Urban Subsurface Environments

Newsletter Volume 6 October 2008

The full implementation of the project "Human Impacts on Urban Subsurface Environment" continues in 2008 and the project members have conducted field experiments, surveys and data gathering in the target cities.

Summary of the group activities of the Material, Urban Economy, and Water groups and research results are featured in this volume of our project's newsletter. This issue also contains introduction of new method by Heat Group, and report from the counterpart group in Seoul.

Inside this issue

Project Activities and Plans

Makoto Taniguchi, RIHN

The RIHN Project C05 "Human impacts on urban subsurface environments" which started at 2003 as incubation study is now on third year of the Full Research (FR3). The domestic meeting on the USE project was held on Nov. 10-11, 2008 at Kasumigaura, Ibaraki, Japan, to discuss and integrate the project results. The progress report No. 5 which shows the summary of the project research during Nov.2007 to Oct 2008 will be published on Dec. 2008.

Up to now, USE project produces the land use/cover maps based on GIS for three ages (1930's, 1970's and 2000's) at seven targeted cities, Tokyo, Osaka, Seoul, Taipei, Bangkok, Manila, and Jakarta, with 0.5 km mesh and 9 categories of the land cover/use. The monitoring of subsurface environment in 7 cities is going on, and continuous date is collected. The GRACE model to evaluate the change in groundwater storage, the precise groundwater model in each city, the integrated subsurface environmental model for 7 cities, and DPSIR + C model for evaluating causality of the subsurface environmental problems have been made. Reconstructions of the subsurface environment in 7 cities from subsurface temperature, subsurface material, and social economical data have been also made. New tracers such as CFC's have been tested to evaluate the origin and process of the groundwater flow.

International conference on "Hydrological changes and watershed management from headwaters to the ocean (Hydrochange2008)" was held on Oct 1 to 3, 2008 at Kyoto, to show some interim results of USE project. Papers were published by CRC Press in "From Headwaters to the Ocean" edited by Taniguchi M. et al. (679pp). Some papers on USE projects were also presented at 36th IAH (International Association of Hydrogeology) which was held on Oct 27-31, 2008, at Toyama, Japan.

Research Aspects of Material Group in Third Year of the Project: results and some views of the goal

Shin-ichi onodera

Graduate school of Integrated Arts and Science,

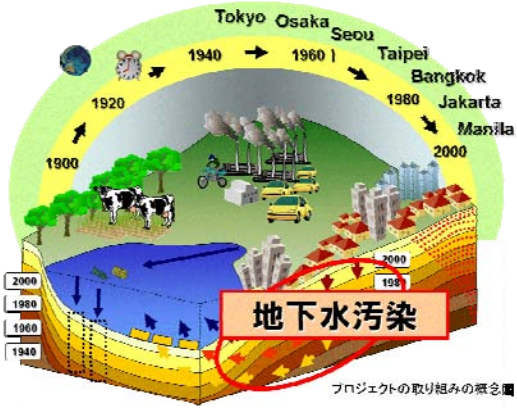
Hiroshima University, Japan

Introduction

We conducted the intensive researches in each main city in 2006 of the first year and the intensive chemical and isotopic analysis of samples as well as field researches in 2007 of the second year of this project. Some of the results were published in STOTEN, IUGG, and HydroChange etc.. We confirmed the some accumulations of pollutants in soil, groundwater and marine sediment, their sources and transport process, solute flux into the ocean in each city. Based on the results, we decided the plan in 2008 of third year. I would like to describe some results and suggest views of the goals of our group in this news letter.

Research Member

Our group is composed of Japanese members, and field counterpart members in Korea, Taiwan, Philippine, Thailand, and Indonesia. 8 Japanese members participated in field researches in the first year of this project and pre research. The detail is as follows,



- Core member: Shin-ichi Onodera (Hiroshima Univ.), Takanori Nakano (RIHN), Takahiro Hosono (Akita University), Yu Umezawa (Nagasaki University), Shinji Nakaya (Shinsyu University), and Jun Yasumoto (RIHN).

- Osaka member: Mitsuru Hayashi (Kobe University)

- Student member: Yuta Shimizu (Hiroshima Univ.)

- additional member: Kazuhiko Takeda (Hiroshima Univ.) sup ported the chemical analysis in the laboratory. Mitsuyo Saito (Ehime University) and Tomotoshi Ishitobi (Nara City) sup port the analysis.

In addition, our group has conducted the researches in all megacities of 6 countries. The international members in all countries have supported our activities and managed the monitoring system.

Research Processes and Results

We have conducted the intensive researches 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, groundwater and porewater at the coastal zone at Manila.

The results are summarized as follows:

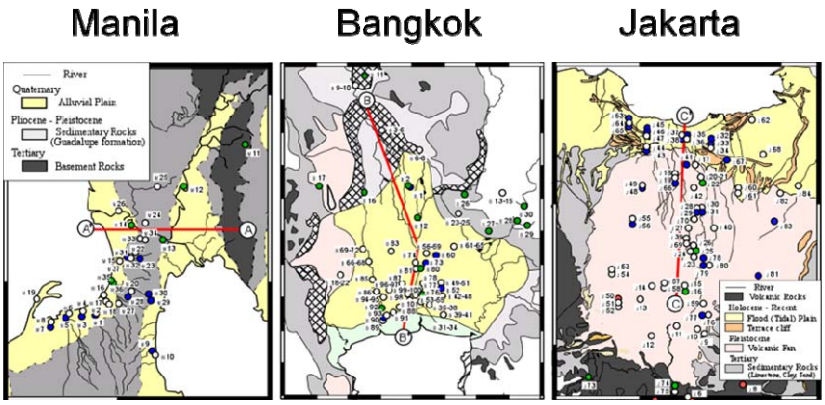
1) we confirmed huge accumulation amount of trace metal, dissolved nitrogen, and chloride in groundwater, especially in Jakarta and Bangkok,

2) we indicated various N sources and denitrification by using N isotope distribution in groundwater,

3) we detected less terrestrial submarine groundwater discharge but huge material flux by total SGD,

4) we suggested As, and NH^{4+} contamination originated by natural sources,

5) we reconstructed organic pollution and metal pollution histories ,using marine sediments.



Research Plans

1) We are starting to collect the groundwater samples in Osaka metropolitan area. We have done the SGD and sediment research. Consequently, we will reconstruct the pollution process history. In addition, salinization process and disturbance of groundwater flow system by pumping will be confirmed, using model approach.

2) We are constructing monitoring stations of SGD and material load in Bangkok as well as in Manila with automated seepage meter and piezometers of two depths for manual water collection.

3) We are also going to develop the new research methods.

a) First one is analysis system of dissolved N_2/Ar in groundwater for reconstruction of dinitrification in groundwater and nitrate content during the groundwater recharge.

b) Second one is Rn analysis system for the quantification of SGD and seawater intrusion.

c) Third one is the purification approach of organic pollution.

4) We had a meeting with the Social-Economic Group on last September. The material flow and material balance model will be produced to compare the process and mass balance at each city.

Urban Economy sub-group Report

Shinji Kaneko[1], Karen Ann Jago-on[1], Medi Sandora[1] and Backjin Lee[2]

1. Hiroshima University, 2. Korea Research Institute for Human Setlements Infrastructure and Construction

In this report, the Urban Economy sub-group presents a brief summary of fieldwork surveys in Jakarta and Manila and the seminars organized by the subgroup in Seoul and Hiroshima.

Summary of Fieldwork surveys

Uncontrolled groundwater abstraction in Jakarta and Metro Manila has lowered groundwater levels and is one of the factors that caused land subsidence in the areas. To address the issue of uncontrolled groundwater abstraction, regulation on groundwater management has been implemented in Indonesia since 1994 and this defines the framework for groundwater management which covers inventory, supervision and licensing of groundwater use. On the other hand, regulation on groundwater use in Manila is subsumed under the Water Code of the Philippines which has been in place since 1976 with amended rules and regulations in 2005. However, the policy lacks provision on land subsidence issues contrary to some other cities where such is integrally considered in groundwater policies.

Land subsidence has aggravated the effects of flooding in the cities, especially in low-lying areas. Places in the northern parts of Jakarta and Metro Manila are frequently flooded not only due to heavy rain but high tide levels. The rise in sea level of a few millimeters a year due to global warming has been acknowledged as a cause of increased frequency of flooding, however, the contribution of land subsidence to flooding has not been taken into much consideration. Studies have been conducted to investigate the phenomena of land subsidence in Jakarta (Abidin et al. 2001) and Manila (Rodolfo and Siringan, 2006).

In order to assess the socio-economic impacts of flooding in the low-lying areas in Jakarta and Metro Manila, a questionnaire survey was conducted last March and April 2008. In both surveys, we tried to assess the nature of flooding and perception of people about the causes of flooding, measure the cost of damages caused by floods and review government programs to prevent flooding. In the Jakarta survey, the amount that households are willing to pay to reduce the risk of flooding was also asked.

Surveys in Jakarta were administered among 300 households, while in Metro Manila, aside from 300 households, 10 companies and institutions were also included as respondents.

Jakarta field survey

The survey in Jakarta was conducted from March 6-16, 2008. The survey aimed to elicit perception and awareness of respondents to avoid flooding through contingent valuation method and to estimate the cost of damages due to flooding. Respondents were asked about their willingness to pay (WTP) to avoid flooding. The WTP values were correlated with variables to their socio-economic background and flood risk exposure. Estimation of flood damages include cost estimates on property damages, income losses, health costs, transportation costs, water costs and cost of flood prevention activities.

Jakarta is divided into six (6) municipalities: North, South, East, West, Central and Kepulaunan Seribu. North Jakarta is mostly lowland area and most vulnerable to flooding. It is divided into 6 districts, which includes Penjaringan, one of the most affected areas during the flood in 2007. Penjaringan is further divided into 5 sub-districts: Kamal, Kapak, Pademangan, Penjaringan and Pluit. The recent survey was done among 300 households in the subdistricts of Penjaringan and Pluit. Penjaringan has a land area of 3.95 km² and the population is around 56,219 people. The population density is 14,217 persons/ km². Pluit on the other hand, has a land area of 7.7 km² and a population of 43,802 persons. The population density is 5,680 persons/ km². Most of the people in these two areas are engaged in the fish processing industries.

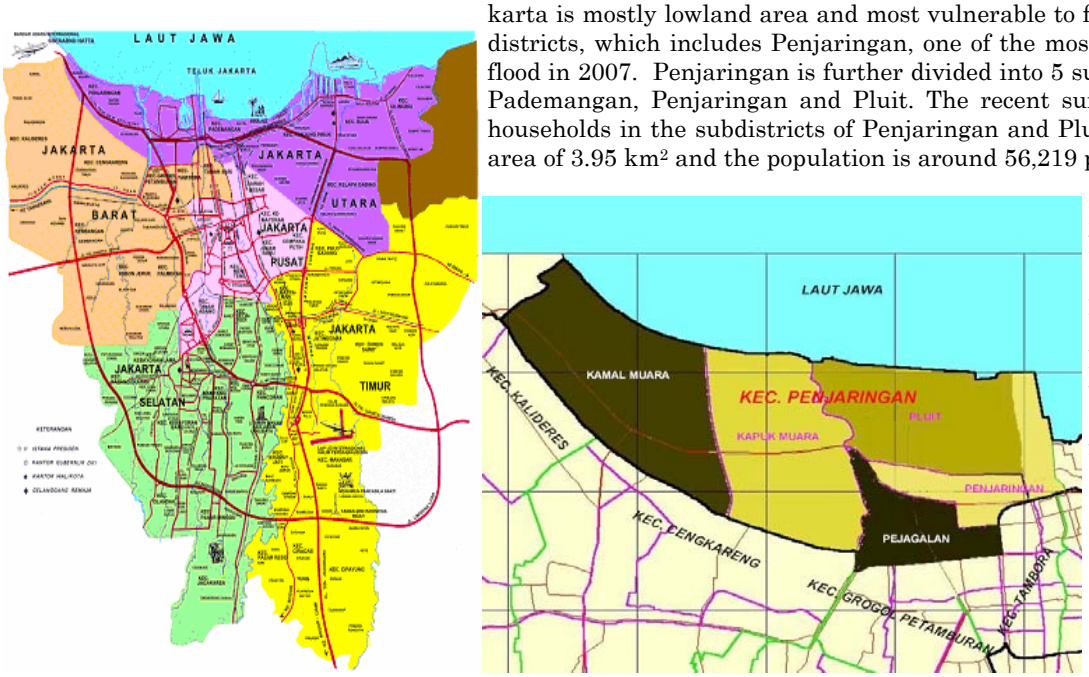


Fig. 1. Location of Jakarta and Penjaringan District

The average damage cost from the last flooding incurred by households in these areas is Rp 877, 702. The willingness to pay to avoid flooding is Rp 46,654. The total estimated cost of damage of flooding in Penjaringan district in 2007 was Rp 3,559,959,312 (USD 386,952).

According to Pemerintah Propinsi DKI Jakarta, the government will repair 7 dikes in Penjaringan district. The budget for the dikes is USD 1.6 million and for rehabilitation of structures along the river is USD 3million. These dikes are perceived to last for 20 years. If we aggregate the amount that the households are willing to pay, the total amount is one third of the cost of the dike.

The preventive program on flooding should not only include structural measures such as repairs of dike, but also non-structural measures, such as early warning systems and information campaigns. Restrictions on groundwater abstraction and improvement of water infrastructures are also necessary in order to minimize land subsidence.

Fig. 2. Transportation used during floods in Penjaringan, Jakarta

Manila Field survey

The KAMANAVA area in the northern part of Metro Manila is composed of the cities of Kalookan (Caloocan), Malabon, Navotas and Valenzuela. The KAMANAVA area has an area of 18.48 km2 and is located in the estuary delta of Navotas-Malabon-Tenejeros-Tullahan River (Pacific Consultants Intl, 1998). It is a low-lying and flat land with an elevation of -0.5 to 1.5 m above mean sea level of Manila Bay. The topographical characteristics make this area prone to flooding caused by heavy rainfall, high water level in rivers, and high tide at Manila Bay. The KAMANAVA area is particularly vulnerable to floods due to continued land subsidence and rapid urbanization. Most of the areas developed for industrial, residential and commercial purposes were originally fish ponds. However, rapid urbanization and land use changes have altered the susceptibility to damage by permanent floods. Figure 4 shows the street flooded during high tide.

According to the census in 2007, the population of Metro Manila is around 11.5 million and the number of people in the KAMANAVA area is 22% of this total population. The people habitually suffer from flooding and these floods carry the heavily polluted water of rivers to streets, homes, schools, and other institutions. The people who can afford to settle in another location usually abandoned their homes after the floods (Fig.5), but those who have no resources to move, continue to stay in the same area despite the health risks of living above stagnant and dirty water. In the future, health impacts are greater as all kinds of wastes are thrown in the water (Fig.6).

Fig. 3. Map of Metro Manila. The KAMANAVA area is located in the northern part of Manila Bay (colored in green).

Since the 1980s, the government has implemented several flood control projects in KAMANAVA, however the problems persist since the infrastructures provided offered only palliative solutions to the problems. People continue to suffer from high cost of damages and health risks. Frequent flooding has also brought huge economic losses and disturbance to commercial, industrial, social and other productive activities in the area. In 1998, the government started a large flood control and drainage system improvement project for the KAMANAVA area. This involves the creation of a polder system in which the area is supposed to be protected by polder dikes, river walls and gates against water inflow from Manila Bay. Flood water is discharged by pumping stations and drainage channels created inside the polders. Despite the large costs and ambitious objectives of the project, several groups have opposed the continued construction because the rate and magnitude of land subsidence as well as the height of storm waves and surges in Manila Bay were not accurately considered in the design.

In order to evaluate the socio-economic impacts of frequent flooding, a questionnaire survey was conducted in the selected villages (“barangays”) of the four cities of Kaloocan, Malabon, Navotas and Valenzuela. The respondents were divided into 3: households, institutions and companies. Three hundred (300) households were chosen as respondents and 10 institutions and companies were also surveyed.

The specific objectives of the survey were to estimate the socio-economic impacts of frequent flooding and calculate the cost of damages from these flooding events. The survey included investigation on the socio-economic situation of the households, physical description of houses and buildings, flooding incidences and perceived cause of floods, height of flood waters inside the house/ building, and flood mitigation measures. Damage cost estimates include cost of mitigation, structures and facilities damaged during floods, cost of damaged household materials, cost of evacuation, cost of cleaning and repair, cost of transportation, and cost of illness or health costs. Results from the survey will help us understand the magnitude of effects of flooding and guide us to formulate concrete and practical steps to alleviate the living conditions of the people in the affected areas.

Fig. 4. Flooded street due to high tide.

Fig. 5. Flooded and abandoned house in Malabon City.

Fig. 6. The waters still remain since the flood in 2004 but more than 150 families continue to stay in the area.

KRIHS and RIHN Joint International Symposium

The Korea Research Institute for Human Settlements (KRIHS) in South Korea conducted a joint international symposium with the Research Institute for Humanity and Nature (RIHN) of Japan. This was part of the commemoration of the 30th year of foundation of KRIHS and was held last June 12, 2008. The theme of the symposium was "Urban Sustainability in Asia: Urban Planning, Environment and Transportation." This was attended by about 60 participants from Korea and Japan.

The symposium aimed for an integrated policy towards a sustainable and environment-friendly development for future Asian cities, with the help of domestic and international experts from urban planning, environment and transportation fields. The two main topics in the symposium dealt with urban sustainability, urban planning and transportation; and urban environmental sustainability. Dr. Shobhakar Dhakal (Executive Director, Global Carbon Project, National Institute for Environmental Studies, Japan), was the keynote speaker and he discussed about urban energy use and urban sustainability from climate change perspectives.

Given below are the presentations during the symposium, together with the name and affiliation of the speakers:

Session 1:

1.1. Environmental efficiency in transport: Akimasa Fujiwara (Graduate School for International Development and Cooperation, Hiroshima University, Japan).

1.2. Promoting environmentally sustainable transport (EST) in Korea: Sungwon Lee (The Korea Transport Institute, Korea)

1.3. Sustainable Urban Form in case of Korea: Kwang-ik Wang (KRIHS, Korea)

Session 2:

2.1. Urban subsurface environment in Asian coastal megacities: Makoto Taniguchi (Research Institute for Humanity and Nature, Japan)

2.2. "Hard" solutions and "Soft" solutions: institutional response to urban water problems: Takahiro Endo (Research Institute for Humanity and Nature, Japan)

2.3. Environmental sustainability from climate change perspectives in Korea: So-won Yoon and Dong-kun Lee (Seoul Facilities Corporation, Korea; Seoul National University, Korea)

2.4. Urban form and greenhouse gas emission and Asian cities: Backjin Lee (KRIHS, Korea)

After the symposium, a closed-door meeting of the RIHN-USE Project Urban economy sub-group, led by Dr. Shinji Kaneko and Project leader, Dr. Makoto Taniguchi, was held. Attendees include Prof. Akimasa Fujiwara, Prof.

Tsuyoshi Imai, Prof. Ryo Fujikura, Dr. Backjin Lee and Dr. Takahiro Endo.

The 152nd IDEC Asia Seminar

Dr. Robert M. Delinom, from the Research Center of Geotechnology, Indonesia Institute of Sciences, and our project counterpart from Indonesia was the speaker of the 152nd IDEC Asia Seminar at the Graduate School for International Development and Cooperation (IDEC), Hiroshima University on April 24, 2008. This seminar was attended by 40 participants. The title of his presentation was "Groundwater Resources Management in the Greater Jakarta Area."

Dr. Delinom began the discussion on the relationship between urbanization and changes in groundwater systems, and focused on groundwater situation of Greater Jakarta area. Jakarta still continues to increase its consumption of groundwater for domestic and industrial needs. Massive groundwater abstraction has caused lowering of groundwater levels and land subsidence, a situation which damages infrastructures and worsens the impact of flooding in coastal areas. Dr. Delinom concluded the lecture by providing strategic measures to strengthen groundwater resources management in Jakarta. The seminar was also enhanced by discussions led by Prof. Takao Yamashita on modeling approaches to water resources management in Indonesia, and Dr. Shinji Kaneko on people's awareness of flood risks in the coastal area of Jakarta.

Fig. 7. Dr. Robert Delinom explains the groundwater situation in Jakarta to students and faculty in IDEC.

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Rodolfo, KS, Siringan, F. Global sea-level rise is recognized, but flooding from anthropogenic land subsidence is ignored around northern Manila Bay, Philippines. Disasters 2006; 30(1):118-139.

How was deep groundwater renewed after excessive pumping in the Bangkok metropolitan area?

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1. Introduction

Excessive groundwater pumping in the Bangkok metropolitan area (BMA), Thailand, have induced large piezometric-level decline in confined aquifers and land subsidence (Ramnarong and Buapeng, 1991; Phien-wej et al., 2006), as in other mega cities in Asia. Since the groundwater pumping peaked in late 1990s and then decreased, restoration of the potentiometric level is now in progress. We found out that the relationship between groundwater pumping rate and piezometric level is nearly linear (Fig. 1). This fact suggests that recharge and flow rates of confined groundwater was enhanced by the pumping. However, it has been unknown whether the enhanced recharge has occurred within BMA or at any other suburban areas. To assess detailed mechanisms of the enhanced recharge, we conducted numerical experiment and multi-tracer study.

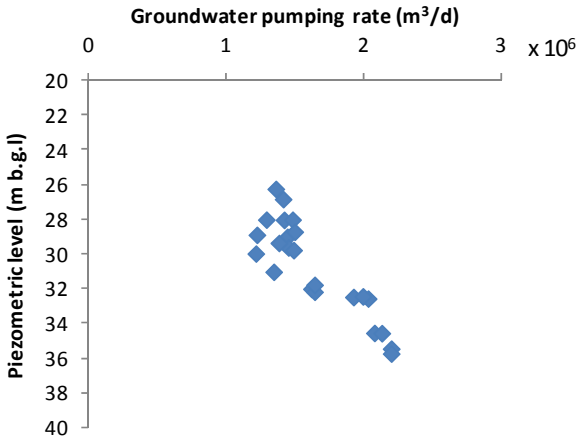

Fig. 1 Relationship between annual groundwater pumping totalized over BMA and mean piezometric level for major three aquifers (i.e., PD, NL and NB) within BMA.

2. Numerical experiment

Visual MODFLOW was used for simulating groundwater flow system. Under steady state condition without pumping, there existed very slow, large-scale flow system from mountainous or hilly suburban areas through BMA to the coast line of Gulf of Thailand (Fig. 2a). Under non-steady state condition with pumping, confined groundwater flow and its recharge at the suburban areas were clearly accelerated (Fig. 2b and 3b). In addition, spotted-recharge across the first confining layer (Bangkok clay), which have several ten meters thickness, was induced, because groundwater pumping created a very steep, vertical hydraulic gradient just around pumping wells. However, estimated contributions of suburban recharge via large-scale flow system and urban spotted-recharge (Fig. 4) depend on model parameters, in particular, hydraulic conductivity of each aquifer and its anisotropy.

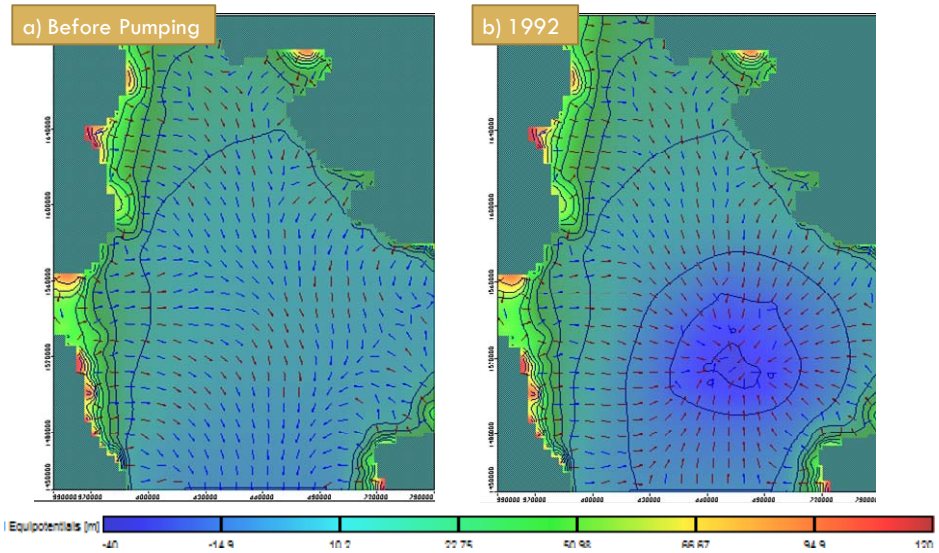

Fig. 2 Horizontal flow direction in NL aquifer. Blue and red arrows denote upward and downward flows, respectively. Contour and color bar represent hydraulic head (m a.m.s.l.).

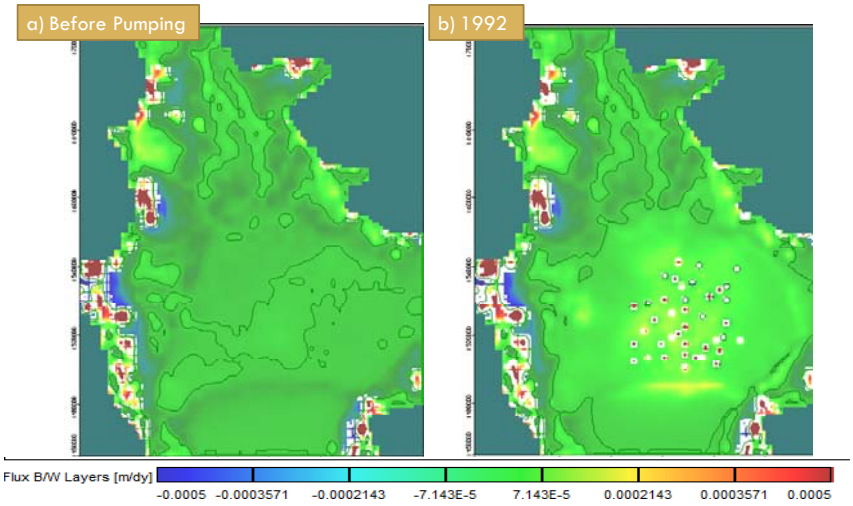

Fig. 3 Spatial distribution of recharge flux.

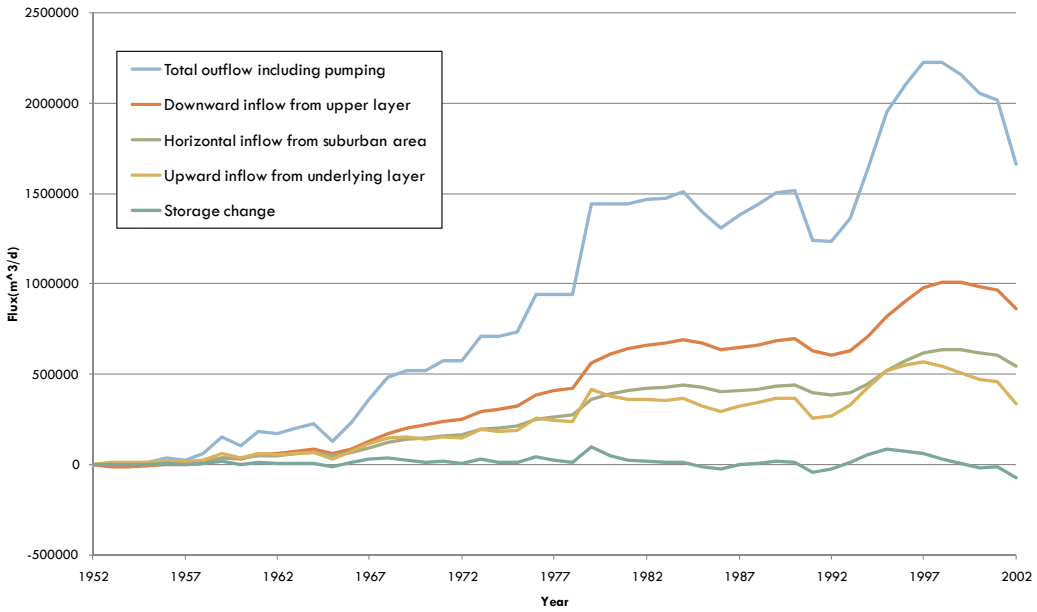

Fig. 4 Historical evolution of water budget of a set of PD, NL and NB aquifer-units within BMA.

3. Multi-tracer study

Three-dimensional distribution of stable isotopes of water (δD and $\delta^{18}O$) indicates large-scale groundwater flow from suburban areas to BMA. Furthermore, it is also suggested that vertical mixing between aquifers occurs in part, especially at the central BMA (Fig. 5). Although C-14 suggests that there still exist paleo-groundwaters, the other dating-tracers (i.e., tritium and CFC) suggest that modern groundwater (e.g., groundwater age < 50 yr) can partially penetrate into confined aquifers across Bangkok clay. Although the numerical experiments depend highly on assumed hydraulic parameters as mentioned above, the numerical results can be calibrated and validated by the multi-tracer results.

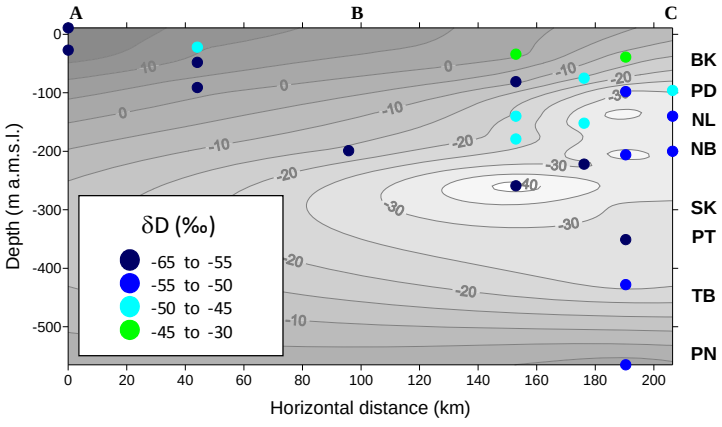

Fig. 5 Spatial variation of hydrogen isotopic composition (δD) of groundwater in a vertical cross section across BMA (A: northern Chainat, B: eastern Angthong, C: eastern Samut Prakarn). Contour represents hydraulic head (m a.m.s.l.).

4. Concluding remarks

We deduce a tentative conclusion that groundwater pumping could enhanced not only recharge at (and horizontal flow from) suburban areas but also spotted recharge across thick clay layers around pumping wells within BMA. This knowledge will be of benefit to sustainable groundwater use and city planning in deltaic plains. However, obviously we need to further improve numerical modeling, in particular, 4-D variation in groundwater pumping as input data. In addition, it's also necessary to examine more exactly the time scale of deep groundwater renewals.

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Ramnarong, V. and Buapeng, S. (1991): Mitigation of groundwater crisis and land subsidence in Bangkok. J. Thai Geosciences, 2, 125-137.

Phien-wej, N., Giao, P.H. and Nutalaya, P. (2006): Land subsidence in Bangkok, Thailand. Engineering Geology, 82, 187-201.

Groundwater study of Osaka Basin using Sr isotope as a hydrogeological tracer

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1. Hydrogeological tracer in groundwater

Groundwater originates from rain, snow, and mountain glacier. It evolves into soilwater and riverwater, and finally flows into sea. Stable isotopes of hydrogen and oxygen have been utilized in water circulation studies, since they provide invaluable information on the origin and flow of water. Water can dissolve many elements, whose combination is termed as water quality. Groundwater quality changes areally by interacting with natural environments and human societies as it flows. Sources of dissolved components in water are different from those of water itself. Sr isotopes have widely been used in a recent decade as a hydrogeological tracer of dissolved Sr. Here, I will introduce the principle of this isotope and its application for the groundwater system in the Osaka basin.

2. Water quality and Sr isotope of freshwater

Freshwater such as river water and groundwater is generally dominated by Ca due to high susceptibility of Ca-dominant mineral to chemical weathering. Sr is utilized as a proxy for Ca, since Sr is alkali-earth as like as Ca and is enriched in Ca-containing minerals. Sr isotope is generally expressed as the ratio of ^{87}Sr to ^{86}Sr ($^{87}Sr/^{86}Sr$). The $^{87}Sr/^{86}Sr$ of freshwater is highly dependent on the watershed geology, since rocks have distinct $^{87}Sr/^{86}Sr$ ratio dependent on their geological processes and the concentration of Sr is high in Ca-mineral. Isotope fractionation is negligible for $^{87}Sr/^{86}Sr$ ratio studies due to the mass-dependent correction during the Sr isotope analysis. Accordingly, the $^{87}Sr/^{86}Sr$ of freshwater reflects its source material and changes only by mixing or interaction of materials with different $^{87}Sr/^{86}Sr$. By making use of these characteristics, Sr isotopes can be used as powerful hydrogeological tracers.

3. Sr isotope analysis

Freshwater contains Sr as trace amounts (generally about 1% of Ca). However, recent Ta-activation technique enabled us to determine the $^{87}Sr/^{86}Sr$ ratio for samples even with a few ng Sr. Analytical precision and accuracy for the Sr isotope analysis have been improved with the advancement of mass spectrometer. The internal and external precision of $^{87}Sr/^{86}Sr$ analysis in thermal ionization mass spectrometer at RIHN (Triton, Thermo Fissher Co.) have been attained to be better better than $5x10^{-6}$. The $^{87}Sr/^{86}Sr$ ratio of ocean water is known to be highly uniform. Quaternary coral in the mid-eastern Pacific showed the $^{87}Sr/^{86}Sr$ to be 0.709175±0.000005 (Ando et al., unpublished data). This variation is within an analytical accuracy. Ocean water is thus considered to have an extremely uniform $^{87}Sr/^{86}Sr$.

4. Application of Sr isotope to groundwater in the Osaka basin

4-1. Cation exchange

Although there are many studies of Sr isotopes in terrestrial water, application to groundwater system is relatively limited. A confined groundwater system is developed in argillaceous marine and freshwater sediments of Pliocene-Holocene age in the Osaka Basin and Takatsuki City to Shimamoto Town in western Japan. The shallow groundwater in the system is recharged in a northern hilly to mountainous area with dominantly Ca-HCO_3 type water, which changes as its flows toward SW to Mg-HCO_3 type and then to Na-HCO_3 type water. Deep groundwater is Na-Cl type water. The concentration of Sr in the groundwater decreases from Ca-type water to Na-type one as it flows. If this zonal change of cation composition in the HCO_3-dominant groundwater is caused by the dissolution of aquifer sediments, the total cation concentration should increase as the groundwater flows, but it is relatively constant irrespective of sites. These data indicate that cation leaching from sediments is negligible but rather the cation zonal pattern of the Osaka groundwater is caused by the loss of Ca from the water as it is exchanged for Mg in aquifer clays, followed by Na.

In accordance with the cation zonal arrangement, the $^{87}Sr/^{86}Sr$ of the groundwater increases from 0.7084±0.0002 to 0.7092±0.0002 from north to SW. This $^{87}Sr/^{86}Sr$ change indicates that the groundwater contains Sr of different origin along

its flowage. The contribution of nearby Yodo river into this aquifer system is neglected since its $^{87}Sr/^{86}Sr$ (~0.711) is significantly higher than those of the groundwater. Aquifered sediments have high $^{87}Sr/^{86}Sr$ (~0.720) irrespective of sites. On the other hand, the $^{87}Sr/^{86}Sr$ of exchangeable fraction in the sediments changes in accordance with the groundwater flow. These data also support a view that the zonal change of cation composition in the groundwater (Ca through Mg to Na) is caused by the cation exchange process.

4-2. Water quality change and flow of groundwater

Why the cation composition and Sr isotopic ratio of groundwater in the Osaka basin change along its flowage. The aquifered sediment in this basin is composed of marine sediment. Seawater is dominated by Na and Cl contents and has a very uniform $^{87}Sr/^{86}Sr$ (~0.70918). The zonal arrangement of cation composition and $^{87}Sr/^{86}Sr$ ratio in the groundwater is explained by a model that Ca and Sr originally trapped in marine sediments is successively exchanged by the Ca-dominant water recharging from rivers in northern area. According to this model, the groundwater quality in marine sediment will change with time from Na-Cl type into Na-HCO_3, followed by Mg-HCO_3 and finally Ca-HCO_3. Based on this cation exchange model, it is possible to predict the flow rate of groundwater by assuming age of marine sediment and amount of exchangeable cations in the sediment. The calculation result shows that the water flux is 1 cm per day, this value being concordant with the reported recharge flux into unconfined aquifer system in Japan.

Prior to Sr isotope analysis, Sr should be separated from water. This separation is based on the application of liquid chromatography, which is packed with cation exchange resin in a column and HCl or HNO_3 acid as elluent. The cation chromatography process was reproduced in a column experiment in which Mg type groundwater with low $^{87}Sr/^{86}Sr$ was in the Osaka basin percolated through marine clays, leading to the generation of Na type groundwater with marine $^{87}Sr/^{86}Sr$. The experiment is a good example showing that scientific process controlling natural phenomena is taking place in both field and experiment. This study demonstrates that Sr isotopes have a potential as a tool to evaluate human impacts on urban subsurface environments. The detail of this report is seen in the following paper.

Yamanaka, M., Nakano, T. and Tase, N. (2005) Hydrogeochemical evolution of confined groundwater in northeastern Osaka Basin, Japan: estimation of confined groundwater flux based on a cation exchange mass balance method Applied Geochemistry v.20, Issue 2, *295-316*.

Development of a Highly Efficient Air Conditioning System with Ground Coupled Heat Pumps (GCHP)

Sachio Ehara

Kyushu University, Japan

One of the most important subjects in the global environment is the relaxation of the global warming. However, the public energy consumption is still increasing and reaches about 30% of the total energy consumption in Japan at present. As a result, the heat island phenomenon in the urban area is rapidly progressing at big cities in Japan. One of the main causes of such heat island phenomenon is the rapid popularization of the conventional air conditioning system in the residential houses and buildings.

We propose a highly efficient air conditioning system with Ground Coupled Heat Pumps in the residential houses (Fig.1). We developed a new system and installed it in an experiment house in Fukuoka city, Southwestern Japan. We introduced the Downhole Coaxial Heat Exchanger (DCHE) system to extract heat from the shallow ground. The DCHE system saves the electric power and oil consumption and also does not discharge waste heat to the air.

We installed our system in a two-story brick symbiosis housing facility (Five rooms, 140m^2). After designing, building and operating the system, we evaluated its performance. As a new heating and cooling system, the system we created attained the highest performance level (Coefficient Of Performance (COP) = 5.0).

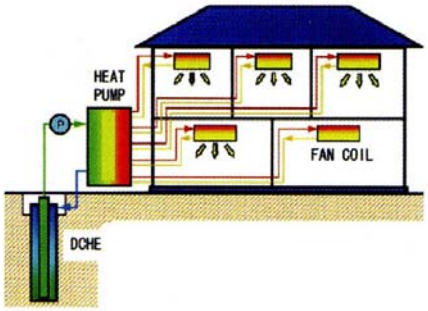


Fig.1 Concept of the newly developed air conditioning system with GCHP.

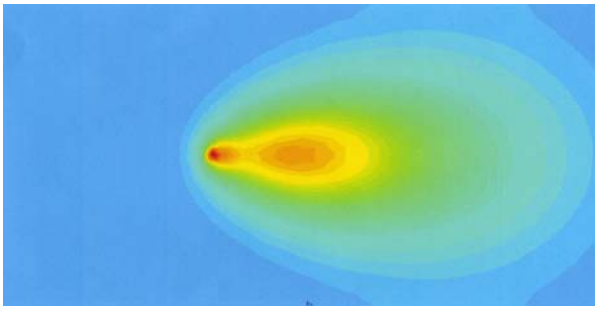
In terms of the design, we first calculated the heating and cooling load based on the home's insulation efficiency and each room's heating and cooling specification. At the same time, we examined the subsurface structure and evaluated the heat transfer characteristics of the underground rocks. Based on the heating and cooling assessment and the heat transfer characteristics, we determined the excavation depth for the heat exchange well.

Next, using the heat exchange well that we excavated, we conducted a thermal response test to determine the thermal conductivity of underground rocks. Based on the thermal conductivity distribution, we conducted a numerical simulation of the system's operating conditions and determined the system's heat pump and indoor equipment capabilities and then installed the newly developed air conditioning system with ground coupled heat pumps (GCHP). The system consisted of the underground vertical heat exchanger (60m length), the heat pump, the indoor equipment, as well as a circulating pump to circulate the heat exchange antifreeze.

The air conditioning system has already operated for six seasons. After each season, we evaluated the system's performance (COP), optimized its operation, studied the circulation flow rate of the antifreeze and cleaned the heat exchanger. As a result of repeatedly conducting these and other improvements, by the summer of 2007, we had managed to create highly efficient system with a COP of 5.0.

Further, we evaluated the system's effect on the underground thermal environment in conjunction with its operation. The heat exchange in the ground was associated, temporally (when the cooling ended in the summer or the heating ended in the winter), with the temperature changes of up to 2 degree C at points three meters from the heat exchange well (Fig.2). However, the heating and cooling had a compensatory effect throughout the year, and field tests and numerical simulations demonstrated the over time, there was no increase and decrease in the temperature of the underground layers on the heat exchange well's periphery.

Through the aforementioned series of studies, we were able to construct an extremely efficient air conditioning system utilizing geothermal heat. In the future, we will operate the system for prolonged periods in order to demonstrate its stability as well as evaluate its continuous operation performance and economic feasibility. We are also promoting our work in order to familiarize people with the system and hope to contribute to the creation of a sustainable society in terms of thermal environment.



Fig,2. An example of simulated temperature change around the heat exchange well during heating with slow groundwater flow.

Variation of Urban Forms and Air Pollution in Asian cities

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1 Dept. of Architecture, Korea University, Seoul, Korea

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1. INTRODUCTION

Global efforts to reduce air pollution and greenhouse effect for the sustainable urban development are being conducted with increasing interests. Asian countries that achieved rapid economical development recently cannot be exemptions, and such ameliorative efforts are being continued in major economical cities. However, the recent tendency appears that the degree of reduction in air pollution and greenhouse gas emission has slowed or even increased. A conjecture can be made that such tendency is due to the limitation of improvement in motor vehicular usage, which acts as the primary variable of air pollution and greenhouse gas emission, while such efforts are constantly devoted in industrial field. Therefore, not only technical part but also a new approach in a different aspect is necessary.

This article aims to draw out implications for the establishment of an ameliorative policy; as a matter of urban form, to practice sustainable development, and to grasp the linkage between the urban form and air pollution at second hand. For such objectives, the changes in urban form and the level of air pollution in Tokyo, Seoul, and Beijing; three major cities leading the growth of Asia, the region that is becoming the center of global economy as radical industrialization and urbanization is taking place, would be observed to analyze the correlation.

2. EMPIRICAL ANALYSIS

2.1. Urban Form Analysis of Subjective Cities

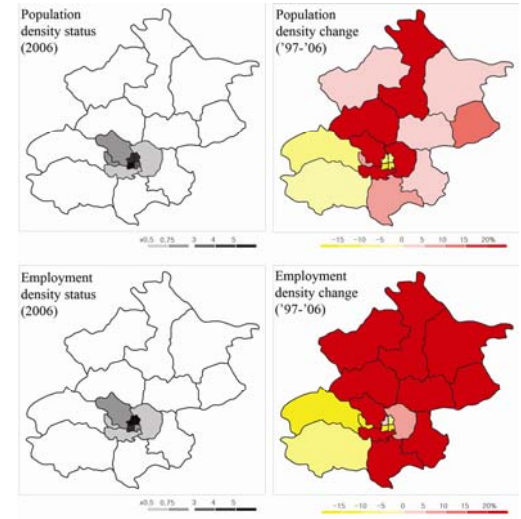
In this article, three major cities, Seoul, Tokyo and Beijing, are selected as subjects of the analysis. These cities represent the developed country-Japan, the nation entering the level of developed country-Korea, and the developing country-China, respectively.

This research examined the changing tendency of urban form in the past 10 years (1997-2006) of the three cities through the Gini and Moran coefficient, which was gained from the utilization of the population and employment indexes. The objective is analysing not the general relationship between the urban form and air pollution, but the specialized correlation of the three cities by considering the particularities in urban form of respective cities.

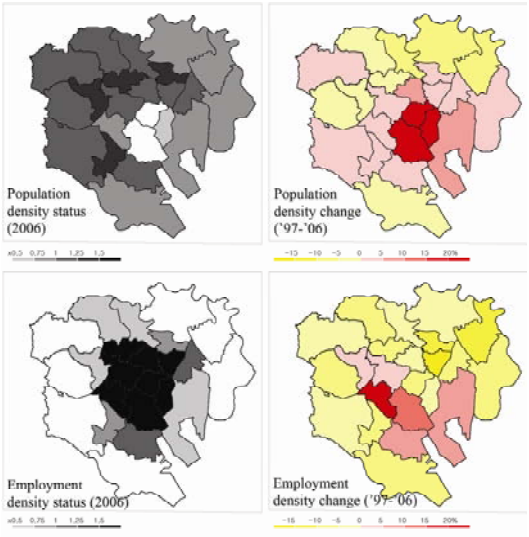
While the total area of Seoul and Tokyo is similar, there is a difference in the area that is urbanized—95.85% in Tokyo, 69.92% in Seoul. However, the population density per urbanized area of Seoul is 1.7 times of Tokyo, 14 times of Beijing. In Beijing, 83.4% of the population is concentrated in four central districts, while the population in the eight major districts, including the central four, reaches approximately 97% of the total. However, the ratio of population and employment per the change in total population of the central four districts from 1997 to 2006 is showing decrease. Except for, the adjacent area Shijingshan, the ratio of change in population and employment of the four districts is in the tendency of increase, and the population and employment being expanded to the north and south part from the urban center.

In Tokyo, the change in population and employment shows a sharp difference. While the population tends to disperse towards the perimeter of the city, a reconcentration of employment in the old urban center is being observed. Thus, it is possible to verify that Tokyo has entered the reconcentration phase, the next level of concentration, sprawling phase.

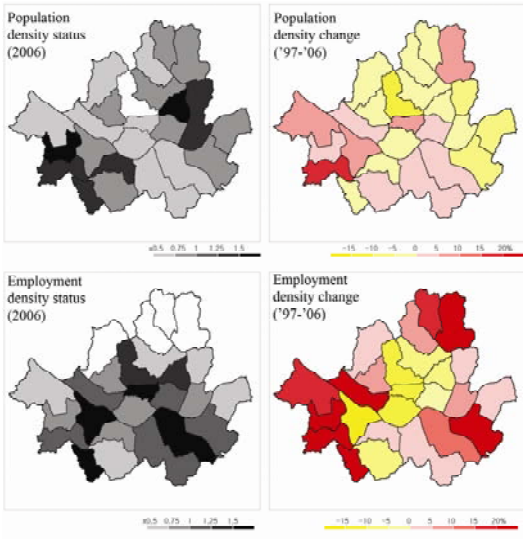
Seoul shows the least concentration in the old urban center of population, and the population is increasing in the southern part. In the case of employment, three cores including the old urban center are formed, with the employment in the old urban center is decreasing, while the increase can be viewed in the perimeter around the cores.



(a) Beijing



(b) Tokyo



(c) Seoul

Figure 1 The Status and Changes of Urban Form of Subject Asian Cities

In short, the urban form of Beijing is monocentric while a gradual change into polycentric form is in progress, an acceleration into spatial structure of polycentric form is occurring in Seoul, and the progress into the polycentric form is considerably advanced in Tokyo, thus a form of compact city in which employment is concentrated in certain old urban center is being observed.

The analysis on the Moran coefficient of the employment and population in these three cities shows the significant dispersion in population and employment of Beijing, compared to Seoul and Tokyo. In the case of Tokyo, the Moran coefficient of population is 0.06~0.065, and 0.02 in employment, indicating that the city is stabilized and possesses polycentric structure, and according to the past tendency, an advance into a compact monocentric form is in progress. In the case of Seoul, the Moran coefficient of population in the past 10 years ranges from 0.035 to 0.045, expressing a settlement into a polycentric form, while the Moran coefficient of employment varies around the value of zero, which can be discerned as a form of dispersion.

In summary, Beijing is in the phase of urban sprawl, Seoul is in a polycentric phase where the population is being concentrated while the employment is being dispersed, and Tokyo exhibits the traits of polycentric form, while a tendency of concentration of population and employment is viewed at the same time, thus can be judged as experiencing reurbanization.

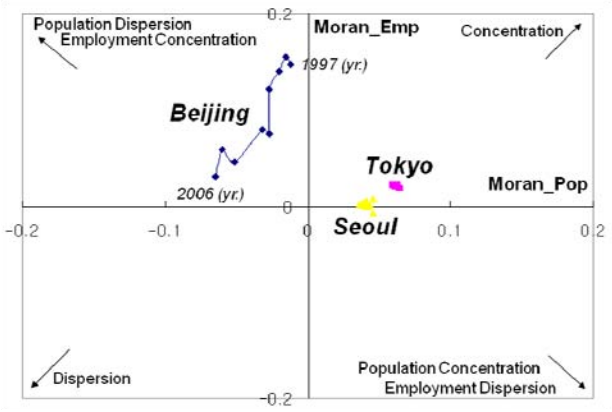


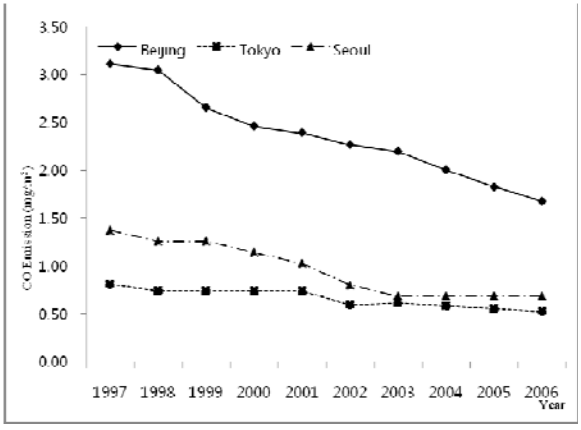
Figure 2 Spatial Changes considering Moran's I of Population and Employment

2.2. Correlation Analysis between Urban Form and CO/CO_2 Emission Index

The total emission of CO and CO_2 in the three cities from 1997 to 2006 is examined to draw out the correlation between the urban forms and air pollution. In the case of CO emission which is controlled approximately 80% by motor vehicular transport, the annual total emission per unit area of the three cities shows the tendency of constant decrease.

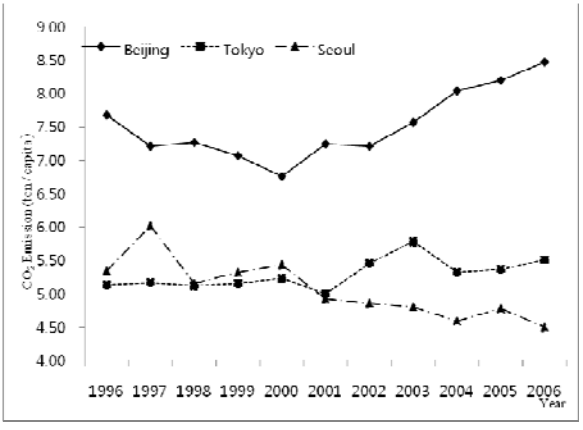
Beijing shows decrease from 3.11(mg/m^3) of 1997 to 1.68 of 2006, and Seoul, from 1.37 to 0.69, and Tokyo, from 0.81 to 0.53. The 3.81 times gap between Beijing and Tokyo in 1997, had been shorten to 3.17 times as of 2006. Meanwhile, the 1,7 times gap between Seoul and Tokyo 10 years ago became only a slight difference in 2006.

In the case of CO_2, Beijing records 8.47 ton per capita as of 2006 which is 1.5times higher than that of Tokyo and Seoul, while Seoul records the lowest, 4.50 ton per capita. When observing the tendency of CO2 emission per population in the past 10 years from 2006, Beijing shows decrease until the year of 2000, but increase since then, and Tokyo exhibits stabilization of 5.0 ton per capita, and a slight increase to 5.5 ton per capita recently. In the case of Seoul, general decrease was shown since 1997, from 6.02 ton per capita to 4.5 ton per capita as of 2006.



source: Statistics Bureau of Each Cities and Nations

Figure 3 Variations of CO Emission



source: Statistics Bureau of Each Cities and Nations

Figure 4 Variations of CO2 Emission

In this research, the correlation of the Gini coefficient and the Moran's I is examined for the purpose of comprehending the relationship between the changing tendency of CO, CO2 emissions of the three cities in the past 10 years and the variation of urban form. As a result of the analysis, the correlation among the variables was at the level of 99%.

In the case of CO, the urban form index concerning population showed negative correlation(-0.874) with the Moran's I, and a positive correlation(0.923) with a Gini coefficient. Meanwhile, the urban form index concerning employment showed positive correlation (0.876) with the Moran's I, and a Gini coefficient (0.717) as well.

Taking the overall results of the analysis in the correlation between CO and urban form indexes into account, the following implications can be drawn out. Firstly, as it is shown in the relationship with the population Moran's I, while emission of CO may decrease in a more concentrated urban form, CO and Gini coefficient shares positive correlation, thus a higher tendency of decrease is presented in an urban form of concentrated population with lower Gini coefficient, in other words, an urban form that possesses an area where population is apparently concentrated yet not holding a significant difference in the degree of concentration from other area. Similarly, since the total emission of CO shares a positive correlation with both the Moran's I of employment and the Gini coefficient, there is a higher tendency of decrease in the emission where the compactness of distribution of the employment area is harder and the gap of concentration of employment with other area is broader. In the case of CO_2, similar to the tendency of CO, the urban form index related to population shares negative correlation with the Moran's I (-0.914), and a positive correlation with the Gini coefficient (0.909).

Also, the urban form index concerning employment shares positive correlation with both the Moran's I (0.677), and the Gini coefficient (0.812). In the analysis of correlation with urban form indexes, the difference that can be pointed out between CO and CO2, is that CO holds higher correlation with employment concerning the distinguishment among monocentric and polycentric urban form, while CO2 possessing higher correlation with population. It is perceived that such properties contain certain connection with the fact that CO emission is controlled approximately 80% by transportation and conveyance field and that 30~40% of CO2 emission come from conveyance field. To explain it analogically, lower level of CO emission can be possible in an urban form where the distance between the office and residence is close, which leads to lesser demand in vehicle usage in rush hour.

Linking this correlation among CO, CO2 and urban form indexes with the result of the previous analysis of distinguishing urban forms, the respective values of Moran's I of the three cities remain in the range not exceeding 0.1. Therefore, an urban form in which the emission of CO and CO2 decreases can be interpreted as a polycentric form where population is distributed relatively even over the entire city, and as a form with concentration of employment in monocentric or polycentric area.

		GE		*Moran*		*Gini*	
		CO	**CO_2**	**Pop**	**Emp**	**Pop**	**Emp**
GE	**CO**						
	CO_2	***0.81*** *					
Moran	**Pop.**	***-0.82*** *	***-0.91*** *				
	Emp.	***0.88*** *	***0.68*** *	***-0.64*** *			
Gini	**Pop.**	***0.92*** *	***0.91*** *	***-0.97*** *	***0.79*** *		
	Emp.	***0.72*** *	***0.81*** *	***-0.66*** *	***0.85*** *	***0.75*** *	

Table 1 Correlation between the Urban Form and Gas Emission Variables (N=30)

** indicates a significant correlation coefficient at the 0.01 level. GE stands for gas emission*

3. CONCLUSION

Concerning the reduction of air pollutants in urban area, there is a necessity to focus on the 'urban growth management', the concept which is being actively studied in recent researches. An inquiry about the connection of the variation of urban forms with air pollution and greenhouse gas emission was performed in this research. Implications on the future sustainable urban form drawn out from the result of this research may be summarized as follows.

First of all, as the result of assessment on three cities in different development phase respectively reveals, through the fact that improvement in CO and CO_2 emission in Tokyo is making a slow progress despite the tight urban compactness by reurbanization, a necessity for Seoul and Beijing to keep on the effort to establish polycentric urban form, which appears to be effective for reduction in CO and CO_2 emission can be underscored.

Secondly, for the purpose of establishing ecofriendly urban form that is effective for the reduction of air pollution and greenhouse gas emission, the development of a city is needed where the population is fairly distributed, employment is concentrated in the polycentric area, and the concentration level of these areas is higher than the adjacent.

Joint Research with RIHN

Makoto Kagabu

Kumamoto University

I'm Makoto Kagabu from Kumamoto University, Japan. I'm in the doctoral program in Science and Technology. My research subject is "to evaluate the groundwater flow system in Jakarta (Indonesia) and Kumamoto (Japan) area". Jakarta and Kumamoto has similar groundwater aquifer (volcanic origin), but these two cities have different developmental stages in terms of population, groundwater withdrawal, land-use and so on. This should cause the difference in groundwater flow system. To evaluate and compare groundwater flow system between both cities, environmental tracers such as δD, $\delta^{18}O$, ^{3}H, ^{14}C, CFCs and water quality will be effectively used. These tracers can determine local to regional scale groundwater flow system.

In the RIHN 2-4 FR Project Human Impacts on Urban Subsurface Environment, I'm member of the water subgroup. My main role in this subgroup is to evaluate groundwater residence time in Jakarta area by using three tracers (CFCs, Tritium and ^{14}C). These age tracers can determine not only natural groundwater flow system of the studied area but also to identify the human induced groundwater perturbation caused by the local groundwater consumption. In March 2008, I participated in the field researches in Jakarta. During this research, more than 55 samples were collected. Samples were analyzed at Kumamoto University's laboratory and groundwater flow ages were detected. The result will support more certain groundwater flow age compare with previous studies and will help to assess the effects of human activities on the subsurface environment.

I stayed in Bandung from February to March 2008 under the framework of Kumamoto University's PhD students training fund. During my staying there, Mr. Robert in LIPI (he is a member of our subgroup) took care of me and I communicated with members in there. It was a good experience for the motivation of my future studies.

ACKNOWLEDGMENT

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

Project 2-4 FR General Meeting

Kasumigaura, Japan

November 9-11, 2008

International Symposium IGS-TH 2009

On Efficient Groundwater Resources Management: The Challenge of Quantity and Quality for Sustain able Future

February 16-20, Thailand

Organized by

Department of Groundwater Resources

Ministry of Natural Resources and Environment

Call for Contributions

For the seventh volume (April 2009), we would like to request the following Groups/individuals to give their articles for the newsletter:

1. Prof. Yoshikoshi's Group
2. Prof. Fukuda's Group
3. Prof. Yamano's Group
4. Prof. Onodera's Group
5. Dr. Gayl D Ness
6. Dr. Vuthy
7. Dr. Shiraki

To allow ample time for editing and layouting, we hope to receive your articles on or before March 31, 2009. For inquiries, please send email to:

makoto@chikyu.ac.jp

Inter-University Research Institute Corporation

National Institutes for Humanities, Japan

Research Institute for Humanity and Nature

Project 2-4 Human Impacts on Urban Subsurface Environments

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Email: yamamoto@chikyu.ac.jp

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.

RIHN Corner

Keiko Yamamoto

Project Researcher

I have been working in RIHN since this April as a project researcher of Urban Subsurface Environments project. I entered Graduate School of Science, Kyoto University in 2002 and since then, I have mainly studied to recover temporally changing mass variation of the Earth using satellite gravity mission GRACE (Gravity Recovery and Climate Experiment) 's data sets. Since the launch in 2002, dedicated gravity satellite GRACE has provided monthly gravity field solutions with unprecedented accuracy. The mass variations derived from the gravity field solutions can be interpreted as geophysical signals accompanying mass movements, e.g. landwater, ocean flow, ice sheet mass change, and mass changes associated with an earthquake, etc. and can be utilized for these studies.

I previously used GRACE data for the study of ice sheet mass variations in Antarctica. Before the launch of GRACE, estimates of continental scale Antarctic ice-sheet mass balance yielded unsatisfactory results because of the lack of reliable data sets over large areas. Using GRACE data, it has been proved interannual mass trend of Antarctic ice sheet mass trend is decreasing at least in the last 5 years.

My tasks in this project is to study groundwater movement on and around the project areas using GRACE satellite gravity data. One of the most promising applications using GRACE data is the monitoring of landwater movements. Because GRACE observes vertical integration of the mass variations of the Earth, it can detect total landwater variations including groundwater variations, which is difficult to observe with other method especially in large scale. I would like to recover landwater signals of the project areas using GRACE data and separate groundwater components from other landwater components, e.g. river storage, soil moisture components etc. For the purpose, I would also like to utilize other satellite data sets , for example, satellite altimetry data, as well as in situ hydrological data.

Further, in this project, a new technique of precise gravity measurements combined with GPS positioning is performed by Gravity Group members for monitoring the local groundwater changes in project areas. However, the data of gravity measurements on land reflect not only the local water variation which is directly connected to the effects of urbanization, but also regional or global scale landwater variations. Therefore, for the purpose of detecting local groundwater variations by means of in-situ measurements, the monitoring of the background variations due to relatively larger scale landwater variation is indispensable. I and other Gravity Group members intend to use GRACE data to obtain an accurate knowledge of regional or relatively large scale landwater variations.