Urban Subsurface Environments

Newsletter Volume 7 April 2009

The full implementation of the project "Human Impacts on Urban Subsurface Environment" continues in 2009 and the project members have conducted field experiments, surveys and data gathering in the target cities.

Summary of the group activities of the Gravity, Heat, and Urban Geography groups and research results are featured in this volume of our project's newsletter. This issue also contains introduction of new method by Material Group, and foreign counterpart report by Prof. Gayl D. Ness.

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 fourth year of the Full Research (FR4). The domestic meeting on the USE project will be held on May 19 at Makuhari, Chiba, Japan, to discuss and integrate the project results.

Interim results of the USE project were successfully published in STOTEN (Science of the Total Environment, Elsevier). One overview paper and fifteen original papers were included in the special issue of the STOTEN Vol. 407, Issue 9.

See http://www.sciencedirect.com/science/journal/00489697

This year is extreme important for the USE project, because we will face the project evaluation on February 2010. We plan many field works and subgroup meeting, and we hope to integrate the whole results through this year to get final results and conclusion.

International conference of IAH/IAHS will be held on September 6 to 12 at Hyderabad, India. Several papers from USE project will be presented at sessions including "Trends and sustainability of groundwater in highly stressed aquifers (JS2)" and others.

Report from the Gravity Group: Groundwater and Land Subsidence Monitoring In Indonesia by Means of Absolute Gravity Measurements and Integrated Geodetic Methods

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1. Introduction

In many of the urbanized cities, in particular in Asian coastal areas, one of the urgent problems is land subsidence due to excess pumping of groundwater. In Jakarta, Indonesia, for instance, there are more than several tens of observation wells and the monitoring of the groundwater levels have been conducted so far. However it is not sufficient to understand the mechanism of the subsidence. To understand the mechanism and to monitor the variations of groundwater storages, we need additional information about groundwater mass variations as well as land movements which can be obtained by modern geodetic techniques. With this view, as a part of the RIHN project FR-2.4, the gravity group aims at establishing a new method to monitor the groundwater variation and land subsidence by means of precise gravity measurements combined with GPS, and InSAR techniques.

Although local hydrological variations crucially affect precise gravity measurements, for instance, superconducting gravity observations, and absolute gravity measurements, not many gravity related studies have been conducted to monitor groundwater variations or to investigate hydrologic problems. The basic principle of the gravimetry for the hydrological application is rather simple; the gravity changes due to groundwater mass movements are measured as gravity changes by means of precise gravimeters. An infinite water table of one meter thickness causes about a 40-µgal gravity change. Thus, an accuracy of 10 µgals (µgal = 10^{-8} meter/sec^2) or better is required for the hydrologic problems. It is not easy to achieve an accuracy of 10 µgals by means of a spring-type relative gravimeter, for instance Scintrex gravimeter. We therefore propose a new method to combine absolute gravity measurements and relative gravity measurements. For this purpose, we employ a portable absolute gravimeter A-10, for the measurements at some control points, and employ relative gravimeters of superior portability for the measurements at most points around the control points.

Because groundwater variations cause vertical land movements in many cases, it is also important to monitor the height changes at the gravity points. Moreover the rate of gravity changes versus height changes depends on the density of the material which causes the gravity changes, thus it gives important information about the mechanism of the deformation. Therefore we employ GPS measurements for monitoring height changes. We also employ InSAR images to increase the spatial resolution and to identify the areas of the subsidence occur. Fig. 1 shows the conceptual illustration of the combined method.

The first experimental measurements in Jakarta have been conducted in August 2008. The same measurements have been conducted in Bandung and Semarang subsequently. In these cities large land subsidence has been expected as well. Fig. 2 shows the location map of the cities. We employed A10 (#17) for the absolute measurements and a Schintrex gravimeter for the relative ones. Due to a vacuum problem of the A10, we could conduct only a few absolute measurements in each city. However, we have successfully obtained at least one absolute gravity value in each city. In addition, using the Schintrex meter, we occupied about 10 points in each city, which have been connected to the absolute points. These points will serve as a set of reference gravity points for future surveys. In this report we briefly describe the outline of the surveys.

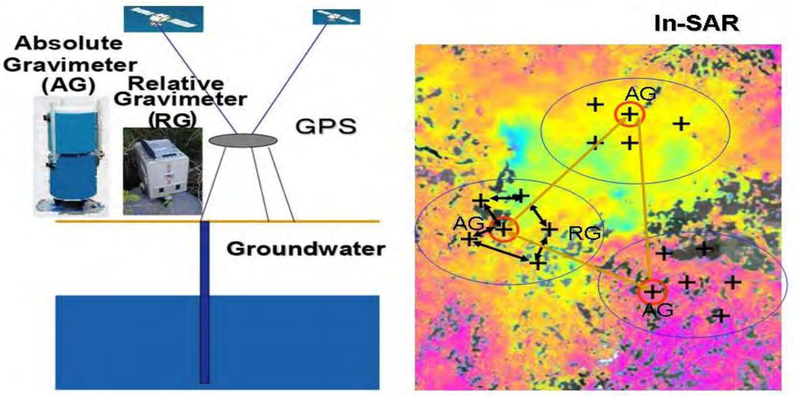


Fig. 1. Conceptual illustration of the combined method to monitor the groundwater variation and land subsidence by means of precise gravity measurements, GPS, and InSAR.

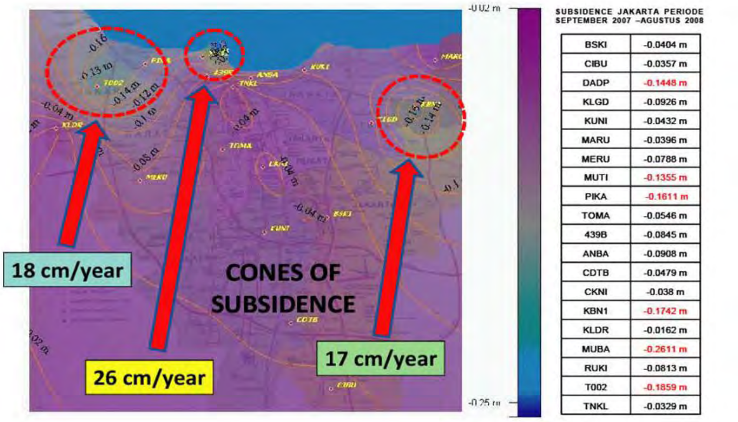
Fig. 2. Location map of the survey areas.

Research areas and the surveys

2.1 Jakarta

Jakarta is the capital city of Indonesia and is the largest city in Southeast Asia. It has a population of more than 10 million, covering an area of about 650 km^2. It is located on the lowland of the northern coast of the West Java Province. The area is relatively flat, with topographical slopes ranging between 0 ° and 2 ° in the northern and central parts, and between 0 ° and 5 ° in the southern part in which the altitude is about 50m above sea level. There are about 13 natural and artificial rivers which form the main drainage system of Jakarta.

The land subsidence in Jakarta was recognized in 1926. The repeated leveling measurements were conducted in the northern part of Jakarta (*e.g.* Schepers, 1926; Suharto, 1971), and the Local Mines Agency reported the subsidence rate of 20 to 200 cm over the period of 1982-1997. The GPS surveys started in 1990s (Abidin *et al.*, 2008a) also show the rate of more than 10 cm/year. Fig. 3 shows the subsidence obtained by the latest GPS surveys of Sep. 2007 and Aug. 2008.



SUBSIDENCE JAKARTA PERIODE
SEPTEMBER 2007 –AGUSTUS 2008

BSKI	-0.0404 m
CIBU	-0.0357 m
DADP	-0.1448 m
KLGD	-0.0926 m
KUNI	-0.0432 m
MARU	-0.0396 m
MERU	-0.0788 m
MUTI	-0.1355 m
PIKA	-0.1611 m
TOMA	-0.0546 m
439B	-0.0845 m
ANBA	-0.0908 m
CDTB	-0.0479 m
CKNI	-0.038 m
KBN1	-0.1742 m
KLDR	-0.0162 m
MUBA	-0.2611 m
RUKI	-0.0813 m
T002	-0.1859 m
TNKL	-0.0329 m

Fig. 3. The result of the GPS surveys Sep. 2007 and Aug. 2008 in Jakarta. The areas of large subsidence are indicated by red circles.

We conducted the gravity measurements during August 26th to 31st, 2008, coincided with the GPS campaign of this year. Referring to the GPS and InSAR results obtained so far, we selected the gravity points in the area of large subsidence and in the relatively stable area as well. Fig. 4 shows the gravity points on an InSAR image. The red flags show the absolute points and the white ones relative points. LIPI and KUNI locate at the stable area. We expect these points can be used as the references for future gravity changes. Fig. 5 shows a photo of the field absolute gravity measurements at KUNI. The A10 gravimeter can be transported by a tailgate mini-van and operated by 12 VDC batteries. The photo shows that it was installed on the GPS point (Bench mark).

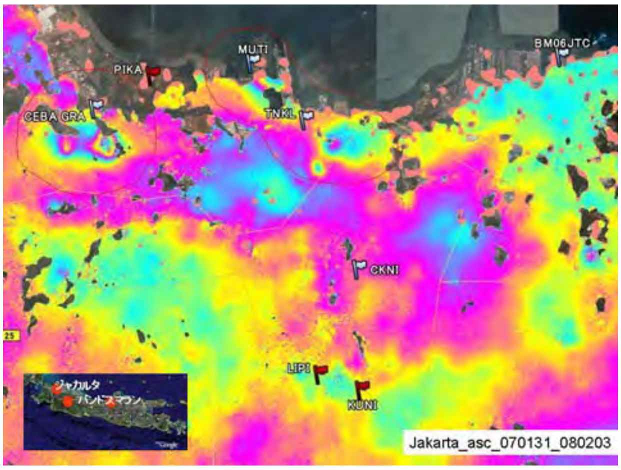


Fig. 4. Gravity points in Jakarta. The red flags show the absolute points and the white ones the relative points. The InSAR image is processed using PALSAR level 1.0 data and it shows the difference between Jan. 31, 2007 and Feb. 3, 2008.

Fig. 5. Field absolute gravity measurement at KUNI.

2.2 Semarang

Semarang is located at the north coast of Central Java covering about 400 km^2. It is the capital of Central Java province with a population about 1.4 million and is one of the five biggest cities in Indonesia. Fig. 6 shows a geological map of Semarang. As shown in this map, the geology of Semarang is characterized by the alluvial coast plain in the north and the basement hilly area in the south. Along the coastal area, it is said that muddy sedimentation occurred at least 500 years ago and the coastline progression has been still undergoing.

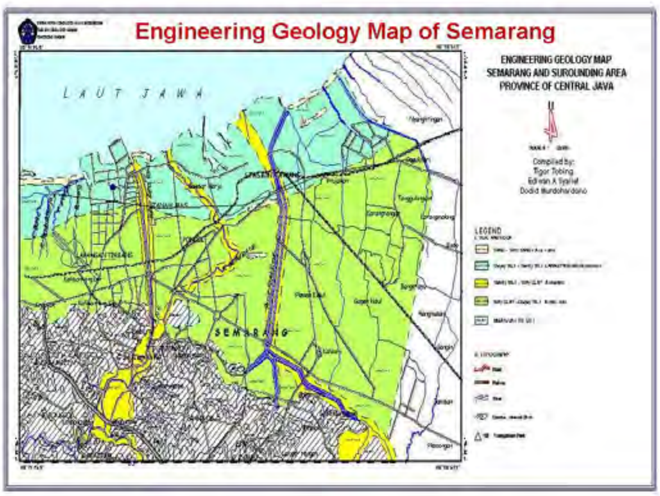


Fig. 6. A geological map of Semarang.

Fig. 7 shows the gravity points on an InSAR image. As shown in the InSAR image, the subsidence along the coast area is very large. The leveling survey conducted by the Geological Agency of Indonesia shows the rate of more than 8 cm/year over the period 2000-2001, while relative gravity surveys (Diharna, 2007, personal communication) shows the rate of more than 15 cm/year. Fig. 8 shows the photo images of the large subsidence in the coastal area. We conducted the first GPS campaign during July 6th to 13th and the gravity measurements during September 7th to 11th, 2008. Fig. 9 shows the absolute, relative gravity measurements and GPS survey at the reference point "SMG1".

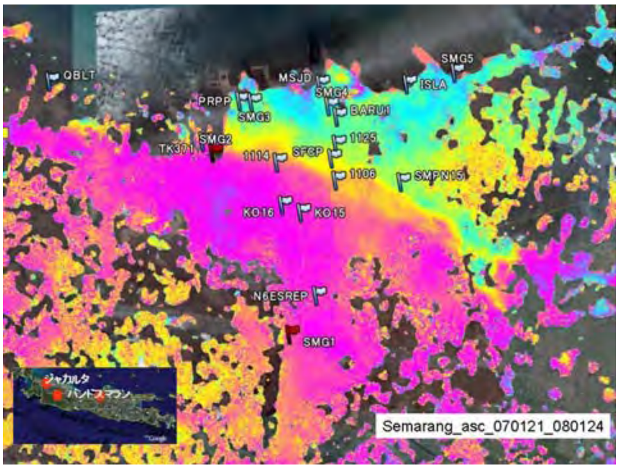


Fig. 7. Gravity points in Semarang. The red flags show the absolute points and the white ones the relative points. The InSAR image is processed using PALSAR level 1.0 data and it show the difference between Jan. 21, 2007 and Jan. 24, 2008.

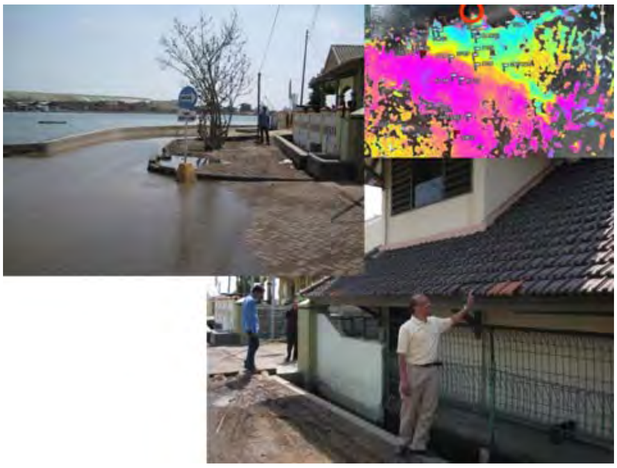


Fig. 8. Photos showing large subsidence along the coastal area. The red circle on the InSAR image shows the location of the photos.

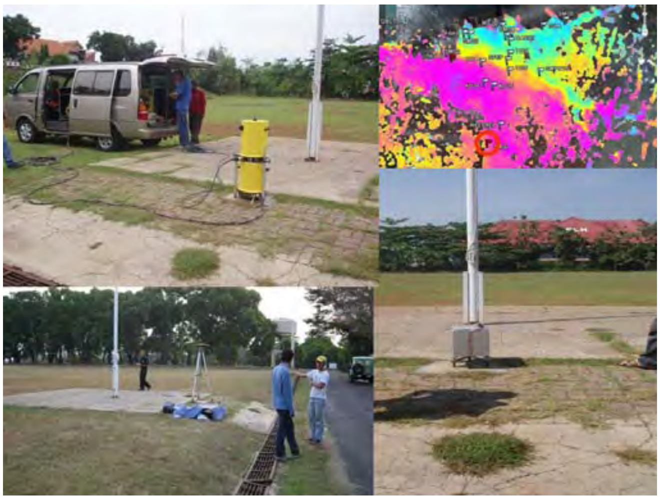


Fig. 9. The reference point for gravity and GPS surveys in Semarang.

2.3 Bandung

Bandung is the capital of West Java Province and has a population of about 2.5 million. It is surrounded by several medium sized towns which formed the Greater Bandung with a total population of about 3.5 million. The Greater Bandung lies in the catchment area of the upper Citarum river and is surrounded by range of hills and volcanoes. The central part of the basin, where most of which occupied by urban and industrial areas, is a plain about 40 km East-West and about 30 km North-South with an altitude about 700 m.

The GPS surveys have been conducted on Feb. 2000, Nov. 2002, July 2002, June 2003, and June 2005 (Abidin *et al.*, 2008b). In this period of about 5 years, land subsidence in a few locations reaches the amount of about 70 cm, with the speed of about 1-2 cm / month. In this year, the campaign GPS survey has been conducted during Aug. 20th-23rd, and the gravity measurements during Sep. 1st to 5th. Fig. 10 shows the gravity points in Bandung. These points are essentially selected from the GPS points.

There is the reference absolute gravity point in Bandung. Historically speaking, the first absolute gravity measurement in Indonesia was conducted at the geological museum in Bandung in November 2002 with a FG-5 absolute gravimeter (Fukuda *et al.*, 2004). The gravity value determined in 2002 was 977976701.2 µgal. This time, we conducted the absolute gravity measurements in front of the museum and made a gravity connection to the absolute point using a Scintrex gravimeter. Fig. 11 shows the photos of the gravity points. The newly obtained gravity value at the reference gravity point was 977976742.4 ± 10.6 µgal. Although there remains uncertainty about the vertical gravity gradient (dg/dz), the comparison shows the gravity increase of about 40 µgal for 6 years. This corresponds to the land subsidence of the rate about 2-3 cm/year, which is comparable with the GPS results.

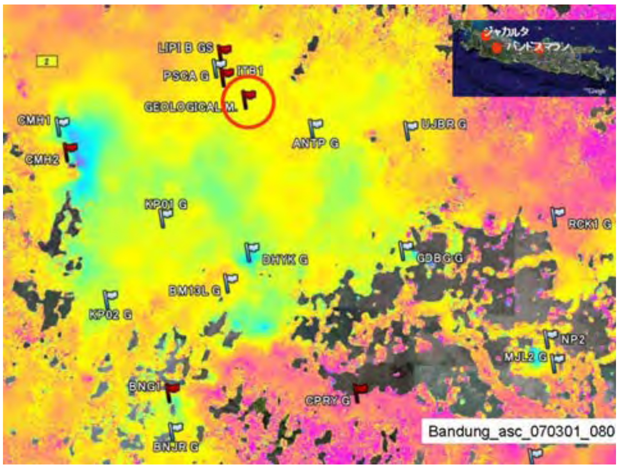


Fig. 10. Gravity points in Bandung. The red flags show the absolute points and the white ones the relative points. The InSAR image is processed using PALSAR level 1.0 data and it show the difference between Mar. 1, 2007 and Jan. 17, 2008.

Fig. 11. The absolute gravity points at the geological museum in Bandung.

Conclusion

For monitoring the groundwater variations and land subsidence at the 3 mega cities in Indonesia, we proposed a new method of integrated geodetic observation using absolute and relative gravity measurements combined with GPS and InSAR observations, and the first field gravity survey in Indonesia have been conducted in August - September, 2008. A key point of the gravity measurements is that an absolute gravimeter (A10-#017) has been employed. Relative gravimeters are usually employed for these studies because absolute gravimeters have not been widely used yet. However, relative measurements always include some uncertainties in interpretation processes. As shown in the gravity comparison in Bandung, absolute gravity measurements yield more accurate and unambiguous data which allow us direct comparison over many years.

Due to instrumental problems, the absolute gravity measurements were not so satisfactory and we have only obtained limited number of absolute gravity values. However it was the first filed survey in Indonesia and we learned many things in both technical and logistical point of view. We plan to conduct the second gravity measurements in July – August, 2009, and expect to reveal secular groundwater changes and associated land subsidence in these cities.

Acknowledgements

In addition to the project members, this study involved T. Higashi, S. Miyazaki, Y. Fukushima and S.Yoshii of Kyoto University, many students and colleagues of ITB and LIPI. We thank all those involved in the study. PALSAR level 1.0 data used in this study are shared among PIXEL (PALSAR Interferometry Consortium to Study our Evolving Land surface), and provided from JAXA under a cooperative research contract with ERI, Univ, Tokyo. The ownership of PALSAR data belongs to METI (Ministry of Economy, Trade and Industry) and JAXA.

References

Abidin H.Z., Andreas H., Djaja R., Darmawan D. and Gamal M. (2008a): Land subsidence characteristics of Jakarta between 1997 and 2005, as estimated using GPS surveys. GPS Solut., 12, 23-32, DOI 10.1007/s10291-007-0061-0.

Abidin H.Z., Andreas H., Gamal M., Wirakusumah A. D., Darmawan D., Deguchi T. and Murayama Y. (2008b): Land subsidence characteristics of the Bandung Basin, Indonesia, as estimated from GPS and InSAR. Journal of Applied Geodesy 2, 167-177, DOI 10.1515/JAG.2008.019.

Fukuda Y., Higashi T., Takemoto S, Abe M., Dwipa S., Kusuma D. S., Andan A., Doi K., Imanishi Y. and Arduino G. (2004): The first absolute gravity measurements in Indonesia, J. Geodynamics, 38, 489-501.

Schepers J. H. G. (1926): De Primaire Kringen Ia En II, Benevens Het Stadsnet Van Batavia En Weltevreden, No.1 De Nauwkeurrig-heidswaterpassing Van Java. Topografische Dienst In Neder-lansch-Indie.Weltevreden Reproductiebedrifj Top. Dienst

Soekardi P., Djaeni A., Soefner, H., Hobler M. and Schmidt G. (1986): Geological aspect of the aquifer system and the ground water situation of the Jakarta Artesian Basin. Paper presented at seminar on geological mapping in the urban development, economic and social commission for Asia and the Pacific, Bangkok, 29 October.

Soetrisno S., Satrio H. and Haryadi T. (1997): To anticipate impacts of reclamation of Jakarta Bay, a groundwater conservation's perspective. Paper presented at workshop on coastal and near shore geological/oceanographical assessment of Jakarta Bay: a basis for coastal zone management and development, Jakarta, 25–28, June.

Suharto P. (1971): Precise leveling in Indonesia. Final undergraduate report. Department of Geodetic Engineering. Institute of Technology, Bandung.

Report from the Heat Group

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The Heat Group has been studying subsurface thermal anomalies in and around the target cities mainly though repeated measurements of temperature profiles in boreholes and long-term monitoring of temperature at shallow depths. The obtained data are being analyzed for reconstruction of histories of the ground surface temperature (GST) and the subsurface thermal environment.

Borehole temperature profiles

Since 2004, we have conducted temperature profile measurements in boreholes in Seoul, Taipei, Bangkok, Jakarta and their surrounding areas (Fig. 1). The total number of measurement sites is 112 as of March 2009 (14, 27, 45, and 26 in the Seoul, Taipei, Bangkok, and Jakarta areas, respectively). Most of the holes are groundwater monitoring wells (Fig. 2) and the depths are generally 100 to 250 m.

Fig. 1. Temperature profile measurement in an observation well in front of a baseball park in the vicinity of Taipei city.

Many of the measured profiles are, however, not suitable for analysis since the temperature profiles were disturbed by groundwater flow. Some profiles were obviously distorted and others were found to be unstable through repeated logging at time intervals of one to two years. After eliminating such disturbed profiles, we attempted reconstruction of the GST history in the past several hundred years using a multi-layer model in which variation of thermal conductivity with depth is taken into account.

In the Bangkok area, GST histories reconstructed at six stations show that the amount of surface warming during the last century varies by site, probably reflecting the influence of urbanization on the thermal environment on the ground, e.g., changes in surface air temperature and land use (Fig. 3). In some of the target cities, Seoul, Tokyo, and Osaka, we have not obtained temperature profiles of good quality in the USE project. We intend to analyze the existing temperature profile data in these cities, including profiles measured in the 1990s.

Fig. 2. Groundwater monitoring well located in a sugar cane field in the western part of Taiwan.

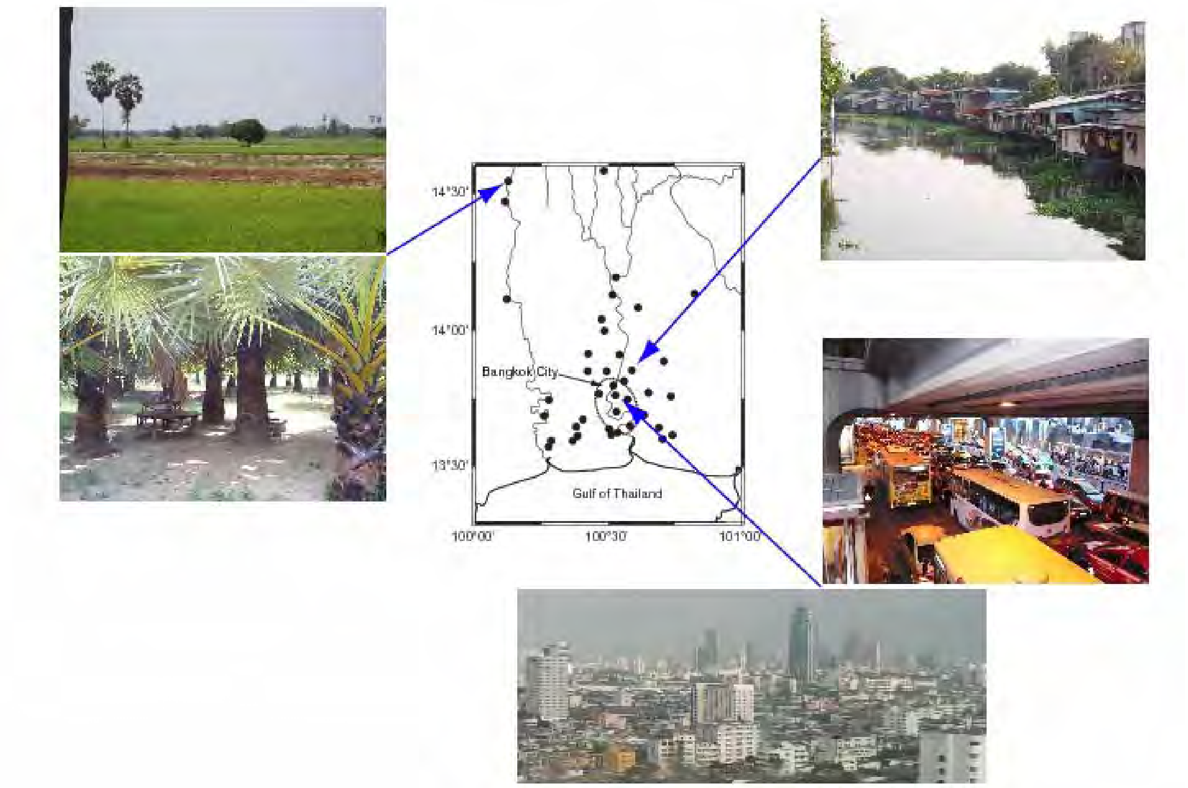

Fig. 3. Differences in environment on the ground surface among temperature measurement sites (closed circles) in the Bangkok area.

Ground heat gain

Surface warming due to global climate change and/or urbanization results in temperature rise in formations beneath the ground surface, or increase of the heat content of the ground (Fig. 4). This heat gain represents absorption of thermal energy by the ground, which should be closely related to the thermal environment above the ground as well.

Increase of the heat content by surface warming can be calculated by integrating the temperature difference between the disturbed and undisturbed temperature profiles multiplied by the heat capacity (Fig. 4). At sites where GST history reconstruction was made, we can estimate how the heat content has changed with time using temperature profiles at various times calculated from the GST histories. The amount of heat stored after a certain reference time (e.g., the year of 1900) may be used as an indicator of evolution of the subsurface thermal environment.

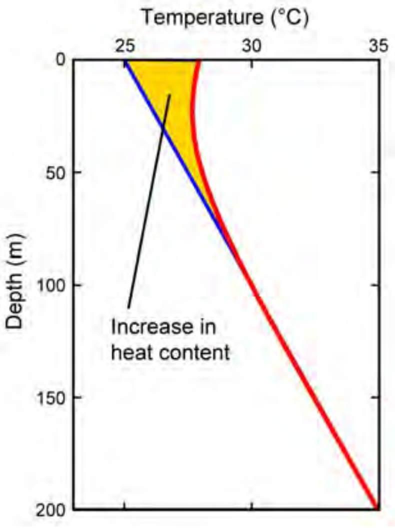

Fig. 4. Integral of the temperature difference between the profile disturbed by surface warming (red) and the undisturbed profile (blue) gives increase in the heat content of the ground.

Long-term temperature monitoring

We have been monitoring borehole temperatures and soil temperatures at selected sites in the Taipei, Bangkok, and Jakarta areas to investigate downward propagation of temporal variation in the GST. Fig. 5 shows temperature records for about 1.5 years obtained in an observation well in the Taipei metropolitan area. Temperatures at three depths, 29 m, 34 m, and 39 m below the ground surface, steadily increased throughout the monitoring period. Part of the observed increase may be attributed to the GST variation in the past.

In a borehole located on the coast of Lake Biwa, Japan, we installed a temperature monitoring system with 10 sensors at 15 m to 130 m below the surface in 2006. After fixing some problems with the system, we could start to obtain temperature records of good quality (Fig. 6). The temperature at 15 m clearly shows annual variation superposed on an increasing trend. An annual component with a smaller amplitude can be recognized at 20 m as well. Combining them with the temperature record at the surface (Fig. 6), we can analyze the vertical heat transfer process through formations around the borehole.

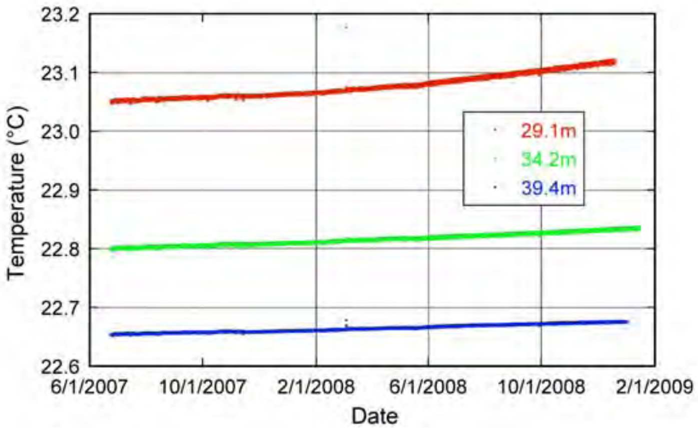

Fig. 5. Long-term temperature records in a well in the Taipei metropolitan area.

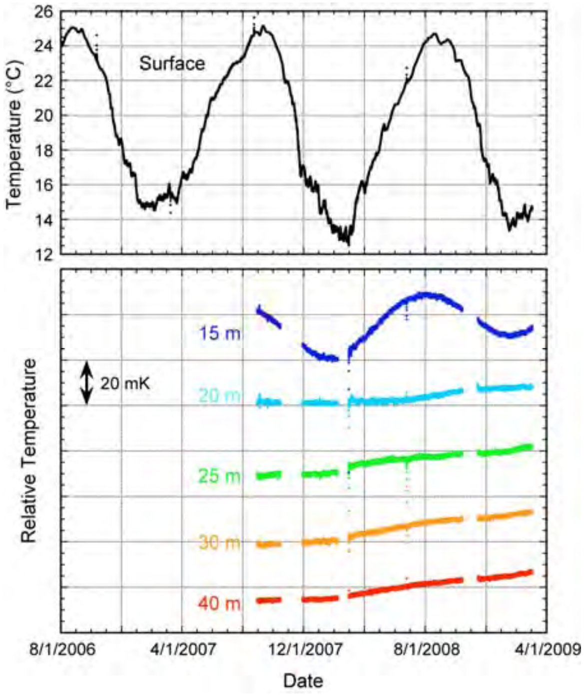

Fig. 6. Long-term temperature records in a borehole and at the surface on the coast of Lake Biwa, Japan.

Studies of the subsurface thermal environment in the Tokyo metropolitan area

–Urban Subsurface heat island–

Akinobu Miyakoshi

Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology

Information on three-dimensional subsurface temperature distribution and its change were examined through measurements of temperature-depth profiles in observation wells in 2001-2002, 2005-2006, and 2007-2008 by Geological Survey of Japan, AIST (National Institute of Advanced Industrial Science and Technology) to evaluate the subsurface thermal environment in the Tokyo metropolitan area (Fig. 1). AIST has also conducted long-term temperature monitoring since 2007 at four stations in Saitama Prefecture. These measurements in the Tokyo Metropolis and Saitama Prefecture were conducted as cooperative studies of Civil Engineering Center, Tokyo Metropolitan Government and AIST, Center for Environmental Science in Saitama, Akita University and AIST, respectively. Part of the temperature data has been published (e.g., Miyakoshi et al, 2008a), and we are using it for analysis of the subsurface thermal environment in the USE project.

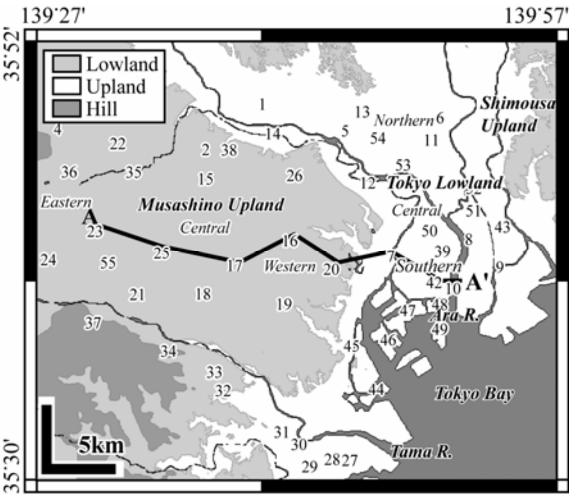

Fig. 1 Study area.

Fig. 2 shows regional subsurface temperature distribution in the study area (Miyakoshi et al., 2008b). The temperature distribution pattern changes with depth. At the depth of 50 m, high temperatures extend from the eastern part of the Upland to the Lowland, and low temperatures are distributed in the central to western part of the Upland. At the depth of 100 m, high temperatures are found only in the central part of the Lowland, and the low temperatures area is wider than at 50 m.

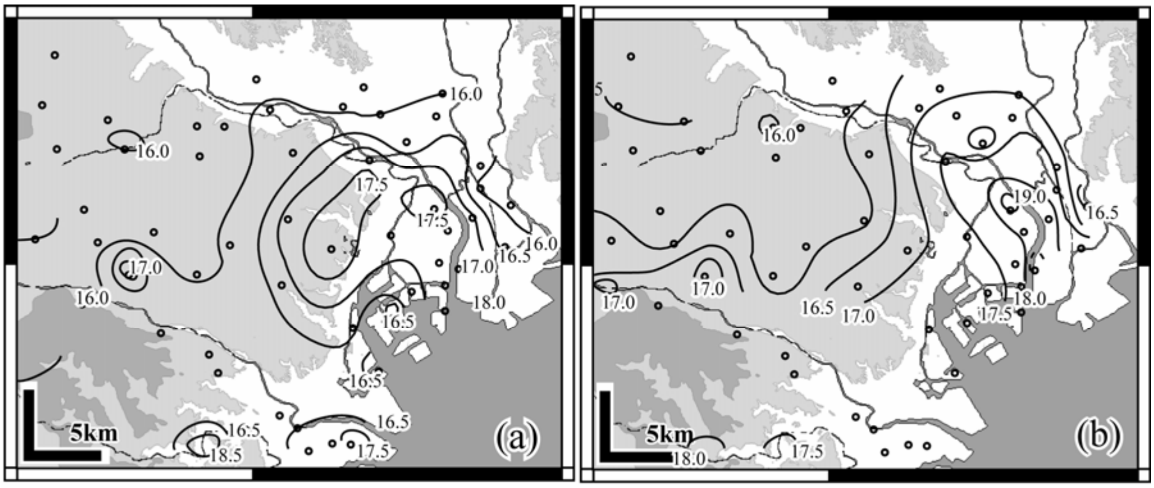

Fig. 2 Distribution of subsurface temperature at the depths of 50 m (a) and 100 m (b).

Fig. 3 is the land-use map of the study area in 1994. Comparison with the distribution of subsurface temperature (Fig. 2) shows that the high temperature area at 50 m corresponds to the urban area. It suggests the existence of urban subsurface heat island phenomena, the center of which is located around the eastern part of the Upland, in the subsurface environment of the Tokyo metropolitan area. Below the depth of 100 m, the high temperature area shifts to the central part of the Lowland. The bottom of permeable layers is relatively shallow in the central part of the Lowland, indicating that the high temperatures at deeper part were formed not only by the effect of ground surface warming but also by heat advection due to upward groundwater flow under the effect of pumping (Miyakoshi et al., 2008b).

Subsurface warming results in a minimum in temperature-depth profile, and the distribution of depths of the temperature minimums is shown in Fig. 3. In the Musashino Upland, depths of the minimums are deeper than in the Lowland. Effect of ground surface warming has reached deeper in the central-western part of the Upland probably due to downward groundwater flow, though the amount of surface warming is smaller. Groundwater has been pumped, and hydraulic heads are still low at the pumping depths in this suburban area. Moreover, ground surfaces have been unpaved in most part of the area, inducing groundwater recharge.

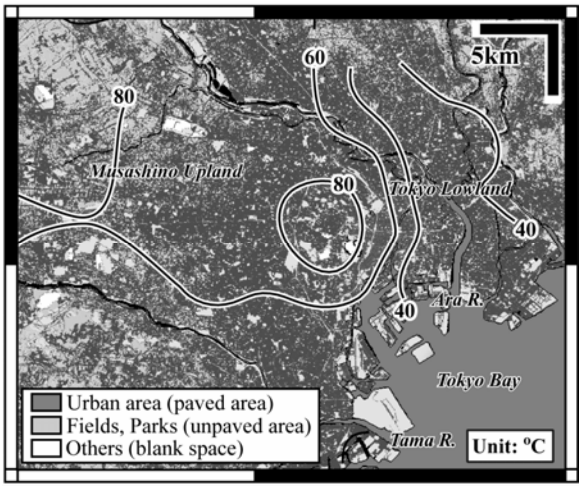

Fig. 3 Land use map (after GSI, 1994) and distribution of minimum temperature depths.

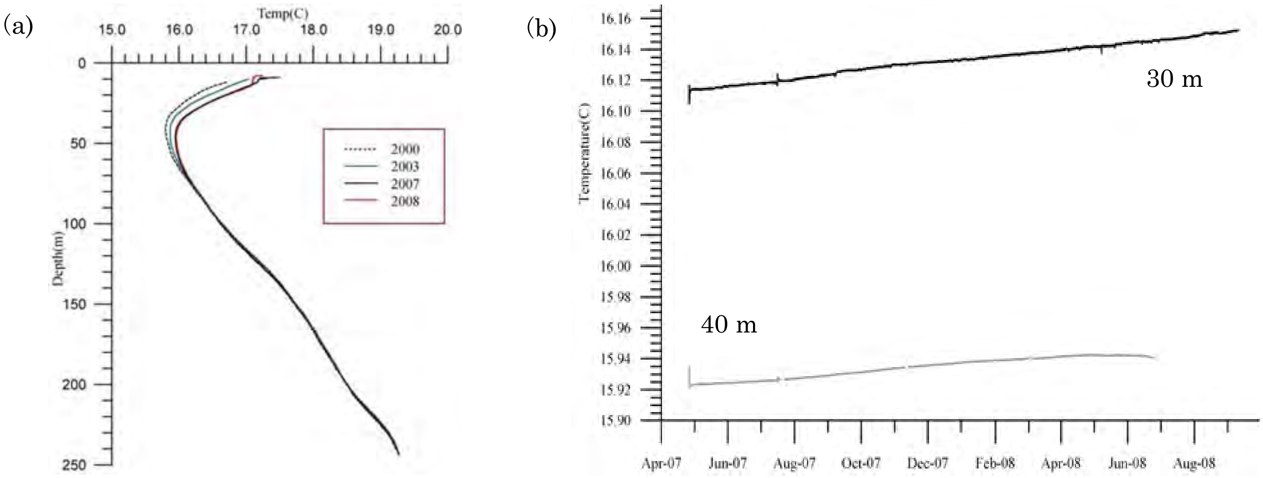

Fig. 4 (a) Temperature-depth profiles at #5 in 2000, 2003, 2007 and 2008, (b) Long-term temperature records at #5.

Fig. 4 shows temperature-depth profiles at the well #5 (Saitama Prefecture) and subsurface temperature change at the depth of 30 m and 40 m (Miyakoshi et al., 2009). Comparison of temperature-depth profiles shows warming of 0.2 K at 30 m from 2000 to 2008. Long-term monitoring results also show warming at a rate of 0.025 K/year at the same depth. They strongly indicate progressive warming in the subsurface environment. Fig. 5 shows temperature-depth profiles at the well #23 in the periphery of the urban area (Miyakoshi et al., 2008b). Subsurface warming is found above 120 m depth, and the warming rate from 2001 to 2005 is higher than that from 1991 to 2001. The depth which the effect of surface warming had reached became deeper from 1991 to 2005. These observations suggest that subsurface temperatures in relatively shallow part have been rising and the urban subsurface heat island phenomena have been expanding in the Tokyo metropolitan area. The subsurface thermal environment is highly variable with depth and location due to the effects of human activity.

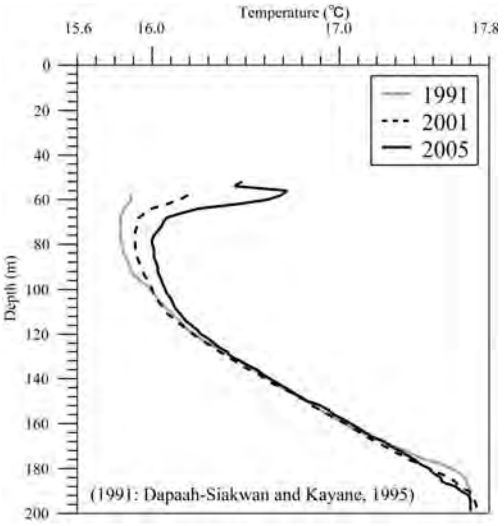

Fig. 5 Temperature-depth profiles at #23 in 1991 (Dapaah-Siakwan and Kayane, 1995), 2001 and 2005.

References

Dapaah-Siakwan, S. and Kayane, I. (1995) Estimation of vertical groundwater and heat flux in the semi-confined aquifers in Tokyo metropolitan area, Japan. Hydrological Processes, 9:143-160.

Miyakoshi, A., Hayashi, T., Monyrath, V., Lubis, R. F. and Sakura, Y. (2008a) Subsurface thermal environment change due to artificial effects in the Tokyo metropolitan area, Japan, in "From Headwaters to the Ocean: Hydrological Changes and Watershed Management", M. Taniguchi, W.C. Burnett, Y. Fukushima, M. Haigh, and Y. Umezawa (eds.), 547-552, Taylor & Francis Group, London.

Miyakoshi, A., Hayashi, T., Marui, A., Sakura Y., Kawashima, S. and Kawai, M. (2008b) Evaluation of change in subsurface thermal environment due to groundwater flow in the Tokyo Lowland, Japan, International Journal of Earth Science, 97:401-411.

Miyakoshi, A., Hayashi, T., Kawashima, S., Kawai, M. and Hachinohe, S. (2009) Change in groundwater and subsurface thermal environment in the Tokyo metropolitan area. Japan Geoscience Union Meeting 2009, Chiba (in press).

Urban heat islands and urban development in Taipei

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As economic development, urbanization and population growth continue in Asian mega- cities, the urban heat island (“UHI”) phenomenon has often been attributed to causing severe environmental problems in large cities, such as energy shortage, air pollution, and deterioration of living conditions. However, UHI researches in large cities in the tropical and subtropical regions are rare. The needs to document and predict UHI in the low- and mid- latitude cities, in order to find effective methods to mitigate the impact of UHI and shed light on the urban development issues for the local government, are acute .

In this report, the Urban Geography sub-group presents a brief summary of fieldwork surveys in Taipei and the results of UHI observation in 2008.

Summary of Taipei Metropolitan Field Surveys

Taipei city with 2.616 million populations (2006) has advanced at an unprecedented pace in urban expansion over the past few decades. This has caused the annual mean temperature has increased (Fig. 1). Furthermore, during 1970-2008, the monthly mean temperature in both the maximum temperature and the minimum temperature in July (the warmest month) has risen over 0.5℃(Fig. 2). Recently in particular, the number of days that minimum temperature is less than 10℃ has been decreasing (Fig. 3). At the same time, the mean annual precipitation has not decreased (Fig. 4).

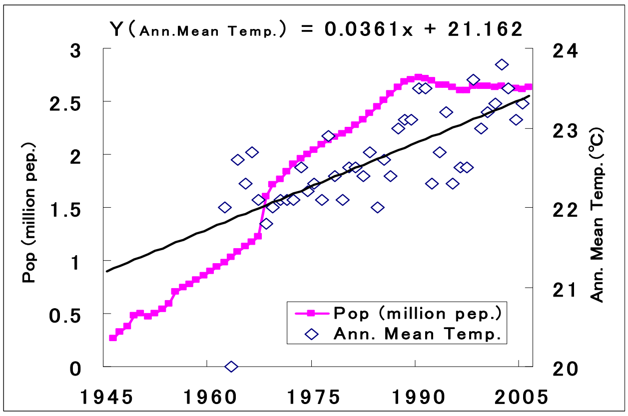


Fig. 1 Relationship between Ann.Mean Temp. and the increase of population (1945-2006)

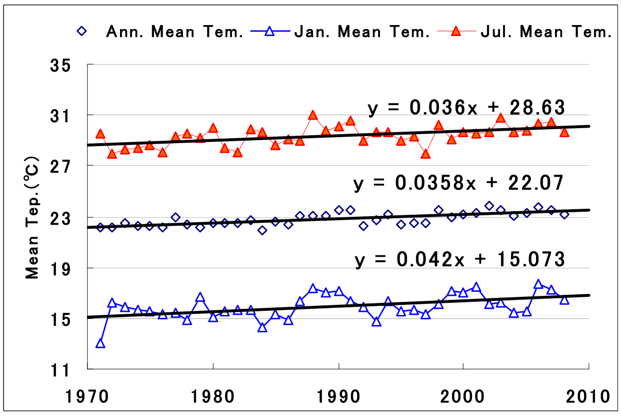


Fig. 2 Long term trend of Ann. Mean Temp., Jan. Temp. and Jul. Temp. (1970-2008)

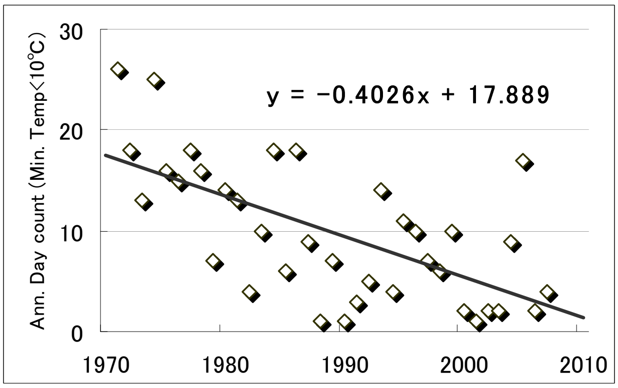


Fig. 3 Long term trend of the number of days (Min. Temp.<10℃, 1970-2008)

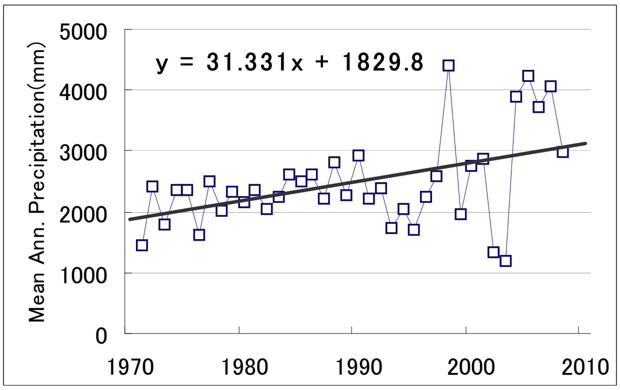


Fig. 4 Long term trend of Mean Ann. Precipitation (1970-2008)

The population in Taipei city(10 districts) was 1,199 million people in1967. Since Neihu, Nangang, Muzha, Jingmei, Shilin and Beitou were incorporated into the city jurisdiction in 1968, Taipei City ruled over 16 districts, so that the population incrased to 1.56 million people. In 1990, the entire city was demarcated in 12 administrative districts, and the population became 2.63 million people.

Before 1990, population growth had been continual. From 1991 on ward, a reverse trend was found with the exception of 1994, 1998, 1999, 2000, 2002 and 2006, which were on the growth. Over those years, the negative growth due to social increase went beyond the growth of natural increase, which resulted in the negative of population (Fig. 5). Meanwhile, Fig. 5 shows that the population growth has been continual in the satellite cities around Taipei City. So, the area where encompasses Taipei City and its satellite cities is an attractive region for studying urban development. There are several reasons. First, the area is the most densely populated area in Taiwan. In just 35 years (1981-2006), the area's population increased 106.23%, from 4.2 million to 8.7 million, which is equivalent to one-third of the total population of Taiwan. Urbanization has been extensive, occurring along the North-South transportation corridors and resulting in uncontrolled urban sprawl. Second, the region has been become more urban in character while the Taipei Rapid System has emerged as an in dispensable mean of transportation for the public from 1996. Now, the rapid transit network (as of the end of 2007, there were 8 operation routes) covers Taipei City and its satellite cities, so that the region can be considered as "Taipei metropolitan".

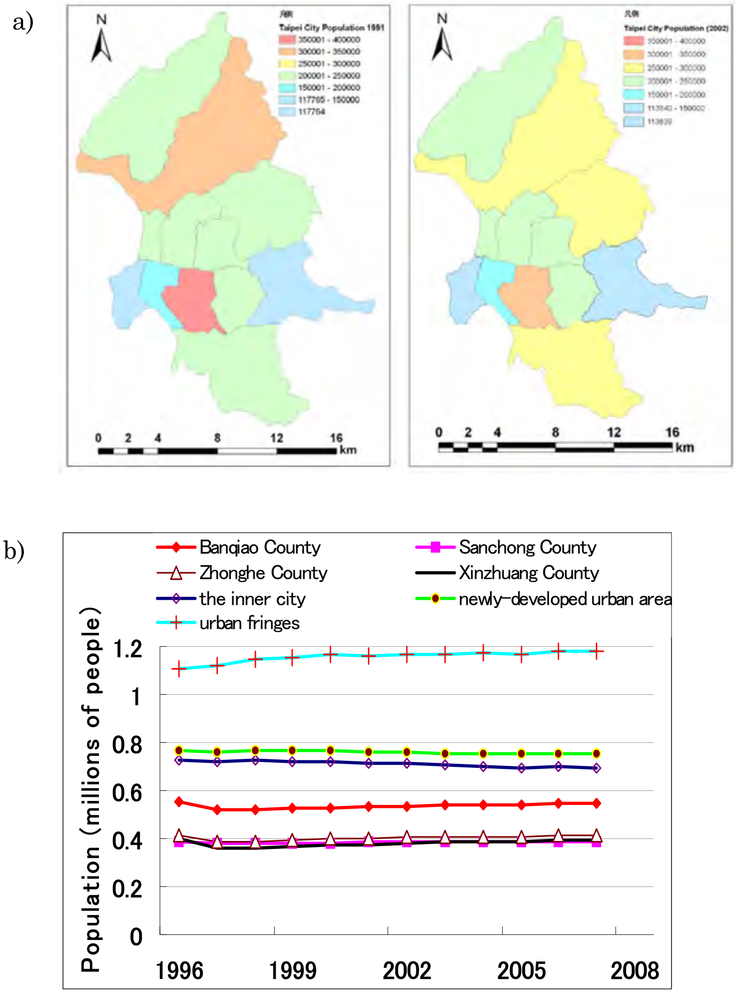


Fig. 5 a) Population mobility within the districts of Taipei City (1991 and 2008)

b) The growth of population in Taipei City and its satellite cities (1996-2008)

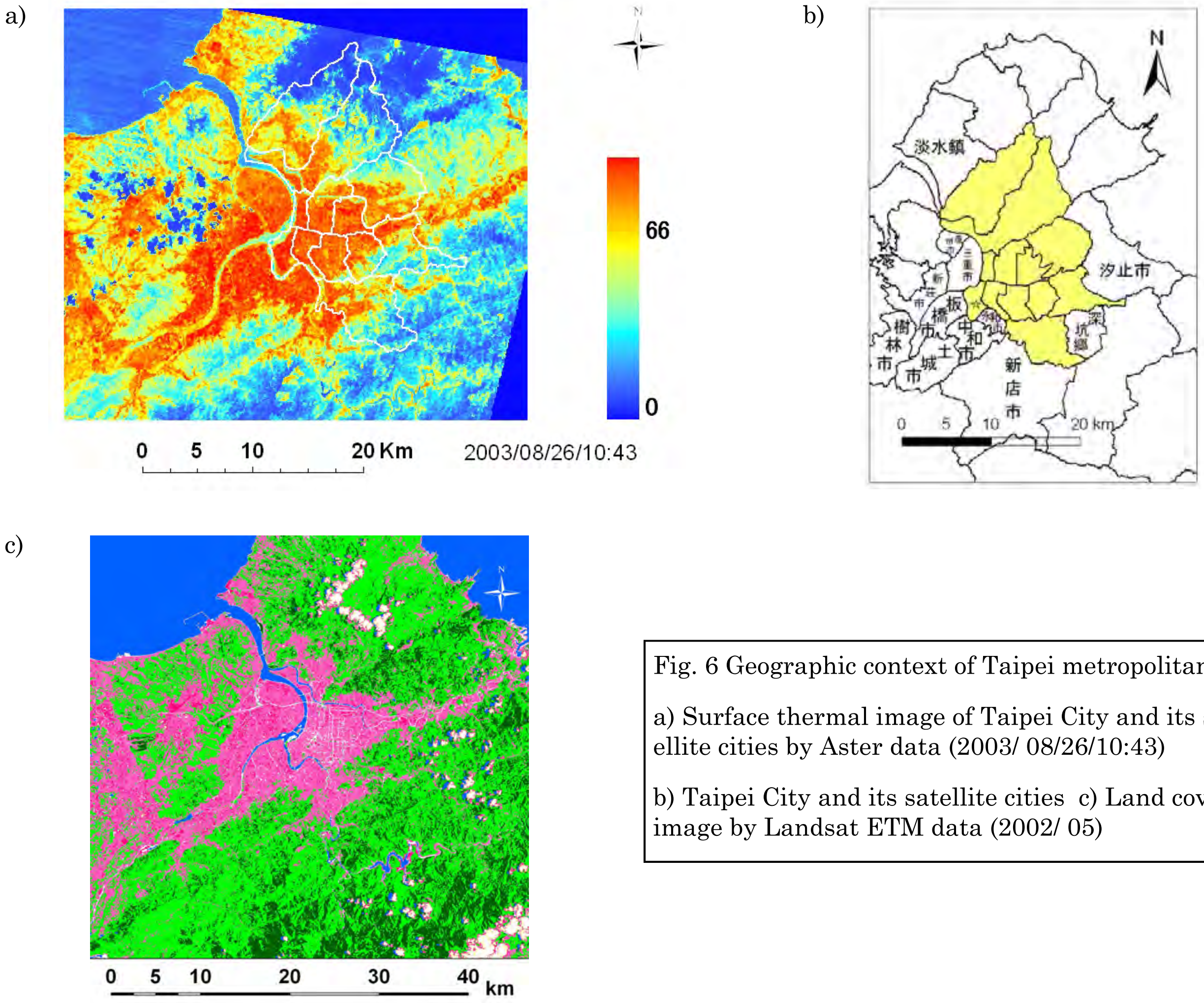


Fig. 6 Geographic context of Taipei metropolitan

a) Surface thermal image of Taipei City and its satellite cities by Aster data (2003/ 08/26/10:43)

b) Taipei City and its satellite cities c) Land cover image by Landsat ETM data (2002/ 05)

Results of UHI Observation in 2008

Through international collaboration, we established automated observation systems (thermal recorder installation, Fig. 7) and collected the first-hand climatic data from Taipei to characterize UHIs form Oct. 2008 (Fig. 8). The paper presents several findings on the UHI formation mechanism in Taipei.

The results of field observation in 2008 proved that the maximum temperature difference was over 2℃ during nighttime between the inner city and the suburb on Oct-Dec 2008(Fig. 9). In particular, the temperature difference continued until before the sunrise. It was also cleared up by the observation data that the temperature difference between the inner city and the satellite cities was little during nighttime. That means the inner city and satellite cities become an expanding high-temperature region in cloudless night. It was revealed by satellite images (Fig.6 a)). From these results, it showed that the distribution of resident population was obviously responsible for the “urban heat island effect”. In additions, the air temperature distribution in a concentric pattern from the inner city was recognized.

Fig. 7 Thermal recorder installation

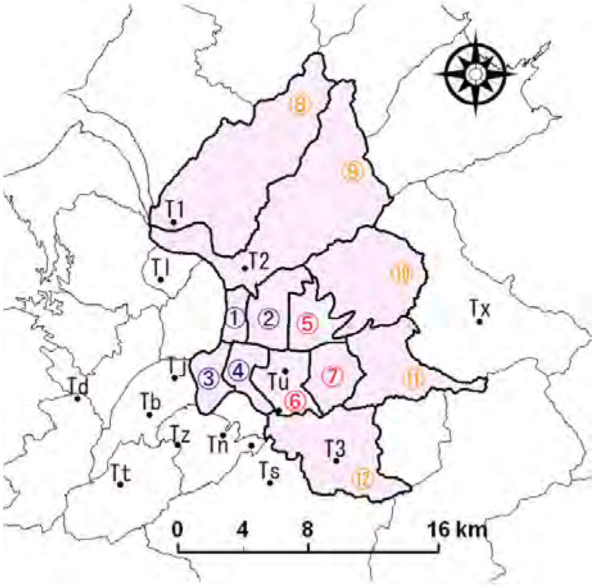
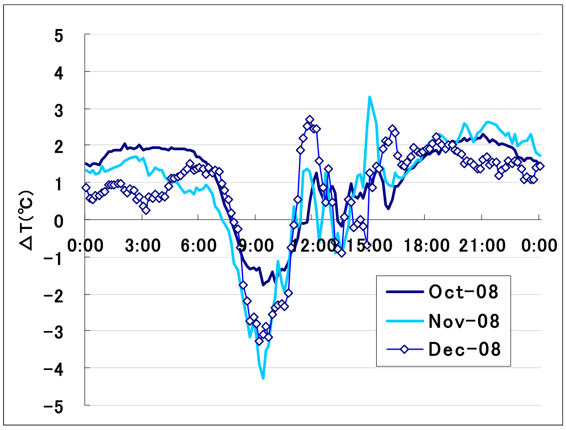


Fig. 8 Location of thermal recorder installation



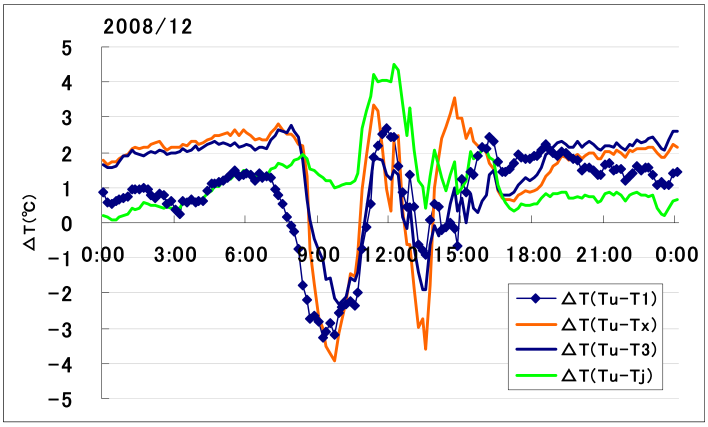


Fig. 9 Temperature difference between the inner city and suburb

Fig. 10 Changes of temperature difference between the inner city and its surrounding area

Introduction of Analysis System for Dissolved Gases in Groundwater

Shin-ichi Onodera

Graduate school of Integrated Arts and Sciences, Hiroshima University, Japan

Introduction

Nitrate contamination in groundwater occurs at various megacities as well as in agricultural area (Burt et al., 1993). For confirming the groundwater pollution at the megacities in various developing stage, we need to investigate the contaminant intensity such as the accumulation content. But nitrate is reactive in groundwater and total nitrate input to groundwater does not correspond with the accumulated nitrate content. The reaction of nitrate in groundwater is mainly denitrification under the reduction condition and nitrification under the oxidation condition, and former is the reaction from nitrate to nitrogen gas and later is from ammonium to nitrate, respectively. Therefore it is necessary to reconstruct the initial nitrate concentration at the groundwater recharge, using the dissolved nitrogen gas and nitrogen ion concentration.

One of the objectives in Material Group is to confirm the contamination intensity at the mega-cities with various developing stage. Nitrate pollution is also main target. In the previous studies (Blicher-Mathiesen et al., 1998; Bölke et al., 2002), the analysis of dissolved nitrogen gas and its application to denitrification research has been reported. In general, the ratio of N_2 and Ar in recharge water to groundwater is same as that of the air. And the solubility of gases varies as a function of temperature. If denitrification occurs in groundwater, dissolved N_2 increases. Such excess gas concentration means denitrification amount. In this research project, our group will examine the nitrogen cycle process in groundwater and confirm the pollution intensity, using the dissolved nitrogen gas and nitrate concentration in groundwater. Then, the analysis system for dissolved gases is built up by Nisshin-seiki co. and Onodera Lab., using examples of USGS system (USGS, 2008) and Yoh system (Yoh et al., 1998). It is installed in the laboratory of Hiroshima University now. In this newsletter, I want to introduce the general aspect of it and the example of analyzed data.

General Aspect of the System

The method of water collection and sample pre-treatment are same as it in USGS (2008). The analytical method of dissolved gases is the head space method by the gas chromatography such as Yoh et al. (1998) and USGS (2008). The sample bottle is used a 125cc glass bottle, and the head space of 10cc is made by the displacement with the helium, using syringe. The head space gas is assumed to be equilibrium to dissolved gas more than 24 hours. After 24 hours since the head space setting, the gas is injected into the analytical system. The overview of this system is shown in Photo 1 and Fig.1. The carrier gas is helium. Two type of standard gas are N_2 of 77.89%, Ar of 2.01% and 21.1% of O_2 and N_2 of 87.9%, Ar of 1.01% and 10.1% of O_2, respectively.

Photo 1 Overview of the analytical system. Injection and separation line of the gas (left), gas chromatogram (right), sample bottles and chromate pack (former).

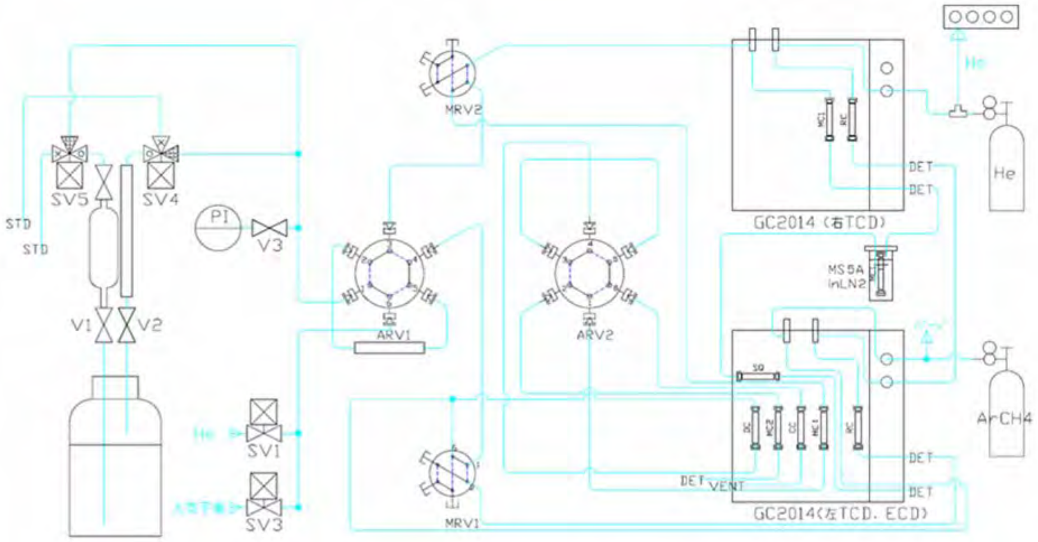


Fig. 1 Schematic diagram of the analytical system. Injection (left) and separation (middle) line of the gas, and gas chromatogram (right).

Example of Standard Gas Analysis

Fig. 2 shows one example of relationship between the chromatographic peak area and dissolved gas concentration of standard samples. This analysis had enough accuracy. However, the stability of standard analysis is still not enough. We are improving the arrangement system of the standard samples and the head space.

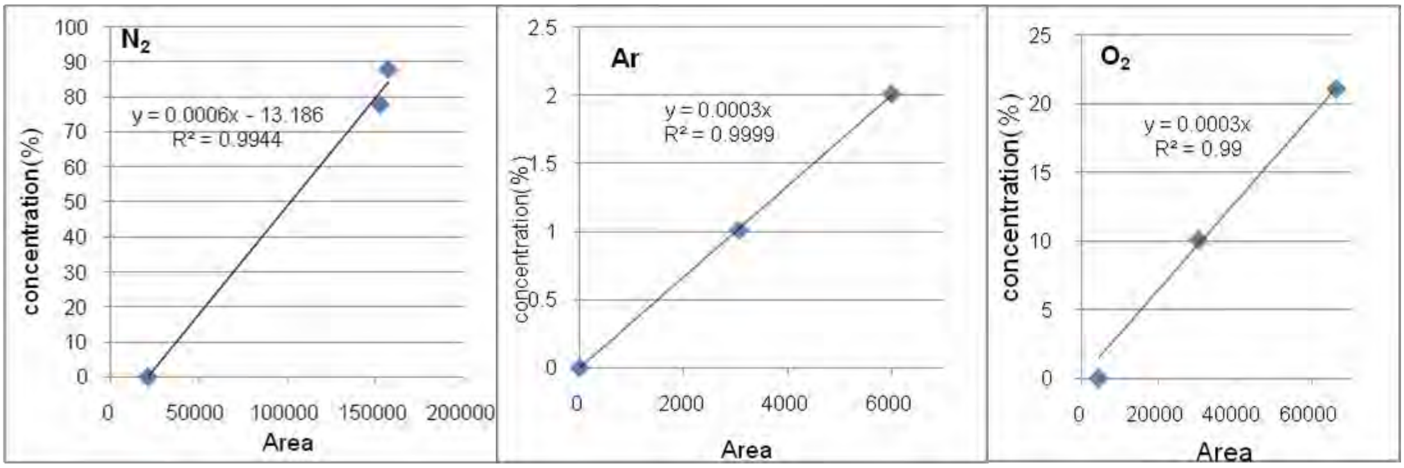


Fig. 2 The example of relationship between the chromatographic peak area and dissolved gas concentration of standard samples.

Methodology for Reconstructing the History of Contamination

Dissolved nitrogen and argon gas concentrations are useful to reconstruct the contamination history, such as the history of fertilizer application and industrial waste (Blicher-Mathiesen et al., 1998). Under the anoxic condition such as groundwater discharge area and deeper layer, denitrification ($NO_3^- \rightarrow N_2$) occurs. In this reaction, N_2 concentration increases against decrease of nitrate concentration. This means that the concentration of dissolved N_2 gas depends on initial NO_3^- concentration. This suggests that initial NO_3^- concentration in groundwater can be estimated by using dissolved N_2 gas concentration.

Fig.3 shows the relationships between dissolved N_2 and Ar gas concentrations in groundwater (Bölke et al., 2002). N_2 concentrations are higher in suboxic groundwater than oxic ones. This result suggests denitrification. This also indicates that N_2 and Ar ratio suggests initial concentrations of NO_3^- in groundwater. If we will get the residence time information of groundwater at the same time by using various methods, we can reconstruct the history of nitrate contamination in groundwater.

We had already collected the water samples at the various cities. After establishing the stability of standard analysis, we will analyze those.

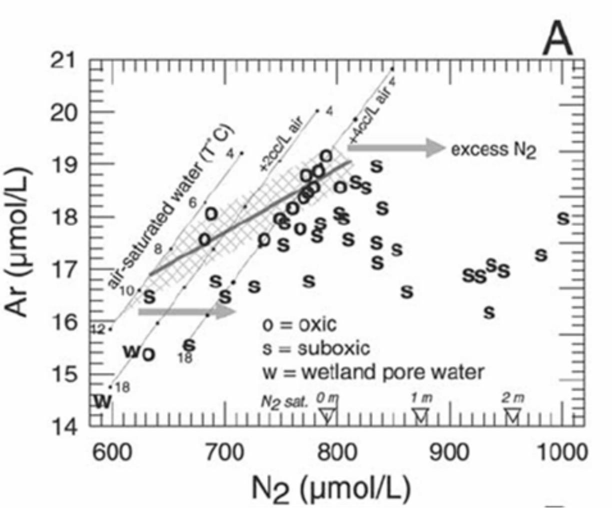


Fig.3 relationships between dissolved N_2 and Ar gas concentrations in groundwater (Bölke et al., 2002).

References

Blicher-Mathiesen, G., McCarty, G.W. and Nielsen, L.P. (1998): Denitrification and degassing in groundwater estimated from dissolved dinitrogen and argon, Journal of Hydrology, 208, 16-24.

Bölke, J.K., Wanty, R., Tuttle, M., Delin, G. and London, M. (2002): Denitrification in the recharge area and discharge area of a transient agricultural nitrate plume in glacial outwash sand aquifer, Minnesota, Water Resources Research, 38, 7, 1105, 10. 1029/2001WR000663.

Burt T.P., Heathwaite A.L. and Trudgill S.T. (1993): Nitrate; Processes, Patterns and Management, John Wiley & Sons.

USGS (2008) Dissolved gas analysis, http://water.usgs.gov/lab/dissolved-gas/

Yoh, M, Takeuchi, M and Toda, H. (1998) Simultaneous measurement of N_2, O_2, Ar, CO_2, CH_4, H_2 and CO in aqueous and gaseous samples: a detection of N2/Ar shifts in environments, Jpn. J. Limnol., 59, 147-157.

Foreign Counterpart Corner

Gayl D. Ness

Department of Sociology, University of Michigan

It is always a great delight to work across disciplines. Some years ago at the University of Michigan I developed a research and training project on Population-Environment Dynamics, working with everyone from atmospheric scientists and anthropologists to sociologists and zoologists. This proved a rich learning experience. The present work with oceanographers, geologists and many others in RIHN was again very instructive. I noted in some writing here that I feared that above ground social challenges would eclipse the challenges arising from subterranean environments, not leaving much time or resources to pay attention to them. It would be especially difficult, as all RIHN members recognized, because the subterranean environment is not all that visible and requires special tools and skills to observe, examine and analyze. Thus this specific research project on the subterranean environment is an especially important one.

To emphasize my point on the difficulties of addressing subterranean challenges, let me recount some of the work we have been doing on the more visible above ground social and physical challenges. I have been working with the Asian Urban Information Center of Kobe (AUICK) (www.auick.org) on a combined UNFPA-Kobe City program of research, training and information dissemination on issues facing Asian Cities. Linked to this is work with the Nihon University Population Research Institute in a recent conference on low fertility in East and Southeast Asia. These papers are available on a IUSSP website, as follows. (http://www.iussp.org/members/restricted/publications/Tokyo08/programme08.php.)

The most imposing Asian social transformation of the past half century is the combined changes in what we call modernization: from rural, agrarian, poor, high mortality-fertility societies to urban, industrial, wealthy, low mortality-fertility societies. As we have said in the RHIN publications, this complex transition follows that of the West from 1750 to 1950, but today in Asia, it moves much more rapidly and involves far greater numbers. The two and a half century Western transition involved a few hundreds of millions of people. The same transition in Asia today involves billons of people in less than a century. Let me here summarize some of the work we have been doing on cities in Asia to illustrate the problems above ground. One of the great challenges for the near future will be dealing with the aged, who are growing very rapidly in some areas. Five cities illustrate the range of aging problems and reactions. Finally, in one Pakistani city, Faisalabad, we face another serious problem in the sustainability of irrigated agriculture in an arid climate.

Weihai China and Khon Kaen, Thailand. China and Thailand have experienced very rapid fertility decline after the population explosion of the early post WWII period (1945-1975), in large part because of excellent state sponsored family planning program. While this relieved one problem of rapid population growth, it now raises another problem of a rapidly growing aged population. In both cases the percent 65 and over are now about 8% and by 2050, will be near 25%. We work with Weihai China, which recently found it has 10,000 abandoned elderly. Weihai is sufficiently wealthy to build homes for these people, but much of China will not be able to provide assistance, and we may well see the tragic passing of a generation of aged. Chinese Communist policies, especially the Great Leap Forward (1956-8) and the Cultural Revolution (19679-74) seriously undermined China's centuries old family structure, leading to the abandoning of many aged people. (By contrast Taiwan's development has not included any anti-familial ideology, and there the aged still command the support of their children.) Unlike China, Khon Kaen, Thailand, finds its elderly relatively well cared for. They remain in the village while their children go off to work in the cities. Thailand has an excellent rural primary health care system, which provides good service to the elderly. Children send money home and visit, and are in constant contact by way of the extensive cell phone system. As often in the past two centuries, the Thais will manage.

Chennai, India and Olongapo City, The Philippines. Both India and the Philippines have had slower fertility decline and thus swill have a slower growth of the aged. In Chennai, India, fertility has fallen now below replacement level, but the growth of the elderly still remains modest. From our AUICK workshop, the Chennai medical director is now transforming many of the neighborhood maternity clinics to geriatric clinics and retaining the staff in geriatric medicine. They believe the public services and the extant family system can well manage the elderly. Similarly, Olongapo City, the Philippines can create effective senior centers for its elderly. Moreover, the Philippines family system remains very much intact. Ten percent (8 million) of Filipinos now work overseas and send remittances home. This flows primarily through the family system, adding further capacities to provide for the elderly. Our RIHN project noted that the Philippines political structure is weak and ineffective. The relevant result for the subterranean environment is that over pumping the aquifer under Manila leads to its deterioration, and the government lacks the capacity to stop the private well pumping that is so destructive. Other Asian cities have been able to arrest or reduce pumping, leading to a raising of the water table.

Kobe, Japan, illustrates perhaps the most serious population challenges East and Southeast Asia now face. Kobe itself is a marvel engineering and superb urban government, but since 2000, Kobe's elderly have constituted an increasingly larger proportion of the population than the young. The problem of aging is severe for all Japan as it now has the world's oldest population. Twenty percent of the population is now 65 and over, and by 2050 that proportion will be just over 35%. Japanese fertility is very low and the total population is now declining. Japan's 128 million in 2005 is expected to shrink to 112 million by 2050, unless fertility can be raised. The low fertility is in large part due to sever financial strains on reproduction. Women have gained access to higher education and the labor market, increasing the opportunity costs of marriage and child raising. Moreover, traditional gender roles have not changed. Men contribute very little to housekeeping and child raising, greatly increasing the burden on women of family and child raising. Consequently, women marry later and have fewer or no children. In addition, the male work pattern keeps men away from the home for long hours, resulting in a high incidence of sexless marriages. If that were not enough of a burden, recent studies suggest that as many as 15-20% of Japanese males may have sperm counts low enough to make them virtually sterile. By contrast, the Scandinavian countries are unique in Europe in changing the industry-family connection to produce dramatically new gender roles. There are extensive maternity and paternity leaves, and men play an active role in housekeeping and child raising. The result is a total fertility rate of 2 in the Scandinavian countries, compared with 1.3 in Japan, also in much of southern Europe. For Japan and southern Europe, raising fertility poses an extremely difficult challenge.

Finally, **Faisalabad, Pakistan** shows a rather different challenge. It is a highly active textile center, producing excellent cottons. But Faisalabad, like all Pakistan is an arid landscape, with only 2-3 inches of rainfall per year. Pakistan's rich agricultural output comes from the great Indus River system that is tapped and canalled to bring life giving waters to the land. But irrigated agriculture in an arid land is perhaps not sustainable. Waters flowing over the land partially evaporate before they percolate down to feed vegetative roots. The evaporation leaves salts behind, which accumulate and ultimately turn the land toxic to crops. Faisalabad has an effective agricultural collage to support this industry, but it finds some soils around the city already too saline to bear crops. A collapse of Pakistan's agriculture is too costly to contemplate.

Here, then are some of the above ground challenges that face Asian countries and cities. It is most useful that the RIHN project is developing new techniques to examine the subterranean environment, but it also means that this is simply adding one more challenge to the already heavy burden Asian countries and cities face.

Joint Research with RIHN

Vuthy Monyrath (Cambodia)

Graduate School of Science and Technology, Chiba University

Environmental pollution is one of the most prominent problems receiving global attention today. The contamination of water resources is one of the key elements contributing to this international condition. The turning of the millennium shows the promise of peace and enduring prosperity for Cambodia. With this event comes the opportunity for this nation to join hands and collectively enable Cambodia to create an infrastructure equal to that of other, more developed, nations. With this potential for development comes the responsibility of planning for waste disposal of burgeoning industries, agricultures, and populations. Historically, when countries with a limited resource base attempt to develop their economies, they do so at the peril of the environment which supports them. Water is the resource of our livelihoods, and therefore must be protected at all costs. While Cambodia's human resource base is currently underdeveloped, there is great potential to be realized in terms of sustainable development if the reserves of the motivated and hard working youth are empowered through education to contribute to Cambodia's future success. It is my belief that through higher education in water related fields I will be able to contribute to a sustainable prosperity for Cambodia in the future

Having finished my undergraduate degree with a thesis about Crocodile Reproductive Biology at the Royal University of Agriculture in Cambodia, I came to Japan without any knowledge about groundwater but soon my interest about groundwater started to grow after entering the laboratory of Prof. Sakura Yasuo and joining RIHN projects in Taiwan and Thailand. I am now researching about groundwater flow system in Tokyo Bay sedimentary basin by using subsurface temperature measured in borehole as a tracer to verify the movement of groundwater for my doctoral degree. Groundwater movement can be very slow and take a very long time to flow depending on the geological structure. Groundwater pollution is costly and time consuming to clean up. Understanding about groundwater flow system in sedimentary basin is vitally important for groundwater management as it is the main fresh water resource. I hope to be able to utilize my knowledge about groundwater for the sustainable development of my country and possible joint research with RIHN projects in Cambodia after the completion of my doctoral degree.

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

http://www.chikyu.ac.jp/USE/

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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.

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.

Call for Contributions

For the eighth volume (October 2009), we would like to request the following Groups/individuals to give their articles for the newsletter: Prof. Kaneko's Group, Prof. Shimada's Group, Prof. Onodera's Group, Dr. Mahara, Dr. Burnett, Dr. Shimizu, Dr. Toyota.

To allow ample time for editing and layouting, we hope to receive your articles on or before September 31, 2009. For inquiries, please send email to: **makoto@chikyu.ac.jp**

RIHN Corner

Yohei Shiraki

Assistant Professor,

Rissho University

I was working as a project researcher of Urban Subsurface Environments Project in Research Institute for Humanity and Nature (RIHN) until March 2009. From April 2009, I have been working in Rissho University as an assistant professor.

I have been studying the relationship between heat island phenomenon and subsurface temperature using Geographic Information System (GIS) and Remote Sensing technique. Heat island phenomenon has been recognized to be one of the serious environmental problems that have been developed due to the concentration of human activities in urban area.

In general, it is known that the signal of past climatic change is preserved in the geothermal gradient. In addition, this climate change effect, past heat island phenomenon is similarly recorded in the subsurface thermal profile in urban areas. Therefore, the relationship between the urbanization process and the past heat island phenomenon can be evaluated by comparing the subsurface temperature distribution at each depth. My study focused on the relationship between subsurface temperature distribution at each depth obtained from subsurface temperature profile in wells and growth of city using the past land use/cover map are analyzed during the 1930's, 1970's and 2000's in Osaka, Japan. The following results were obtained, 1) The effect of heat island was found to be deeper in the center of the city where urbanization started first in Osaka area. 2) The subsurface temperature distribution with 30-40m depth was corresponding to the land use/cover in the 1930's.

In this project, I belong to GIS/Database Working Group. Creation of land use maps (0.5 km grid) of 3 periods at each city (Tokyo, Osaka, Seoul, Taipei, Manila, Jakarta and Bangkok) has been conducted under the leaderships of GIS/Database Working Group and Urban Geography Group up to the present time. As of April 2009, the maps of three periods at Osaka, Tokyo, and Seoul were completed. Furthermore, other cities will be completed until this current year. Finally, we are planning to create KML portal site to effectively show our results using Google Earth.

I hope you will use KML portal site effectively.