Urban Subsurface Environments

Newsletter Volume 1 April 2006

Introduction on RIHN Project 2-4

"Human Impacts on Urban Subsurface Environments"

This newsletter is produced to broadly share information among project members, research staff, foreign partners in the RIHN project on "Human Impacts on Urban Subsurface Environments" and to other related scientists and researchers . This is to keep everyone posted on the activities of each research team and provide updates on survey results and other research endeavors. This is also a venue to exchange research experiences from the field.

This newsletter is published twice a year; (1) April and (2) October. The first volume contains introduction on the project and its research components, as well as photos and profiles of project members and foreign counterparts.

Makoto Taniguchi

Most global environmental studies have long been focused on the environmental issues above the ground surface such as air pollution, global warming, seawater pollution, and decrease in biodiversity. Subsurface environments are also important for human life in the present and future, but the issues have been largely ignored because of the invisibility of the phenomena and difficulty of the evaluations.

A new integrated research project "Human Impacts on Urban Subsurface Environments" of the Research Institute for Humanity and Nature (RIHN) in Kyoto, has been launched in 2005 (6-year term) to assess the effects of human activities on the urban subsurface environment, an important aspect of human life in the present and future but not evaluated yet. The primary goal of this project is to evaluate the relationships between the stages of development of cities and various subsurface environmental problems, including extreme subsidence, groundwater contamination, and subsurface thermal anomalies.

This project will suggest better future development plans for human well-being by reconstructing changes in urban environments, and by developing integrated nature-social models. Subsurface environmental indices will be used from the points of view of (1) human activities, (2) climate change, and (3) stage of urban development and social policies.

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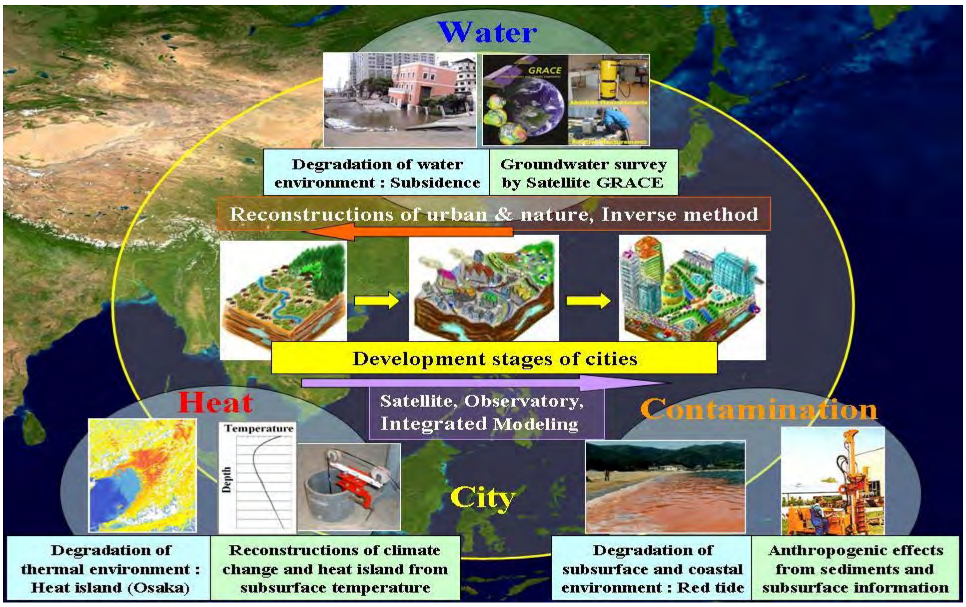


Fig. 1 Integration of four subjects (Urban, Water, Heat and Material) of the RIHN Project 2-4

In order to achieve the research objectives mentioned above in five years, four subthemes have been chosen and eight methodologies will be applied (Figure 1). Tokyo, Osaka, Bangkok, Jakarta are targeted as primary study cities, and Taipei, Manila and Seoul are selected as secondary study cities depending on the four subthemes. The project will target relationships between subsurface environmental changes and human activities during the past 100 years, while some reconstructions will be extended up to 1000 years.

Four Components of the Project

(1) **Development stages of cities and subsurface environmental problems**

Relationships between the development stages of cities and subsurface environmental problems will be assessed by socio-economic analyses and reconstructions of urban areas by using historical records.

(2) **Degradation of subsurface environments and change in reliable water resources**

Fig. 2 Development stages of cities

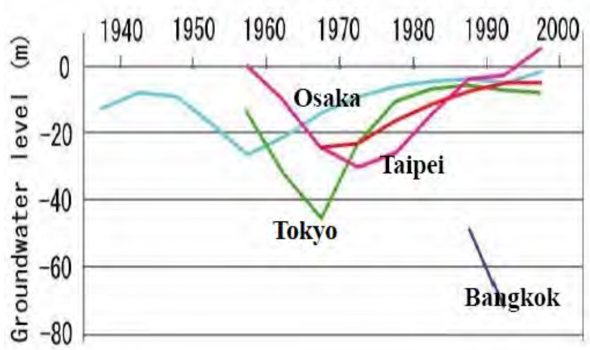


Fig. 3 Decrease and recovery of groundwater

Relationships between serious subsurface environmental problems and change in reliable water resources will be studied after evaluations of groundwater flow systems and changes in groundwater storage by using hydrogeochemical data and in-situ/satellite-GRACE gravity data.

(3) **Subsurface contamination and loads to the coast**

Accumulation of materials (contaminants) in subsurface and their transports from land to ocean including groundwater pathways will be evaluated using chemical analyses of subsurface waters, sediments and tracers.

(4) **Heat island effect and subsurface thermal anomalies**

Subsurface thermal contamination due to the "heat island" effect in urban areas will be evaluated by reconstruction of surface temperature history and urban

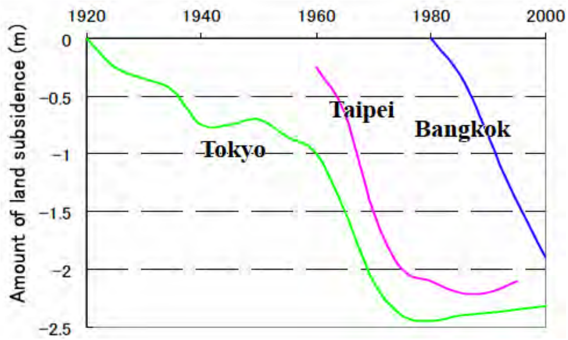


Fig. 4 Land subsidence

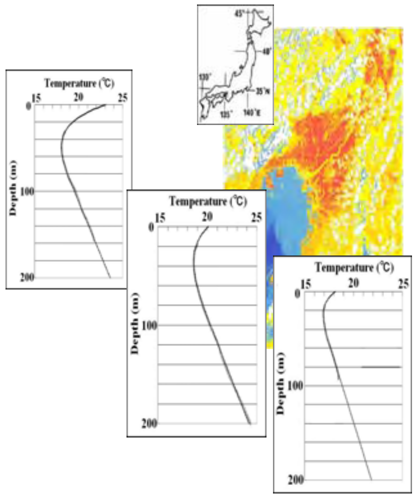


Fig. 5 Subsurface thermal anomalies in the urban area of Osaka.

Sub-Theme 1. Development Stages of Cities and Subsurface Environmental Problems

Urbanization and Subsurface Environmental Changes in Asia: Socioeconomic Dimensions of Causal Relations

Shinji Kaneko

The unprecedented rapid urban growth in Asia has socio-economic and environmental impacts and these have been magnified with the increasing emergence of large cities. Many of the environmental problems in urban areas occur simultaneously and sequentially with the stages in development. These complex causal relations or mechanisms of urbanization, which is often attributed to population growth and spatial expansion and concentration, and the environmental problems, have always been one of the most important discussions on urban sustainability (Alberti, 1996). However, in the past subsurface environments in urban areas have not been given much attention and most of the environmental studies are focused on the issues occurring above the ground. Our knowledge on subsurface environmental issues is quite limited. There are many large cities located in coastal areas, where intensive and active interactions between the continent and the oceans are taking place under the ground. These cities have rapidly expanded and developed over the last several decades with certain time intervals, which can be characterized in a development pattern.

Research Objectives

This study attempts to improve our basic understanding would include of the complex causalities of various subsurface environmental changes. Specific objectives would include:

1. Assessment and comparison of long-term urban development patterns for each city case studies;
2. Description of major causalities between urban development and the changes in subsurface environments from a long-term perspective;
3. Identification of measurable critical factors in human dimension which cause environmental stresses on subsurface environments in each urban development stage;
4. Quantification of dynamic changes in causal relations among key factors;

Research Methodology

(1) Determination of the major cause and effect relations of the subsurface environmental issues using the DPSER/DPSIR (Driving Forces-Pressure-State-Effect/Impact-Response) framework;

(2) Selection of key indicators to capture the major evolutionary process of urban development and apply it in the city case studies (Tokyo, Osaka, Seoul, Taipei, Jakarta, Bangkok, and Manila);

(3) Development of stage model of interactions between human activities and urban subsurface environments;

(4) Construction of a system dynamics model (economy-population-environment dynamics model) with the demographic module as the central component; and

(5) Conduct of what-if type simulation studies under various technology and policy scenarios.

Research Foci

Special priority is given to the following four areas of study:

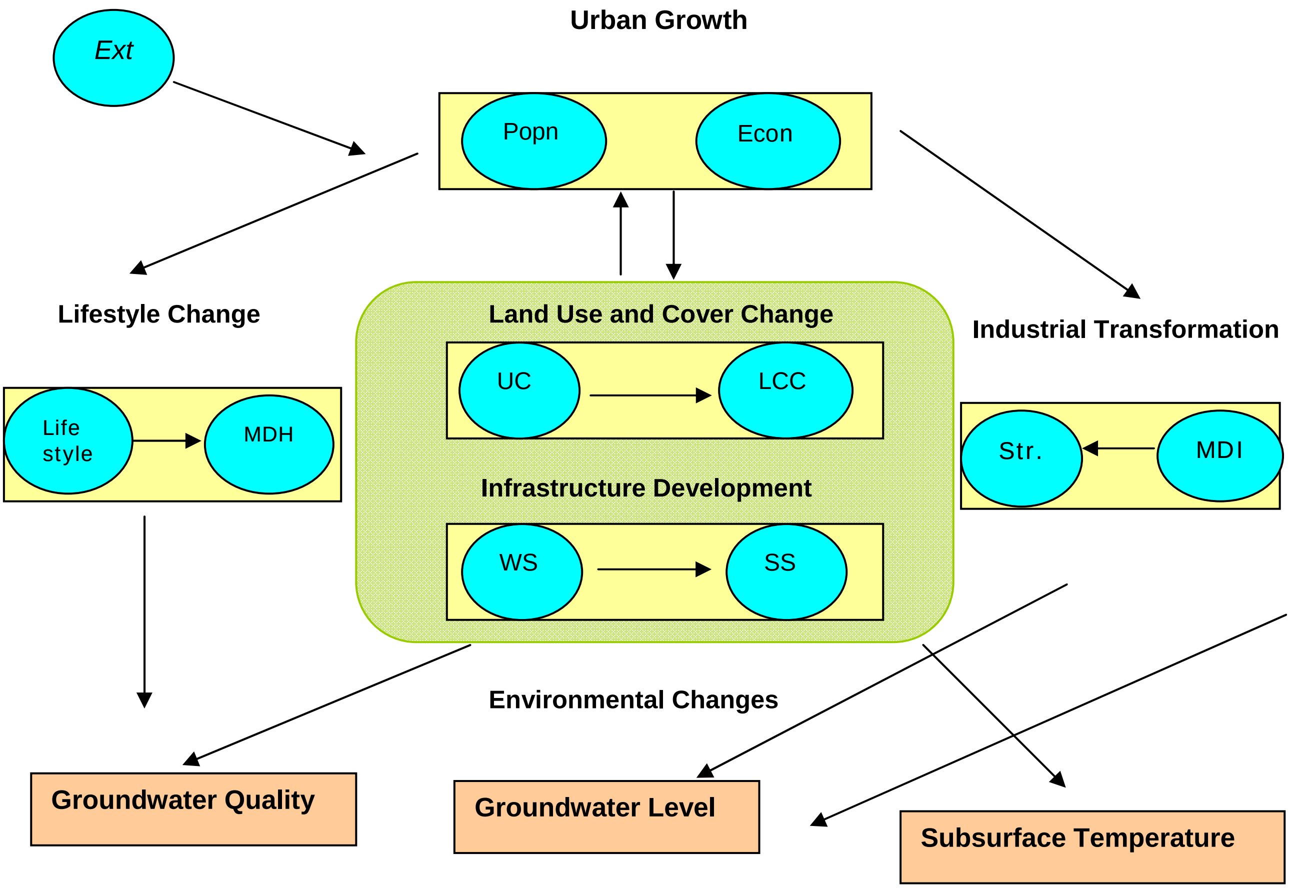
(1) City-specific urban demographic model to quantify the driving forces in a half-century urban population growth and change.

(2) Urban land use and land cover changes and its related planning policies

(3) Technology and institutional assessment for the long-term development of water supply and waste water treatment infrastructures

(4) Dynamic material flow analysis with special focus on carbon, nitrogen and phosphorous.

The interrelations of these areas of study are summarized and shown in the following figure below:



Geographical Development Process of Many Asian Cities and Change of Hydrological Environment

Akihisa Yoshikoshi

The first objective of this research is to collect the urban geographical data of many Asian cities (Tokyo, Osaka, Seoul, Taipei, Manila, Bangkok and Jakarta). Geographical data is the geographical reference of each city, including city statistics, maps, and satellite imagery (LANSAT imagery, IKONOS imagery, etc.) for a fixed interval period of 10 years, considering the creation time of satellite imagery. Geographical development process of many Asian cities will be clarified based on these data. Special emphasis will be on the boundary of urban areas and internal land use of the city for every fixed period.

The second objective is to clarify the change of the hydrological environment of the specific cities (Tokyo, Osaka, Seoul, Taipei and Bangkok). The position of rivers, lakes, spring waters, swamps will be expressed in the map in details as much as possible, and the changes for every fixed period will be clarified as well. Furthermore, our aim is to relate the cause of this change with a city development process.

Prediction of research

There is change in the earth surface which happens to be one of the biggest reasons that many of these problems occur with urbanization as shown in the model in Figure 1 (Yoshikoshi, 1998). The biggest difference between before and after urbanization is whether water permeability is shown in earth surface and whether the place which stores water is shown in the earth surface. Non-water permeability prevents surface water to turn into groundwater.

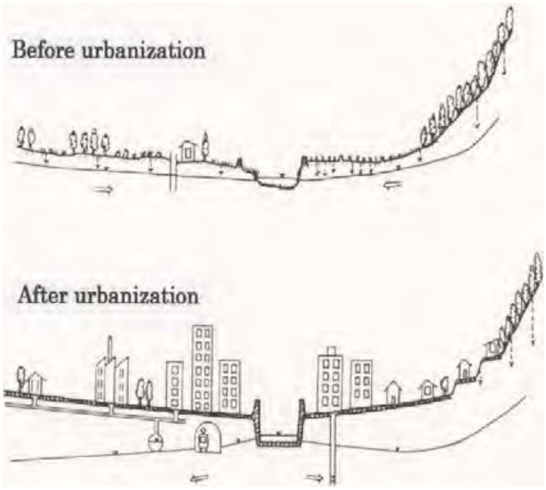


Fig. 1 Comparison of hydrological environment before and after urbanization

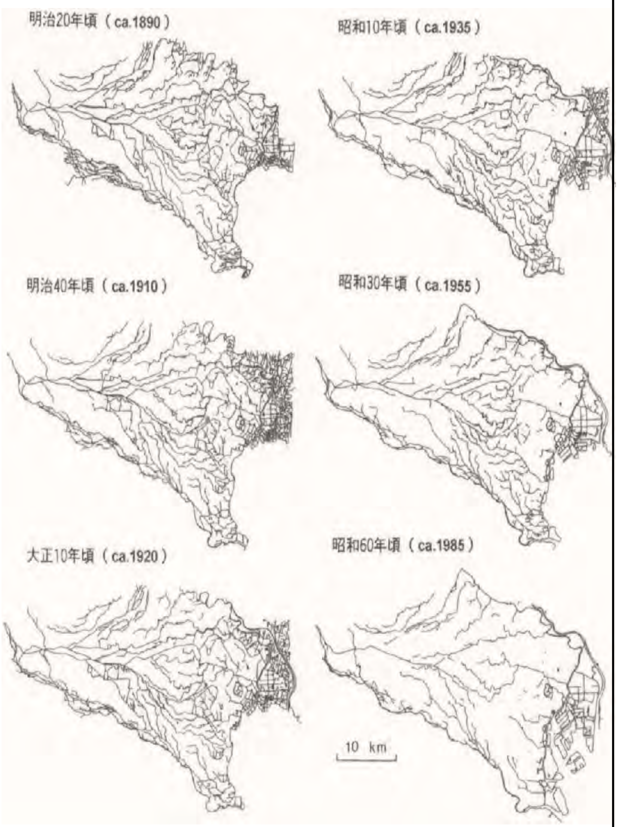


Fig. 2 Change of rivers and waterways in Tokyo (Arai,1996)

Figure 2 by T. Arai shows changes of the waterway in various periods in Tokyo (T. Arai, 1996). This figure was created by extracting the waterway of the map in each period. From this figure we can see that the waterway of the earth's surface is decreasing gradually. This waterway has been changed to road, parks and others. In order to prevent a flood, the drainage tunnel and the reservoir are built underground. However, it has caused to easily generate heavy rain by an urban climate that the earth surface of water permeability was lost, that the waterway decreased, and it is clear that a flood can easily happen in the city.

4. Method of research

First, the reference of urban geography and city statistics are collected. Information from maps, aerial photographs, satellite imageries, etc. will also be added. Database will include features of cities and the hydrological environment for every fixed period and the results of the field survey. The period for this research will the past 100 years. Moreover, research findings will be expressed visually using GIS (Geographical Information System).

Sub-Theme 2. Degradation of Subsurface Environments and Change in Reliable Water Resources

Subsurface water environment in and around Asian Cities

Jun Shimada

Groundwater problems in Asia

Excessive groundwater use caused by human concentration in city areas and their land use change have created large impact on the groundwater environment in and around the city not only on their quality but also on their quantity. Most of Asian big cities are developed over the alluvial sediments and the groundwater aquifer in these unconsolidated materials has easily induced huge groundwater disaster; such as land subsidence, groundwater salinization, dry-up wells and oxygen-deficit air troubles.

Big city areas in Japan such as Tokyo, Nagoya, and Osaka, have experienced these groundwater disasters in the 1970's and they have succeeded to solve the problems by regulating the groundwater use. Many Asian big cities have suffered from these disasters in the past 10 to 20 years and some of them have not yet found any solution until the present. The development stage, geographical size, population, geology and hydrology of each city can influence the level of groundwater disaster. Moreover, the recovery of the groundwater by regulating the water use, can be affected mostly by the hydrological condition of the location of the problem cities. The success of groundwater recovery by pumping regulation in Japan must have been caused by the positive natural groundwater recharge rate (800-900mm/yr) in the humid temperate climate of Japan.

Paleo hydrology (paleo information extracted from groundwater aquifer)

One major purpose of groundwater hydrology is to clarify the flow system in groundwater aquifer. The use of environmental isotope is very helpful to understand this system because of their isotopic tracer characteristics such as age and origin. The recent development of isotope hydrology study has created another aspect which is called paleo hydrology.This is the study to extract the paleo information from groundwater aquifer by using isotopes. In isotope hydrology we can determine the change of chemistry along groundwater flow line and groundwater age. Major chemical component in the aquifer shows evolutional trend along this line. However, stable isotope ratio does not show any evolutional trend but fluctuates somehow in most cases. Though the stable isotope ratio could be directly affected by the temperature, their fluctuation should reflect the recharge temperature which stands for a climate proxy (see Figure 1). This research method is named paleo hydrology and has developed during the recent 15 years to supply inland paleo information on the relatively huge aquifer system in the world.

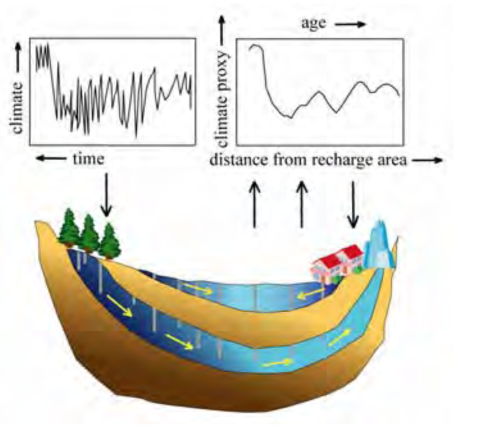


Fig. 1 Paleo hydrology (paleo-information extracted from groundwater aquifer)

Effect of induced groundwater flow (possibility to receive better resolution than natural groundwater flow)

As mentioned previously, the excessive pumping in the urban area has created huge groundwater drawdown in many Asian cities. This drawdown could be considered as the kind of man-made groundwater flow system over the natural flow system.

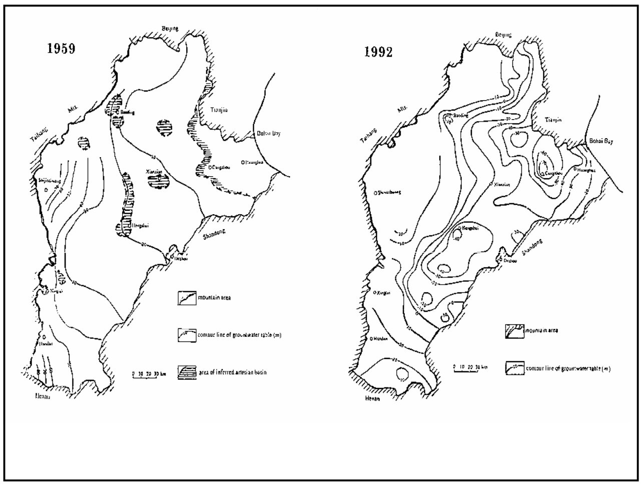


Figure 4 shows the example of North China Plain, China. This area has experienced huge over pumping both for city water use and for irrigation purposes during the last 50 years. In 1959 soon after the Chinese revolution, the groundwater flow system of the area is almost natural. However, 43 years later there existed many cones of depression in the big city area and also the 0 m (sea level) groundwater potential contour line develops nearly 150km inland from the yellow sea coast in the eastern side.

Need for modern groundwater age tracer technique

In the study of environmental isotope hydrology, the representative young groundwater age tracer was the radioactive tritium. However, recent tritium concentration in precipitation has decreased at almost in natural level (less than 10 T.U.) and the age resolution by using tritium has been declining annually. After the 1990's the development of the new young groundwater age tracer technique has been recognized. Atmospheric CFCs have been introduced to the groundwater through recharge process and could be used as the shallow aquifer age trace like tritium. Also another anthropogenic substance, Kr-85 which is the artificial production through nuclear reactor or reprocessing plant of used nuclear fuel, is also thought to be the useful young age tracer after tritium.

In Japan, the use of those age tracers has not been recognized in the hydrological study. CFC concentration in groundwater has been widely used in the USA, and become one of the representative young age tracers. Although the urban industrial activity may affect the local CFC concentration somehow, this might be used as another indicator of urbanization. While the Kr-85 has not much used as CFC, this is because of both the difficulty of water sampling and the analytical technique. In the present project, the author would like to introduce those young age tracers to detect the groundwater age in the induced groundwater flow caused by the over pumping in the urban area. This should contribute not only for the urban groundwater research, but also for the potential development of new groundwater age tracer in Japan.

Monitoring of the Ground Water Variation in Urban area by Combining GRACE Data and in-situ Gravity Measurement

Yoichi Fukuda, Keiko Yamamoto, Toshiyuki Nakaegawa and Jun Nishijima

Changes of reliable of water resources between ground water and surface water occurred in many cities depending on the development stage of urbanization. A project to evaluate ground water flow systems in and around the developing cities has started. In the project, precise gravity measurements with a relative gravimeter and an absolute gravimeter is planned to monitor the ground water changes. On the other hand, the monthly gravity field solutions derived from GRACE satellite are expected to reveal global water circulations. The data of surface gravity measurements include not only local gravity changes but also regional to global scale gravity variations. For estimating and removing such long wavelength gravity signals, we intend to utilize GRACE data for the correction of the surface gravity data. In this study, using the GRACE monthly gravity field solutions, we estimated regional scale gravity changes around Bangkok due to water variations. The results clearly show that GRACE data detected the relatively long wavelength mass variation over the combined area of Chao Phraya, Mekong, Salween and Irrawaddy rivers. By combining GRACE data with the precise gravity measurements on land, we expect that more accurate estimation of local and/or regional water variation should be possible.

Test areas

Because Bangkok is located at the lower region of Chao Phraya river basin, we primarily tried to detect the signal of mass variations in the basin. However the spatial scale of the basin may be too small to be detected by GRACE data. Thus, for evaluating the applicability of the GRACE data, we also estimated the mass variation of the combined area of Chao Phraya river basin and the neighboring 3 river basins, namely, Mekong, Salween and Irrawaddy river basins. The locations of the rivers are shown in Figure 1.

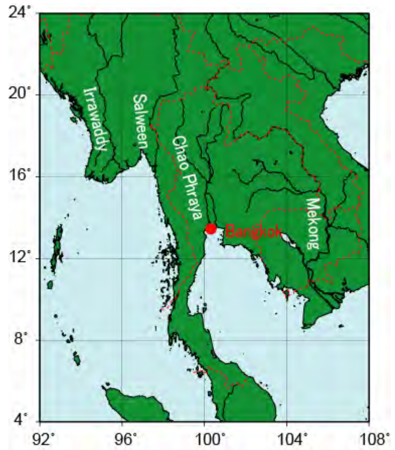


Fig.1. Locations of Bangkok and Chao Phraya, Mekong, Salween and Irrawaddy river.

Table 1. Drainage areas of 4 rivers and the combined region.

River Name	*Drainage Area (km²)*
Chao Phraya	*178 000*
Mekong	*814 000*
Salween	*330 000*
Irrawaddy	*425 000*
Total	*1 750 000*

For the recovery of the mass variations associated with the regions, regional spatial filters were designed on the basis of the Swenson and Wahr (2003). Fig. 2 shows the regional filter designed for the 4-river combined area. Applying the filter to the each of 22 data sets, surface mass variability of each region $\Delta\sigma_{region}$ was recovered by the following equations:

$$\Delta\sigma_{region} = \sum_{l=0}^{l\max}\sum_{m=0}^{l}\frac{1}{\Omega_{region}}\frac{a\rho_E}{3}\frac{(2l+1)}{(1+k_l)}\left(W_{lm}^{C}\Delta C_{lm} + W_{lm}^{S}\Delta S_{lm}\right)$$

(1)

where a is the equatorial radius, ΔC_{lm} and ΔS_{lm} are the variable components of GRACE solution, W_{lm}^{C} and W_{lm}^{S} are the designed filter coefficients, r_E is the average density of the Earth, W_{region} is the angular area of the region, l_{max} is the maximum degree of the GRACE variable components and k_l is the load Love number of degree l.

Degree 0 and degree 1 components were not taken into account in the recovery of the mass variations, because these components are not included in the GRACE Level 2 products. The component of C_{20} was further omitted in the recovery because of its large error. We also calculated the estimated errors of the mass recovered by applying same regional filters to the calibrated standard deviations of GRACE data.

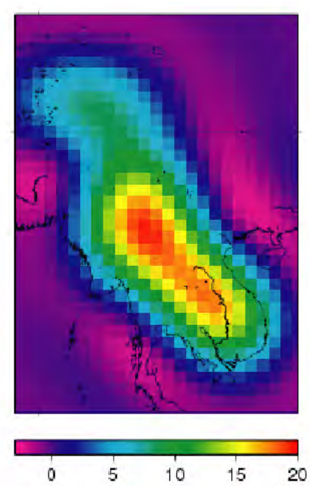


Fig. 2. Designed filter of the combined area of Chao Phraya, Mekong, Salween and Irrawaddy river basins.

Recovery of mass variations over the Chao Phraya river basin

Figure 3 shows the mass variations over the Chao Phraya river basin derived from the GRACE solutions and the hydrological model as well. The mass variations derived from the GRACE solutions show unrealistic large values and they did not agree with the model's values. The reason of this disagreement is probably due to the insufficient spatial resolution of GRACE data. In fact, the mass recovery up to degree 70 corresponds to the half wavelength of about 290 km, which is relatively larger than the longitudinal width of Chao Phraya river basin as shown in Fig. 1. Further, the designed regional filter based on the Gaussian filter, the amplitude of which rapidly approaches to zero at the higher degree, decreases the short wavelength errors effectively, but also decreased the signals. Although there should be some space to refine the data processing, the recovery of mass variation over Chao Phraya river basin may be difficult from the currently released GRACE data.

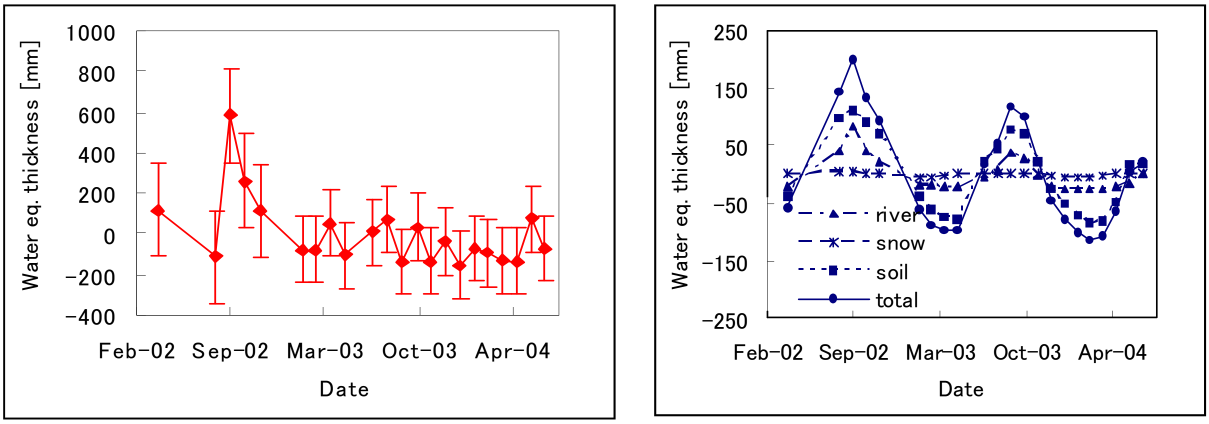
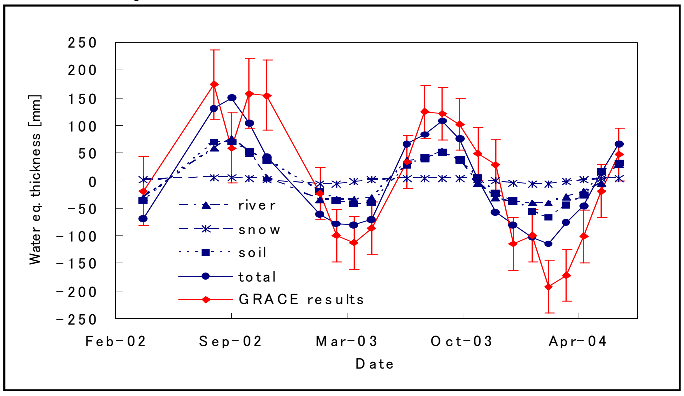


Fig. 3. Mass variations over the Chao Phraya river basin derived from GRACE solutions (left) and the model (right).

Recovery of mass variations over the 4 river combined area



The spatial scale of the combined area of Chao Phraya, Mekong, Salween and Irrawaddy river basin is enough large compared with the resolution of GRACE. The latitudinal and longitudinal width of the region are larger than 1000 km, at which it is reported that GRACE data shows a good agreement with the seasonal varying signals (Wahr et al. (2004)). Fig. 4 shows the recovery of mass variations from GRACE data and the values estimated from the hydrological model in the combined area. The variations derived from GRACE solutions show good agreement with the model, especially in phases. On the other hand, the amplitude is about 1.5 times larger than that of the total (soil + snow + river) of the model. This disagreement is probably due to the effects of unmodelled ground water and lake storage.

Discussion

As described previously, the mass variations over the Chao Phraya river basin derived from presently released GRACE data sets were not so reliable, mainly due to the lack of the spatial resolution. There maybe several space to improve the spatial filtering techniques, especially introducing an anisotropic spatial filter. We also expect the accuracy of the GRACE Level 2 data will be improved especially at high degrees in near future.

Regarding the result of the wider region of the 4 river combined area, the amplitude of the GRACE derived signal is larger than the one derived from the hydrological model. Besides the model errors and the observation errors of GRACE, it is probably due to the effects of the ground water and lake storage which are not included in the model. This proves that GRACE result will be very useful for estimating the long wavelength mass variation due to several effects including ground water variations. Moreover, by comparing the results with models and other meteorological data, more reliable estimation of ground water variations is expected. The GRACE data should contribute to improve the ground water model around the region.

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Sub-Theme 3. Subsurface Contamination and Loads to the Coast

Approaches to Estimation of Contaminant Load Variation in Mega-cities

Shin-ichi Onodera and Mitsuyo Saito

Large quantity of mass generally converges in the mega-city (World Bank, 1997; Tsunekawa, 1998). As a result, a part of consumed mass had been leached into rivers, groundwater and ocean. Most mega-cities in the world exist in Asia, and the most of them are located in the coastal area (Jiang et al., 2001). Growing Asian mega-cities have some of the severe pollution problems such as those in Tokyo or London about 30 years ago. To prevent the expansion of these problems, it is necessary to find the relationship between water pollution characteristics and growing stages of mega-city, and to propose the possible problems in the future and measure them in accordance to the growth of Asian mega-cities.

This research seeks to confirm the current conditions of the water pollution in mega-cities and to select a reasonable methodology for reconstructing contaminant history and defining the relationship between water pollution and the stages of growth of mega-cities. A review of research papers has been conducted and these issues have been discussed based on the example of Osaka, Japan.

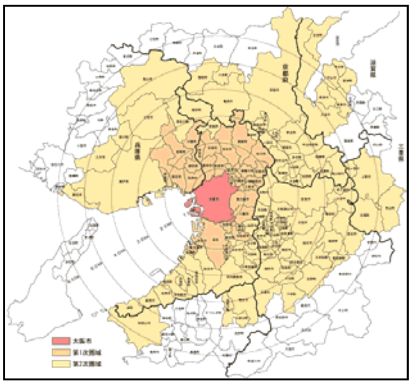
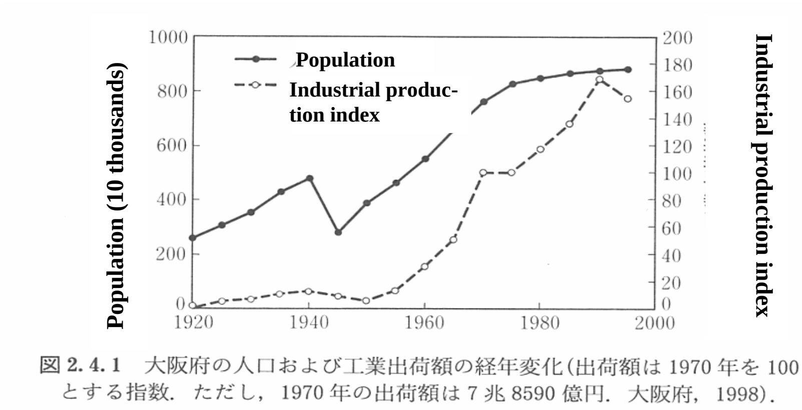


Fig. 1 Osaka City and surrounding areas.

Growth situation in Osaka City

Figure 1 shows Osaka city and its surrounding areas. Population of Osaka Metropolitan district is more than 10 million and the area is characterized by relatively small suburban area. Figure 2a indicates variation in population and industrial production index of Osaka prefecture. Both population and industrial production index increased significantly from 1920s to 1970s as well as the urban area.

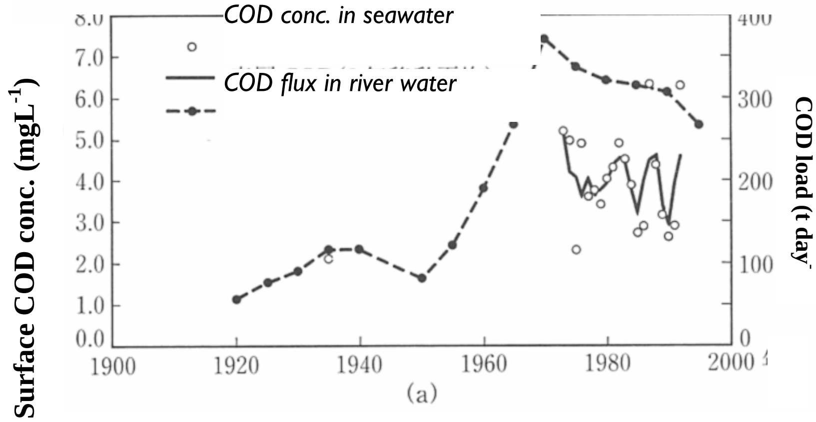
a)



Pollution Problem in Osaka

Figure 2b shows the variations of surface COD concentration in Osaka bay and COD load from river to the sea for the last 30 years. COD concentration and COD load were a maximum around 1970. COD load from river to the sea was still a minimum in 1950 but it has increased 4 times from 1950 to 1970. This period coincides with the period of rapid population increase. These results suggest the effect of urbanization on the quality of river water and seawater.

b)



Since 1970s, population has increased gradually as well as the industrial production index, however COD concentration and load have decreased. This downward trend suggests to have originated in the development of sewage treatment system. But even if river water pollution has decreased, the impact of pollution before 1970s would still be reflected in subsurface environment. Figure 3 shows the condition of groundwater contamination in Osaka prefecture from 1993 to 2003 (Environment Council, Osaka Prefectural Government, 2004). The various contaminants include Br, B, Hg, As, nitrate, Pb and VOC. This result indicates that various contaminants are detected in groundwater in recent years.

In the coastal mega-cities in Japan, not only the water pollution but also the seawater intrusion or decline of groundwater level has occurred. Therefore, we also have to consider how these affect subsurface contamination.

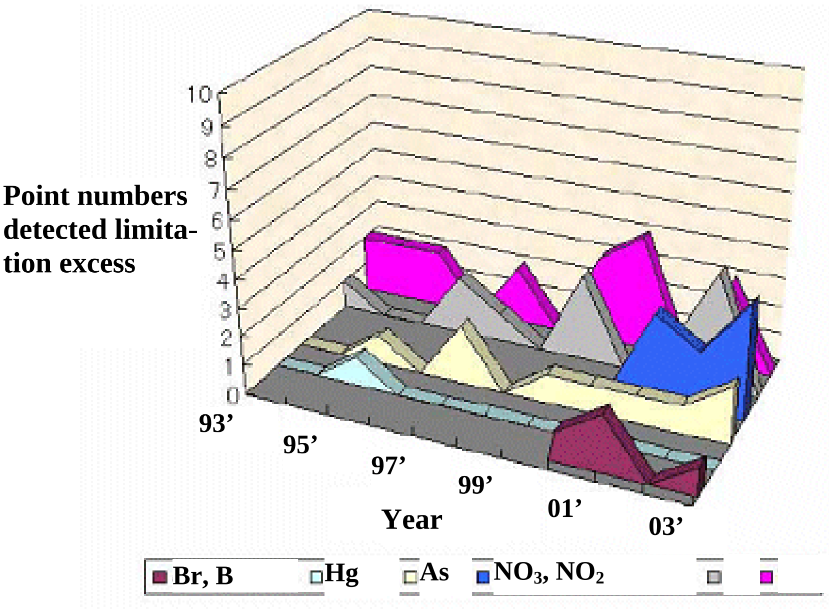


Fig. 3 Various groundwater contaminants in Osaka

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Pollution Property in Various Development Stages of City

In the 1950s, pollution and its corresponding damage had been recognized in local scale such as in the river in Osaka city. This period is the first stage of water pollution along with accelerated economic growth and population increase in the mega-city process. In this stage, the main contaminant is composed of dissolved nitrogen from domestic and agricultural waste and heavy metals from industrial activities.

In the 1960s and 1970s, Japan mega-cities had the most severe contamination in river and seawater by human sewage and industrial waste. This period is the second stage with the gradual growth of city. More than 10 years later, Japan was faced with groundwater and soil contamination by nitrate, heavy metals and organic compound, while the river contamination had begun to improve due the development of sewage system. This period is the third stage. The subsurface contamination generally appears with delay because of the difficulty of detection and longer transport time. In addition, as cited in previous studies, the distribution of trace metal content in sediments in various Asian mega-cities indicated the change in pollution properties with the stages of growth such as direct leaching to atmospheric deposit. (Williams et al., 2000; Jiang et al., 2001 etc.)

Methodology for Reconstructing the History of Contamination

Pollution properties are useful to reconstruct the contamination history, such as the history of fertilizer application and industrial waste. Stable isotope and dissolved gas component of nitrogen are especially effective for the reconstruction (Blicher-Mathiesen et al., 1998). Initial NO_3^- concentration in groundwater can be estimated by using dissolved N_2 gas concentration.

Human impact on the quality of river and ground water in Japan:
examples using stable isotopes for the watershed of Lake Biwa

Takanori Nakano

The chemical composition of river water and groundwater changes along the direction of water flow owing to a variety of processes (i.e., mixing of water body, mineral dissolution, ion-exchange, reduction-oxidation reactions). Stable isotopes (i.e., N, S, Sr, Pb) are useful in elucidating these processes and assessing human impacts on water quality. Our recent studies (Nakano et al., 2005; Yamanaka et al., 2005) show that (1) the chemical composition of dissolved ions in river water is controlled mainly by the dissolution and neutralization processes of rock-forming minerals by acids whose concentrations are increased by human activities, (2) whereas that of underground water in shallow aquifer is controlled by the cation-exchange and reduction processes.

Human impact on water quality in tributary rivers of Lake Biwa, Central Japan

Lake Biwa, the largest lake in Japan and one of the oldest lakes in the world, has many endemic species and is a major water resource for 14 million people living in its downstream watershed. The water quality and biodiversity of Lake Biwa has been deteriorating owing to expansion of human activities in the watershed, but the principal cause for the water quality deterioration has not yet been resolved. Ogawa et al. (2001) have shown that the $\delta^{15}N$ values of fish specimens (Isaza fish, *Leucopsarion petersi*) collected in northern Lake Biwa increased steadily from 1960 to 1999, whereas the $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ values of Isaza fish decreased (Fig. 1).

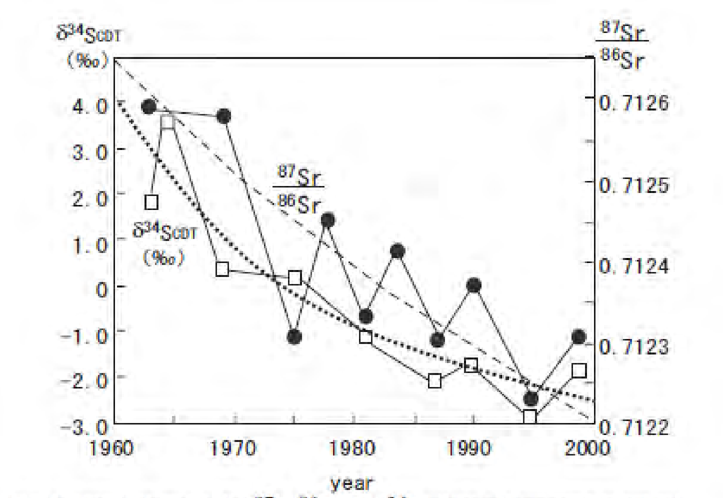

Fig. 1. Annual change of the $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ values of Leucopsarion petersi over 40 years from 1960 to 1999. Broken a along dotted lines represent the calculated change in $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ values of the lake water by inputs of small rivers from the eastern agricultural area. The $\delta^{34}S$ value of Isaza fish is assumed to be 2% lower than that of the ambient water. See Nakano et al (2005) in detail.

Tributary rivers of Lake Biwa can be divided into four areas based on the geology and human activity in the watershed. The concentrations of dissolved ions (i.e., SO_4, NO_3, Sr) of inflowing rivers at downstream sites were generally high in the southern urban area and in the eastern area, where a large agricultural plain is situated, but low in the northern and western areas, wherein watersheds are mountainous and with low population density. The solute concentrations are also lower at upstream sites, which are closer to mountainous areas. Thus, the inflowing river receives large amounts of anions and cations as it flows across the plain, where human activity levels are high.

The $\delta^{34}S$ or $^{87}Sr/^{86}Sr$ values of most eastern rivers at downstream sites are lower than, and the $\delta^{15}N$ values of organic particles in the water are higher, than those of water in Lake Biwa, and the $\delta^{34}S$ and $^{87}Sr/^{86}Sr$ values become more uniform as the proportion of the plain area in the watershed increases. River water in other areas has higher values of $\delta^{34}S$ or $^{87}Sr/^{86}Sr$ than the lake water. This result indicates that the decadal decrease of $\delta^{34}S$, $\delta^{15}N$, and $^{87}Sr/^{86}Sr$ in the lake water has been caused mainly by the increased flux of SO_4, NO_3, Sr, and other solutes from rivers in the eastern plain. The observed $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ trends in the lake water can be reproduced by assuming that all water from inflowing rivers is completely mixed with the lake water within a year and that the contribution of water mass from the eastern small rivers to Lake Biwa is 1% (Fig. 1), supporting this hypothesis.

It is likely that in the plain, sulfur, nitrogen, and organic compounds induced by agricultural and other human activities generate sulfuric, nitric, and organic acids in the water, which accelerate the extraction of Sr and other metals from bedrocks, leading to the generation of Sr in the river water in the area.

Water quality change of confined groundwater in northeastern Osaka Basin

A confined groundwater system has developed in argillaceous marine sediments in the Osaka Basin, which is in the downstream of Lake Biwa. The water quality of shallow groundwater (<100 m) changes from Ca-HCO_3 type to Mg-HCO_3 type and then to Na-HCO_3 type as it flows from northern hilly to mountainous area to southwestern area where many wells are pumping from the aquifers (Fig. 2). The H_4SiO_4 content of the groundwater is relatively constant irrespective of groundwater type, indicating that the contribution of cations from the dissolution of silicate minerals was small. The chemical and Sr isotopic compositions of the non-exchangeable fractions of the sediments do not change along the groundwater flowpaths, but their exchangeable components have the same $^{87}Sr/^{86}Sr$ ratios as the ambient groundwater and vary in accordance with the groundwater type. It is proposed that the loss of Ca from the water as it is exchanged for Mg in clays, followed by loss of Mg+Ca as they are exchanged for Na+K in clays occurred sequentially between the Ca-HCO_3 type recharge water and the exchangeable cations on the clay layers as the groundwater interacted with them (Fig. 2).

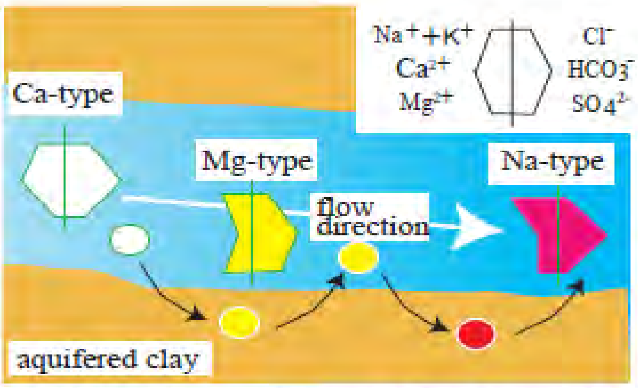

Fig. 2. Change of water quality type of groundwater in the northeastern area of the Osaka basin, central Japan. Water quality change is explained by cation-exchange process between water and aquifered clay as it flows. See Yamanaka et al (2005) in detail.

Except ground waters along faults, the □^{34}S value of Mg-HCO_3 groundwater and Na-HCO_3 one were higher and more uniform than those of the Ca-HCO_3 groundwater and two rivers, which are considered as the recharging water. The concentration of SO_4 in the deep Na-HCO_3 type groundwater was distinctly lower than other types of groundwater.

This change of isotopic ratio and concentration of SO_4 in the water can be reproduced by the Rayleigh type distillation model in which SO_4 in water was reduced by the activity of sulfur reducing bacteria into H_2S in a closed system. Model calculation shows that the SO_4 reduction progressed from the Ca-HCO_3 type (0-40 %) through the Mg-HCO_3 type (10-60 %) to the Na-HCO_3 type (20-80%).

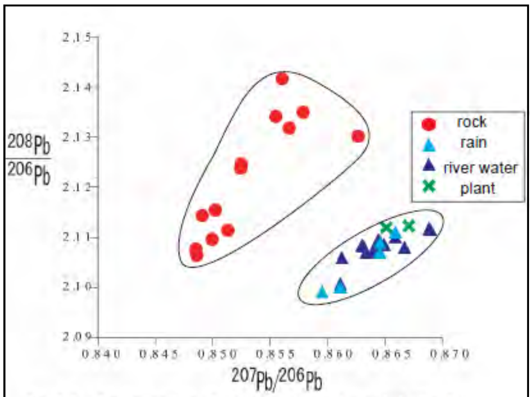

Fig. 3. Lead isotopic ratios of rock, rain, river water, and plant in the granite watershed of Tsukuba area of central Japan.

Potential application of Pb isotope into fresh water system

Recent studies have also shown that stable isotopes of Pb in river water are different from those of associated river sediments, but are indistinguishable from those of their exchangeable components and those of rain waters which are regionally and temporally variable depending on the use of Pb industrially and domestically in individual districts. One example is shown in Figure 3 for the fresh water system in the watershed of Tsukuba areas in central Japan. It is evident that the Pb isotope ratios of river water is indistinguishable from those of rainwater and plant but are different from those of rocks in the watershed.

A combination of multiple stable isotopes and major-trace elements is expected to provide valuable information regarding human impacts on the quality of subsurface urban environments.

Sub-Theme 4. Heat Island Effect and Subsurface Thermal Anomalies

Reconstruction of the Thermal Environment Evolution in Urban Areas from Underground Temperature Distribution

Makoto Yamano and Shusako Goto

Temporal variation of the ground surface temperature (GST) propagates into subsurface sediments and basement rocks by thermal diffusion. It is a rather slow process since the thermal diffusivity of sediments and rocks are low, 10^{-6} to 10^{-7} m^2/s. As a result, the GST variations in the last several hundred years have been recorded in the underground temperature distribution in the upper several hundred meters. It is therefore possible to estimate the history of GST (closely related to the surface air temperature)

Figure 1 shows an example of the results of GST history reconstruction studies in East Asian countries, such as Japan and Korea, including reconstruction of GST history from borehole temperature data in Awaji Island, SW Japan. Our results can be compared with the results of similar studies in China and Siberia (Figure 2). All of the GST histories show surface warming in the last 100 to 200 years, but the amplitude and timing of the warming are different from each other. These differences may result not only from regional variations in the global warming but also from surface environment changes due to human activities around the boreholes. It should be noted that in some cases effects of groundwater flow on the subsurface temperature distribution need to be considered (e.g. Taniguchi et al., 1999).

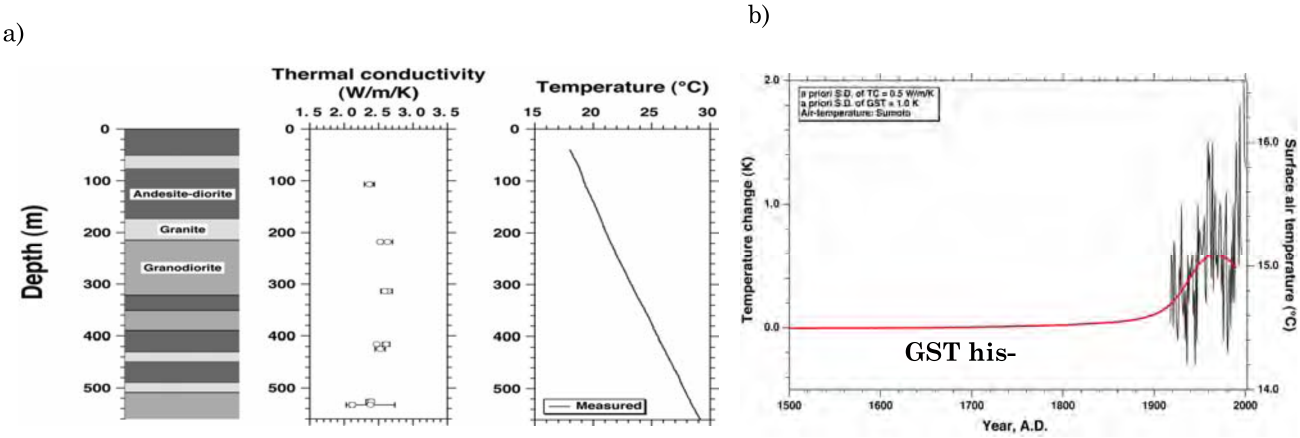

Fig. 1 (a) Temperature and thermal conductivity data obtained in a borehole in Awaji Island, SW Japan; (b) Reconstructed GST history (red) with the mean annual surface air temperature at a nearby meteorological station.

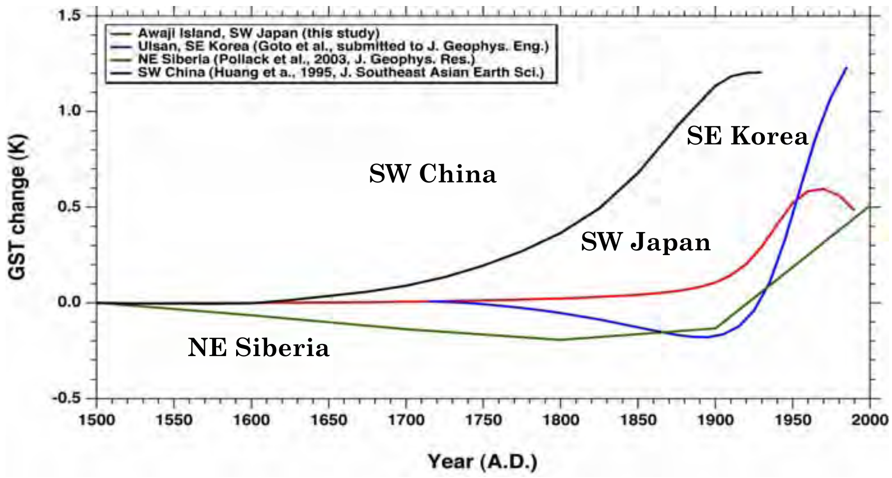

Fig. 2 Comparison of reconstructed GST histories in East Asian countries

Reconstruction of the thermal environment evolution in urban areas

As a part of the project "Human Impacts on Urban Subsurface Environment", we will investigate the evolution of the thermal environment at the ground surface in and around large cities in East Asia, using the geothermal method of GST history reconstruction. Main research items are: (1) temperature logging in boreholes, (2) thermal conductivity measurement, (3) long-term temperature monitoring in boreholes. Meteorological data at nearby stations should be collected as well. For comparison with other information on the thermal environment, we may need to convert the reconstructed GST into the surface air temperature using the meteorological data.

Long-term temperature monitoring in boreholes

We also intend to conduct long-term temperature monitoring at multiple depths in selected boreholes. The obtained data will show the ongoing downward propagation process of the GST variation, which may provide an evidence to support the result of GST reconstruction from borehole temperature profiles.

Target areas

We plan to conduct GST history reconstruction studies described above mainly in Tokyo, Seoul, Bangkok, Taipei and their suburbs. Osaka, Jakarta, and Manila can also be research targets. In addition, we will make surveys in relatively large areas around the target cities in Japan, Korea, and Taiwan, in which boreholes are widely distributed over the countries.

Urban Heat Island in Asian Cities

Toshiaki Ichinose

Urban heat island (UHI) phenomenon, exemplified by the warming of urban areas, is of great concern (e.g. Landsberg, 1981). Warming of urban areas is generally regarded not only as making urban life uncomfortable but also as creating several social damages such as increased energy use for air conditioning, air pollution accelerated by less ventilation, and changes in flora and fauna in urban areas. Previous research on urban climatology has shown the causes of heat island phenomena (Figure 1) to be anthropogenic heat emission, reduction of green space and water surface in urban areas, change of heat capacity of the material on urban surfaces, change of environment with regards to radiation, and the combination of these factors. Research progress on the improvement of urban thermal environments has been inadequate, while a great amount of knowledge on urban climate has been accumulated in the long history of urban climatology (Yoshino, 1990/1991).

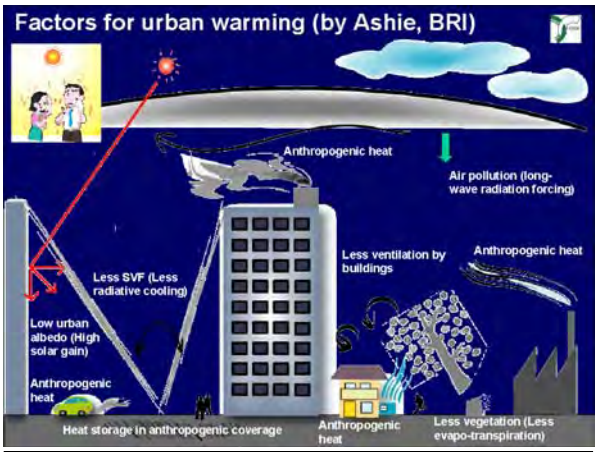

Fig. 1. Factors of urban warming (by Ashie Building Research Institute of Japan

Recent Significant Scientific Progresses and Related Movements

Monitoring of UHI phenomena was done by the authors group in three Asian cities (Tokyo, Shanghai and Bangkok) from 1997-1999. This project showed the importance of urban thermal environment and recommendation for urban planning process with basic routine on urban climate analysis (including evaluation of anthropogenic heat, building structure and vegetation coverage). After this project, Ministry of Environment (MoE) has started making systematic counteractions against UHI in Japanese regional autonomies.

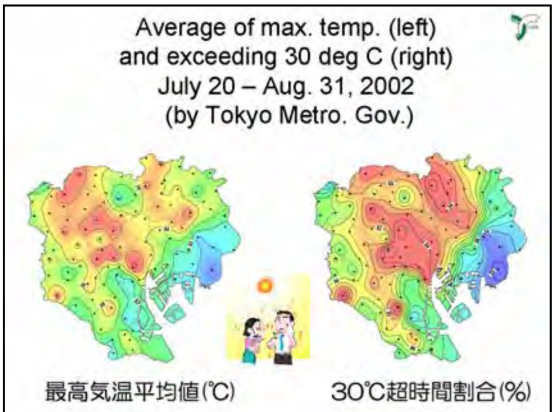

Fig. 2 Result of monitoring project of Tokyo Metropolitan Government.

The main environmental problems of Asian megacities arise from the fact that priority is given to economic development more than to environmental protection. It is necessary to control technologies used in creating the urban environment together with methods of urban planning.

Research Plan

Relations among the changes in surface climatic factors, land use and strength of human activity are systematically provided in the subject cities in Asia. Here the influence of urbanization with regards to the vertical profile of subsurface temperature will also be clarified. These results are useful in separating the influence of global warming from the influence of warming caused by urbanization. And these will contribute as a quantitative guideline for countermeasures for the mitigation of urban thermal environment in Asian cities based on social-scientific discussion. The possibility of ground water usage as a means of thermal environmental mitigation in urban areas in the subject cities and whether it is successful to mitigate thermal environment with a system of urban planning will also be systematically clarified.

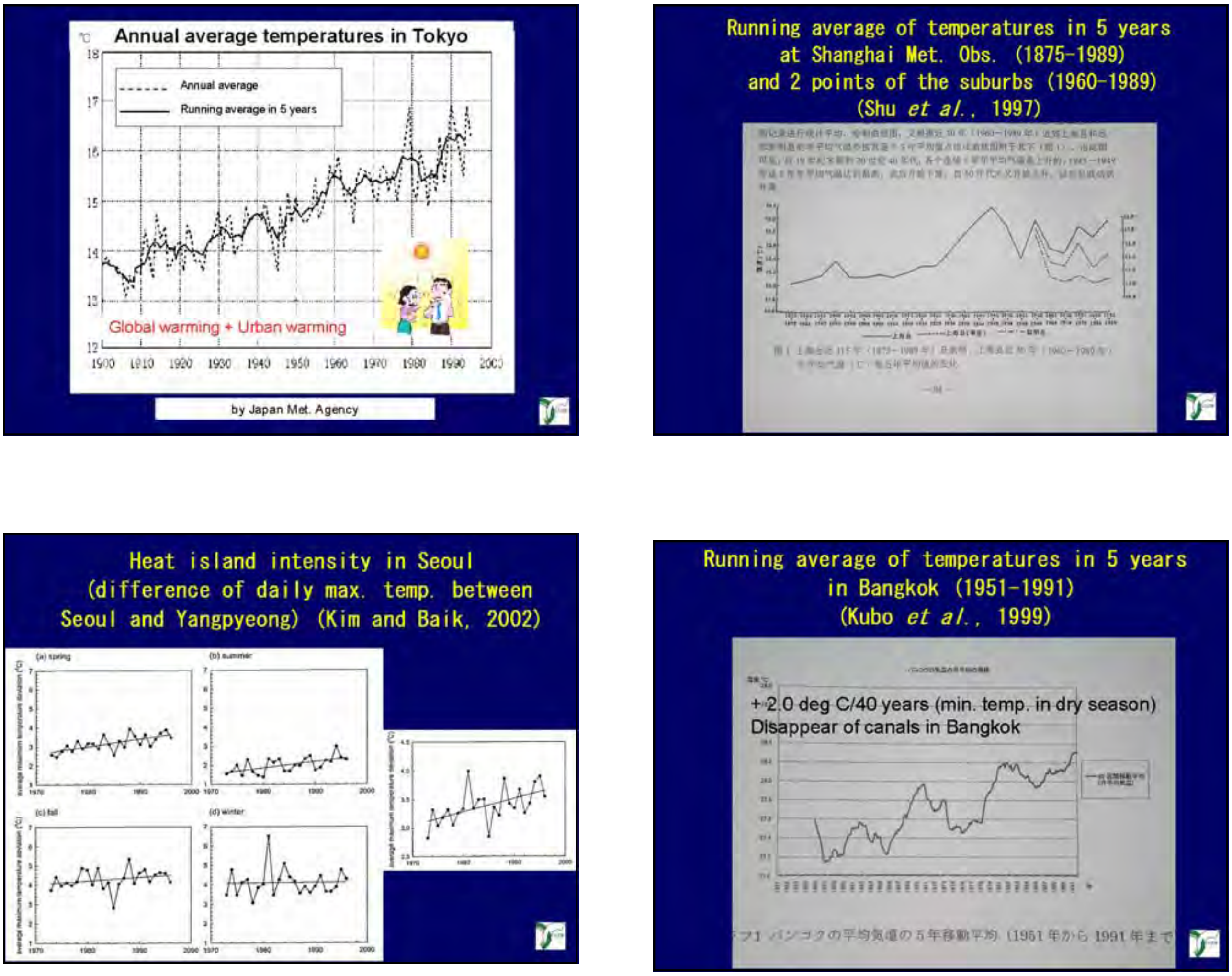

Fig. 3 Examples of recent warming in Asian megacities.

Inter-University Research Institute Corporation

National Institutes for Humanities, Japan

Research Institute for Humanity and Nature

Human Impacts on Urban Subsurface Environments

This project will assess the effects of human activities on the urban subsurface environment, an important aspect of human life in the present and future but not yet evaluated. This is especially true in Asian coastal cities where population and density have expanded rapidly and uses of subsurface environmental have increased. The primary goal of this project is to evaluate the relationships between the development stage of cities and various subsurface environmental problems, including extreme subsidence, groundwater contamination, and subsurface thermal anomalies. We will address the sustainable use of groundwater and subsurface environments to provide for better future development and human being.

Project 2-4 Human Impacts on Urban Subsurface Environments

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ACKNOWLEDGMENTS

We wish to thank all project members who have contributed to our newsletter. Your articles and reports are very valuable and informative. We hope for your continued support and cooperation in the succeeding issues of our newsletter.

ANNOUNCEMENTS

RIHN 1st International Symposium

Theme: “Water and Better Human Life in the Future”

Kyoto International Conference Hall

Kyoto, Japan

November 6-8, 2006

Project 2-4 FR General Meeting

Hiroshima, Japan

November 27-29, 2006

Call for Contributions

For the next issue, we would like to request article contribution again from each Group. It may be in the form of a summary report of the Group’s activities or individual contribution from a member of the Group. We also encourage project members to discuss new methodologies or the use of new equipment in our research project. The newsletter will also provide special columns for our foreign counterparts, graduate students and the RIHN-based project researchers to share research updates and opinion on their involvement in the project.

For the third volume (October 2006), we would like to request the following Groups/individuals to give their articles for the newsletter:

1. Dr. Kaneko’s Group
2. Dr. Shimada’s Group
3. Dr. Onodera’s Group
4. Dr. Tsujimura
5. Dr. Chung-Ho Wang
6. Fajar Lubis

To allow ample time for editing and layouting, we hope to receive your articles on or before September 30, 2006.

For inquiries, please send email to:

Karen@chikyu.ac.jp