loading, this has amounted to a maximum recorded settlement of 100 cm over a 21-year period (1978-1999) and groundwater level has declined to 55 m from ground surface. The increasing of groundwater abstraction reached it maximum at 2.2 million cubic meters per day (Mm^3/d) in 1999. The mitigation actions have been required if they are to be reinstated and stabilized. The subsequent strict mitigations such as declaration of "Groundwater Critical Zone" covered large area totally seven provinces including Bangkok. The mitigation included reducing the permissible pumpage of registered wells, promoting public awareness in groundwater conservation, and finally implementing "No permission for groundwater development in public water supply service area" in the Bangkok metropolis. In addition, Groundwater Tariff and Groundwater Conservation Tax have been implemented. All these mitigations have been determined to control the total abstraction to meet permissible yield which has been studied at 1.25 Mm^3/d. The strict mitigations finally return good result.

Dissolution Rates of Kauriyala Shale, Lesser Himalaya, India : Implications for Sub-SurfaceWater Composition

Sri Krishan YADAV and G.J. CHAKRAPANI*

*Department of Earth Sciences, Indian Institute of Technology, Roorkee 247 667, Uttarakhand., India
gjcurfes@iitr.ernet.in (G.J. Chakrapani), chakrapani.govind@gmail.com

Rock-water interaction plays an important role in deciphering the resultant surface and sub-surface water compositions. The Himalayan catchment is comprised of Archean to Miocene rocks, which weather to form the vast Gangetic Alluvium downstream of the Ganga river, which represent an important aquifer system. The rocks weather at variable rates and are conrtolled by numerous rock properties, composition, climate and tectonics. In the present study, we report on the dissolution rate of the highly radiogenic Kauriyala Shale in the Lesser Himalaya, situated near to the origin of the Ganga River. To estimate dissolution rates of shale (KS) and its pH and temperature dependencies, batch dissolution experiments were conducted for 30-35 days in the laboratory at fixed pH (8.4, 4, and 2.2) and temperature (5 and 25° C) conditions. Dissolution rates vary mainly as a function of pH and temperature in the range 10^{-11} - 10^{-15} $molm^{-2}s^{-1}$. KS dissolution kinetics can be visualized mainly as interplay of its constituent clay minerals with organic and inorganic ligands through surface-complexation and ion-exchange mechanism resulting in high release rate of Ca and Mg at pH 2.2 and 4. pH dependency curves of dissolution rates with respect to Si-release are highly controlled by temperature change as we move from acidic to alkaline pH conditions. This is reflected in terms of apparent activation energies (E_a) involved in dissolution of the lithology as the values of E_a derived at fixed temperature points also increases with increasing pH. The study shows that global warming can have serious implications on rock weathering and water compositions.

Monitoring Groundwater Variations Using Precise Gravimetry on Land and from Space

Yoichi FUKUDA*[1], Jun NISHIJIMA[2], Keiko YAMAMOTO[3], Takashi HASEGAWA[1], Toshiyuki NAKAEGAWA[4], Makoto TANIGUCHI [3]

1. Department of Geophysics, Kyoto University
2. Department of Earth Resources Engineering. Kyushu University
3. Research Institute for Humanity and Nature, Japan
4. Meteorological Research Institute, Japan Meteorological Agency

*Corresponding author: fukuda@kugi.kyoto-u.ac.jp

We investigated the applicability of precise in-situ gravity measurements and the GRACE (Gravity Recovery and Climate Experiment) satellite gravity data in order to establish a new technique for monitoring groundwater variations in urban areas and regional to continental scales.

In urbanized areas, one of the urgent problems is the monitoring groundwater variations especially connected with land subsidence. In Jakarta, for instance, there are more than several tens of observation wells and the monitoring of the groundwater levels have been conducted so far. However, for more accurate groundwater managements, we need additional information about groundwater mass variations. We employed a portable type absolute gravimeter with high precision for the measurements at some control points, and employ relative gravimeters of superior portability for the measurements at most points around the control points. By this way, we could strike a balance between accuracy and efficiency of the measurements. Several test measurements conducted so far showed that a 10 μgal (10 nm/s^2) accuracy has been achieved in the field surveys.

GRACE is providing extremely high precision gravity field data from space. These data are precise enough to reveal the gravity changes due to large scale groundwater variations. Using the GRACE data, we estimated terrestrial water storage (TWS) variations in four major river basins of the Indochina Peninsula. The results basically showed good agreements with Soil-Vegetation-Atmosphere Transfer Scheme (SVATS) models. The agreements can be improved by tuning the model parameters, because the GRACE TWS can be used as a constrain condition of the models.

We also detected the gravity changes due to the 2006 drought in Australia. This suggested that GRACE data can be applicable for monitoring secular or long-term groundwater variations as well.

Key words: groundwater monitoring, absolute gravimeter, land subsidence, GRACE

Repeat Gravity Measurement for Groundwater level monitoring
-An Application to the Shallow Groundwater Level Monitoring-

Jun NISHIJIMA*

*Department of Earth Resources Engineering, Faculty of Engineering,
Kyushu University, Fukuoka, Japan
nishijima@mine.kyushu-u.ac.jp

It is necessary to monitor the aquifer balance of pumping up and recharge to use the ground water for a long term. The pumping up of ground water causes mass fluid movement and mass redistributions, which can cause measurable gravity changes and ground deformation at the ground surface.

We carried out the preliminary gravity and GPS survey at Jakarta in order to detect the gravity changes caused by groundwater level changes. There are two methods to measure the gravity. We combined the Absolute gravity measurement and the relative gravity measurement. We used the instruments for the relative gravity measurement (CG-3M gravimeter: Scintrex Ltd.) and the absolute gravity measurement (A-10 gravimeter: Micro-g LaCoste, Inc.). The A-10 absolute gravimeter (A10 -#017) was introduced on Dec. 10 2007, and we got the training for the operation, theory, data processing at the same time.

The A10 absolute gravimeter is a portable absolute gravimeter produced by Micro-g LaCoste Inc. It operates on a 12V DC power supply (i.e. vehicle battery). We can measure the absolute gravity using the vehicle battery at the field. The principle of this instrument is simple. A test mass is dropped vertically in a vacuum chamber, and then allowed to fall an average distance 7cm. The A10 uses a laser, interferometer, long period inertial isolation device and an atomic clock to measure the position of the test mass very accurately.

We will report the preliminary gravity measurement using the A10 absolute gravimeter at Jakarta and Kyushu University.

Keywords: Absolute gravimetry, A10 absolute gravimeter, gravity changes, underground mass movement

Study of landwater variation over Chao Phraya river basin using GRACE satellite gravity data

Keiko YAMAMOTO[1]*, Yoichi FUKUDA[2], Toshiyuki NAKAEGAWA[3], Takashi HASEGAWA[2], Makoto TANIGUCHI[1]

[1]Research Institute for Humanity and Nature, Kyoto, Japan

[2]Department of Geophysics, Graduate School of Science, Kyoto University, Kyoto, Japan

[3]Climate Research Department, Meteorological Research Institute, Tsukuba, Japan

*yamamoto@chikyu.ac.jp

A project to assess the effects of human activities on the subsurface environment in Asian developing cities has been in progress (Research Institute for Humanity and Nature, Japan, 2009). Bangkok, Thailand is one of the study cities in this project. Using GRACE satellite gravity data, we recovered landwater mass variation over the Chao Phraya river basin, where Bangkok is located on the downstream. One of the advantages using GRACE data for the study of landwater variation is that GRACE can detect total terrestrial water storage over large area including groundwater, which is generally difficult to detect by other methods. The result shows that a negative interannual mass trend was observed over the Chao Phraya river basin, while positive trend values were observed over the other neighbouring river basins, like Mekong, Irrawaddy and Salween.

To investigate why the mass decrease were occurred over the Chao Phraya basin, we firstly compared the GRACE-derived mass variation with a groundwater storage variation calculated by a regional numerical groundwater model (Yamanaka, personal communication, 2009). The result shows that the model-estimated confined groundwater storage shows positive interannual trend over the GRACE mission time period, which is in contrast to GRACE-derived negative mass change. Further, the magnitude of the confined groundwater storage change is much smaller than that of the GRACE-derived mass change. Thus, it is expected that the negative mass trend was not caused by regional confined groundwater decrease. On the other hand, the terrestrial water storage variation derived from global scale hydrological model shows similar change with the GRACE-derived mass variation. Thus, we concluded that the negative mass change over Chao Phraya basin does not mainly come from impacts of local human activities, but from large-scale meteorological or climatological factors.

Keywords: GRACE, terrestrial water storage, groundwater, satellite gravity mission

Long-term trends of terrestrial water storage in south-east Australia detected by GRACE

Takashi HASEGAWA[1], Yoichi FUKUDA[1], Keiko YAMAMOTO[2],
Toshiyuki NAKAEGAWA[3], Yoshiaki TAMURA[4]

1. Department of Geophysics, Graduate School of Science, Kyoto University, Kyoto, Japan
2. Research Institute for Humanity and Nature, Kyoto, Japan
3. Climate Research Department, Meteorological Research Institute, Ibaragi, Japan
4. Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, Iwate, Japan

hasegawa@kugi.kyoto-u.ac.jp

In south-east Australia, the areal extent and frequency of exceptionally hot years and low rainfall years has been increasing rapidly over recent decades. Although these climatic trends are expected to induce long-term terrestrial water storage (TWS) decreases on continental to sub-continental scale, conventional observations cannot reveal such large-scale TWS changes due to sparse distribution of measurement points.

GRACE satellite gravimeter, launched in March 2002, has been measuring changing gravity field with an unprecedented accuracy. The temporal variations of the Earth's gravity fields recovered by GRACE reflect large-scale mass redistribution in and on the Earth. In this study, TWS variations in south-east Australia are investigated employing GRACE gravity field models released from CNES/GRGS. The results are compared with a data-integrating hydrological modeling system, the GLDAS model developed by NASA.

In 2006 and 2007, both GRACE data and hydrological model indicate distinct TWS decreases which can be interpreted as effects of the 2006 historic rainfall deficiencies. However, the results from GRACE data show much steeper than the model estimation. Because ground gravity measurements at Canberra agree with GRACE data, we conclude GRACE successfully monitors the TWS changes caused by the drought, although the changes are not represented by the model.

Furthermore, GRACE data shows TWS decreases with longer time-scale in this region. The model shows any corresponding trends and we consider the trends revealed by GRACE indicate effects of long-term climatic changes.

Keywords: GRACE, Gravity change, Terrestrial water storage, Drought

Repeat Gravity Measurement for Groundwater level monitoring -An Application to the Reservoir Monitoring in Geothermal Power Plant-

Yayan SOFYAN*

*Department of Earth Resources Engineering, Graduate School of Engineering,
Kyushu University, Fukuoka, Japan
yayan_sofyan @mine.kyushu-u.ac.jp

Kamojang Geothermal Field (KGF) located in West Java is the oldest developed geothermal field in Indonesia. It is a typical vapor dominated hydrothermal system. From 1983 to 2005, more than 160 million tons of steam has been exploited from the KGF and more than 30 million tons of condensed water and river water were injected to the reservoir system. Regarding to the electricity demand, installed capacity of KGF increased from 30 MWe to 140 MWe in 1987 and 200 MWe in the end of 2007. The evaluation of steam production in 1999 showed the decline of steam flow rate notably occurred at some production wells in KGF. The changes of the reservoir during exploitation influenced some decline production of the wells.

Repeat gravity measurement can be used to monitor the reservoir condition. Gravity monitoring between 1999 and 2005 at 51 benchmarks are interpreted in terms of a change of mass. The amount of mass changed associated with the production and injection activities. Based on Gauss's potential theorem, the 1999-2005 gravity changes indicate mass decrease of about 3.34 Mt/year in KGF. In the end of 2008, repeat gravity measurement was conducted for reservoir monitoring. We used Scintrex CG-3 gravimeters to measure precise gravity change. Concerning to the production increase, therefore the KGF has average mass decrease between 1999 and 2008 bigger than between 1999 and 2005. In 2009, The A10 absolute gravimeter (Micro-g LaCoste, Inc) was introduced to detect the gravity changes in KGF. This absolute gravity measurement also assessed the gravity changes at reference station. It is very important to monitor the geothermal reservoir to continue the sustainable production..

Keywords: Absolute gravimetry, A10 absolute gravimeter, gravity changes, reservoir monitoring

Groundwater and Soil Pollutions Status in Asian Subsurface Environment

Shin-ichi ONODERA*

* Graduate school of Integrated Arts and Sciences, Hiroshima University, Japan
sonodera@hiroshima-u.ac.jp

Urbanization causes the convergence, consumption and disposal of material. Consequently, soil and groundwater pollution occurs at many cities. In the Material Group of the RIHN project, we have conducted the intensive researches of groundwater pollution in two different seasons at Bangkok, Jakarta and Manila as well as research in one season at Taipei and Seoul. In addition, we have conducted the monitoring of SGD and collection of rainwater, sediment core and porewater at the coastal zone at Osaka, Manila, Bangkok, and Jakarta. In my presentation, I would like to report the review of our researches.

The results are summarized as follows:

1) Our researches indicated huge accumulation amount of trace metal and dissolved nitrogen in groundwater, especially in Jakarta and Manila. Then, various N sources and denitrification were confirmed by using N isotope distribution in groundwater. In addition, As contamination in deep groundwater were detected at some cities. But As and NH_4^+ contamination originated by natural sources were suggested by some results.
2) Various groundwater salinisations were compared in Osaka, Bangkok and Jakarta. The difference of marine alluvium volume (same as topographic gradient), natural recharge and intensive pumping period controlled salinisation.
3) Soil pollution was confirmed in Bangkok. Trace metal content was higher in the central of the city than in the others. And organic pollution and metal pollution histories were reconstructed, using marine sediments. In addition, the differences of the peak in each trace metal were confirmed.
4) Less terrestrial submarine groundwater discharge but huge material flux by total SGD was confirmed. Spatial variation in SGD was estimated in around each cities, using topographic model and Rn measurements.
5) Some new methods were established. Firstly, analysis system of dissolved N_2/Ar in groundwater was applied for reconstruction of dinitrification in groundwater and nitrate content during the groundwater recharge. Second one is Rn analysis system for the quantification of SGD and seawater intrusion. Third one is the purification method of organic chlorine pollution.

Keywords: pollution, groundwater, soil, sediment, salinisation, SGD

Reconstruction of the Anthropogenic Pollution History in Asian Megacities Based on the Characteristics of Organic Matter and Heavy Metals in the Sediment Core Sampled in the Adjacent Bays

Yu UMEZAWA*

*Faculty of Fisheries, Nagasaki University, Nagasaki, Japan

umezawa@nagasaki-u.ac.jp

As the city developed with an increase of population and productivity in the society, human activities have changed environmental conditions in adjacent aquatic ecosystems. Such a historical change of human impacts on coastal ecosystems can be reflected into vertical profiles of materials in the sediments. In our study, therefore, we have collected marine sediment core samples at Osaka Bay, Jakarta Bay and Manila Bay, and analyzed nutrient contents (e.g., organic carbon, nitrogen and phosphorus: Y. Umezawa), their stable isotopic signatures ($\delta^{15}N$ and $\delta^{13}C$: Yu Umezawa) and heavy metals (e.g., Pb, Zn, Cu: T. Hosono). The age of sediment in each layer was calculated based on ^{210}Pb activities (C.-C. Su), then contaminations in sediments were oriented according to the age. The results suggested that the response of contaminant accumulations to the historical social developments and emission regulations were different between organic matter and heavy metals. And the vulnerability to the contaminant loadings seemed to be also different among the cities depending on the topography and characteristics of the bay. Briefly, 1) Historical trend of an increase of sedimentary C%, N% and P% at each bay has correspondence with an increase of population and associated material fluxes. 2) Gradual decreases of Pb contamination in Osaka city after 1970 and in Manila and Jakarta after 2000 have correspondence with phase out of leaded gasoline and lead-based paint. 3) Recent trend of chemical characteristics in Jakarta and Manila seemed to be similar to those in previous period in Osaka Bay. 4) At semi-enclosed bay, Osaka bay and Manila bay, the accumulations of organic matter are severe, while not so severe at open bay, Jakarta Bay. 5) Continuous increase of “consumptions per person” at Manila may result in further deterioration at adjacent bay. 6) The effect of temperature and redox conditions on the decomposition rate of organic matter in sediment should be estimated, when historical contaminations are reconstructed from the chemical profiles in marine sediment.

Keywords: marine sediment, carbon, nitrogen, phosphorus, $\delta^{15}N$ and $\delta^{13}C$, heavy metals, eutrophication, Jakarta Bay, Manila Bay, Osaka Bay

The status of groundwater quality and pollution mechanism in the Asian metropolitan areas

Takahiro HOSONO*

*Priority Organization for Innovation and Excellence, Kumamoto University

hosono@kumamoto-u.ac.jp

The status of groundwater quality and the pollution mechanism are presented for each Asian metropolitan area (Osaka, Seoul, Taipei, Bangkok, Manila and Jakarta) to discuss the prominent pollution mechanisms in Asian urban area. The compilation of chemical data clarified that the nitrate and arsenic contaminations are the most important environmental concerns in such fields in terms of dissolved constituents. Elevated concentrations of lead were also found in some groundwaters and the groundwater salinization is another big concern for groundwater quality. The application of multi-isotope ratios was successful in determining the source of nitrate (i.e. sewage and fertilizers) and arsenic (geological constituents) and the behaviour of the contaminants. Consequently, it is summarized that the hydrogeological setting is the most important factor controlling the groundwater nitrate and arsenic concentration in the aquifer at the present time. The degree of the contamination is not directly related to the development status of the city.

Keywords: Asia, groundwater, contamination, multi-isotope ratios

Evaluation of nitrate attenuation potential on the aquifers of developing Asian megacities

Mitsuyo SAITO[1], Shin-ichi ONODERA[2] and Yu UMEZAWA[3]

[1] Center for marine environmental studies (CMES), Ehime University, Japan

[2] Graduate School of Integrated Arts and Sciences, Hiroshima University, Japan

[3] Faculty of Fisheries, Nagasaki University, Japan

misaito@sci.ehime-u.ac.jp

Nitrate (NO_3^-) is a widespread pollutant derived from human activities. In the developing megacities, groundwater contamination by nitrate is one of the critical environmental problems. For the sustainable use of groundwater resources, it is important to clarify about the natural function of nitrate attenuation such as denitrification process in groundwater. The aim of this study is to examine the nitrate attenuation process and evaluate its potential on the aquifers of the three Asian megacities (Metro Manila, Bangkok and Jakarta).

We examined spatial variations in nitrate-nitrogen (NO_3^--N) concentration and nitrogen stable isotope ratio ($\delta^{15}N$) in groundwater, and tried to evaluate the NO_3^--N attenuation potential in the study aquifers focusing on 1) the amount of nitrogen input, 2) the content of organic matter as an electron donor and 3) groundwater flow condition, as the controlling factors of denitrification process. The relation between NO_3^--N concentration and $\delta^{15}N$ in groundwater suggests that NO_3^--N attenuation by denitrification occurs in the groundwater of the all these study sites. However, isotopic enrichment ratio is higher in the Metro Manila (MM) and Jakarta (JK) than that of Bangkok (BK). On the nitrogen input to the aquifer, in case of the BK, the soft clay layer overlies the top of the aquifer and it suggests that nitrogen load by human activity is difficult to reach to the saturated zone. Therefore, nitrogen input should be smaller in the BK aquifer than that in others. On the contrary, it should be largest in the JK aquifer because the surface layer is composed of alluvial and volcanic fan deposit with high permeability, and wide expanse of urban and agricultural area within the basin. The content of organic matter as an electron donor in the aquifer is assumed to be largest in BK and smallest in MM from the basin scale and thickness of alluvial deposit. Groundwater velocity is estimated to be largest in JK and smallest in BK from the hydraulic gradient and hydraulic conductivity in the aquifer. These results and conditions suggest that NO_3^--N attenuation potential by denitrification should be highest in BK, though the process apparently occurs more significant in MM and JK aquifers because of large nutrient input. However, overall trend shows that NO_3^--N attenuation potential is relatively high in all these study area.

Keywords: groundwater, nitrate, denitrification, attenuation potential, developing Asian megacities

Effect of nearshore bathymetry on submarine groundwater discharge and seawater circulation in the subterranean estuarine

Satoshi NAKADA [1]
Makoto TANIGUCHI [1]
Hiroya YAMANO [2]

[1] Research Institute for Humanity and Nature, Kyoto, Japan
[2] National Institute for Environmental Studies
snakada@chikyu.ac.jp

This study presents numerical simulations of submarine groundwater discharge (SGD) that is now recognized as an important water pathway between land and sea. Recent idealized simulations succeeded to quantitatively estimate the SGD caused by tidally induced seawater recirculation and a terrestrial hydraulic gradient (e.g. Robinson et al., 2006). The present numerical study focused on the topographic effect on the seawater recirculation and SGD because the configuration of the bathymetry (beach morphology) is the potentially important factors for chemical fluxes from nearshore aquifers to coastal waters. A two-dimensional hydrogeological model was applied to the realistic bathymetry in Omae-hama beach in Osaka, Japan and Laura inlet in Majuro, Marshall islands Republic, where previous SGD measurements were intensively performed using the automated seepage meters (e.g. Taniguchi et al., 2007). A density-variable numerical code, SEAWAT2000, was used to accurately simulate density-driven circulation such as SGD from a coastal sandy aquifer under various influencing numerical boundary conditions such as tidal forcing and terrestrial volume flux during spring and neap tide. The tidally influenced seawater recirculation and the fresh water–salt water mixing zones are successfully reproduced around intertidal zone of a sandy meso-tidal beach. Numerical simulations in case of Laura inlet show that salt input associated with tidally driven seawater recirculation leads to the formation of an upper saline plume in the intertidal zone, which represented as the general features of the subterranean estuarine. On the other hand, the results in the case of Omae-hama beach suggested the twin seawater circulations in the nearshore slope and offshore slope. The nearshore circulation is temporal and smaller than offshore and the offshore is quite steady. The most important factors on the seawater recirculation are slopes of bathymetry and the width of intertidal zone of a tidal beach.

Keywords: submarine groundwater discharge. seawater recirculation, intertidal zone, SEAWAT, subterranean estuarine

The existence of submarine groundwater discharge off the Southwestern Taiwan and its possible role in submarine landslide geohazards

Chih-Chieh SU*

* Institute of Oceanography, National Taiwan University, Taipei, Taiwan
donccsu@ntu.edu.tw

The Hengchun Earthquake which occurred on December 26, 2006, triggered turbidity current made the submarine cables lying downslope of the Fangliao Canyon and Gaoping Canyon were broken and caused huge economic lost. Three years later, in August 8-9, 2009, the Morakot typhoon brought heavy rains in southern Taiwan and spark off serious landslides and flooding events on land. In the Gaoping Canyon, the typhoon also induced the cable break events. Besides the earthquake activities, typhoons and torrential rains induced flooding events, are there any other environmental conditions may triggered or accelerated such submarine geohazards at this area. All these events may record in the marine stratum.

The chirp sonar and EK-500 sonar profiles, in conjunction with X-ray radiographs, grain size analysis, and ^{210}Pb radionuclide results are used to identify the sources, transportations and deposition times of the turbidites (or hyperpycnite) and reconstruct the history of the earthquakes and flooding events in the study area. All the evidences point out the turbidites in Gaoping and Fangliao Canyons were formed under different geological environments. For Gaoping Canyon, the existence of river system (Gaoping River) connected to the submarine canyon is important for the development of the submarine canyon. On contrary, in the vicinity of Fangliao Canyon, the submarine groundwater discharge may play an important role on trigger or accelerate the submarine slumping or landslide events.

Keywords: turbidite, submarine canyon, submarine groundwater discharge, geohazard

Detecting Groundwater Inputs into Bangkok Canals via Radon and Thoron Measurements

William C. BURNETT[1*], Makoto TANIGUCHI[2], and Supitcha CHANYOTHA[3]

[1]Florida State University, Tallahassee, FL 32309 USA; [2]Research Institute for Humanity and Nature, Kyoto, Japan; [3]Department of Nuclear Technology, Chulalongkorn University, Bangkok, Thailand
*wburnett@fsu.edu

Naturally-occurring radon (^{222}Rn) is very concentrated in groundwater relative to surface waters and thus serves as an effective groundwater discharge tracer. Conductivity is also typically different in groundwater than associated surface waters and thus may also be used as a tracer of interactions between these water masses. Previous studies by our group using radon and conductivity as groundwater tracers indicated that there is shallow groundwater seeping into the man-made canals ("klongs") around Bangkok. Furthermore, the groundwater was shown to be an important pathway of nutrient contamination to the surface waters. In the present study, we have re-examined some of the same canals but added thoron (^{220}Rn) measurements in order to evaluate if this would provide more site-specific information.

Thoron is a member of the natural ^{232}Th decay chain, has exactly the same chemical properties as radon, but a much shorter half-life (56 s). Because of its rapid decay, if one detects thoron in the environment, there must be a source nearby. Thus, thoron is potentially an excellent prospecting tool. In the case of measurements in natural waters, sources of thoron (as radon) could indicate groundwater seeps. During our surveys in the canals of Bangkok, we did successfully measure thoron and its distribution was more variable than that of radon (Fig. 1), suggesting that seepage into the canals is not uniform. Areas of higher ground elevation, often where Thai temples are located, were particularly high in thoron.

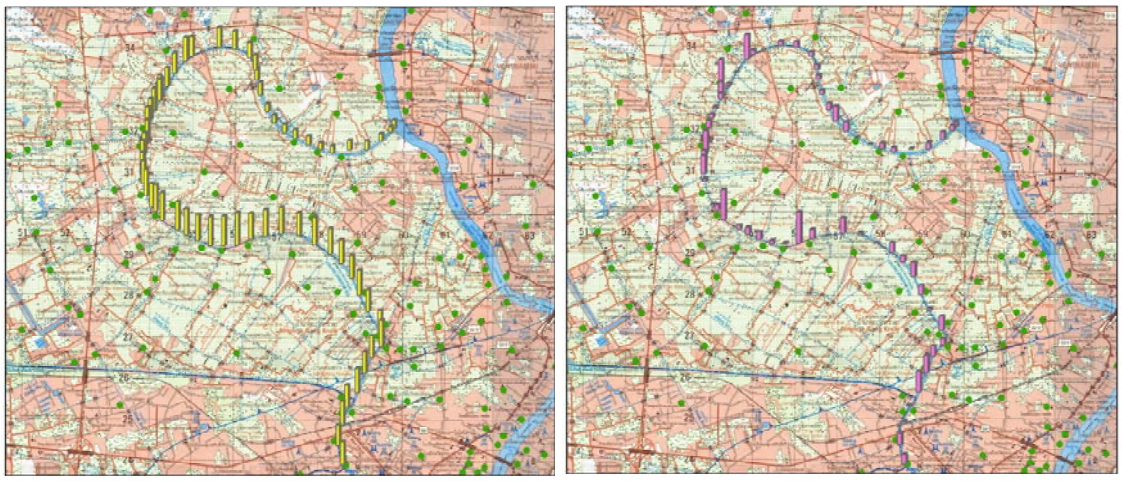

Figure 1. Distribution of ^{222}Rn (left) and ^{220}Rn (right) in K. Bangkok Noi, August 26, 2009.

Keywords: Groundwater; seepage, radon; thoron; Bangkok.

Evolution of the Subsurface Thermal Environment in Urban Areas -Studies in Large Cities in East Asia-

Makoto YAMANO* and
the Heat Group for the Project "Human Impacts on Urban Subsurface Environments"

*Earthquake Research Institute, University of Tokyo, Tokyo, Japan
yamano@eri.u-tokyo.ac.jp

Temporal variation in the ground surface temperature (GST) propagates downward and disturbs the subsurface temperature structure. Analysis of the disturbance extracted from temperature profiles in boreholes allows us to estimate the past GST history. This geothermal method of GST history reconstruction is useful for studies of thermal environment evolution in urban areas. To investigate subsurface thermal environment in large cities in East Asia, we carried out temperature logging in boreholes at 112 sites in and around Bangkok, Jakarta, Taipei and Seoul. Existing temperature profile data in the Tokyo, Osaka and Seoul areas can also be used for analysis. We conducted GST history reconstruction analysis on selected temperature profiles, which were not disturbed by groundwater flow. Most of the estimated GST histories show significant surface warming in the last century. In the Bangkok area, the amount of the GST increase is larger in the city center than that in suburban and rural areas, probably reflecting the degree of urbanization.

Subsurface heat storage, the amount of heat accumulated in the subsurface as a result of surface warming, can be calculated based on GST history reconstructed from borehole temperature profiles. It may be a useful indicator of the subsurface thermal environment and we may compare the values at specific times with those of other parameters representing urban subsurface environment obtained through various approaches.

Long-term monitoring of borehole temperature and soil temperature was conducted aiming to detect propagation of the effect of GST variation and to investigate heat transfer mechanism. Data obtained in some wells show steady temperature increase, while we observed peculiar one-week component in a well in the Taipei area, which results from vertical movement of borehole water probably caused by human activity. In a borehole on the coast of Lake Biwa, Japan, temperature records for two years at multi depths demonstrated decay of the annual component with depth by thermal diffusion. Soil temperatures measured within 1 m of the ground surface showed prominent annual variation with shorter period components. These data should provide information on thermal diffusivity and average GST at the stations.

Keywords: ground surface temperature, borehole temperature, heat storage, heat transfer

Human Impact on Subsurface Thermal Regime in Jakarta, Indonesia

[1]Rachmat FAJAR LUBIS, [2]Makoto YAMANO, [1]Robert DELINOM, Sudar YANTO
[3] Yasuo SAKURA, [4] Shusaku GOTO, [4] Akinobu MIYAKOSHI and
[5] Makoto TANIGUCHI

[1] Research Center for Geotechnology Indonesian Institute of Sciences Jln Cisitu Sangkuriang Bandung 40135 Indonesia, e-mail: fajardichiba@yahoo.com, rm.delinom@geotek.or.id, sudaryanto@geotek.or.id

[2] Earthquake Research Institute, University of Tokyo, Japan, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan e-mail: yamano@eri.u-tokyo.ac.jp

[3] Faculty of Science Chiba University 1-33 Yayoi-Cho, Inage-Ku Chiba 263-0043 Japan, e-mail: ysakura@faculty.chiba-u.jp

[4] National Institute of Advanced Industrial Science and Technology, Japan1-1-1 Higashi, Tsukuba 305-8567, Japan, e-mail : s.gotou@aist.go.jp, miyakoshi-a@aist.go.jp

[5] Research Institute for Humanity and Nature, Japan457-4 Motoyama, Kamigamo, Kita-ku, Kyoto 603-8047, Japan, e-mail : makoto@chikyu.ac.jp

In Jakarta, as a megacity in Indonesia, the use of groundwater has greatly accelerated conforming to the rise in its population and the development of industrial sector. Urban groundwater loading can also cause problems relating to the subsurface temperature regime. Groundwater can be affected by surface warming due to both climate change and urban 'heat island' effects leading to thermal signals of up to 100 m depth into the subsurface environment. Therefore an assessment of subsurface thermal regime using groundwater trends in the urban area is a necessary action.

Subsurface temperatures in Jakarta city have been analyzed to evaluate the effects of rapidly increasing population density. Groundwater temperature-depth profiles and groundwater levels were measured simultaneously on three observation wells in the area. As a result it can be intrepreted that the T–D profiles in observed wells are affected by groundwater flux, the climatic change and surface warming. This is the preliminary results of inversion analysis of the ground surface temperature (GST) profiles during the last century in Jakarta groundwater basin.

Keywords: Urban Groundwater, Subsurface Temperature Regime, Jakarta, Indonesia.

Evaluation of the subsurface thermal environment in the Tokyo metropolitan area - Urban subsurface heat island-

Akinobu MIYAKOSHI*

*Geological Survey of Japan, AIST, Tsukuba, Japan
miyakoshi-a@aist.go.jp

Information on three-dimensional subsurface temperature distribution and its change were examined through multiple measurements of temperature-depth profiles in observation wells in 2000-2009 to evaluate the subsurface thermal environment in the Tokyo metropolitan area, Japan. Additionally, we have conducted long-term temperature monitoring since 2007 at four stations in Saitama Prefecture which locates the northern part of this area.

Subsurface temperature distribution pattern changes with depth. At the depth of 50 m, high temperatures extend from the eastern part of the Upland to the Lowland, and low temperatures are distributed in the central to western part of the Upland. At the depth of 100 m, high temperatures are found only in the central part of the Lowland. High temperature area at the shallow part is considered to have been formed by effects of surface warming because of the continuity of subsurface temperature distribution. This high temperature area corresponds to the urban area, and subsurface temperature difference between the urban area and the suburban area was found. It suggests the existence of urban subsurface heat island, the centre of which is located around the eastern part of the Upland. Below the depth of 100 m, the high temperature area shifts to the central part of the Lowland. The bottom of permeable layers is relatively shallow in the central part of the Lowland, indicating that the high temperatures at deeper part were formed not only by the effect of surface warming but also by heat advection due to upward groundwater flow under the effect of pumping.

Continuous increases were found by the comparison of temperature-depth profiles, and it was shown that their increase tendency vary with depth. Temperature increases at the depth of 40-50m were estimated at about 1.2^{o}C in the suburban area by the analysis of present temperature-depth profile. In the urban area, subsurface temperature increases were estimated at 1.3-2.5^{o}C, which is almost twice as high as the increases of the suburban area. Additionally, continual increases of subsurface temperature were also found by the long-term monitoring of subsurface temperature. These suggest that subsurface temperatures in relatively shallow part have been rising and the urban subsurface heat island have been expanding in the Tokyo metropolitan area. The subsurface thermal environment is highly variable with depth and location due to the effects of human activity.

Keywords: subsurface thermal environment, groundwater flow, urbanization, Tokyo metropolitan area, subsurface heat island

Reconstruction of the thermal environment evolution from subsurface temperature distribution in Bangkok

Hideki HAMAMOTO[1], Makoto YAMANO[2], Shusaku GOTO[3], Monyrath VUTHY[4], Shin KAMIOKA[5], Jun NISHIJIMA[5], Oranuj LORPHENSRI[6], Makoto TANIGUCHI[7]

[1]Center for Environmental Science in Saitama, Saitama, Japan

[2]Earthquake Research Institute, the University of Tokyo, Tokyo, Japan

[3]Institute for Geo-Resources and Environment , National Institute of Advanced Industrial Science and Technology, Ibaraki, Japan

[4]Graduate school of Science and Technology, Chiba University, Chiba, Japan

[5] Faculty of Engineering, Kyushu University, Fukuoka, Japan

[6]Bureau of Groundwater Conservation and Restoration, Bangkok, Thailand

[7] Research Institute for Humanity and Nature, Kyoto, Japan

hamamoto.hideki@pref.saitama.lg.jp

Temperature changes at the ground surface propagate into the underground and disturb the subsurface temperature structure. Analyzing disturbances in the subsurface temperature structure, we can reconstruct the past ground surface temperature (GST) change, which is closely related to the past surface air temperature change. This method can be applied to studies of thermal environment evolution in urban areas such as the development of “heat islands”.

We conducted measurements of temperature profiles in groundwater monitoring wells at 45 sites in the city of Bangkok and its surrounding area in 2004, 2006, and 2008. At 17 sites of them, measurements were repeated to test the stability of temperature profiles. We examined the shapes of the stable temperature profiles and selected ones that are not significantly disturbed by groundwater flow. Reconstruction of GST history for the last several hundred years was made using the selected profiles at six sites. We used a multi-layer model that allows layers with different thermal properties, determining layer boundaries based on lithology of the formations around the wells. All of the reconstructed GST histories show surface warming in the last century. The amount of the temperature increase ranges from 0.4 to 2.6 K and is larger in the city than in the area to the west of Bangkok and in the northern rural area. This tendency may reflect difference in the degree of urbanization or human activities. These results should be combined with other information on development of the city to investigate the main cause of the surface warming, e.g., increase in the surface air temperature and land use change. We also estimated the amount of heat stored in the subsurface after 1900 based on the reconstructed GST histories.

Keywords: borehole temperature, subsurface environment, heat transfer, urbanization, Bangkok

Comparisons between air and subsurface temperatures in Taiwan for the past century: a global warming perspective

Chieh Hung CHEN and Chung-Ho WANG*

*Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, ROC

nonono@url.com.tw and chwang@earth.sinica.edu.tw

Air and sea surface temperature increases due to global warming have been widely observed around the world at various rates. This temperature rising has also been documented in many subsurface records recently. The air-ground temperature coupling system introduces an important factor in disturbing the original thermal balance and provides a new dimension to comprehend the effects of global warming on the Earth system. Ten meteorological stations of Central Weather Bureau in Taiwan that have been routinely measured for air (1.5m above the ground) and subsurface (at depths of 0, 5, 20, 10, 30, 50, 100, 200, 300 and 500 cm below the ground) temperatures are used for in-depth comparison in this study. These stations have a mean observation period of 82 years (as of 2008) to provide good coverage for a preliminary examination of air-ground temperature coupling relationship. Results show that patterns of air and subsurface temperature are quite different among stations in Taiwan. In general, air and subsurface temperatures exhibit consistent linear trends after 1980, but display complex and inconsistent tendencies before 1980. More work is needed to further decipher this discrepancy between air and subsurface temperature records.

Keywords: air and subsurface temperature, Taiwan, global warming

Long-term urbanization and subsurface environmental changes in Asian megacities: Stage model with DPSIR framework

Shinji KANEKO* and Tomoyo TOYOTA**

* Hiroshima University, Hiroshima, Japan
kshinji@hiroshima-u.ac.jp
** Research Institute for Humanity and Nature, Kyoto, Japan
toyota@chikyu.ac.jp

In Asian megacities, land subsidence has been taking place from one place to another historically from Tokyo and Osaka, Seoul and Taipei, Bangkok and to recently Manila and Jakarta. This implies that flying geese type of patterns of common causal relationship between urbanization and subsurface environmental changes may exist. As a synthesis of the interdisciplinary and international research project of RIHN on subsurface environmental changes (SEC) in Asian megacities, this study attempts to develop a stage model for the relation between long-term urban development and SEC in Asian megacities, based on the outcomes from a series of individual studies of the project. We first collect and construct thirteen annual indicators on urbanization and SEC for seven Asian megacities from 1900 to 2000. Then the indicators are categorized into five groups according to DPSIR framework. Taking Tokyo as a reference city due to the availability of most rich and reliable empirical evidences, we divide the stages into five while judging dynamic changes of the DPSIR causal relations. That is stage I as earlier stage of urbanization (1900-1923), stage II as recognition of land subsidence (1923-1947), stage III as acute land subsidence (1947-1962), stage IV as control of land subsidence (1962-1975), and stage V as transition to other subsurface environmental issues (1975-2000). Based on the stages defined by the experiences of Tokyo, current stages of other Asian megacities are found as follows. Osaka, Seoul and Taipei have already reached at the stage V in 1975, 1977 and 1982, respectively, while Bangkok is very close to the stage V but still in the stage IV. Manila and Jakarta are still stuck in the stage III. Finally various indicators in the DPISR framework at the year of stage transitions are compared for seven cities.

Keywords: DPSIR, stage model, urbanization, land subsidence, subsurface environmental changes

Model Working Group

Jun Yasumoto*

*University of the Ryukyus

yasumoto@agr.u-ryukyu.ac.jp

Subsurface environment project started-up the model working group (MWG) to integrate the corrected data of observations. This project are analyzed the groundwater flow in each cities by numerical simulation. The MWG constructs a framework in order to compare among the seven urban cities and finds the common indices in urban subsurface groundwater models. The MWG quantitatively estimate the nature and human factors to the urban subsurface environments using the common indices extracted from the result of the groundwater analysis in each city. The common indices decided MWG was shown table 1 and results of common indices are shown Fg.1 to Fig.3.

Table.1 The common indices decided MWG

Common indices1	1. Inflow from the Top (=Recharge)
	2. Inflow from the Side
	3. Inflow from the Sea (=Saltwater Intrusion)
	4. Outflow to the Sea (=Submarine Groundwater Discharge)
	5. Extraction (groundwater pumping)
Common indices2	6. Turnover time
	7. Renewed fraction α (since the beginning of GW use)
	8. 3-dimensional distribution of Renewed fraction

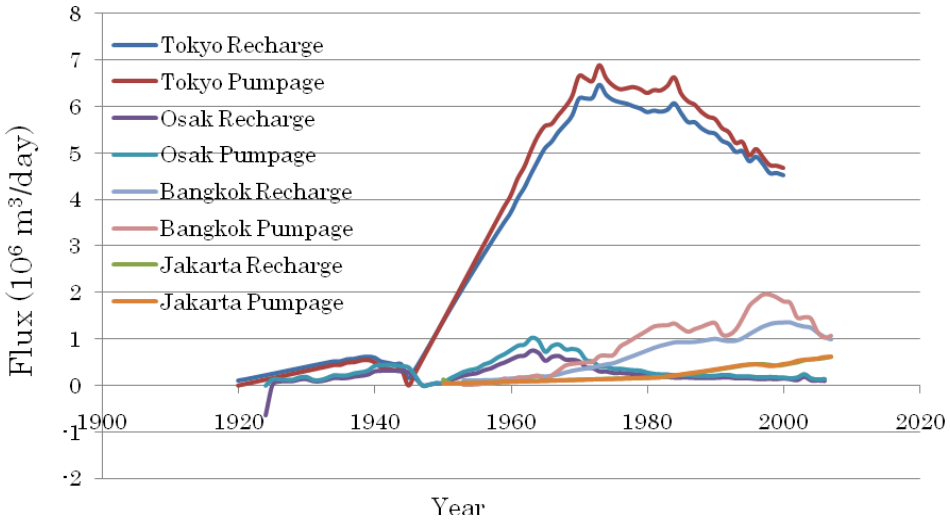

Fig.1 The common indices1-3.

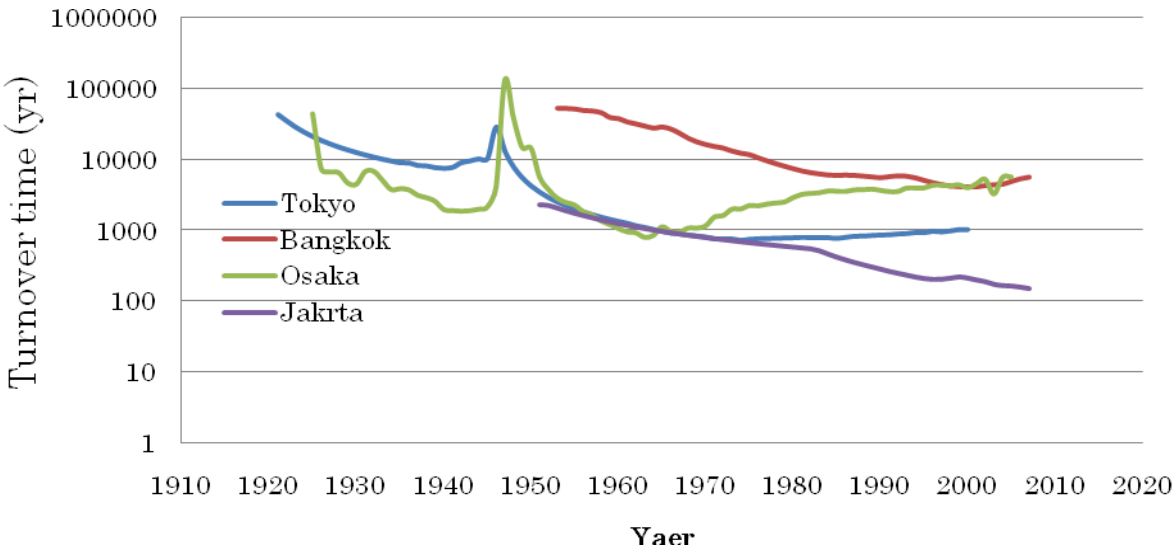

Fig.2 The common indices 6

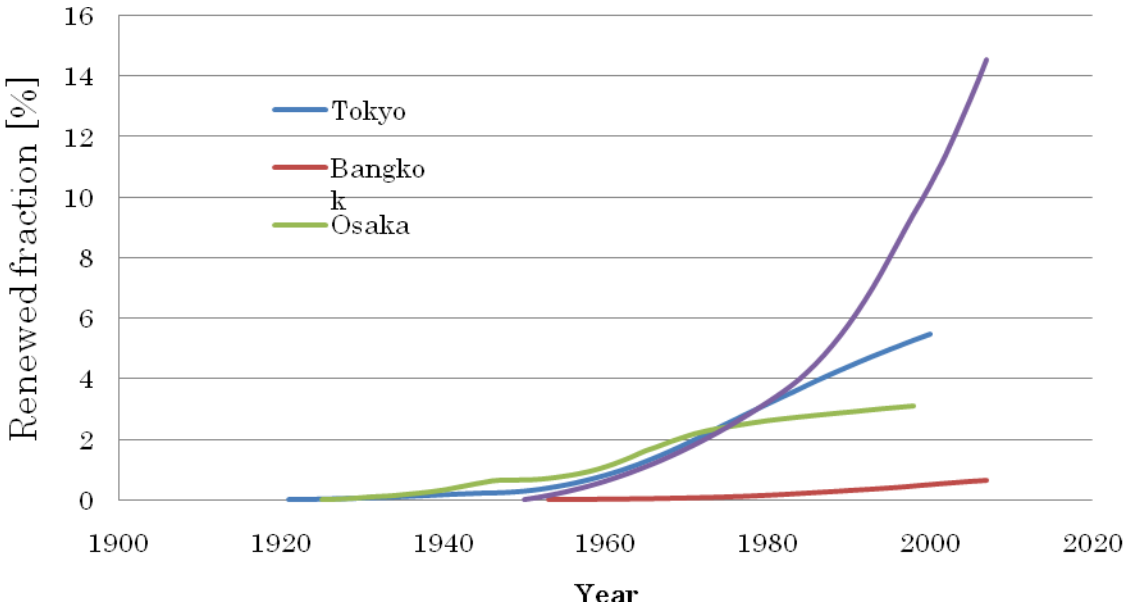

Fig.3 The common indices7

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The 3rd International Symposium

Research Institute for Humanity and Nature Project

“Human Impacts on Urban Subsurface Environment”

17-20 November 2009

Institute of Earth Sciences, Academia Sinica, Taipei

The 3rd International Symposium in Taiwan

Human Impacts on Urban Subsurface Environment

17 -20 November 2009

Tuesday,17 th November

9:00 - 9:20	Makoto Taniguchi	(R I H N)

Session 1 — Social economic Group — Chair: Shinji Kaneko

9:20 - 9:40	Tomoyo Toyota	(R I H N)
9:40 - 10:00	Tsuyoshi Imai	(Yamaguchi University)
10:00 - 10:20	Katsuya Tanaka	(Shiga University)
10:20 - 10:30	-Break-	
10:30 - 10:50	Karen Ann Jago-on	(Hiroshima University)
10:50 - 11:10	Gayl D Ness	(University of Michigan)

Session 2 — Urban geography Group — Chair: Akihisa Yoshikoshi

11:10 - 11:30	Akihisa Yoshikoshi	(Ritsumeikan University)
11:30 - 11:50	Toshiaki Ichinose	(National Institute for Environmental Studies)
11:50 - 12:10	Yingjiu Bai	(Tohoku Koeki University)
12:10 - 13:30	-Lunch-	
13:30 - 13:50	Akio Yamashita	(Rakuno Gakuen University)
13:50 - 14:10	Takahiro Endo	(R I H N)

Session 3 — Water Group — Chair: Anirut Ladawadee

14:10 - 14:30	Jun Shimada	(Kumamoto University)
14:30 - 14:50	Noriyuki Momoshima	(Kyusyu University)
14:50 - 15:10	Tsutomu Yamanaka	(University of Tsukuba)
15:10 - 15:30	Makoto Kagabu	(Kumamoto University)
15:30 - 15:50	Robert Delinom	(Indonesia Institute of Science)
15:50 - 16:00	-Break-	
16:00 - 16:20	Anirut Ladawadee	(Ministry of Natural Resources and Environment, Thailand)
16:20 - 16:40	Govind Chakrapani	(Indian Institute of Technology)
16:40 - 18:00	Discussion	

Thursday,19 th November — Business meeting

Friday,20 th November — Field excursion

Wednesday,18 th November

Session 4 — Gravity Group — Chair: Yoichi Fukuda

9:00 - 9:20	Yoichi Fukuda	(Kyoto University)
9:20 - 9:40	Jun Nishijima	(Kyusyu University)
9:40 - 10:00	Keiko Yamamoto	(R I H N)
10:00 - 10:20	Takashi Hasegawa	(Kyoto University)
10:20 - 10:40	Sofyan Yayan	(Kyusyu University)
10:40 - 10:50	-Break-	

Session 5 — Material Group — Chair: Chih-Chieh Su

10:50 - 11:10	Shin-ichi Onodera	(Hiroshima University)
11:10 - 11:30	Yu Umezawa	(Nagasaki University)
11:30 - 11:50	Takahiro Hosono	(Kumamoto University)
11:50 - 12:10	Mitsuyo Saito	(Ehime University)
12:10 - 13:30	-Lunch-	
13:30 - 13:50	Satoshi Nakada	(R I H N)
13:50 - 14:10	Chih-Chieh Su	(National Taiwan University)
14:10 - 14:30	William C. Burnett	(Florida State University)

Session 6 — Heat Group — Chair: Makoto Yamano

14:30 - 14:50	Makoto Yamano	(Tokyo University)
14:50 - 15:10	Rachmat Fajar Lubis	(Indonesia Institute of Science)
15:10 - 15:30	Akinobu Miyakoshi	(NIAIST)
15:30 - 15:40	-Break-	
15:40 - 16:00	Hideki Hamamoto	(Center for Environmental Science in Saitama)
16:00 - 16:20	Chung-Ho Wang	(Institute of Earth Sciences, Academia Sinica)

Session 7 — GIS/Model/Integration — Chair: Shinji Kaneko

16:20 - 16:40	Shinji Kaneko	(Hiroshima University)
16:40 - 17:00	Jun Yasumoto	(Ryukyu University)
17:00 - 18:00	Discussion	

Institute of Earth Sciences, Academia Sinica, Taipei
Add: No 128.2,Academia District,Taipei Tel: 886-2-27822120~9