Proceedings of RIHN International Symposium on

Human Impacts on Urban Subsurface Environments

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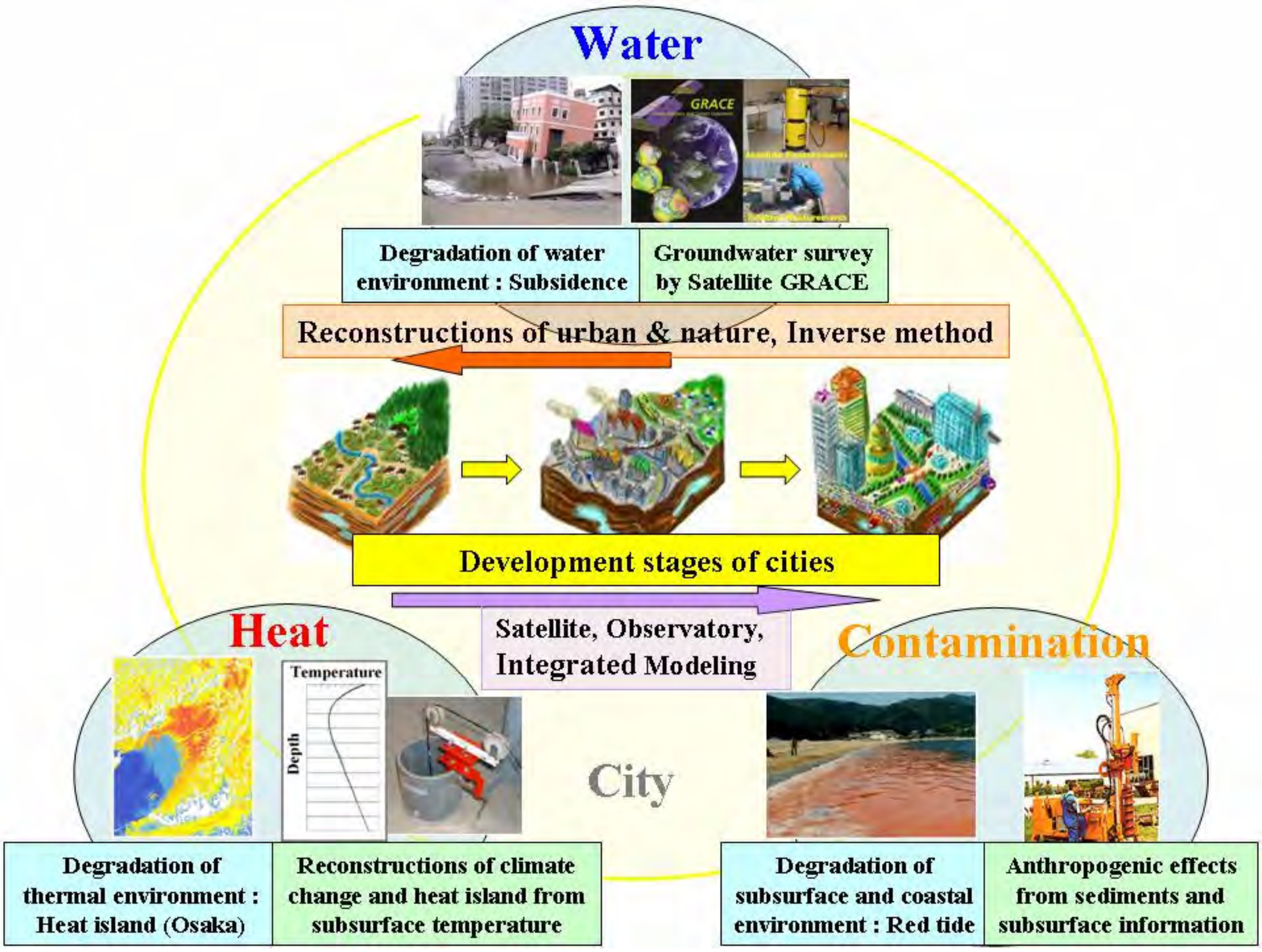

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Introduction of RIHN Project 2-4
"Human Impacts on Urban Subsurface Environment"

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Abstract

This project will assess the effects of human activities on the 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 numbers and density have expanded rapidly and uses of subsurface environment 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 well-being.

1. Introduction

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

Change in reliable water resources between groundwater and surface water occurred in many Asian cities depending on the development stage of urbanization. Although surface water is relatively easy to evaluate, changes in regional groundwater storage remain a difficult task. Recent new techniques using Satellite GRACE (Gravity Recovery and Climate Experiment, Tapley *et al*., 2004) and isotope data to evaluate groundwater flow systems may be able to evaluate the regional scale of groundwater issues.

Regarding material (contaminant) transport to the coast, direct groundwater discharge is recently recognized as a significant water and material pathway from land to ocean (Moore, 1996, Burnett *et al*., 2001, Taniguchi *et al*., 2002). Many Asian major cities are located in the coastal zone, so material and contaminant transport by groundwater is key to understanding the coastal water pollution (Protano *et al*., 2000,Capone and Bautista,1985) and the effects on associated ecosystems. Previous studies have showed some relationships between direct groundwater discharge and coastal ecological problems such as harmful algal blooms.

Recent global warming is considered as a global environmental issue only above the ground. However, subsurface temperatures are also effected by surface warming (Pollack *et al*., 1998, Huang *et al*., 2000). In addition, the heat island effect due to urbanization creates subsurface thermal contamination in many cities (Taniguchi *et al*., 1999). The combined effects of heat island and global warming reaches up to more than 100 meters below the surface, and the increased rate of subsurface temperature in cities by the heat island effect is much larger than that of global warming.

Subsurface environmental problems such as subsidence due to excessive pumping, groundwater contamination, have occurred repeatedly in Asian major cities (Foster, 2003) with a time lag depending on the development stage of urbanization. Therefore, we may be able to assess future scenarios if we can evaluate the relationships between subsurface environmental problems and the development stage of the city.

This project will suggest better future development plans for human well-being by reconstructing changes in urban environments (from present to past), and by developing integrated nature-social models (from past, present to future). Subsurface environmental indices will be used from the points of view of (1) human activities, (2) climate change, and (3) stage of urban development and social policies. Water, heat, and material environments will be evaluated by investigating changes in groundwater resources using satellite data, reconstructions of climate changes and urbanization using subsurface thermal regimes, and evaluations of contamination from preserved subsurface indices.

In order to achieve the research objectives mentioned above in five years, four sub-themes have been chosen and eight methodologies will be applied (Fig.1). Tokyo, Osaka, Bangkok, Jakarta are targeted as primary study cities, and Nagoya, Taipei, Manila and Seoul are selected as secondary study cities depending on the four sub-themes. The project will focus on the urban subsurface environments, however, we will treat the problems on a basin scale, because subsurface water, heat, and material transports are interconnected on this scale. We will target the relationships between subsurface environmental changes and human activities during the past 100 years, while some reconstructions will be extended up to 1000 years.

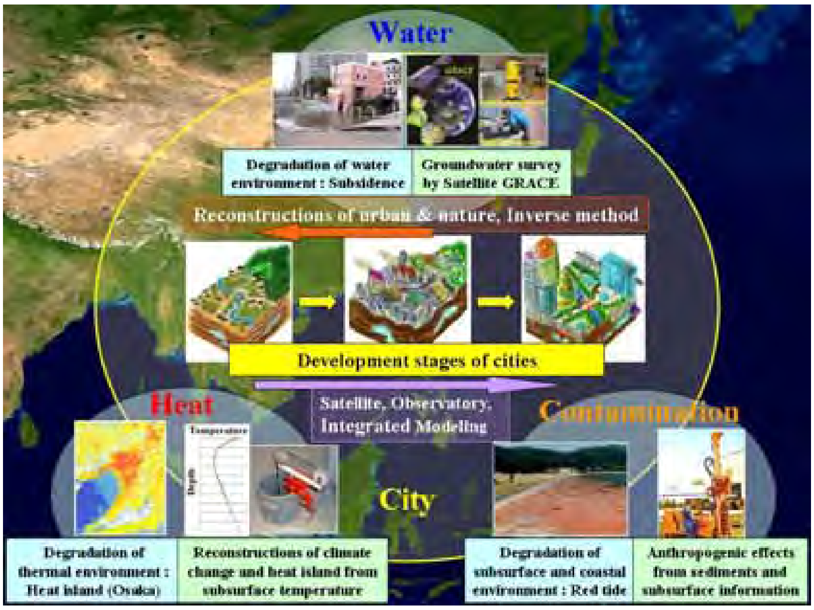


Fig.1 Four subjects (Urban, Water, Heat, and Material) of the RIHN Project 2-4

2. Development stage of the Asian city and subsurface environments (Sub-theme 1)

Subsurface environmental problems occurred one after another in Asian major cities with a time lag depending on the development stage of each of the cities including the population number (Fig.2). Sub-theme 1 (Development stage of the Asian city and subsurface environments) will focus on identifying the factors in human dimension causing the environmental stresses on the subsurface environments in the urban settings. We will identify the different development stages and describe the major causalities with respect to urbanization and changes in subsurface environment over a long-term perspective. Two approaches will be conducted to address these issues. The first one is a socioeconomic approach to human impacts on the urban subsurface environment, and the other involves a reconstruction of urban and subsurface water environments using historical records.

Most urban environmental studies dealing with the interaction between human activities and the natural environment within cities have long been focusing on the environmental issues on the ground such as air pollution, water pollution and waste management (Ness and Low, 2000). In contrast, the main focus of this project will be placed on the comprehensive environmental changes under the ground which has not yet been fully studied and elucidated. These factors broadly encompass socioeconomic and physical dimensions of human activities and the man-made environment of cities including land use change and urban infrastructure development (Bai, 2003). To meet our objectives, socio-economic group has set up a list of research questions to be answered over the course of the proposed research as follows:

1. Are there any common factors in the driving forces of long-term urban development behind the subsurface environmental changes across the mega-cities in the coastal area in Asia?
2. Can long-term urban development patterns be divided into a series of common stages?
3. Does the relationship between urban economic growth and urban subsurface environmental issue correspond to an Environmental Kuznets Curve (EKC)?
4. Is the high population density of urban areas environmentally benign to the subsurface environments?
5. Have new technologies including urban infrastructures made a difference to the changes in the urban subsurface environment?
6. Have urban policies and planning made a difference to the changes in the urban subsurface environment?

The purposes of the reconstructions of urban and subsurface environment from historical records are to (1) reconstruct the historical changes in the land-use and human activities in the study cities, (2) reconstruct the historical water environments for a database of historical environmental records, and (3) analyze the relationships between human activities and water environments of the study cities in the present and over the past 100 years. The methodology of this group will be use of topographical and geologic maps, land use/cover/condition maps, aero photographs, hygiene images, and borehole data. At the same time, reconstruction of water environments will make use of historical data, such as old documents, old maps, art pictures and photographs. Mapping of the historical changes in the land-use and human activities will be analyzed based on statistical data, old maps and so on. Then the relationships between human activities and water environments will be summarized and analyzed.

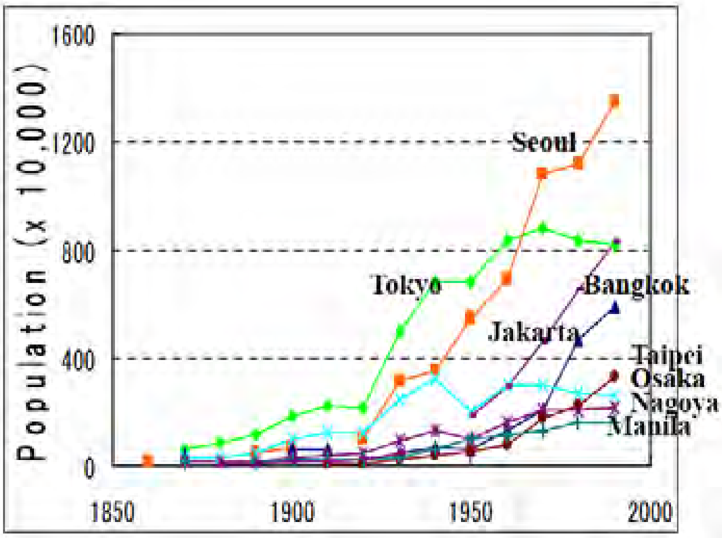
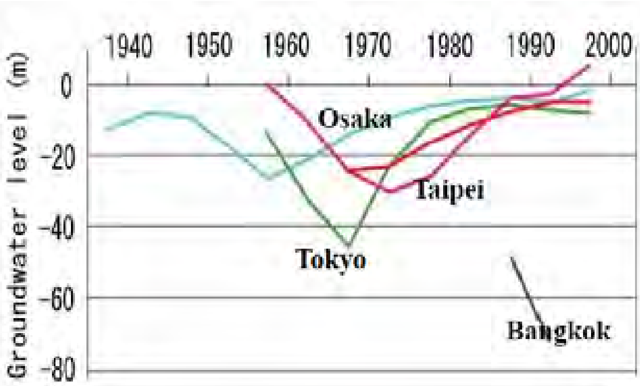


Fig. 2 Change of population number in Asian cities

3. Changes in reliable water resources between surface water and groundwater (Sub-theme 2)

Subsidence due to excessive groundwater pumping has occurred repeatedly in large Asian cities after an increase in water resources demand (Fig.3 and Fig.4). Changes in reliable water resources from groundwater to surface water supplies have been initiated in many cases, yet subsidence has still not stopped in many areas. This has resulted in a serious danger of flooding in many coastal cities of Asia. On the other hand, although land subsidence in the Tokyo and Osaka areas have ceased due to regulation of groundwater pumping, the associated increase in groundwater level has caused new types of damages by buoyant force to the underground infrastructures (e.g., subways) which were constructed during the drawdown period.



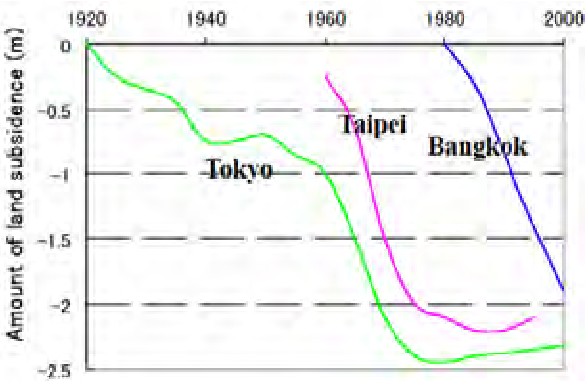


Fig. 3 Changes in groundwater levels Fig. 4 Changes in the amount of land subsidence

Also, increases in the variation of precipitation due to global warming have caused the opposite transformation of water resources (from surface water to groundwater) in some Asian countries. Taiwan is now using more groundwater because of the decrease in reliability using surface water stored behind dams. In this sub-theme, changes in groundwater storage and groundwater flow systems will first be evaluated. Then the reasons and factors of these water resource transformations will be evaluated as well as the relationships between the transformation and social factors such as population and economic factors. Two methodologies will be applied as described below.

The group for sub-theme 2 will focus on the evaluations of changes in groundwater storage and groundwater flow systems by using hydrological and geochemical data including isotopic compositions (e.g. Kr-85, O-18, D, C-14). The objectives of this study group are: (1) to understand the past and present groundwater fluctuation caused by the urbanization of the study cities, (2) to evaluate the groundwater flow system in the aquifers in and around the selected major Asian cities, (3) to extract paleo-hydrological information from the studied groundwater aquifer, and (4) to establish the methodology for the sustainable use of the groundwater resources in the urban area. The following four methodologies will be applied: (1) collection of fundamental long-term hydro-geological information in each selected city, (2) describe the present groundwater flow system by using groundwater potential, water chemistry, and environmental isotope information in groundwater observation boreholes in the study area, (3) collection of groundwater observation records from monitoring boreholes which will illustrate the past and present groundwater situation caused by human activities in each selected city, and (4) characterization of the potential groundwater recharge rate of the selected groundwater aquifers by field groundwater hydrological measurements and by related hydro-meteorological data.　Such information is the key for sustainable use of groundwater.

In order to establish a new technique for monitoring groundwater variations in urban areas, we plan to investigate the applicability of precise in-situ gravimetry and satellite gravimetry.　For precise gravimetry on land, the effects of groundwater variations are one of the largest sources of gravity changes, especially for high-precision gravity measurements using superconducting gravimeters and/or absolute gravimeters.　Conversely, this means that the gravitational effects give us important information about the hydrological characteristics in the area concerned, if the effects are appropriately analyzed.　On the other hand, satellite gravimetry is a brand new technique and it is expected to reveal global water circulations.　In our study, we will attempt to utilize this new technology for analysis of local as well as regional scale phenomena.

4. Groundwater contamination and loads to the ocean (Sub-theme 3)

The main objective of this group is to evaluate the effect of mega-cities on subsurface contamination and coastal ocean pollution.　We will focus on nitrate, organic compounds (organic chlorine based compounds) minerals, and trace metals.　The main anthropogenic source of nitrate is agricultural fertilizer around city and wastewater within the city.　On the other hand, the main sources of trace metals are air pollution, industrial waste, and mineral processing.　The development stage of mega-cities is related to contaminant type and flux. During early stages of development, urban areas have inferior infrastructures, therefore various wastes are released.　Some wastes are discharged directly to the ocean through rivers, but some is accumulated in the subsurface zone and will discharge via groundwater pathways.　The later discharge will occur a long time after the development of infrastructure.

The first specific purpose of these groups is to evaluate the cumulative conditions of contamination in subsurface layers around some Asian coastal mega-cities at present, and to clarify the relationship between the contamination condition and development stage of the mega-city (Fig. 5, Fig. 6).　The second goal is to reconstruct the contaminant fluxes from some mega-cities to the coastal zone via river and groundwater transport during the last 100 years. This will be addressed using chemical and isotopic tracers in tree rings, subsurface waters, and estuary and marine sediments.　The following methodologies will be applied to characterize the cumulative contamination: (1) to collect subsurface waters and sediment from core samples at various sites around cities, (2) to analyze the chemical (nitrate, organic compound, and trace metal) and isotopic composition (H, N, C, S, Sr, Pb), (3) to examine the effects of groundwater depression such as N accumulation in the unsaturated zone and As mobilization resulting from oxidation, (4) to conduct statistical analysis, using chemical and mega-city environment information output by other groups, especially infrastructure and political information, and (5) to construct a conceptual model of the variations in types and fluxes of contaminants originated by human activity during the development of mega-city.

To reconstruct contaminant fluxes, we will apply the following approaches: (1) to make a clear relationship between surface and subsurface flux to ocean in various mega-cities, (2) to estimate the variation of source and flux of trace metals from the atmosphere to land and from land to the ocean during the last 100 years.　Especially, Sr-Pb isotopic ratios can be used as a powerful tracer to reconstruct the source and pathway of trace metals in underground environment, which has been changed with the expansion of mega-cities, and (3) to estimate the variation in nitrate and organic compound flux of land to ocean via river and groundwater pathways during last 100 years, using dissolved gas and particle chemical and isotopic tracers in subsurface water and soil, and estuary sediment. Especially, the ratio of Ar and N in subsurface waters and the N isotopic ratio may be used for reconstruction of the nitrate concentration before reactions as denitrification.

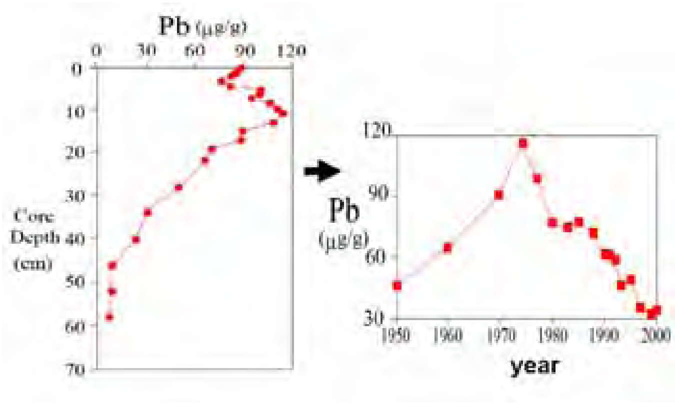


Fig. 5 Reconstruction of contaminant flux (Graney and Eriksen, 2004)

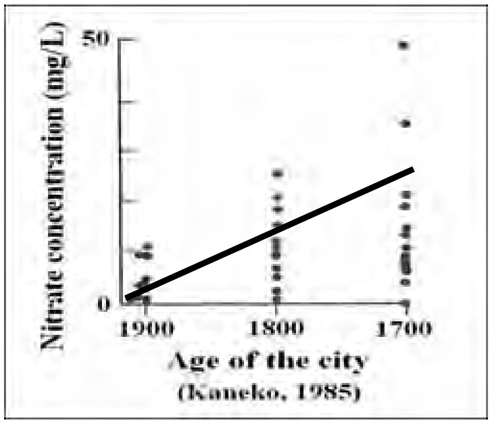


Fig.6 Groundwater concentration in the different age of the city (Kaneko, 1985)

5. Subsurface temperature anomaly (Sub-theme 4)

Subsurface thermal contamination occurs in many mega-cities in Asia due to urbanization in addition to global warming (Fig. 7). In sub-theme 4, the relationship between the development stage of mega-cities and the heat island effect due to urbanization will be evaluated from subsurface temperature data. Thermal contaminant transport by groundwater flow to rivers and the coastal zone will also be evaluated. Throughout this sub-theme, we will separate the effects of global warming and heat island from subsurface thermal data.

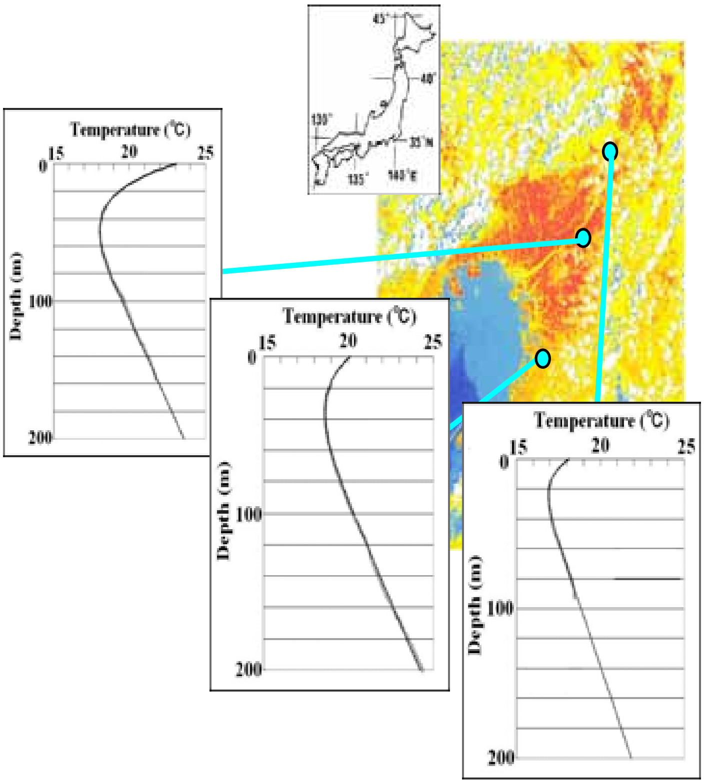


Fig.7 Subsurface thermal anomalies in urban area of Osaka

The purpose of this study group is the reconstruction of the evolution of the thermal environment in urban areas from underground temperature distributions. The geothermal method can provide the ground surface temperature (GST) history covering the times and areas with no meteorological data. Combining the results with meteorological data, we will be able to estimate the temporal and spatial variations of local climates in large cities and their surroundings. The GST history also contains information on changes in land use, an important factor in evolution of the thermal environment. We will also assess relationships by collecting information on the changes in the ground climate factors, compared to vertical profiles of subsurface temperature obtained from the targeted cities in Asia. Concurrent information concerning the transition in land use and human activities (social economic indices) will enable us to explain changes in the ground climate over time. We intend to compare an urban area and a suburban area within the same city, so we can clarify the influence of urbanization with respect to the subsurface temperature-depth profile. These tasks are useful to separate the influence of global warming from the influence of warming caused by urbanization.

6. Expected Results

The expected results of this project are summarized as follows;

(1) We will provide a descriptive summary of the long-term evolutionary processes of urban subsurface environmental issues for the selected case study cities. Quantitative relationships between urban development and the subsurface environmental issues will be evaluated.

(2) We will examine the successes and failures of past urban policy and planning with respect to its influence on urban subsurface environmental changes. We will also make policy recommendations toward environmentally sustainable development for cities.

(3) Historical fact books of urban development and associated environmental issues for cities in Asia will be prepared as well as a statistical database of socioeconomic and environmental indicators of mega-cities in Asia.

(4) Our reconstructions of historical subsurface water environments and land-use can provide information concerning historical relationships between human activity and the subsurface water environment.

(5) Past and present groundwater fluctuations caused by urbanization will be evaluated in the studied cities which can be used as basic information to establish the methodology for the sustainable use of the groundwater resources in urban areas.

(6) In the case of a huge aquifer system, it may be possible to extract paleo-hydrological information from the studied groundwater aquifer which will represent the local paleo information of the selected inland area.

(7) The gravity data will provide the most basic information to manage the urban water usability together with other integrated hydrological information such as regional groundwater levels at area without wells.

(8) Satellite GRACE can provide long-term monitoring data of global and regional groundwater circulation. We also expect that the satellite GRACE data can be calibrated and validate in-situ gravity data.

(9) The present cumulative types and amounts of contaminants will be estimated in subsurface layer around some Asian coastal mega-cities. The relationship between this contamination and development stage of the mega-city will be assessed.

(10) Reconstruction of the contaminant flux from some mega-cities to the coastal ocean via river and groundwater discharges over the past 100 years will be evaluated.
(11) Precise borehole temperature logging and interpretations will provide reconstructions of urban surface temperature histories during the last several hundred years, and relationship between urbanization and heat island.
(12) We will document the magnitude of subsurface thermal contamination due to urbanization and global warming, and various contaminants transported by groundwater to the river and coastal zone.
(13) Our analysis will allow separation of the effects of global worming and heat island due to urbanization.

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

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Introduction

The total global population is now widely estimated to be over six billion people, and the population is increasingly concentrated in high density conurbations (United Nations, 2001). In the 1990s, the average urban population growth per year was estimated at 3 percent for East Asia and 3.2 percent for South Asia which is higher than the world average of 2.1 percent (WDI, 2001). The potential of urban growth is greater in Asia and it is estimated that population in cities will increase from the present 40 percent to over 52 percent by 2020 (Habitat, 2001).

Contemporary urban growth in Asia has socioeconomic and environmental impacts and these impacts have been magnified with the increasing emergence of large cities. Projections show that in 2015, 358 cities worldwide will consist of population of more than 1 million people and among these, 153 cities are expected to be in Asia (Habitat, 2001). From an estimated 27 megacities, 15 such cities will be in Asia. A megacity is defined by the United Nations as a city with more than 10 million people or more and is often characterized by high population density and high material demand. These megacities are mostly the "front-runners" in industrial transformation, in the formation of global production bases, in the pursuit of economic and environmental efficiency, in the formulation and implementation of government policies and even in social dynamics and lifestyle changes.

The unprecedented rapid urban growth constitutes an environmental challenge. Many of the environmental problems in urban areas occur simultaneously and sequentially with the stages in development. These complex causal relations or mechanisms of urbanization and environmental problems have always been one of the most important discussions on urban sustainability (Alberti, 1996). Urbanization, which is mainly attributed to population growth and spatial expansion and concentration (Murakami et.al., 2005) has many related factors such as economic activities, social services, infrastructure, transportation, governance, etc. (Alberti, 1996).

However, in the past subsurface environments in urban areas have not been given much attention and most of the environmental studies are focused on the issues occurring above the ground. Our knowledge on subsurface environmental issues is quite limited. There are many large cities located in coastal areas, where intensive and active interactions between the continent and the oceans are taking place under the ground. These cities have rapidly expanded and developed over the last several decades with certain time intervals, which can be characterized in a development pattern.

Research Objectives

Given the background discussed above, it is necessary to identify the human dimensional factors causing environmental stresses on subsurface environments in different development stages. This study attempts to improve our basic understanding of the complex causalities of various subsurface environmental changes and seeks answers to the following research questions: Can transitional patterns in subsurface environmental issues be divided into a couple of common stages across the megacities in the coastal areas in Asia? Is there any commonality among the driving forces for long-term development and the subsurface environmental changes? Are there any cumulative effects and path dependent environmental impacts in subsurface environmental changes? Does technology including urban infrastructures make a difference to the changes in urban subsurface environment? Has urban policy and planning influence the changes in urban subsurface environment?

Taking these questions into consideration, the objectives of this research would be:

1. To assess and compare long-term urban development patterns for each city case studies;
2. To describe the major causalities between urban development and the changes in subsurface environments from a long-term perspective;
3. To identify the measurable critical factors in human dimension which cause environmental stresses on subsurface environments in each urban development stages;
4. To quantify the dynamic changes in causal relations among key factors;
5. To construct and maintain a database, which comprehensively includes all indicators related to the project in a coherent format.

Research Methodology

The complexities of urban subsurface environmental changes will be explored by conducting different studies in five approaches. First, we identify and described the major cause and effect relations of the subsurface environmental issues using the DPSER/DPSIR (Driving Forces-Pressure-State-Effect/Impact-Response) framework. Secondly, we select the key indicators to capture the major evolutionary process of urban development and apply it in the city case studies. Based on the results of the above two approaches, the next step is to develop the stage model of interactions between human activities and urban subsurface environments. From the collected data and information, the system dynamics model (economy-population-environment dynamics model) with the demographic module as the central component will be constructed. With the above model, the last approach is to conduct "what-if" type simulation studies under various technology and policy scenarios. It also applies to the policy simulation for the future environmental sustainability of Asian coastal cities.

Research Foci

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

(1) City-specific urban demographic model to quantify the driving forces in long-term urban population growth

This model will describe half-century demographic changes using common indicators of population growth and change. A five-year interval system dynamic model on income growth and job opportunities will also be included and a coherent structure will be constructed to allow comparisons among city case studies (Tokyo, Osaka, Seoul, Jakarta, Bangkok, Manila and Taipei).

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

This will involve data construction of simplified land use and cover maps in multiple years (in close collaboration with Urban Geography Group) for built-up area, urban infrastructure, urban green, agricultural land, water body, etc.

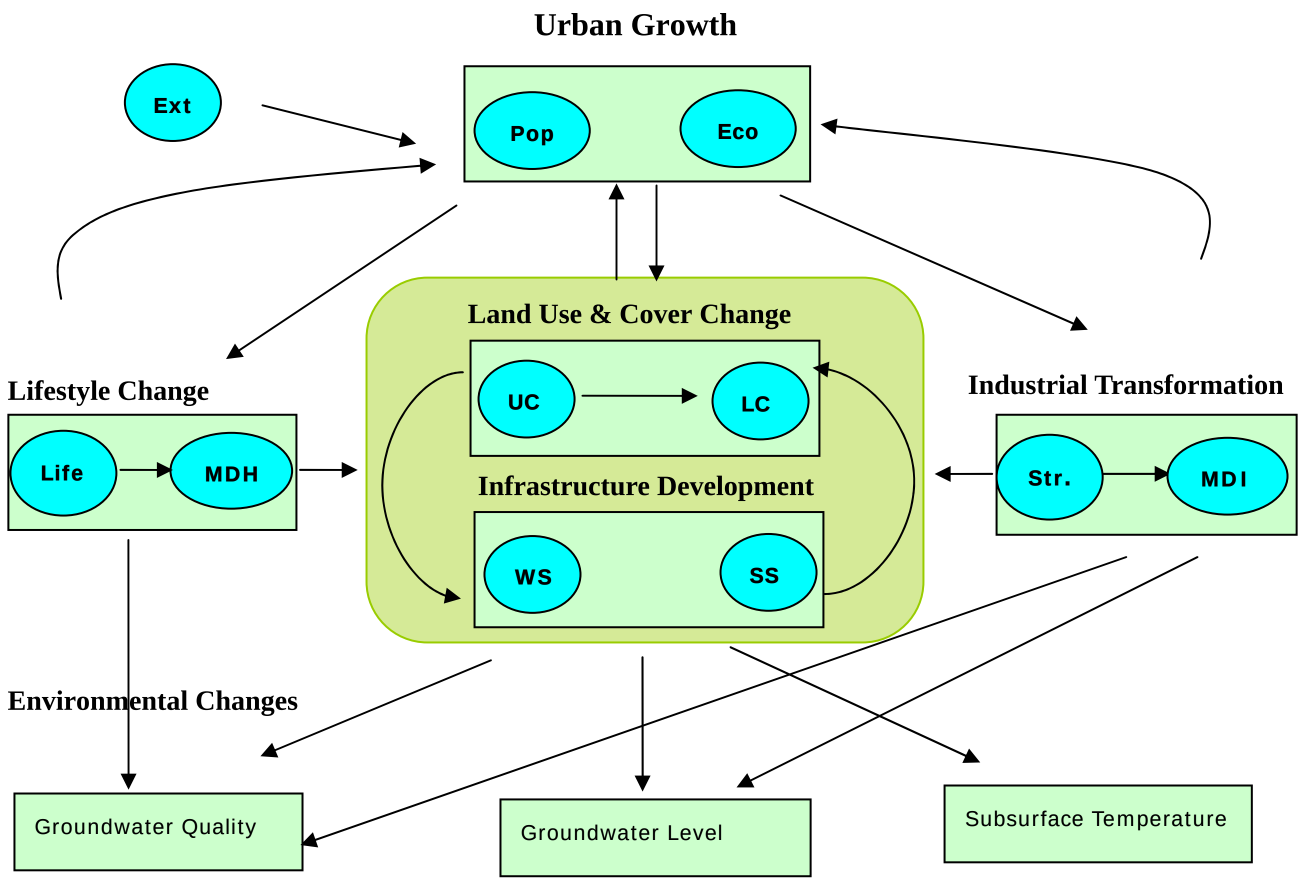
Land use and cover change (LUCC) indicators with spatial information in selected years will be developed and further be converted into annual data by interpolation and extrapolation, if possible. This will also review and summarize urban planning and policies, which are related to LUCC in order to assess and analyze the relation between LUCC and urban planning and policies.

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

This will take a careful examination in selecting indicators to capture the system development in view of long-term data availability and comparability. In addition to infrastructure developments in water supply and sewage in cities, it will also focus on technology and institutional aspects. This topic is conducted in close coordination with material flow of analysis.

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

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



Basic Principles for database design

Data for each indicator should be annual-based sequential data which alone can represent a city and a year without any exception during the period 1950-2005. The missing data will be estimated by performing interpolation or extrapolation with detailed notes on grounds for estimation, methodology and expert judgments on accuracy. The information collected or measured will be systematically arranged by the data manager in the socioeconomic team. Moreover, during the entire project period, it is necessary to exert our best efforts to continuously improve the quality of data collected.

The following tables below contain some examples of selected indicators:

Nature Condition

Temperature	Water resource	Area
Average temperature	Groundwater level	Total area
Above earth's surface by 1m, 3m and 10m	Rainfall	Population density
Below earth's surface by 1m, 3m, and 10m	Water resource endowment	Built-up area coverage
	Surface water	Agricultural area

Demographic

Population	Population Change
Total population	Death rate
Demographic structure	Birth rate
Total number of households	TFR
	Life Expectancy
	Migrant Population

Economy and Infrastructure

Economic	Infrastructure	Infrastructure for water
GRP	Number of incinerators	Dam reservoir capacity
Labor population	Final landfill disposal	Pumped water level
Employment by sector	Waste disposal	Water supply pipelines
Consumer price index	Total length of paved road	Well water temperature
Gross income per household	Household land area	Well water material residue
Production of chemical fertilizer		Users of tap water
Crop production		Sewer treatment

Environment

Air	Water	Material	
SO_2 concentration	Ammonia nitrogen emission	Nitrogen flux	Subsidence level
NO_2 concentration	Wastewater discharge	Phosphorous flux	Subsidence are
CO concentration		COD	Heat exhaustion
TSP			

Transportation	**Government**
Users of public transportation	Budget size
Kilometers of operating railways	Independent revenue source
Number of automobiles	Number of personnel

Material data

Electric power sales
Gas consumption
Coal consumption
Biogas consumption
Water consumption by sector
Chemical fertilizer consumption
Daily calorie intake per person
Iron supply
Cement consumption

Major Expected Outputs

Aside from publication in academic journals, the results of this research are planned to be published in a series of books (7 cities) to synthesize all the information collected by the project activities on urban development and subsurface environmental changes for each city. Datasets authorized by the project will also add to the output of this research component.

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World Development Indicators 2001

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

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This is the outline of a research program which A.Yoshikoshi announced on behalf of urban geographical group of this project.

1. Purpose of research

The first purpose of research is collecting the urban geographical data of many Asian cities (Tokyo, Osaka, Seoul, Taipei, Manila, Bangkok and Jakarta). Geographical data is the geographical reference about each city, many city statistics, maps(up to the thing of the past to the present as much as possible, what is large scale as much as possible), aerial photographs(up to the thing of the past to the present as much as possible, from a meso-scale to a large-scale) and satellite imagery(LANSAT imagery, IKONOS imagery and so on for every fixed period). With the period of a fixed interval, although influenced also at the creation time of the satellite imagery, we consider about 10 years. Geographical development process of many Asian cities is clarified based on these data. Especially, we would like to express the boundary of urban area and internal land use of the city in a map for every fixed period

The second purpose of research is clarifying the change of the hydrological environment of the specific cities (Tokyo, Osaka, Seoul, Taipei and Bangkok). We are going to express the position of rivers, lakes, spring waters, swamps and so on in a map as in detail as possible, and to clarify those change for every fixed period, in order to attain the above-mentioned purpose. Furthermore, our aim is getting to relate the cause of this change with a city development process.

2. Prediction of research

I will describe the prediction of this research based on past research.

This is a figure(Fig.1) by M.J.Hall showing the effect of urbanization on hydrological process. It is thought that urbanization causes four problems. They are " water resource problem" (that is, water shortage), "urban climate changes"(for example, frequent occurrence of a heavy rain and the formation of heat island. However, this is although it is not a direct water problem.), "pollution control problems"(that is, water pollution) and "flood control problems"(that is, frequent occurrence of a flood). In

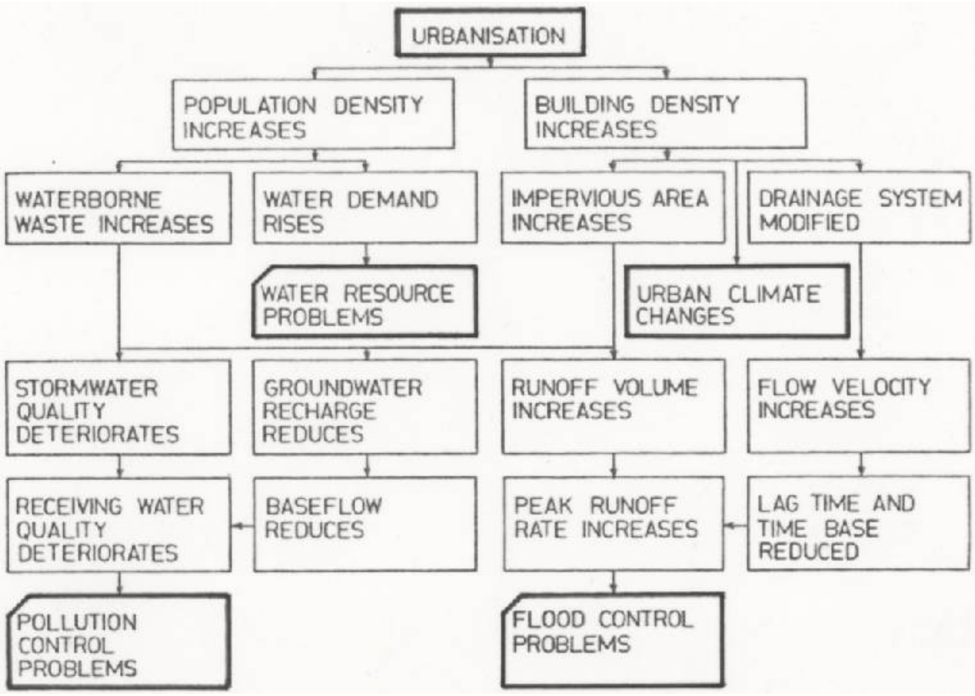

Fig.1 Effects of urbanization on hydrological processes M.J.Hall(1984)

short, if the water problem accompanying urbanization is limited to the problem of quantity, it will call it a flood or water shortage.

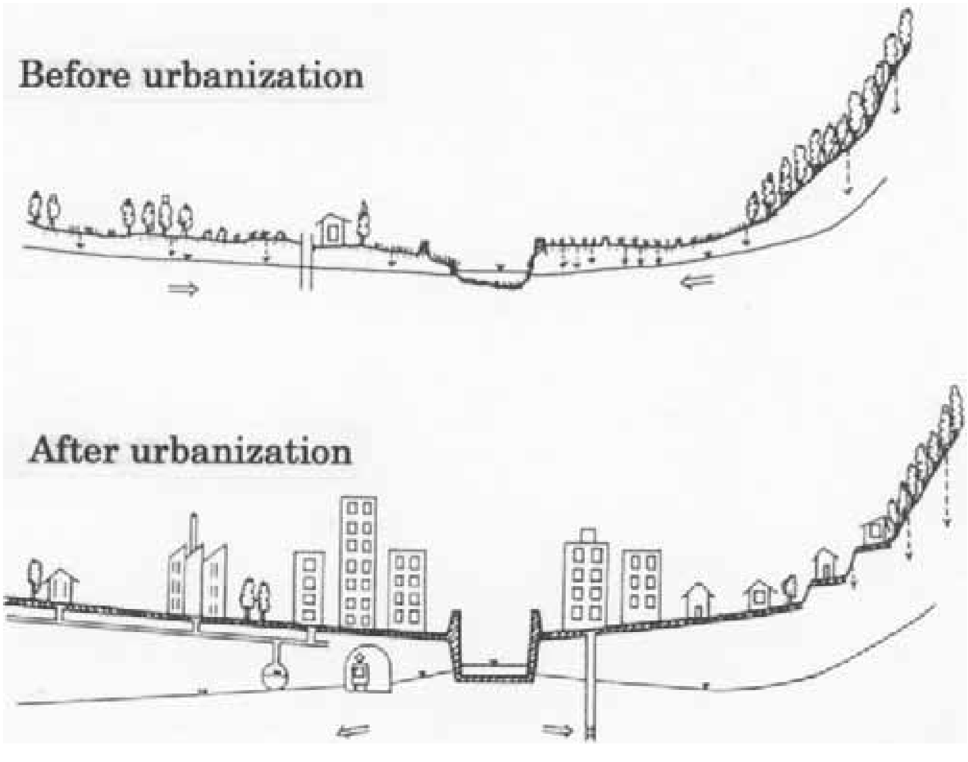

Fig.2 Comparison of the hydrological environment before and after urbanization
A.Yoshikoshi(1998)

There is change of the earth surface which happens to one of the biggest reasons that many of these problems generate with urbanization. This is the model figure(Fig.2) by A.Yoshikoshi. The biggest difference between before and after urbanization is whether water permeability is shown in earth surface and whether the place which stores water is shown in earth surface. Non-water permeability prevent that surface water turns into groundwater.

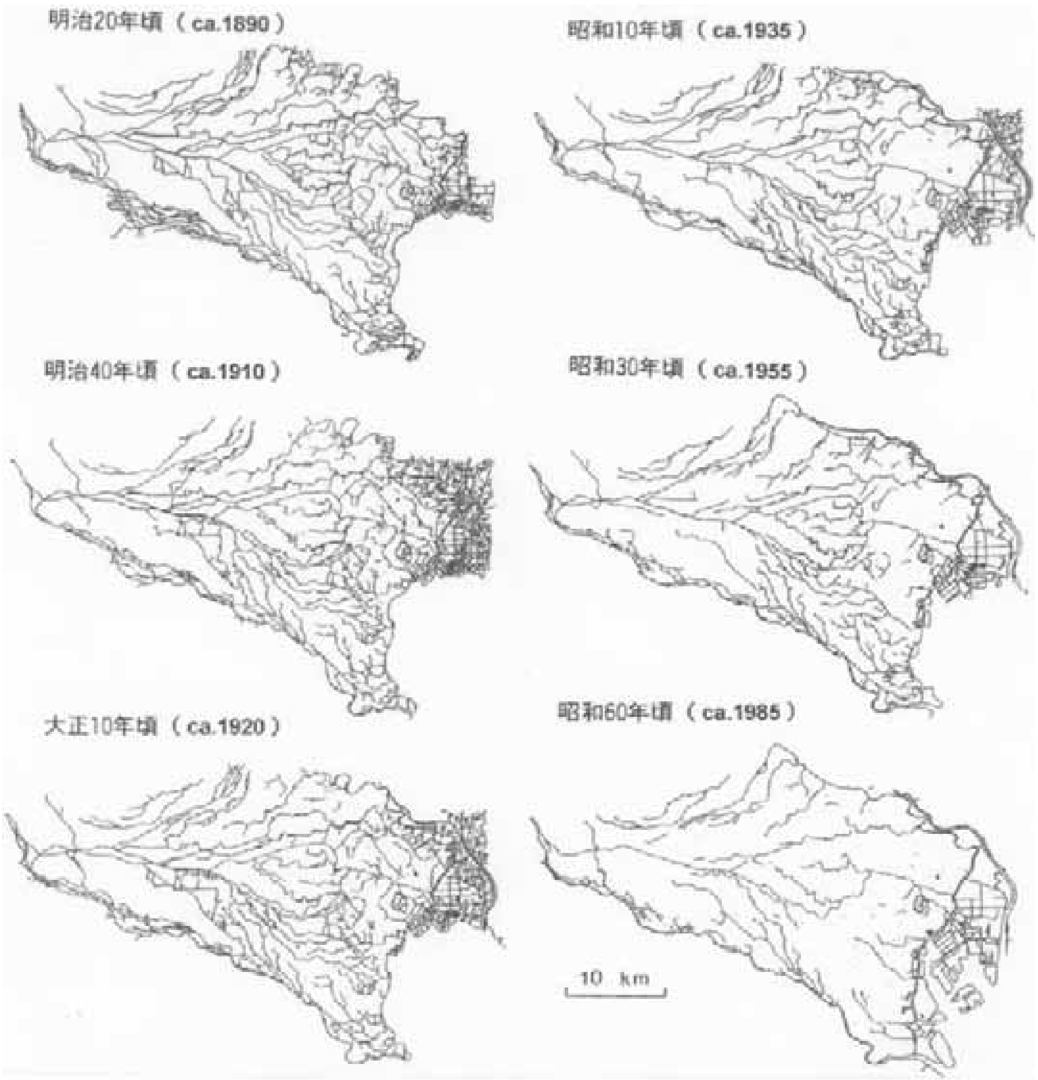

Fig.3 Change of rivers and waterways in Tokyo T.Arai(1996)

Fig.3 by T.Arai shows changes of the waterway of various times in Tokyo. This figure was created by extracting the waterway of the map of each time. When this figure is seen, it turns out that the waterway of earth surface is decreasing gradually. This waterway changed to the road, the park and so on. Of course, in order to prevent a flood, the drainage tunnel and the reservoir are built underground. However, it becomes a cause to become easy to generate a heavy rain by an urban climate, that the earth surface of water permeability was lost, that the waterway decreased, etc., and it is clear that a flood become easy to happen in a city.

Therefore, if change of the waterway of various times in the city region are clarified, a city water problem can be predicted. And if land use of earth surface is clarified, exchange of surface water and groundwater will become intelligible. It will have the above prediction and we will advance research.

3. Contribution of research

We are sure of the following things.

The research findings of the first purpose contribute by providing the member of other groups with the fundamental data about city development. Moreover, we think that the researcher in the world comes to use these database(references, maps, aerial photographs, satellite imageries, etc. of many Asian cities).

And, the research findings of the second purpose contribute to development of academic circles. Probably, this contributes by urban hydrology as a region of research, and contribute by exchange of surface water and groundwater as contents of research.

4. Method of research

The method of research is shown in this flow chart(Fig.4). First, the reference of urban geography and city statistics are collected. The features of cities are searched for base on them. The information from maps, aerial photographs, satellite imageries etc. are added there.

Consequently, the features of cities for every fixed period and the hydrological environment for every fixed period are clarified. There are put in a database. Then, the field survey is added to these and it results in a conclusion through theoretical examination and hypothetical verification. The period for research in made into the past 100 years.

Moreover, we want to make them easy to express research findings using GIS(Geographical Information System) and to understand them also visually.

5. Research organization and subject of urban geography group

The following seven members are in the urban geography group. Each member's rough contents of research are as follows. The details of research will be introduced by each member's announcement. I would like to limit for introducing only member's name and title of research.

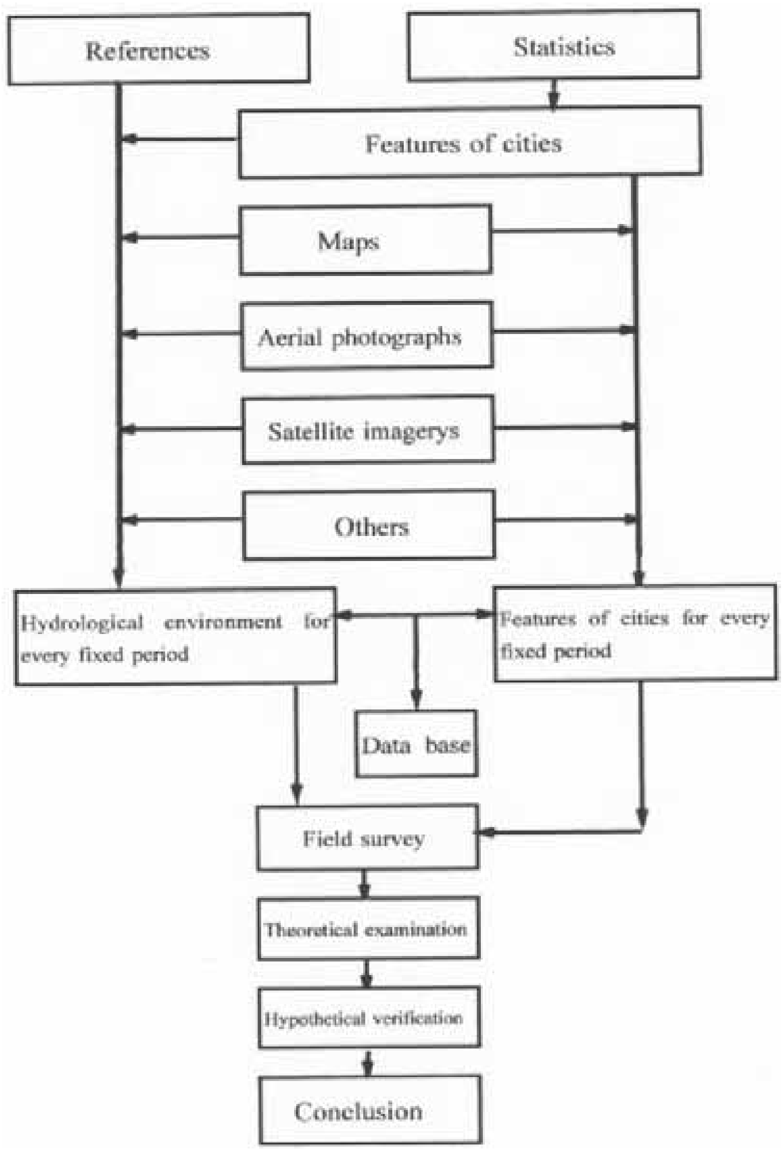

Fig.4 Flow chart of a method of research

A.Yoshikoshi (Ritsumeikan University)

"Geographical development process of many Asian cities, and change of hydrological environment"

I.Adachi (Japan International Cooperation Agency)

Undecidedness

T.Taniguchi (Rissho University)

"A geographical approach to the restoration of historical water environment in historical materials and topographical maps"

Y.Kagawa (Yokohama City University)

"Industrial urbanization on Metropolitan area of Asia and change of hydrological environment"

S.Kato (University of Marketing and Distribution Sciences)

"Change of hydro-environment in Asian cities through modernization"

A.Yamashita (Rakuno Gakuen University)

"The relationship between urban resident's lives and water environment-analysis on watershed scale and community scale"

T.Todokoro (Ritsumeikan University, Graduate School)

"The change in hydrological landscape and human activities related to urbanization in Asia cities "

Although main members are as above, if we have necessity, we may ask for cooperation the researcher who knows the city well, and ask for cooperation the foreign student who is coming to Japan from the city.

6. Research program

A research program is shown for every fiscal year. These are near standards and may change according to a situation.

2005 fiscal year

Creation of the reference list, the map list, the aerial photograph list, the satellite imagery list; Collection of data; Planned decision of the change of hydrological environment of the urban area; Field survey(Tokyo ,Osaka)

2006 fiscal year

Creation of reference list, etc.; Collection of data; Hydrological environment research; Field survey(Tokyo, Osaka,Seoul,Bangkok)

2007 fiscal year

Creation of the reference list, etc.; Collection of data; Examination of the GIS displaying method; Hydrological environment research; Field survey(Tokyo, Osaka,Taipei,Manila,Jakarta)

2008 fiscal year

Collection of data; GIS research; Hydrological environment research; Field survey(Tokyo, Osaka, Bangkok, Seoul, Jakarta)

2009 fiscal year

Collection of data; Construction of an urban development theory; Research of hydrological change; Field survey(Tokyo, Osaka, Taipei, Manila, Bangkok)

2010 fiscal year

Supplement of collection of data; Supplement of field survey; Field survey(Tokyo,Osaka,Bangkok, Seoul, Taipei); Conclusion of research

Subsurface water environment in and around Asian Cities

Jun Shimada, Kumamoto Univ., Japan

I. Groundwater problems in Asian cities

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

In the big city area of Japan; Tokyo, Nagoya, and Osaka, has experienced these groundwater disasters in 1970's and they have succeeded to compensate the problems by regulating the groundwater use. While the many Asian big cities has been suffered to these disasters during recent 10 to 20 years and some cities have not yet found any solution until present. Development stage, their geographical size, population, geology and hydrology of each city must influence the level of groundwater disaster. Also the recovery of the groundwater by regulating the water use must be affected mostly by the hydrological condition of the location of the problem cities. The success of groundwater recovery by pumping regulation in Japan must be caused by the positive natural groundwater recharge rate (800-900mm/yr) in the humid temperate climate of Japan.

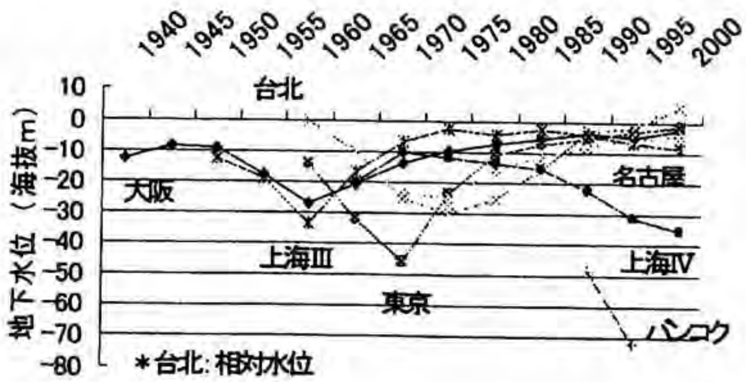

Fig. 1 Change of groundwater level in Major Asian cities during recent half century.

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

The one major purpose of groundwater hydrology is to make clear the flow sytem in the groundwater aquifer. The use of environmental isotope is very helpful to understand this system because of their isotopic tracer characteristics such as age and origin. The recent development of those isotope hydrology study has create another aspect of research purpose which is called paleo hydrology. This is the study to extract the paleo information from groundwater aquifer by using isotopes. In the case of isotope hydrology study, we will create the change of chemistry along the groundwater flow line which is the distance from recharge area and also the groundwater age.

Major chmical component in the aquifer shows evolutional trend along this line. However, stable isotope ratio does not show any evolutional trend but fluctuate somehow in most cases.

Though the stable isotope ratio could be directly affected by the temperature, their fluctuation should reflect the recharge temperature which stands for a climate proxy (see Fig. 2). This research method is named paleo hydrology and has developed during recent 15 years to supply the inland paleo information by the relatively huge aquifer system in the world (Fig.3).

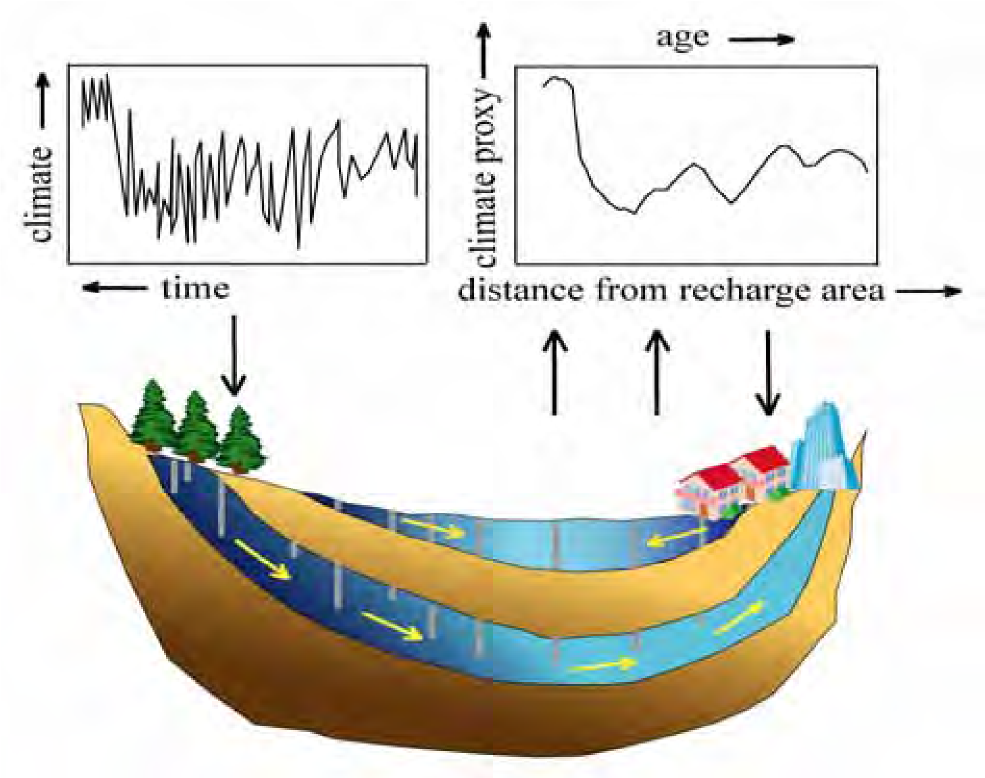

Fig. 2 Paleo hydrology (paleo-information extracted from groundwater aquifer) EOS.No.24,1998

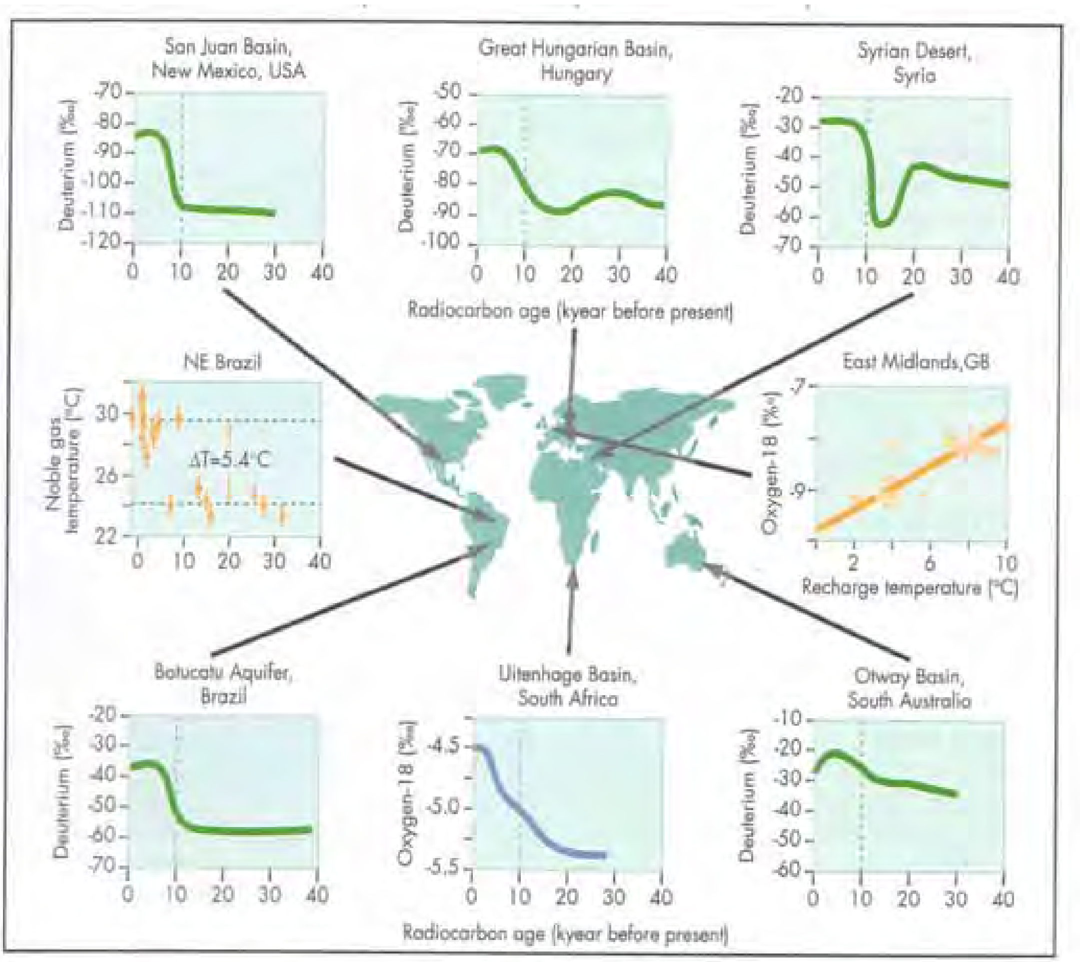

Fig. 3 Paleo information from the major continental aquifer in the world
(IAEA,1995 after GNIP pamphlet)

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

As mentioned previously, the excessive pumping in the urban area has created huge groundwater drawdown in many Asian cities. This drawdown could be considered as the kind of man-made groundwater flow system over the natural flow system. Fig. 4 shows the example of North China Plain, China. This area has experienced huge over pumping both city water use and irrigation purposes during last 50 years. In 1959 soon after the chinese revolution, the groundwater flow sytem of the area is almost natural. While 43 years later, there exists many cones of depression in the big city area and also the 0 m (sea level) groundwater potential contour line develops nearly 150ｋｍ inland from the yellow sea coast in the eastern side.

Because of the very steep hydraulic gradient, this man-made flow is much faster than the natural condition in most case. Fig.5 shows the tritium and ^{14}C content in the groundwater of this area.

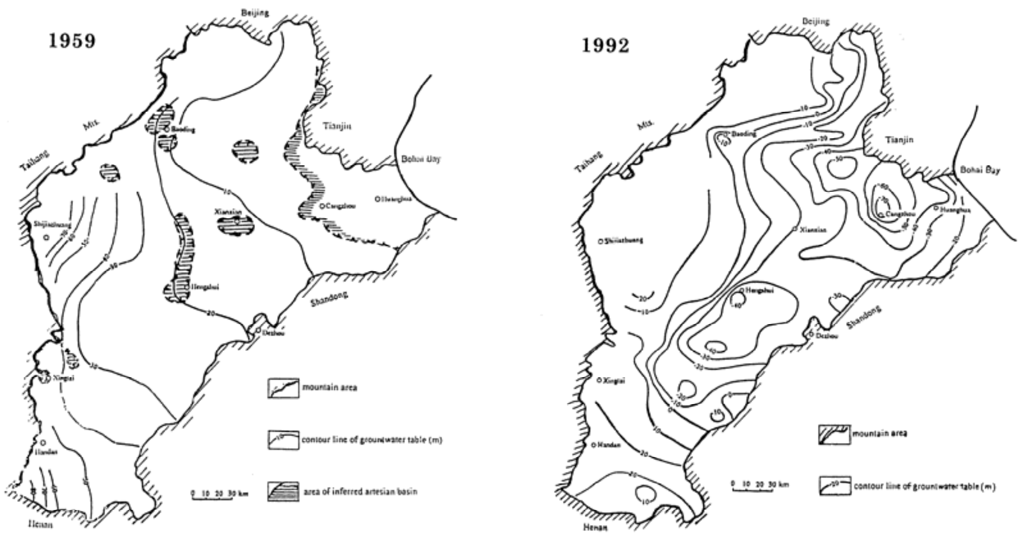

Fig. 4 Change of groundwater level at North China Plain (Shimada *et al*, 2002)

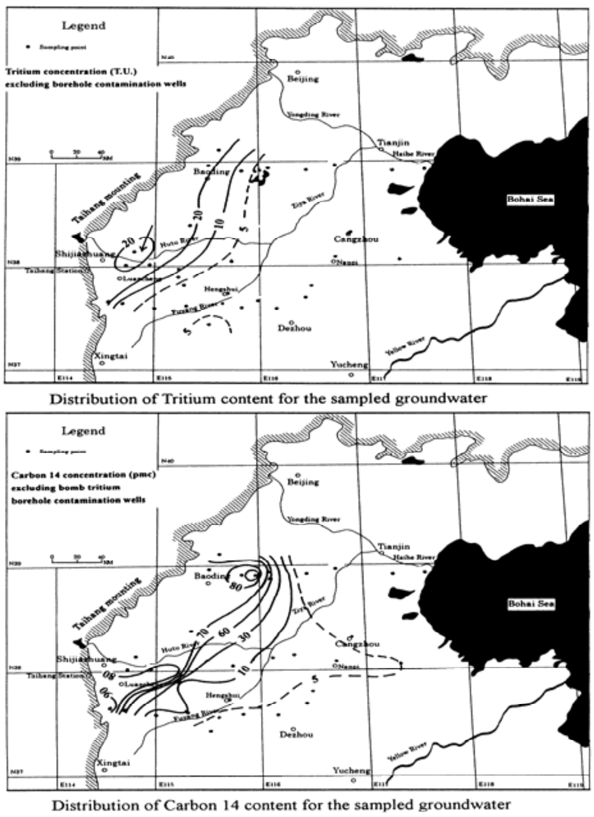

Fig. 5 The distribution of ^{3}H and ^{14}C content in NCP groundwater. (Shimada *et al*, 2002)

The western part of the North China Plain has relatively modern tritium and ^{14}C content, and this is the evidence of man made induced groundwater flow caused by regional over pumping. The rough calculation of this induced groundwater flow by using bomb tritium front shows 4 m/day which could not be explained by the natural groundwater flow of the area.

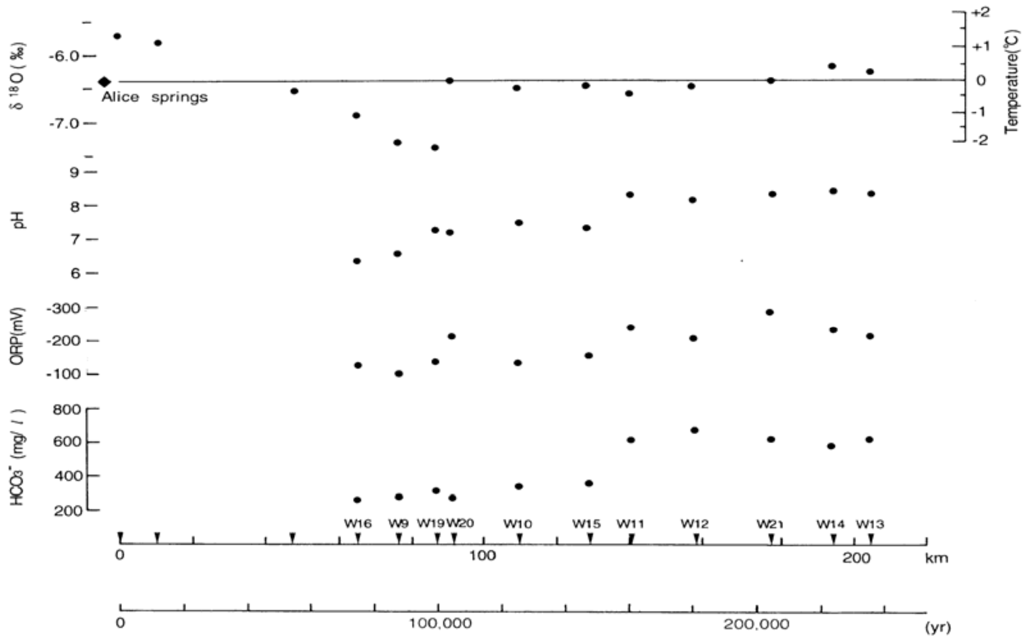

Fig. 6 Paleo water information from Great Artesian Basin, Australia. (Shimada *et al*, 1999)

Fig. 6 shows the similar paleo information but much old age that can be dated by using ^{36}Cl age tracer in the case of Great Artesian Basin Australia (shimada *et al*. 1999). HCO_3 ion, ORP, and pH show the evolutional trend along the sampling line down to the age of 200 K years before present.

Fig.7 shows the groundwater potential distribution of the sampling area during last 100 years. The development of this area has started almost 1880's and after this the development of the artesian well which is mostly used for the cattle farming by using flowing artesian well groundwater. The artesian condition of the well is very efficient because they do not need any powers to pump up the groundwater. As the result excessive borehole exploitation has been created in this area during last 100 years, and this caused the groundwater potential draw-down about 40-50m than the previous natural condition. At present, it still keeps artesian condition fortunately, thus people has much efforts to mange the over pumping to keep the sustainable artesian condition of the area. The groundwater sampling points are shown as dots in figure 7. The sampling line shown in figure 7 has evolutional chemical trend as shown in figure 6. While other points do not show any meaningful trend at all.

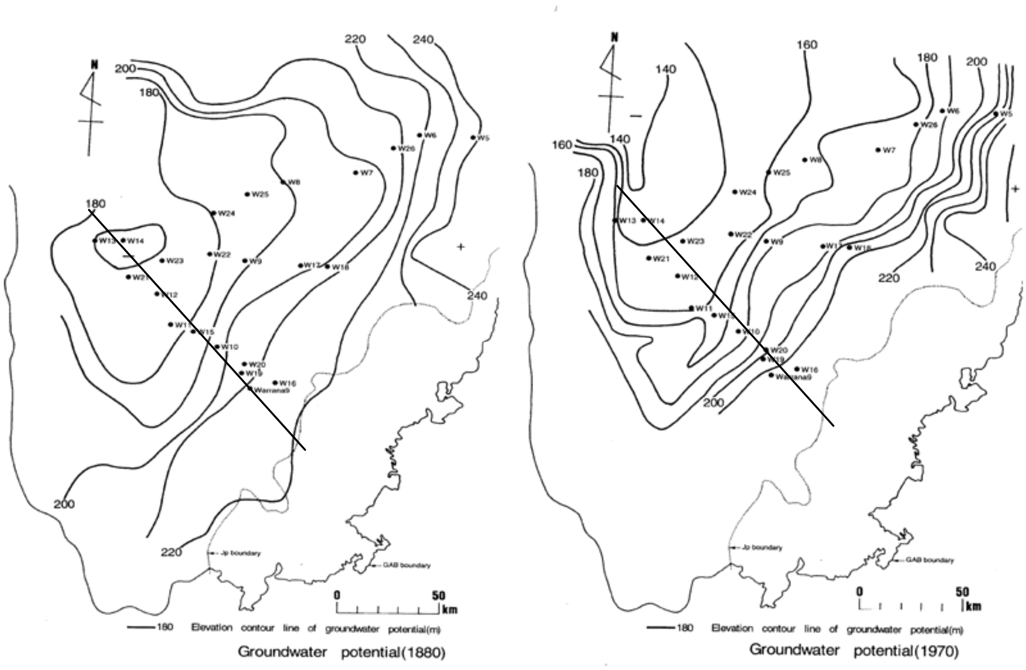

Fig. 7 Change of groundwater potential from 1880 to 1970 and the groundwater sampling points. (Shimada *et al*, 1999)

This is because the only the Fig 6 sampling line has not much changed its flow direction during last 100 year. Thus it can be thought that the important point is the selection of the sampling line when we consider the man-made induced groundwater flow change condition.

IV. Needs for the modern groundwater age tracer technique

In the study of environmental isotope hydrology, the representative young groundwater age tracer was the radioactive tritium. However, recent tritium concentration in precipitation has been decreased almost natural level (less than 10 T.U.) and the age resolution by using tritium has become lower year by year. After 1990's the development of the new young groundwater age tracer technique has been appreciated. The Cloro-fluoro Carbon (CFC), the refrigerant liquid which has been widely used in 1980's and stopped to use because of the global ozone hole problem. The atmospheric CFC has been introduced to the groundwater through recharge process and could be used as the shallow aquifer age trace like tritium. Also another anthropogenic substances, Kr-85 which is the artificial production through nuclear reactor or reprocessing plant of used nuclear fuel, is also thought to be the useful young age tracer after tritium. Fig. 8 shows the recent trend of these age tracers.

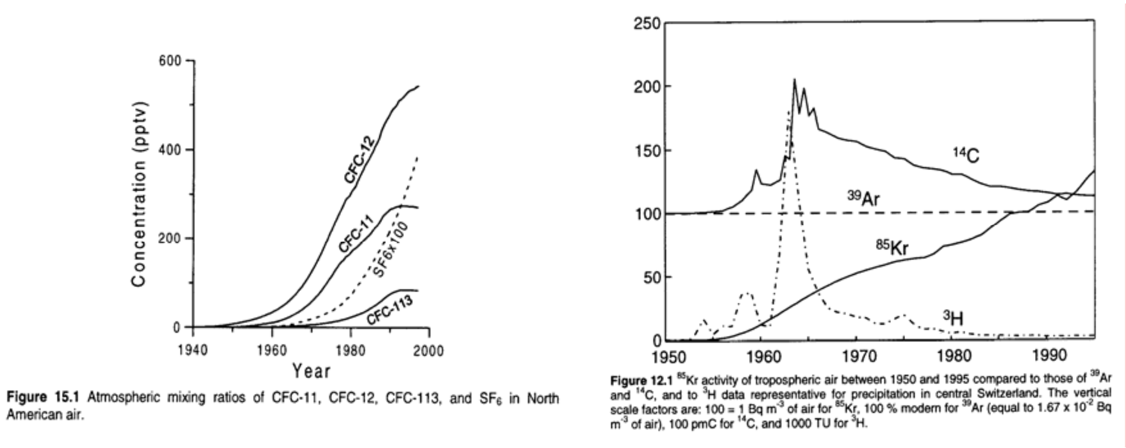

Fig. 8 The recent concentration trend of CFC and Kr-85 for groundwater age tracers.

In Japan, the use of those age tracers has not been recognized in the hydrological study. CFC concentration in groundwater has widely used in the USA, and become one of the representative young age tracers. Although the urban industrial activity may affect the local CFC concentration somehow, this might be used as another indicator of urbanization. While the Kr-85 has not much used as CFC, this is because of both the difficulty of water sampling and the analytical technique.

In the present project, the author would like to introduce those young age tracers to detect the groundwater age in the induced groundwater flow caused by the over pumping in the urban area. This should contribute not only for the urban groundwater research, but also for the potential development of new groundwater age tracer in Japan.

V. Concluding remarks

The possibility to extract recent 50 to 100 years paleo-information from the urban groundwater aquifer in the Asian cities has been discussed. Urban excessive groundwater use has caused the huge groundwater draw-down in many Asian cities. Those draw-down condition must be the source of induced groundwater flow which is much faster than the natural condition. If we could select the directionally undisturbed flow line in the urban aquifer for the periods after excessive groundwater use, there will be the possibility to receive much precise paleo-record than the natural flow condition. It is no doubt that the introduction of modern young groundwater age tracer technique and the good selection of the representative directionally undisturbed flow line must inform us the 'human impact of subsurface environment in urban areas'.

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

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Abstract

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

1. Introduction

Water is indispensable for human beings. Securing of water resources is one of the most important issues for 21st century. In urban areas, transformation of water resources between ground water and surface water is occurring. It is especially serious in many Asian cities depending on the development stage of urbanization (Global Water System Project (2005)). The project to assess the effects of human activities on the subsurface environment in Asian cities has started (Research Institute for Humanity and Nature (2005)). In this project, for monitoring the ground water changes, we intend to employ a new technique of precise gravity measurements combined with GPS positioning. The effects of ground water variations are one of the largest sources which cause the local temporal gravity changes. Therefore precise gravimetry on land should be a powerful tool to monitor the ground water variations.

The data of gravity measurements on land reflect the local gravity variation which is directly connected to the effects of urbanization, and also regional or global scale gravity variations. For precise and accurate estimation of the local ground water variations, it is necessary to separate the regional or global signals from the observed signals. For this purpose, we intend to utilize GRACE data to estimate global or regional mass variations. GRACE is providing us monthly solutions of global gravity fields as a set of spherical harmonic coefficients (e.g. Tapley et al. (2004)). The data show a good agreement with the seasonal varying signal in the spatial scale about 1000 km (Wahr et al. (2004)). One of the interesting questions is how well the data represent more fine scale mass movements and can be applied for the purposes of urban scale phenomena. Thus, in this study, we attempted the recovery of mass variation over the surrounding region of Bangkok, Thailand, as a sample case of a typical urbanizing city in Asia.

2. Test areas

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

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

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

River Name	Drainage Area (km^2)
Chao Phraya	178 000
Mekong	814 000
Salween	330 000
Irrawaddy	425 000
Total	1 750 000

3. Data processing

3.1 GRACE data

Currently 22 data sets of GRACE Level 2 (near) monthly gravity field solutions up to degree/order 120 or 70 have been released (Center for Space Research (2004)), and we employed those data in this study. The time period of each solution corresponds to Apr/May, Aug, Sep, Oct, Nov in 2002, Feb, Mar, Apr, May, Jul, Aug, Sep, Oct, Nov, Dec in 2003 and Jan, Feb, Mar, Apr, May, Jun, Jul in 2004, respectively. Because the effects of ocean pole tide had not been corrected in the GRACE Level 2 products (Wahr et al. (2004)), those effects were estimated and corrected by the method given by Wahr (1985) using the IERS polar motion values. Further, because the effects of Sa and Ssa ocean tides have been corrected only up to degree 10 in the

GRACE Level 2 coefficients, these effects of the higher degrees were estimated with NAO99L ocean tide model (Takanezawa (2001)) and removed from the GRACE coefficients. To obtain the gravity variations over the 22 period, the average of the 22 data solutions were subtracted from each of data sets. The derived variable components were truncated at degree and order of 70.

3.2 Removal of the load effect of ocean and land water of other area

The ocean load effects of the period longer than the time resolution of the GRACE Level 2 solutions, namely about 1 month, were estimated from the bottom pressure data of ECCO (Estimating the Circulation and Climate of the Ocean) - JPL Ocean Data Assimilation Project model (Lee et al. (2002)). We calculated the ocean effects as follows. We first calculated the effects corresponding to the each of GRACE solution periods, and then the variable components were calculated by subtracting the average of the whole 22 data sets period. Finally corresponding Stokes coefficients of the variable ocean effects were subtracted from the GRACE variable components.

The load effects of the land water outside of the test area were estimated from the terrestrial water storage data estimated by Japan Meteorological Agency SiB and GRivet model (Hosaka et al. (2005)). The model contains the components of soil moisture storage (top ̃1 m), snow storage (water equivalent) and river channel storage. We replaced the model value inside the test area to 0 and transformed to Stokes coefficients as the same way of the estimation of the ocean load effects.

3.4 Recovery of regional mass variations

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

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

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

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

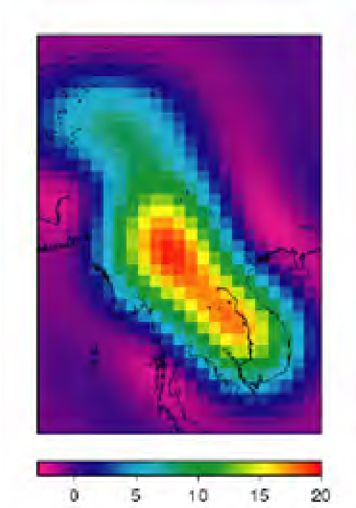

Fig. 2 Designed filter of the combined area of Chao Phraya, Mekong, Salween and Irrawaddy river basins.

3.5 Comparison with hydrological model

SiB and GRivet model were also used as the hydrological model for the comparisons with the results derived from GRACE data. The components of C_{00}, C_{10}, C_{11}, S_{11} and C_{20} were removed from the model for the consistency with the GRACE data.

4. Results

4.1 Recovery of mass variations over the Chao Phraya river basin

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

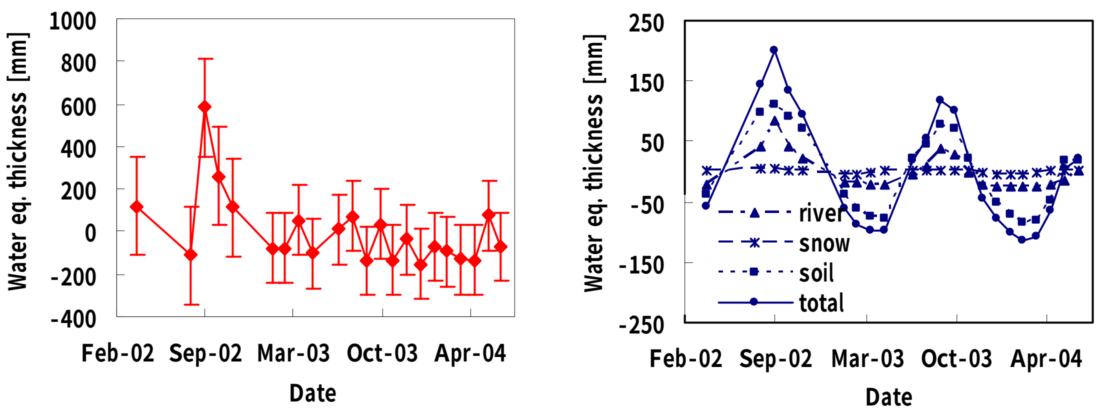

Fig. 3 Mass variations over the Chao Phraya river basin derived from GRACE solutions (left) and the model (right).

4.2 Recovery of mass variations over the 4 river combined area

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

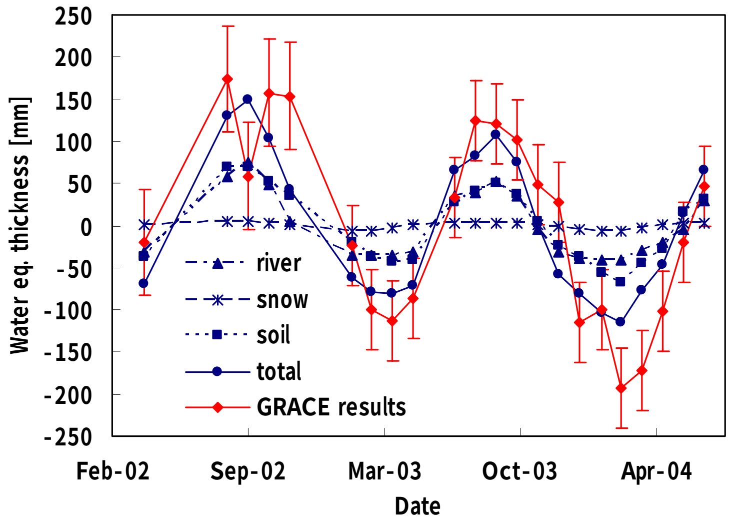

Fig. 4 Mass variations over the combined area of Chao Phraya, Mekong, Salween and Irrawaddy river basin derived from GRACE solutions and the model.

5. Discussion

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

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

As shown in Fig. 4, the mass variation of the 4-river combined area can be recovered with the accuracy of several cm from GRACE Level 2 solutions. The expected accuracy of the precise gravity measurements on land in this project is about a few 10 μGal, which corresponds to infinite water table of sub meter. The accuracy can be achieved by combining absolute gravity measurements at some selected control points and relative gravity measurements which cover whole survey area. The estimated error of GRACE is small enough to constrain the regional mass variations. Therefore we can use the data to remove the long wavelength variable components from the observed values on land.

6. Conclusion

We have started a new project to monitor ground water variations in urban areas in Asia. In the project, in-situ measurements of absolute and relative gravity measurements together with GPS positioning play fundamental roles. Addition to those measurements, GRACE data are strongly expected to estimate and remove the regional effects. In this study, we employed currently released GRACE Level 2 data sets for the estimation, and confirmed that the data should be useful to detect the relatively long wavelength mass variations, at least over the combined area of Chao Phraya, Mekong, Salween and Irrawaddy river basin. Although currently released data sets maybe insufficient to reveal the Chao Phraya basin scale variations, there may be several spaces to improve the filtering techniques and we expect improvements in the accuracy of GRACE data as well.

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Approaches to Estimation of Contaminant Load Variation at Mega-cities

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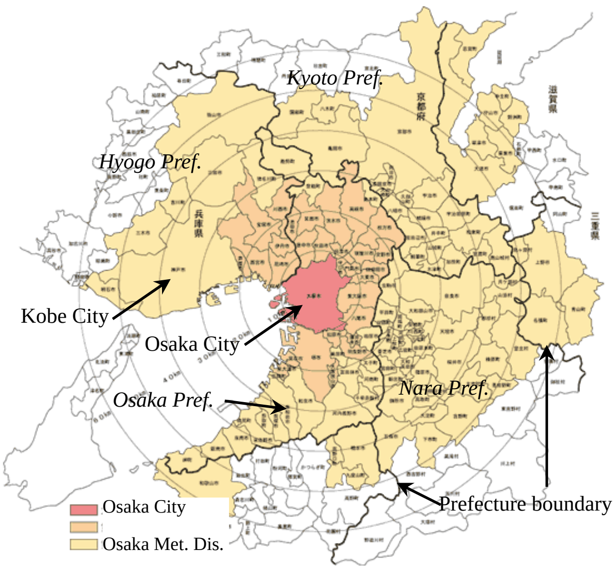
Abstract
To confirm the variation of contaminant load at mega-cities in Asia, we conducted the review of research papers in regarding to the pollution in Osaka, Japan and methodology for reconstructing the history of contamination. The results are summarized as follows: 1) based on the relationship between developing stage of city and pollution condition on Osaka, Asian cities are categorized into 3 main types. Bangkok and Jakarta are "developing" cities. Seoul is "developed" city. Osaka is "developed" with infrastructure. 2) Stable isotope of nitrogen, carbon and sulfate, dissolved ion, dissolved gas and trace metals are suggested to be reasonable method for reconstruction of pollutant history.

Keywords; contaminant, mega-cities, Asia, Osaka, groundwater, history

Introduction

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

The objective of this research is to confirm the current conditions of the water pollution in mega-cities, and to select the reasonable methodology for reconstructing of contaminant history and confirming of the relationship between water pollution and growing stage of mega-city. In this paper, these are discussed based on the example of Osaka, Japan.



Growing Situation of Osaka city

Fig.1 shows Osaka city and the around areas, Japan. The area shown by dark color in Fig.1 is Osaka city, and colored area is Osaka Metropolitan district. The later one includes Kobe city and Kyoto city. Population of Osaka Metropolitan district is more than 10 million. This area is characterized by relatively small suburban area.

Fig.2a shows the variation of population and industrial production index of Osaka prefecture. Both of population and industrial production index increased significantly from 1920s to 1970s. Population was less than 3 millions in 1945, but it became more than 8 millions in 1970s. The urban area expanded from the center city to around area shown by medium color in Fig.1 with increase of population. Consequently, suburban area narrowed in these areas. Since 1970s, the prefecture population increased slightly less than 1 million for 30 years. But Industrial production index kept increasing 1.5 times of that for 20 years.

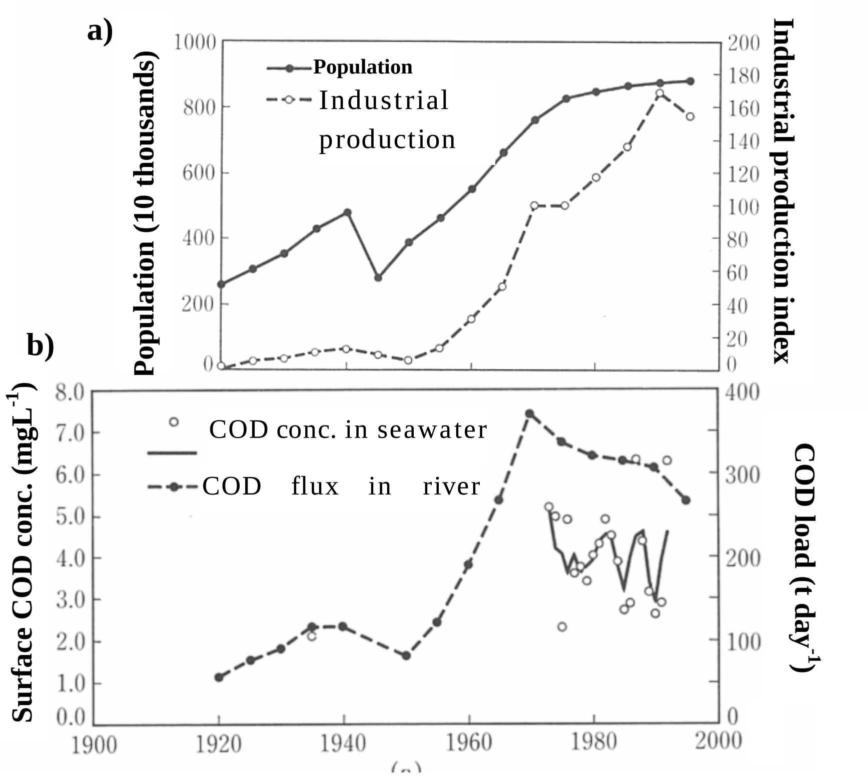


Fig.2 Variation of a) population and industrial production index, and b) surface COD concentration in Osaka bay and COD flux from river (Nakatsuji, 1998).

Pollution Problem in Osaka

Fig.2b shows the variations of surface COD concentration in Osaka bay and COD load from river to the sea for more than last 30 years (Nakatsuji, 1998). But surface COD concentration in Osaka bay is only since 1970. COD concentration and COD load were a maximum in around 1970. COD load from river to the sea was a minimum in around 1950. It was approximately constant before 1950. COD load in river became 4 times for 20 years from 1950 to 1970. This period coincides with rapid increasing period of population. These results suggest the effect of urbanization on the quality of river water and seawater.

Since 1970s, population increased gradually and industrial production index also increased, however COD concentration and load decreased. This downward trend suggests to be originated in the development of sewage treatment system. However, even if river water pollution decreased, the impact of pollution before 1970s would be reflected in subsurface environment. Burt et al. (1993) introduced the example of sluggish transport of contaminant accumulated for 30 years in unsaturated zone of upland in England. It means that we need to notice the groundwater contamination after the peak of river water pollution.

Fig.3 shows the condition of groundwater contamination in Osaka prefecture from 1993 to 2003 (Environment Council, Osaka Prefectural Government, 2004). The various contaminants include Br, B, Hg, As, nitrate, Pb and VOC in this figure. This result indicates that various contaminants are detected in groundwater in

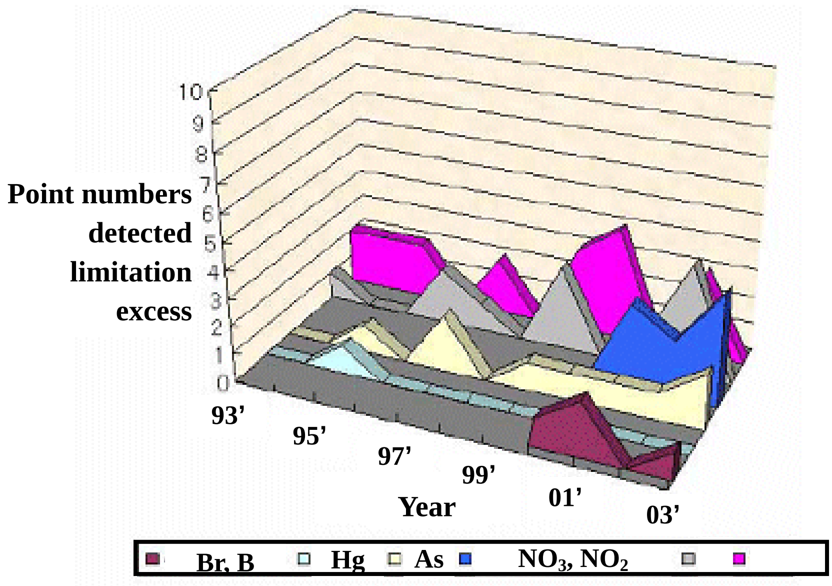


Fig.3 Various groundwater contamination in Osaka

recent years.

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

Pollution Property in Various Developing Stage of City

Based on the example of Osaka, we discuss about pollution property in various developing stage of city. In 1950s, some pollutions and damages by them had begun to recognize in the local scale such as a river in Osaka city. This period is the first stage of water pollution with accelerated economic growth and population increment in the mega-city process. In this stage, the main contaminant is composed of the dissolved nitrogen in domestic and agricultural waste and heavy metal originated in industrial activity.

In 1960s and 1970s, Japanese mega-cities had an experience of the most severe contamination in river and seawater by human sewage and industrial waste. This period is the second stage with the change to gradual growth of city.

In the over 10 years later, we faced with the groundwater and soil contamination by nitrate, heavy metal and organic compound, while the river contamination had been begun to improve by the development of sewage system. This period is third stage. The subsurface contamination generally appears with delay because of the difficulty of its detection and long transport time.

In addition, the distribution of trace metal content in the sediment in various Asian mega-cities by some previous studies (Williams et al., 2000; Jiang et al., 2001 etc.) indicated the change of pollution properties with the growing stage like from the direct leaching to atmospheric deposit. It also suggests that the trace metal discharges with delay in future.

Methodology for Reconstructing the History of Contamination

Pollution properties are useful to reconstruct the contamination history, such as the history of fertilizer application and industrial waste. Especially, the stable isotope and dissolved gas component of nitrogen (Blicher-Mathiesen et al., 1998) would be effective for the reconstruction. Under the anoxic condition such as groundwater discharge area and deeper layer, denitrification (NO_3^- -> 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.

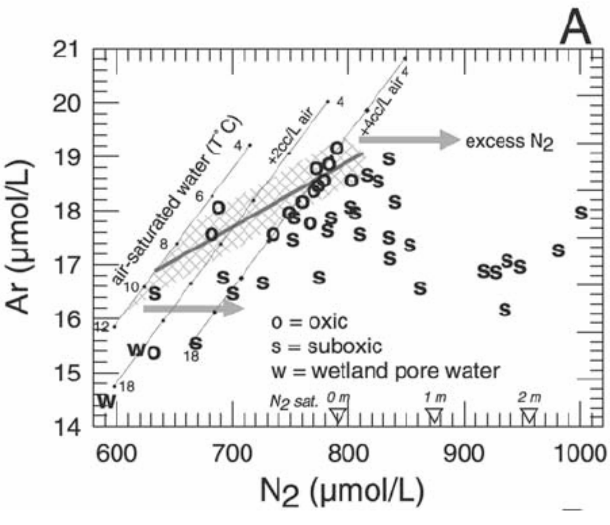


Fig.4 relationships between dissolved N_2 and Ar gas concentrations in groundwater (Bölke et al., 2002).

Fig.5 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.

Furthermore, we also need to analyze the isotopic ratio of trace metal in sediment as well as the contents to determine the source of pollutants and sedimentation age.

Concluding Remarks

To confirm the variation of contaminant load at mega-cities in Asia, we conducted the review of research papers in regarding to the pollution in Osaka, Japan and methodology for reconstructing the history of contamination. The results are summarized as follows:

1) based on the relationship between developing stage of city and pollution condition on Osaka, Asian cities are categorized into 3 main types. Bangkok and Jakarta are "developing" cities. Seoul is "developed" city. Osaka is "developed" with infrastructure.
2) Stable isotope of nitrogen, carbon and sulfate, dissolved ion, dissolved gas and trace metals are suggested to be reasonable method for reconstruction of pollutant history.

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

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Abstract

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

1. Human impact on water quality in tributary rivers of Lake Biwa, central Japan

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

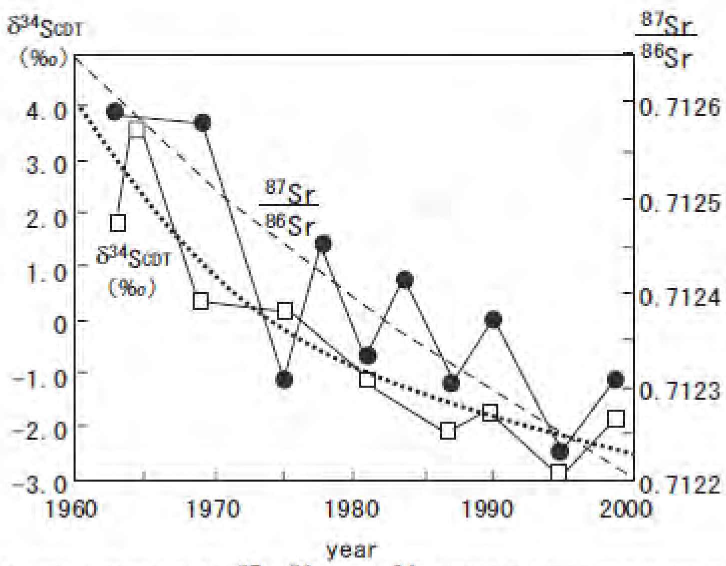

Fig. 1. Annual change of the $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ values of Leucopsarion petersi over 40 years from 1960 to 1999. Broken a along dotted lines represent the calculated change in $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ values of the lake water by inputs of small rivers from the eastern agricultural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

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

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

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

2. Water quality change of confined groundwater in northeastern Osaka Basin

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

Except ground waters along faults, the ^{34}S value of Mg-HCO_3 groundwater and Na-HCO_3 one were higher and more uniform than those of the Ca-HCO_3 groundwater and two rivers, which are considered as the recharging water. The concentration of SO_4 in the deep Na-HCO_3 type groundwater was distinctly lower than other types of groundwater. This change of isotopic ratio and concentration of SO_4 in the water can be reproduced by the Rayleigh type distillation model in which SO_4 in water was reduced by the activity of sulfur reducing bacteria into H_2S in a closed system. Model calculation shows that the SO_4 reduction progressed from the Ca-HCO_3

type (0-40 %) through the Mg-HCO_3 type (10-60 %) to the Na-HCO_3 type (20-80%).

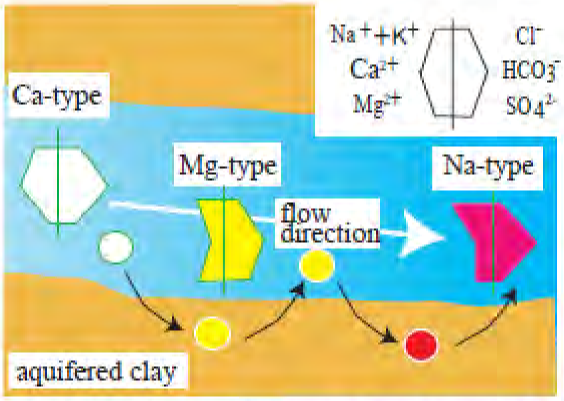

Fig. 2. Change of water quality type of groundwater in the northeastern area of the Osaka basin, central Japan. Water quality change is explained by cation-exchange process between water and aquifered clay as it flows. See Yamanaka et al (2005) in detail.

3. Potential application of Pb isotope into fresh water system

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

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

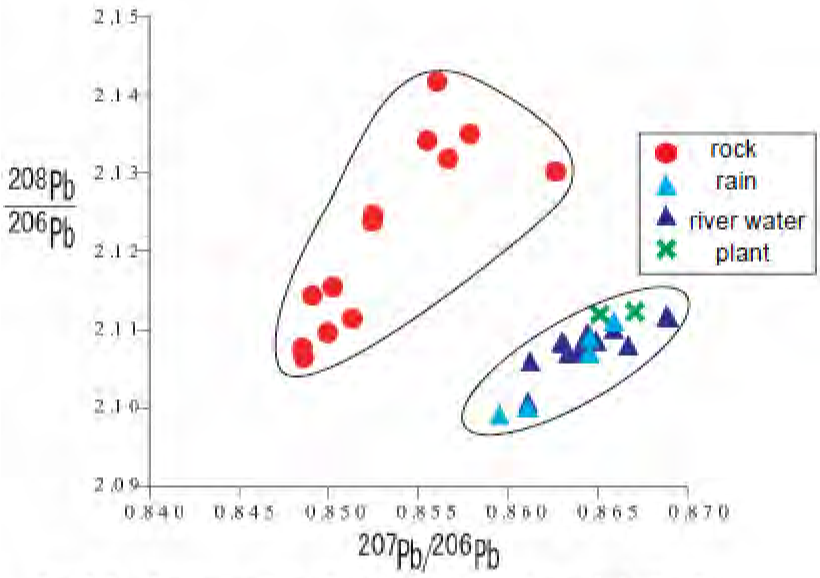

Fig. 3. Lead isotopic ratios of rock, rain, river water, and plant in the granite watershed of Tsukuba area of central Japan.

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

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Abstract

It is possible to estimate the past ground surface temperature (GST) history from temperature profiles measured in boreholes. This geothermal method of GST history reconstruction will be applied to studies of the evolution of the surface thermal environment (e.g. surface air temperature, land use) in large cities in East Asian countries. We also plan to conduct long-term monitoring in selected boreholes to observe the penetration process of GST variation and to examine the heat transfer mechanism. In Japan, Korea, and Taiwan, we will survey larger areas around the target cities to delineate the "heat island" effect.

1. Introduction

Temporal variation of the ground surface temperature (GST) propagates into subsurface sediments and basement rocks by thermal diffusion. It is a rather slow process since the thermal diffusivity of sediments and rocks are low, 10^{-6} to 10^{-7} m^2/s. As a result, the GST variations in the last several hundred years have been recorded in the underground temperature distribution in the upper several hundred meters. It is therefore possible to estimate the history of GST (closely related to the surface air temperature) from vertical temperature profiles measured in boreholes. This "geothermal method" for past climate reconstruction has some important features: (1) the temperature history is directly determined from temperature data, not through conversion from the proxies (such as tree-ring data), (2) the long-term trend (century scale) of temperature variation is obtained, (3) times and areas with no meteorological data can be covered. Reconstruction of GST by this method has been extensively conducted in the last few decades mainly in North America and in Europe and analysis methods have been well investigated (e.g. Lewis and Wang, 1992)..

2. GST reconstruction studies in East Asia

Japanese research groups including the authors recently started GST history reconstruction studies in East Asian countries, such as Japan and Korea (e.g. Goto et al., 2005a; 2005b). Fig. 1 shows an example of the results of these studies, reconstruction of the GST history from borehole temperature data in Awaji Island, SW Japan. The obtained GST history seems to be consistent with the surface air temperature data at a nearby meteorological station.

Our results can be compared with the results of similar studies in China and Siberia (Fig. 2). All of the GST histories show surface warming in the last 100 to 200 years, but the amplitude and timing of the warming are different from each other. These differences may result not only from regional variations in the global warming but also from surface environment changes due to human activities around the boreholes (e.g. "heat island" effect, land use change). It should be noted that in some cases effects of groundwater flow on the subsurface temperature distribution need to be considered (e.g. Taniguchi et al., 1999).

(a)

(b)

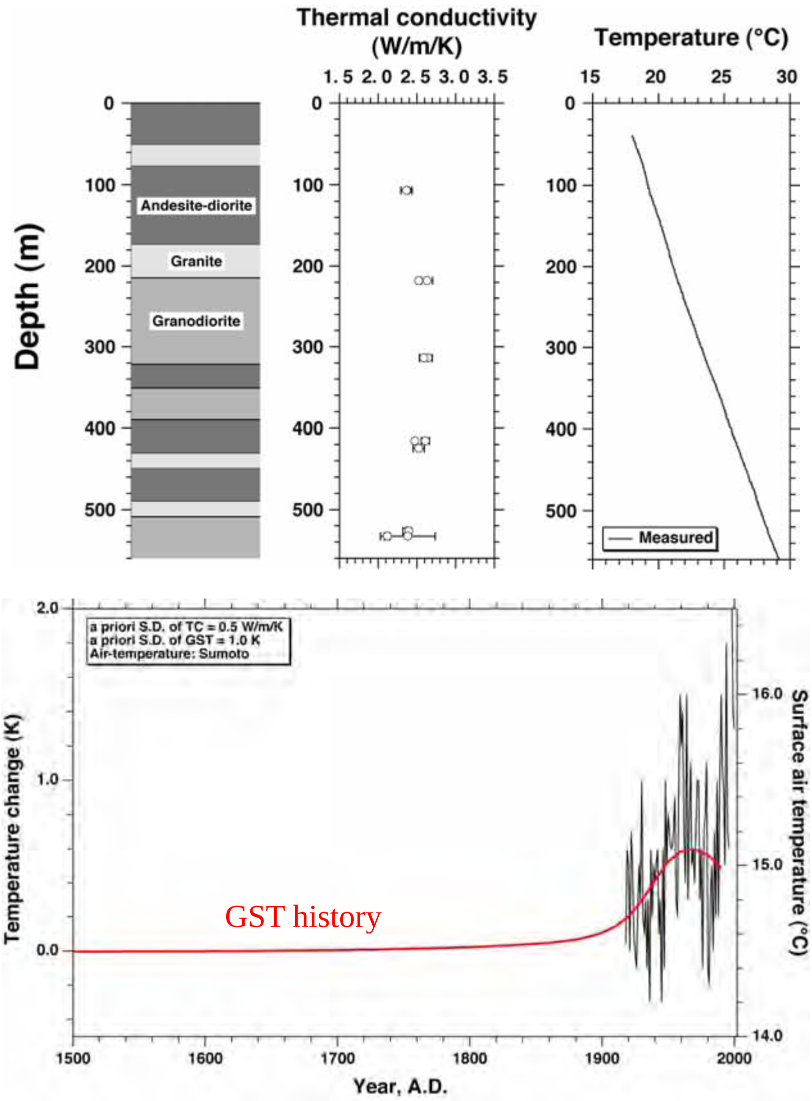

Fig.1 (a) Temperature and thermal conductivity data obtained in a borehole in Awaji Island, SW Japan. (b) Reconstructed GST history (red) with the mean annual surface air temperature at a nearby meteorological station, Sumoto (black) .

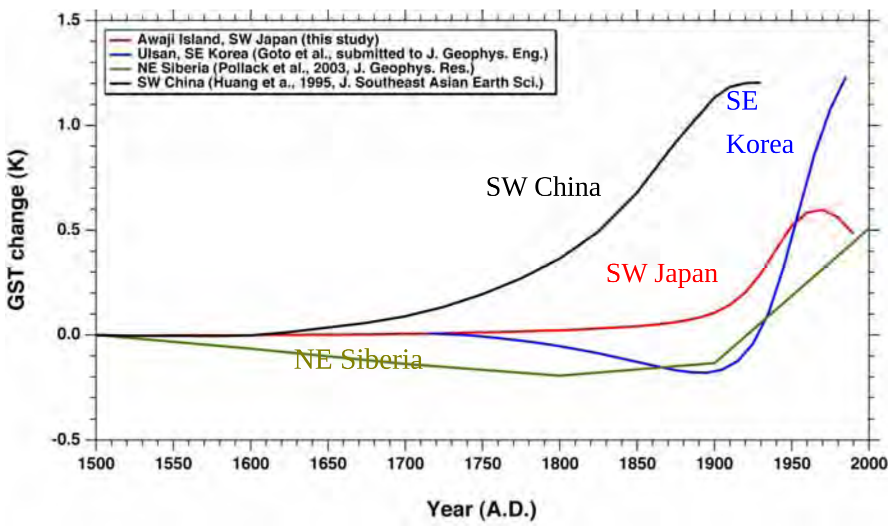

Fig. 2 Comparison of reconstructed GST histories in East Asian countries.

3. Reconstruction of the thermal environment evolution in urban areas

As a part of the project “Human Impacts on Urban Subsurface Environment”, we will investigate the evolution of the thermal environment at the ground surface in and around large cities in East Asia, using the geothermal method of GST history reconstruction. Main research items are: (1) temperature logging in boreholes, (2) thermal conductivity measurement, (3) long-term temperature monitoring in boreholes.

We will conduct temperature logging in boreholes to obtain vertical temperature profiles, from which the GST histories are estimated. Repeated measurements in the same borehole with some time interval are necessary to examine the stability of the temperature profiles. Temperature logging in boreholes in which temperature profiles were measured previously (10 to 20 years ago) would be very useful, because simultaneous analysis of the old and new temperature profiles provides more reliable GST histories (Wang and Lewis, 1992).

Information on thermal conductivity of formations around the boreholes is important, especially in areas with multi-layer subsurface structures. We will measure thermal conductivity on core samples from the boreholes used for GST reconstruction. If core samples are not available, thermal conductivity will be estimated from lithological data based on measurements on similar types of rocks.

Meteorological data at nearby stations (air temperature, soil temperature, solar radiation, etc.) should be collected as well. For comparison with other information on the thermal environment, we may need to convert the reconstructed GST into the surface air temperature using the meteorological data. It is also possible to use the surface air temperature data as a constraint on GST reconstruction analyses (e.g. Harris and Chapman, 2001).

4. Long-term temperature monitoring in boreholes

We also intend to conduct long-term temperature monitoring at multiple depths in selected boreholes. The obtained data will show the ongoing downward propagation process of the GST variation, which may provide an evidence to support the result of GST reconstruction from borehole temperature profiles. Cermak et al. (2000) carried out long-term monitoring of temperature in boreholes in the Czech Republic and showed that temperature records at about 40 m depth demonstrate penetration of long-period components of GST variation (Fig. 3). We will also be able to obtain information on the mechanism of heat transfer (conduction or advection) and estimate the thermal diffusivity from long-term temperature data.

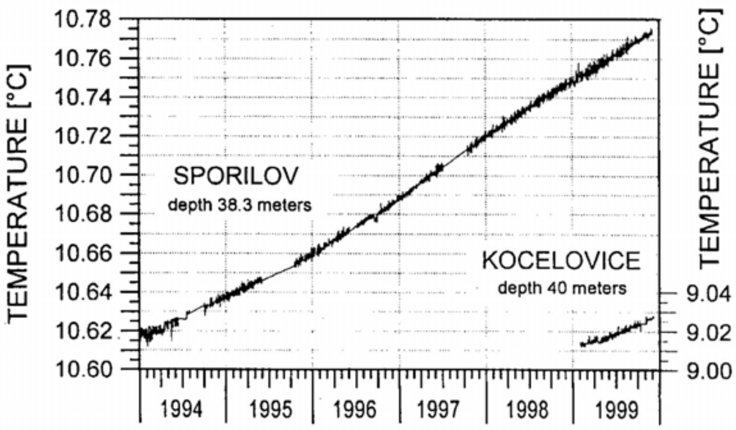

Fig. 3 Long-term temperature records at 38.3 m depth in one hole and at 40 m depth in another hole in the Czech Republic (Cermak et al., 2000).

Long-term monitoring can also be a tool to investigate the cause of the disturbed temperature profile. Repeated temperature logging in a borehole on the coast of Lake Biwa revealed that the temperature in the upper 70 m significantly increased between 1993 and 2002. We conducted monitoring of the temperature at 30 m depth to investigate the nature of the temperature variation and detected a steady temperature increase at a nearly constant rate, about 20 mK/yr (Fig. 4). This temperature increase can be explained as a result of a sudden rise in the average GST due to construction of a building covering the top of the borehole in 1996.

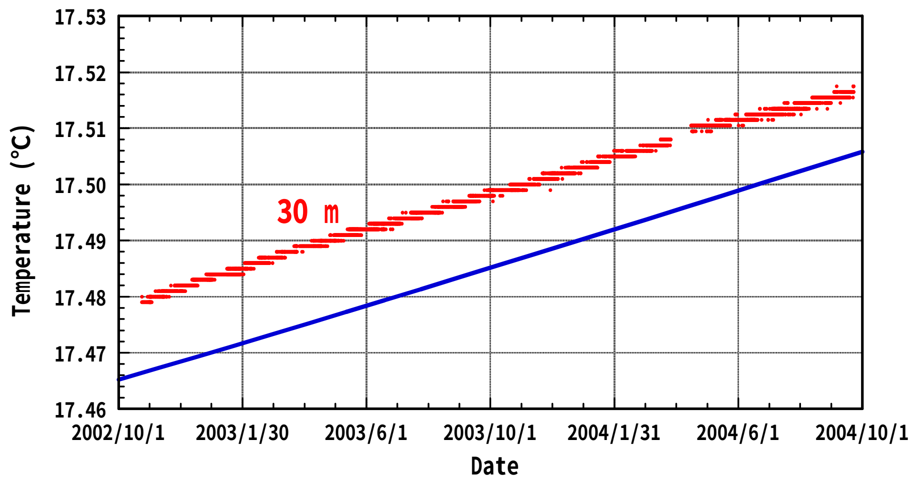

Fig. 4 Two-year temperature records at 30 m depth in the Lake Biwa borehole (red). Temperature change calculated for a sudden rise in GST by 1.15 K in 1996 (blue) well explains the observed data.

5. Target areas

We plan to conduct GST history reconstruction studies described above mainly in Tokyo, Seoul, Bangkok, Taipei and their suburbs. Osaka, Jakarta, and Manila can also be research targets.

In addition, we will make surveys in relatively large areas around the target cities in Japan, Korea, and Taiwan, in which boreholes are widely distributed over the countries. GST histories reconstructed in wide areas may delineate the thermal effect of urbanization (heat island) in a large scale (e.g. Beltrami et al., 2003).

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Urban Heat Island in Asian Cities

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Abstract

In the authors' research plan, relations among the changes in surface climatic factors, land use and strength of human activity (social economic indexes) are systematically provided in the subjected cities in Asia. Here the influence of urbanization in regard to the vertical profile of subsurface temperature is also clarified. These results are useful in separating the influence of global warming from the influence of warming caused by urbanization. And they are contributable as a quantitative guideline for countermeasures for the mitigation of urban thermal environment in Asian cities based on social-scientific discussion. The possibility of ground water usage as a means of thermal environmental mitigation in urban areas in the subjected cities and whether it is successful to mitigate thermal environment with a system of urban planning are also systematically clarified.

1. Introduction

Urban heat island (UHI) phenomena (e.g. Landsberg, 1981), exemplified by the warming of urban areas, are of great concern. Warming of urban areas is generally regarded as not only making urban life uncomfortable (e.g. thermal discomfort, health impacts like heat shock) but also giving several social damages like increasing energy use for air conditioning, air pollution accelerated by less ventilation, changing flora and fauna in urban areas. Previous research on urban climatology has shown the causes of heat island phenomena (Fig.1) to be anthropogenic heat emission, reduction of green space and water surface in urban areas, change of heat capacity of the material on urban surfaces, change of environment with regard to radiation, and the combination of these factors (e.g. Oke, 1987). Research progress on the improvement of urban thermal environments has been inadequate, while a great amount of knowledge on urban climate has been accumulated in the long history of urban climatology (Yoshino, 1990/1991).

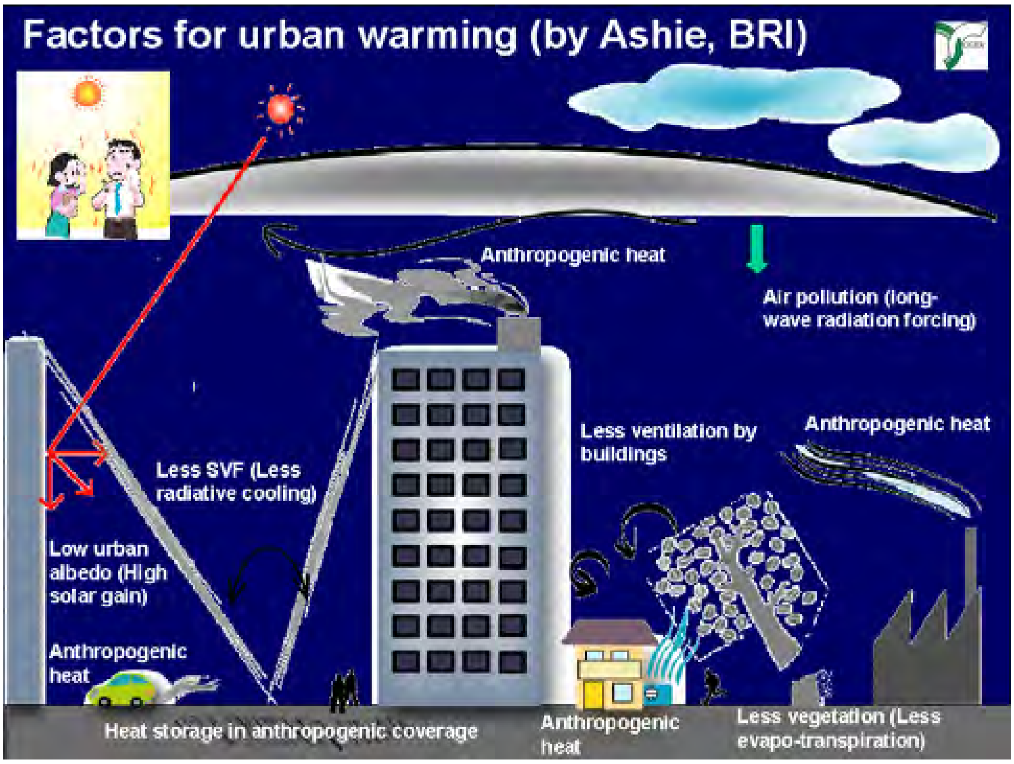


Fig.1 Factors for urban warming (by Ashie, Building Research Institute of Japan)

2. Recent Significant Scientific Progresses and Related Movements

Monitoring of UHI phenomena were performed by the authors group during three years (1997-1999) in Asian three cities (Tokyo, Shanghai and Bangkok). Then, guidelines for urban planning in the future were indicated by considering the data taken in the monitoring and their numerical simulation with climate models (e.g. Mikami *et al.*, 2000; Ichinose Eds., 1997). This project showed the importance of viewpoint of urban thermal environment and recommendation for urban planning process with basic routine on urban climate analysis (including evaluation of anthropogenic heat, building structure and vegetation coverage). After this project, Ministry of Environment (MoE) has started making systematic counteractions against UHI in Japanese regional autonomies regarding UHI as one of air pollution by heat (e.g. MoE, 2001a; MoE, 2001b; Fig.2).

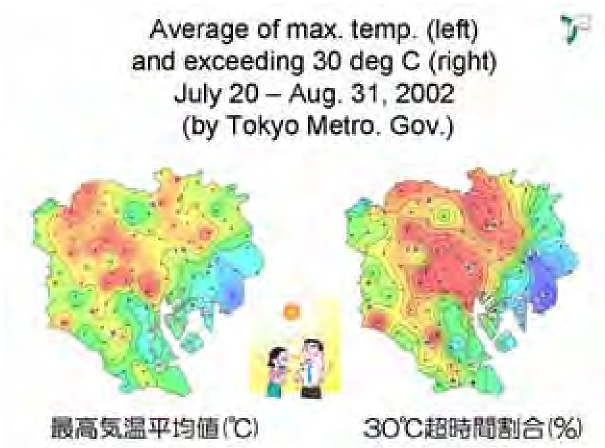


Fig.2 A result of monitoring project of Tokyo Metropolitan Government; as an impact of activities of Ministry of Environment in a regional autonomy. (by Tokyo Metropolitan Government)

The main environmental problems of Asian mega-cities arise from the fact that priority is given to economic development more than to environmental protection. It is necessary to control technologies used in creating the urban environment together with methods of urban planning. Figure 3 shows an on-going restoration project of inner-city stream in central Seoul, Korea. This project appeared not by request from urban thermal comfort. However, this will be an epoch-making of urban planning considering urban thermal comfort. In Japan, owners of small patch of land have a right to decide how they use their own land. However, top-down approach in urban development is still available in many Asian countries. Such aggressive social experiments to promote ideal urban construction in view point of urban climate protection seem to be possible in these countries. Before this restoration project, the author's group has started monitoring what is going on (Ichinose, 2005). Not in numerical simulation, we got a big chance to notify the atmospheric impact by such drastic change of surface coverage in a real urban space. It will lead a world-wide paradigm shift of urban development (Fig.4).

Fig.3 Landscape around Dongdaemun before restoration of the Cheong-Gye Stream and the future plan (Seoul Metropolitan Government; before June, 2003 and future image after October, 2005)

Fig.4 Photographs at reclamation stage since 1960s (Seoul Metropolitan Government) and restoration stage of the Cheong-Gye Stream

3. Our Research Plan

In the authors' research plan, relations among the changes in surface climatic factors, land use and strength of human activity (social economic indexes) are systematically provided in the subjected cities in Asia. Here the influence of urbanization in regard to the vertical profile of subsurface temperature is also clarified. These results are useful in separating the influence of global warming from the influence of warming caused by urbanization. And they are contributable as a quantitative guideline for countermeasures for the mitigation of urban thermal environment in Asian cities based on social-scientific discussion. The possibility of ground water usage as a means of thermal environmental mitigation in urban areas in the subjected cities and whether it is successful to mitigate thermal environment with a system of urban planning are also systematically clarified.

The authors will prove mutual relations by collecting information on the changes in surface climatic factors (temperature, precipitation, daylight hours, amount of cloud, wind velocity, etc), comparing to a vertical profile of subsurface temperature obtained from the subjected cities in Asia, information on the transition in land use and strength of human activity (social economic indexes) which enable to explain the changes in inter-annual surface climatic factors (Fig.5), and information on the changes in air pollution which relates to these. Here, they choose cities where enable them to compare an urban area and a suburban area within the same city, and they clarify the influence of urbanization in regard to the vertical profile of subsurface temperature. They mainly collect observation data up to the past 150 years, and up to the past 250 years, they rely on the restoration of climatic factors from the numerical computing (Fig.6).

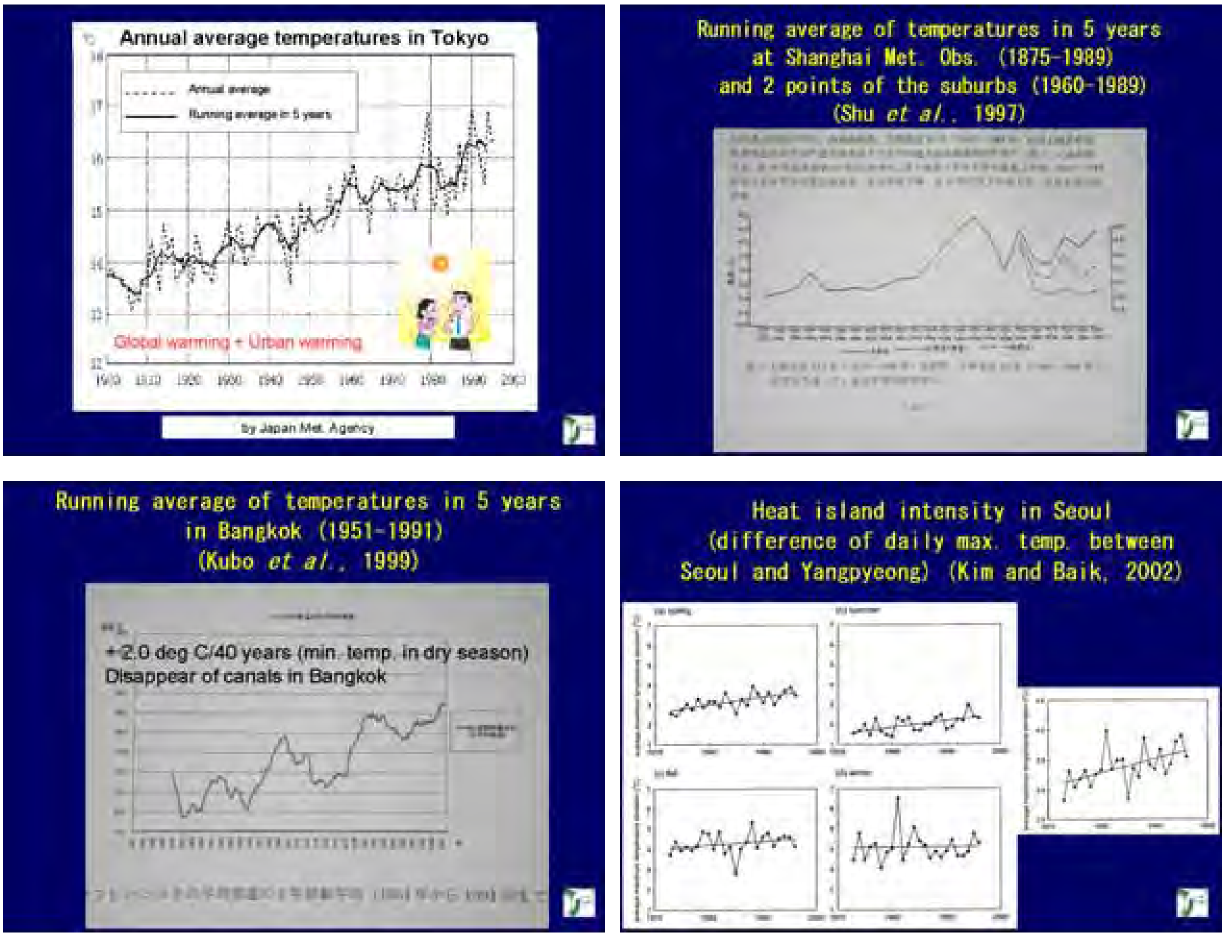


Fig.5 Examples of recent warming in Asian mega-cities

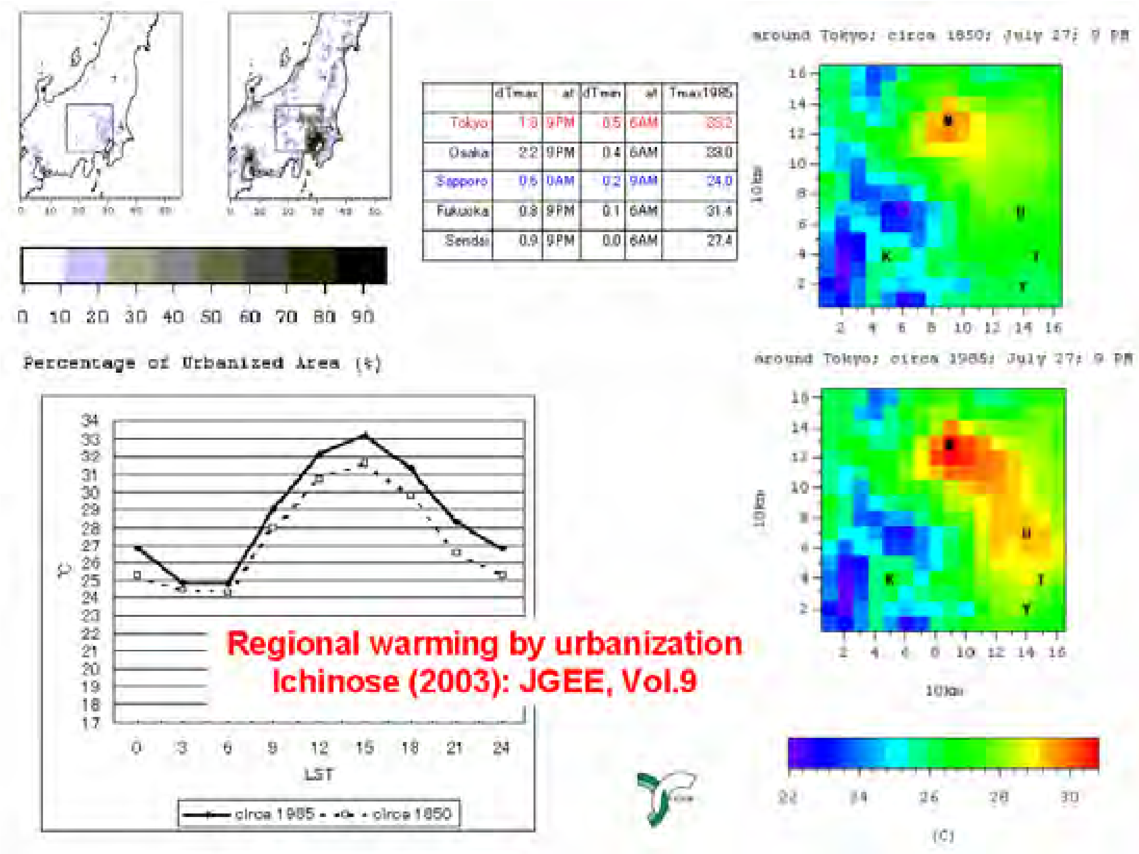
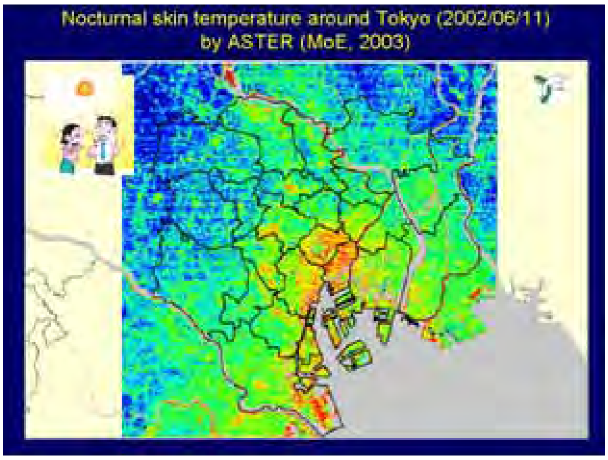
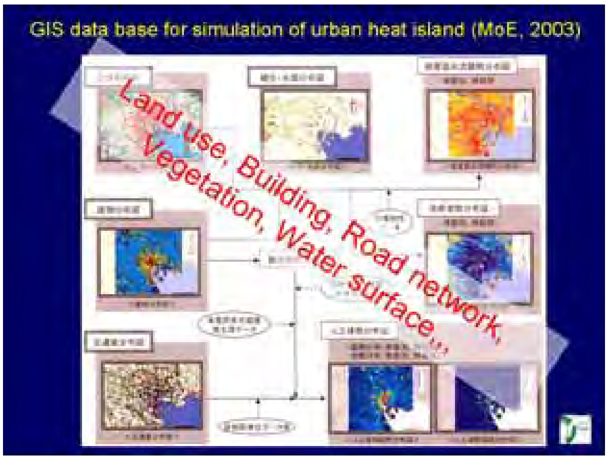


Fig.6 An example of numerical computing of regional warming around Tokyo by urbanization (Ichinose, 2003)

Concerning to the numerical computing, anthropogenic heat emissions are necessary as a parameter, and they make a database from these collected data and provide them to input to a climate model (Fig.7;Fig.8).





(left) Fig.7 Skin temperature as a bridge between air and subsurface temperatures (MoE, 2003).
(right) Fig.8 GIS data base for simulation of urban heat island (MoE, 2003)

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General Aspects of Groundwater System in Seoul, Korea

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Abstract

Groundwater in Seoul is abstracted for public water supply and industrial use, and to drain underground facilities such as subway and construction sites. Though most tap water is supplied from the Han River, the quantity and quality of groundwater is of great concern to Seoul's citizens, because the public interest on the use of groundwater in emergency condition is continuously increasing. The city of Seoul installed 119 monitoring wells and started periodic monitoring of basic parameters on groundwater quantity and quality since 1999. This study uses the hydrogeological data and monitoring data to illustrate the hydrogeological conditions of the Seoul area. Major factors affecting the urban groundwater budget and groundwater quality include leakage from the municipal water-supply system and sewer systems, precipitation infiltration, water-level fluctuations of the Han River, the subway pumping system, and domestic pumping.

1. Introduction

As of 2004 Seoul has the area of 605 km^2 or 0.6% of the entire country and is home to 10.2 million people. The first survey of groundwater resources in the Seoul area was conducted by the city of Seoul and the Korea Agricultural & Rural Infrastructure Corporation (KARICO) (formerly Rural Development Corporation) from 1995 to 1996 (Seoul Metropolitan City, 1996). The survey focused on compiling groundwater statistics and assessing the prospects of future groundwater use. A second evaluation was performed jointly by the Korea Institute of Geology and Mineral Resources (KIGAM) and Seoul National University from 1995 to 1997 (Sung et al. 1997; Kim et al., 2001) and involved well inventory, measurement of groundwater tables, location of potential groundwater contamination sources, and collection of chemical-analysis data. The city of Seoul installed 119 monitoring wells with telemetry monitoring system in 1999 and started regular monitoring of water tables and basic hydrochemical parameters such as pH, electrical conductivity (EC), and temperature. An automated telemetry system delivers measured data of water pressure, pH, EC and temperature with the interval of an hour.

The objective of this study is to use the monitoring data and the specific hydrogeological information of the study area to identify and analyze the major components affecting the groundwater environment of a large and heavily populated urban area.

2. hydrogeologic Setting

The geology comprises a relatively small area of Precambrian banded biotite gneiss and a large area of granite (Fig. 1). The gneiss fabric dips generally to the southeast. In boundary areas of the gneiss, rock phases show slow gradational changes. During the Jurassic period, granite intruded the metamorphic rocks.

Aquifers in the area are of two types: unconsolidated alluvium of the Han River and its tributaries, and fractured rocks. Alluvium is mainly composed of coarse-grained sediments inter-layered with fine-grained sediments that result in variable permeability within the alluvial aquifer. The fractured-rock aquifer comprises granite, schist, and gneiss.

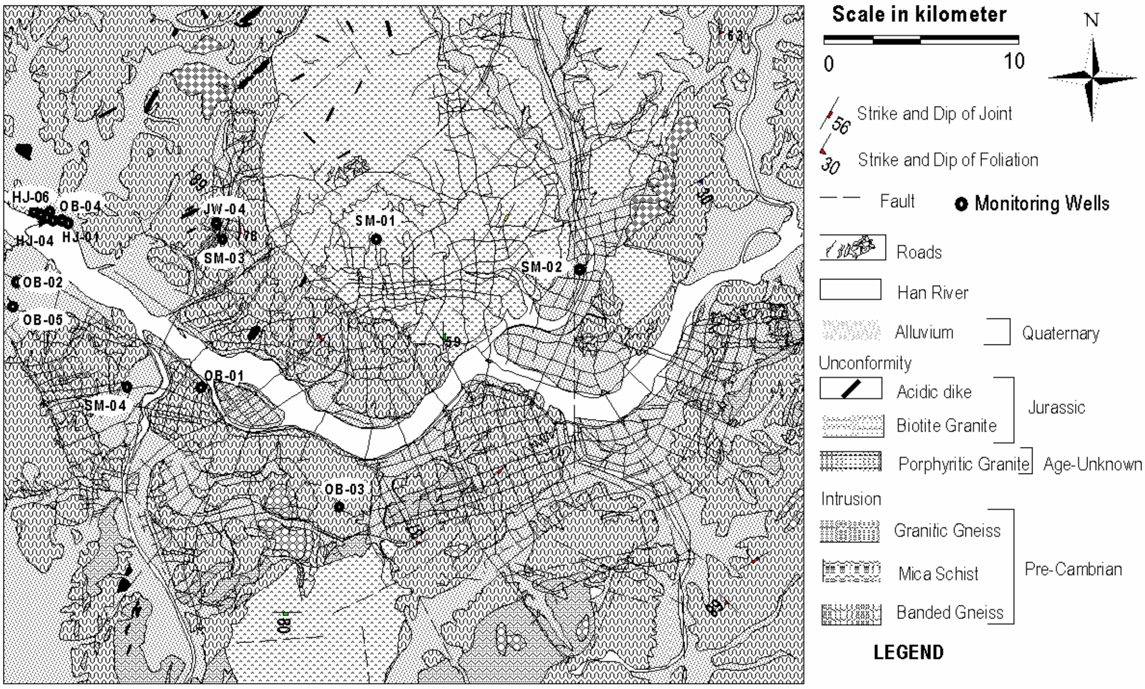

Fig. 1. Geologic map of Seoul area.

3. Water level fluctuation

Water table variation patterns are shown in Fig. 2. The wells with depths to water table less than 5 m show relatively clear response to the precipitation. The response weakens as the depth to water table increases. Some wells showing very rapid water-level change are probably influenced by flooding of the observation well by surface water, leaking drains, or sewer channels. Periodic drawdowns are related to nearby pumping whereas large declines without recovery are associated with subway pumping. Evaluation of the monitoring data suggest that the pattern of hydraulic-head fluctuations in the urban area are determined by the following factors: flooding by surface water, groundwater pumping for domestic or industrial uses, sewer and water-supply leakage, rainfall, river-level fluctuations, barometric-pressure variations, and groundwater drainage from subways and underground construction.

1.

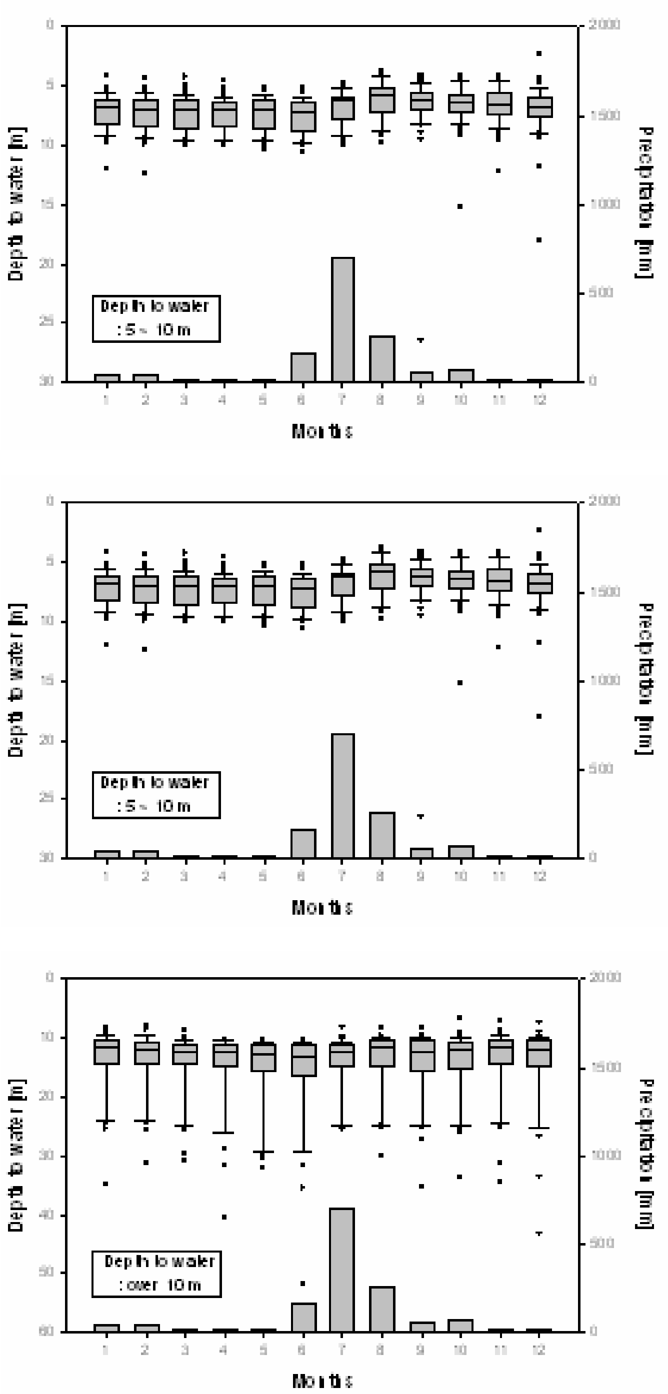

Fig. 2. Water level fluctuation in monitoring wells with different depth levels (based on monitoring data in 2001).

4. Factors affecting groundwater budget in Seoul area

Water table fluctuation patterns and variation trends of several years indicate that urban hydrological factors together with natural factors affect the groundwater level variation in Seoul area. The major elements of the groundwater budget include net infiltration from precipitation, groundwater recharge by leakage from water-supply pipelines, groundwater interaction with sewage lines, groundwater extraction for domestic and industrial use, pumping of groundwater from underground subway tunnels and construction sites, and interaction with the Han River.

5. Summary

Preliminary study on the groundwater system change and water budget in Seoul area was performed. The groundwater system in Seoul area has some additional urban factors other than usual natural factors that affect the balance bwtween the recharge and discharge of groundwater. Some of the urban factors are leakage of municipal water supply lines, groundwater discharge or recharge to sewage system, and subway pumping. The problem to know how and how much these factors affect the groundwater system of Seoul area is one of important issues in the subsequent researches.

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Subsurface Environmental Changes in Taipei, Taiwan: current status

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Abstract

Taipei and neighboring counties are surrounded by mountains on all sides and shape as a distinctive basin in the northern Taiwan. Along with the continuous city expansion during the past decades, global warming and anthropogenic influences have generated perceivable effects on the Taipei Basin. The impacts of the urban heat island phenomenon and air pollution in this subtropical basin are alarming, as many metropolitans show elsewhere. Other environmental parameters are presented in this report to illustrate the unfavorable consequences and trends due to natural and human-derived disturbances in recent decades. The unique setting and abundant data from numerous previous studies make the Taipei Basin one of the ideal study sites for the RIHN Project 2-4.

1. Introduction

Taipei is the capital city and serve as political, economic, educational, cultural, transportation, information and technology hub of Taiwan. Surrounded by mountains on all sides, Taipei city and neighboring areas shape as a distinctive basin in the northern Taiwan (25.1^{o} N, 121.3^{o} E; Fig. 1) with an area of 380 sq. km and approximately 4 million inhabitants. Its climate is hot and relative low humidity in summer, cool and relative high humidity in winter. Along with the continuous city expansion during the past decades, global warming has generated perceivable effects on the Taipei Basin. The impacts of the urban heat island phenomenon and air pollution in this subtropical basin are alarming (Lin et al., 2005), as many metropolitans show elsewhere. Three rivers that come from east (Keelung), southeast (Hsintien) and south (Tahan) catchments, respectively, merge into one major stream (Tanshui) in the middle of Taipei Basin and flow northwesterly toward the Taiwan Strait. Many research topics that related to the subsurface environment have been proposed and conducted in the Taipei Basin. To be as one studied site in the RIHN Project 2-4 "Human Impacts on Urban Subsurface Environment", Taipei Basin has its unique features and will contribute significant results along with other metropolitan areas.

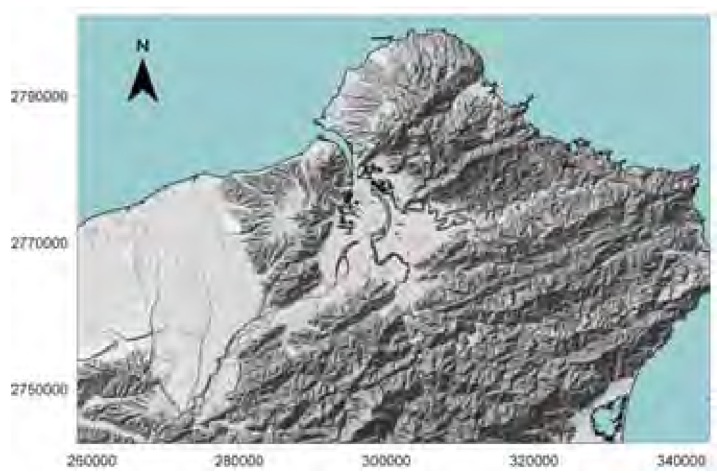

Fig.1. Location of Taipei Basin. Red circles are groundwater level monitoring sites.

2. Temperature records

As elsewhere in the world, Taipei has experienced a steady increasing tendency in the air temperature due to both the global warming and urban heat island effects (Lin et al., 2005). Figure 2 displays the annual temperature variations from 1897 to 2004. The annual temperatures are expressed as anomalies relative to the long-term average (22.2°C) which serves as the base line. The general feature of the temperature change agrees well with the global average trend. It is evident that Taipei has a linear rising rate of 0.15°C per decade. Before 1940, only one year (1915) had an annual temperature higher that the long-term average. There were some minor fluctuations between 1940 to 1975 with a relative small value (0.03°C/10 years) for the temperature rising slope. After 1975, all annual temperatures were higher than the long-term average except years of 1976, 1979 and 1984. The rising rate after 1980 (0.38°C/10 years) is more than two times faster than the linear rate for the past century, indicating the recent acceleration of climate warming in the Taipei Basin.

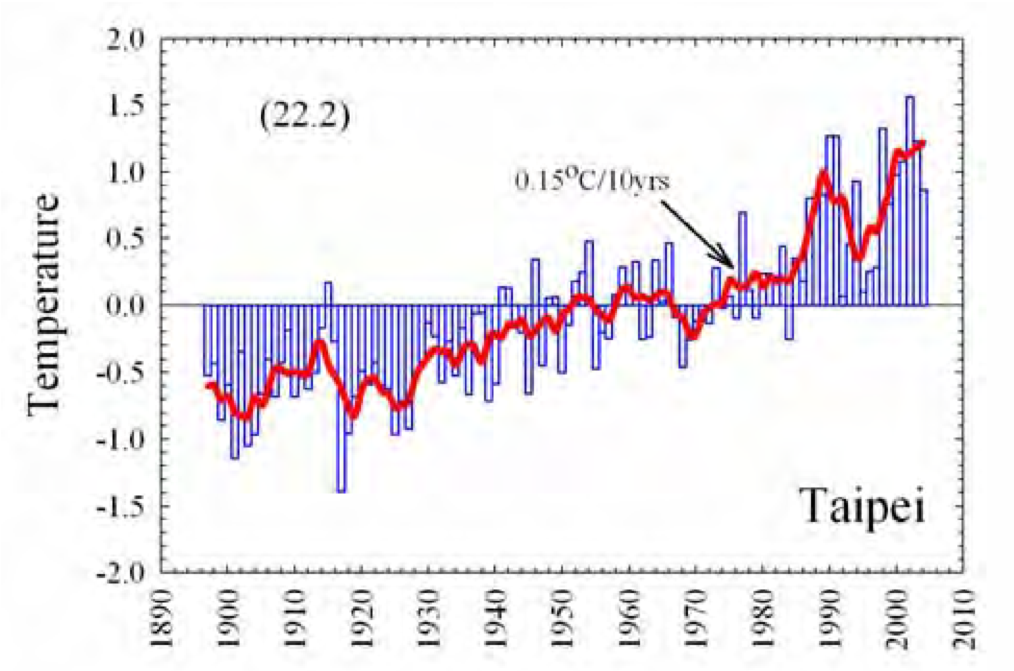

Fig.2 The long-term annual temperature trend of Taipei. Long-term temperature average is served as reference line and its value is shown in the parentheses. Five-year moving trend is illustrated as red lines.

3. Precipitation records

The long-term changes of precipitation patterns in Taipei are shown in Figure 3: the precipitation amount (in mm), rainy days and intensity (in mm/day) from the top to the bottom, respectively. In short, there is a great variation in the precipitation amount annually, ranging from 4405 mm (in 1998) to 1193 mm (in 2003), with an average of 2158 mm for the past 108 years (top plot). A gradually increasing trend (24 mm per decade) is found for the precipitation amount and substantial fluctuations become apparent in recent years.

The long-term trend for rainy-day in Taipei shows a clearly and steady declining during the latter half of the 20th century (middle plot). Before 1950, the average annual rainy-day is about 185 days; but this value drops to about 170 days after 1950. During the latest decade (1995-2004) the average annual rainy-day even falls to a value of 163 days, a significant reduction (12%)

relative to that before 1950s. The recent increase of aerosol concentrations in Taiwan and east Asia due to industry booming is regarded as one of the main factors in causing the decrease of rainy days island-wide (Chang & Wang, 2003; Liu et al., 2000, 2002; Wang, 2004a, 2004b).

The precipitation intensity that is defined as the ratio of amount over time (day) represents an index of the rainfall extremity. The intensity variations of Taipei from 1897 to 2004 are shown in the lower plot of Figure 3. On average, Taipei has a mean value of 11.9 mm/day with high fluctuations since 1980; the highest intensity is found in 1998 (21.78) and the lowest in 1945 (7.4). The precipitation intensity of Taipei is gradually increasing (slope = 0.02) due to opposite trends for precipitation amount and rainy-day in the past 100 years.

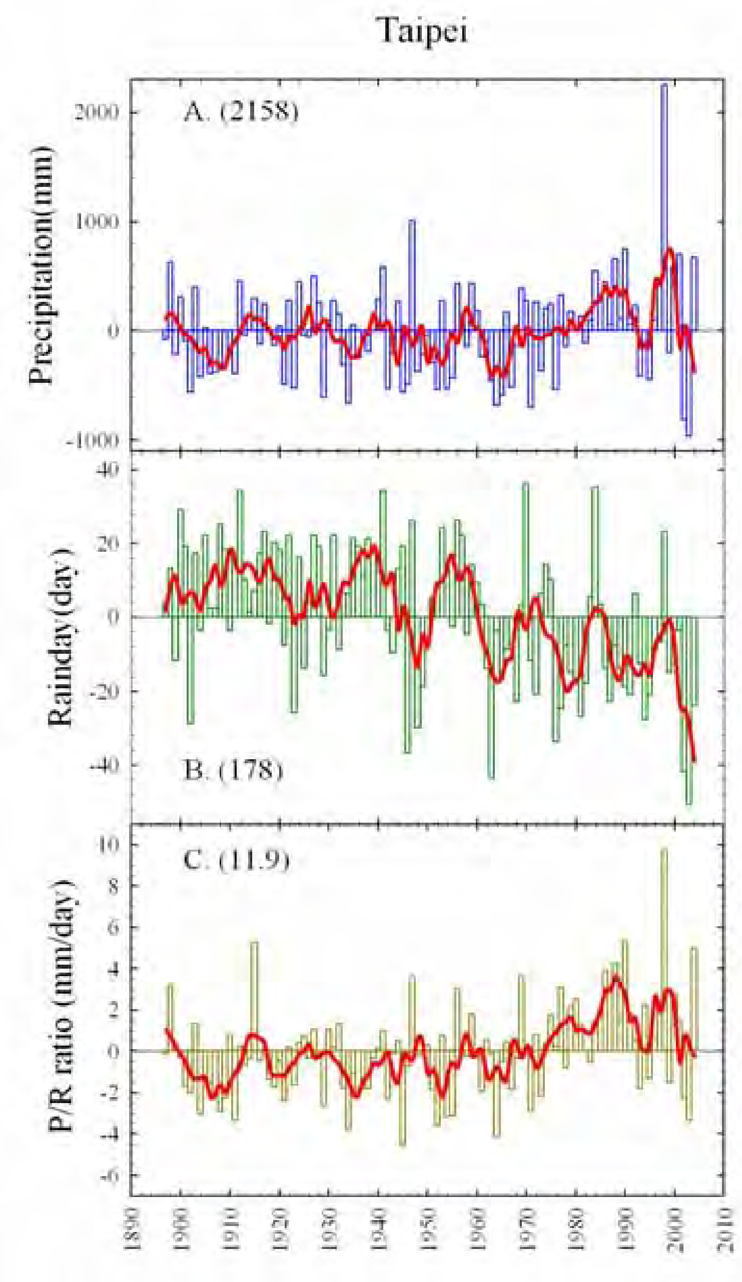

Fig.3 The long-term annual precipitation trends of Taipei. Top: annual amount in mm; middle: annual raindays; lower: annual intensity expressed by amount against rainy day (in mm/day). Long-term averages for each plots are served as reference line and their respective values are shown in the parentheses. Five-year moving trends are illustrated as red lines.

4. Groundwater level variations

Subsurface environment of Taipei has experienced substantial changes paralleling with the city development (Wang et al., 2004). The most prominent feature is the decreasing of groundwater level. Due to overdraft of groundwater for the civil and industrial needs, groundwater level of Taipei Basin dropped to about 40 m below sea-level in the late 1960s to early 1970s. Consequently, land subsidence resulted and affected to an area of 252 sq. km with a total vertical settlement of 2.1 m, greatly elevating the flooding risk along the river banks of Taipei Basin. Owing to the strict regulation on groundwater pumping and completion of the Feitsui Dam in 1986 for sufficiently supplying the surface water, the groundwater level has gradually recovered up to a height of about 4 meters below sea-level in early 2004. The average rising rate is about 1.3 m/year for the past three decades.

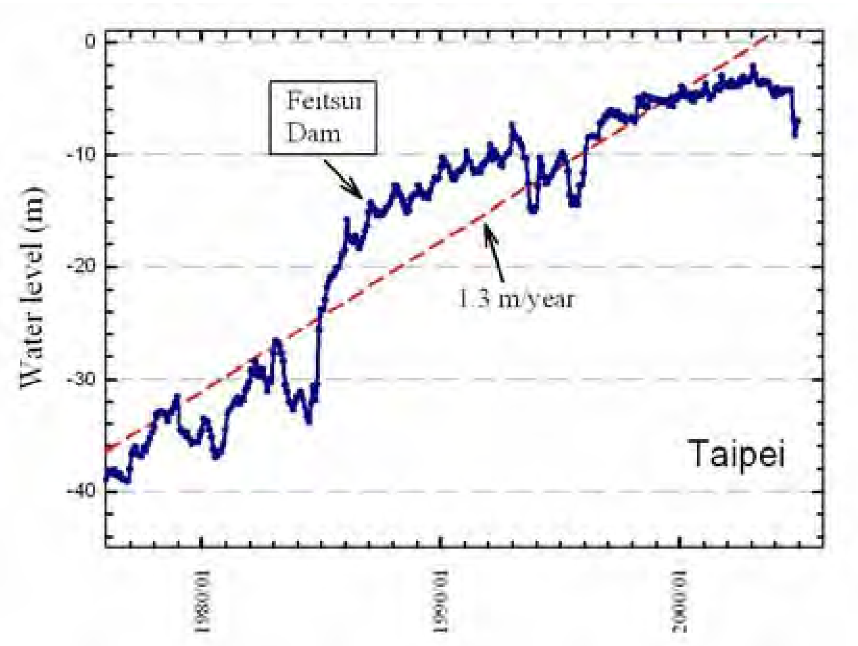

Fig.4. The long-term monthly trend of groundwater level in the Taipei station from January 1976 to December, 2004 . The red dashed line is the linear rising trend. Feitsui Dam began its operation in May 1986 and accelerated the rising rate of groundwater level.

5. Prospects and future studies

In this report, observations for the temperature, precipitation and groundwater level records of Taipei for the past century are presented. Certain unfavorable phenomena and trends are very evident and become the major factors in generating the recent environmental problems in Taipei. A multidisciplinary effort is timely needed to decipher the complicating relationships among possible parameters that apparently induced from the human disturbance on the natural environment. In addition, an appropriate strategy for the effective management of natural resources and living environment in Taipei Basin is urgently needed in perceiving these persistent and gloomy trends in the future.

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Groundwater Situation in Bangkok and Its Vicinity

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Abstract

Bangkok is situated on the tidal flat of marine clays of the Chao Phraya River delta. Hence, the ground surface of Bangkok is entirely underlain by marine clay, 15 m to 30 m in thickness, known as Bangkok clay. Unconsolidated and semi-consolidated sediment overlying the basement have a totally thickness of about 400 m to more than 1800 m. The aquifer system consisted mainly of sand and gravel separated by clays. Eight aquifers within the depth about 600 m have been identified. The water in the top most aquifer is not potable due to high salinity occurring since the deposition. The subsequent three aquifers (PD-100 m, NL-150 m, and NB-200 m) are the most used. However, the high production and newly developed wells at the greater depths are mostly served for industrial purposes.

Due to the past uncontrolled over pumping of groundwater, certain aquifers and overlying clay layer are under substantial stress, leading to serious land subsidence which at its most severe amounts to 10 cm/year (1978-1981). In certain places, with combined surface loading, this has amounted to a maximum recorded settlement of 100 cm over a 21-year period (1978-1999) and groundwater level has declined to 55 m from ground surface. The increasing of groundwater abstraction reached it maximum at 2.6 MCMD in 1999. The mitigation actions have been required if they are to be reinstated and stabilized. The subsequent strict mitigations such as declaration of “Groundwater Critical Zone” covered large area totally seven provinces including Bangkok. The mitigation included reducing the permissible pumpage of registered wells, promoting public awareness in groundwater conservation, and finally implementing “No permission for new well rule” in the Bangkok metropolis. All these mitigations have been determined to control the total abstraction to meet permissible yield which has been studied at 1.25 MCDD. The strict mitigations finally return the good result. The current groundwater abstraction is under 1 MCMD. The overall subsidence rate has been improved to less than 2-3 cm/year in central Bangkok and less than 1 cm/year in overall area. Water level has been recovered to 40 m from ground surface. While, the ground water cone of depression areas are shift to the newly developed zone at the skirt of Bangkok metropolis.

Subsidence is not the only problem when considering groundwater pumping, salt-water intrusion has become one of the major problems of groundwater. The rapid lowering of the water table by excessive extraction of groundwater has caused the shallow aquifers in Bangkok to become contaminated by salt water from the nearby ocean.

Introduction

Bangkok is located in the central part of Thailand on the low-flat plain of the Chao Phraya River, which is the most important river that can be compared to the main artery of the nation, at a distance extending from 27 - 56 Km. from the river mouth adjacent to the Gulf of Thailand. Bangkok City has been undergoing rapid urbanization and industrialization since 1960. The increasing population is due to the development of infrastructures such as road networks, real estate developments, land value, public policy as well as advancing economy which resulted in expansion into the surrounding areas; i.e. Samut Prakarn and Nonthaburi. Both the residential and industrial demand for piped water was more than the capability of the Metropolitan Water Works Authority to provide it, using surface-water based resources only. As a result, underground water is used extensively both publicly and privately, which is the main cause of soil subsidence throughout Bangkok at present.

Geology and Hydrogeology

The ground surface of Bangkok is entirely underlain by blue to gray marine clay up to 30 metres thick, known as the Bangkok Clay. The upper 15 metres of the Bangkok Clay, generally called the Bangkok Soft Clay, is very soft and highly compressible. The lower part, referred to as the Bangkok Stiff Clay, which is rather stiff and less compressible, extends to an average depth of 25-30 metres. The water in these clays is very saline and salty. The water-bearing formations of Bangkok consist mainly of sands and gravels with minor clay lenses. They are similar in occurrence and composition but can be zoned according to the geoelectrical properties (Figure 1) into 8 principal artesian aquifers, separated by thick confining clay or sandy clay layers; namely: Bangkok Aquifer (50 m zone), Sam Khok Aquifer (300 m zone), Phra Pradaeng Aquifer (100 m zone), Phaya Thai Aquifer (350 m zone), Nakhon Luang Aquifer (150 m zone), Thon Buri Aquifer (450 m zone), Nonthaburi Aquifer (200 m zone), and Pak Nam Aquifer (550 m zone).

In the **Bangkok Aquifer** (BKA) which is divided into two units (BKA and BKL) and where silt to coarse sand with clay alternate with gravel and/or sand, the water is **rather salty**, unsuitable for domestic consumption or industrial use. The **Phra Pradaeng Aquifer** (PPA) comprises gravel mixed with white sand, has high yield of water but the water is saline or salty. No groundwater well draws from this aquifer for use, except in the south of Bangkok-Thonburi, at the depth of about 70 to 100m, where there is a freshwater layer breaking in. However, this freshwater layer is not mighty. The third aquifer, the **Nakhon Luang Aquifer** (NLA), is important for the water supply, domestic as well as industry. Most groundwater wells in Bangkok, both of the Metropolitan Water Works Authority (MWA) or of industrial plants (e.g., beverage manufacturing plants and breweries) obtain water from this gravel and sand aquifer. This aquifer seems to be over-exploited, seawater intrusion is reported in the south of Bangkok and Thonburi. In the Samut Prakarn area saline to salty water is found in this aquifer. The **Nonthaburi Aquifer** (NTA) has similar hydrogeological features to that of NLA, i.e. mostly gravel and sand, and can supply water of good quality and at higher rate than NLA and is the most frequently used aquifer by industry. The **Sam Khok Aquifer** (SKA) consists of thin layers of gravel and sand alternating with clay layers. Due to this it is less high in yield than NLA and NTA. Freshwater of the same quality like NLA and NTA is found only in the north, the east and the southeast of Bangkok while salty in the south. The **Phya Thai Aquifer** (PTA) consists of dirty brown gravel and sand. The yield and water quality also the distribution - is similar to that of SKA . Freshwater can be produced from PTA in the north, the east and the southeast of Bangkok, however it is saline or salty in the south. The water quality of the **Thonburi Aquifer** (TBA) is reported to be salty in the west and southwest of Thonburi, fresh in the north, the east and the southeast of Bangkok. The deepest gravel and sand aquifer in the Bangkok area, is the **Pak Nam Aquifer** (PNA), which yields freshwater at high rate and good quality, however with water temperature of 43 to 50ºC. It is exploited by the Electricity Authority of Thailand for power production. Almost all aquifers in the central part of the dalta are found of having high transmissivity, (15 to 150 m^2/ hour). Towards the rim the transmissivity becomes lower. The storage coefficient is in the range of 0.0005 and 0.001.

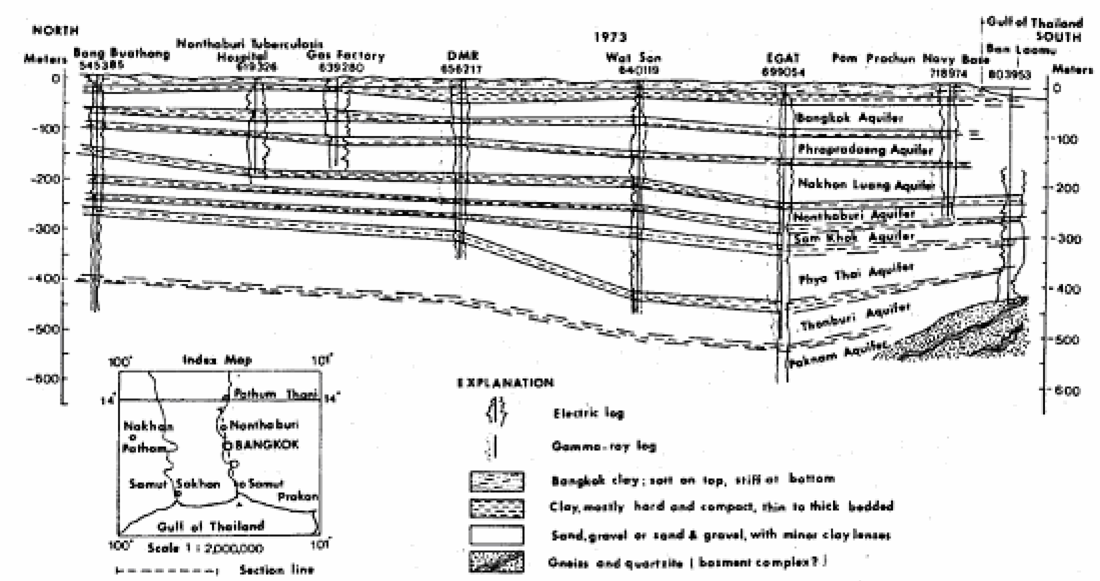

Figure 1. Hydrogeologic north-south section of the Lower Chao Phraya Delta showing principal aquifers of Bangkok Metropolis (after Piancharoen, 1977).

Groundwater use and water supply

The Metropolitan Waterworks Authority (MWA) supplies water to the Bangkok Metropolis and to the provinces of Samut Prakarn and Nonthaburi mainly (97%) from the water treatment plant using surface water from the Chao Phraya River as the main source. Groundwater (about 3%) is used as supplemental source for residential, commercial and industrial water supplies in areas not covered by the MWA network. Groundwater is also extracted from thousands of private wells for domestic and industrial consumption.

Due to the past uncontrolled over pumping of groundwater, certain aquifers and overlying clay layer are under substantial stress, leading to serious land subsidence which at its most severe amounts to 10 cm/year (1978-1981). In certain places, with combined surface loading, this has amounted to a maximum recorded settlement of 100 cm over a 21-year period (1978-1999) and groundwater level has declined to 55 m from ground surface. The increasing of groundwater abstraction reached it maximum at 2.6 MCMD in 1999. The mitigation actions have been required if they are to be reinstated and stabilized. The subsequent strict mitigations such as declaration of “Groundwater Critical Zone” covered large area totally seven provinces including Bangkok. The mitigation included reducing the permissible pumpage of registered wells, promoting public awareness in groundwater conservation, and finally implementing “No permission for new well rule" in the Bangkok metropolis. All these mitigations have been determined to control the total abstraction to meet permissible yield which has been studied at 1.25 MCDD. The strict mitigations finally return the good result. The current groundwater abstraction is under 1 MCMD. The overall subsidence rate has been improved to less than 2-3 cm/year in central Bangkok and less than 1 cm/year in overall area. Water level has been recovered to 40 m from ground surface. While, the ground water cone of depression areas are shift to the newly developed zone at the skirt of Bangkok metropolis.

Subsidence is not the only problem when considering groundwater pumping, salt-water intrusion has become one of the major problems of groundwater. The rapid lowering of the water table by excessive extraction of groundwater has caused the shallow aquifers in Bangkok to become contaminated by salt water from the nearby ocean.

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Groundwater overuse and its consequences in Metro Manila, Philippines

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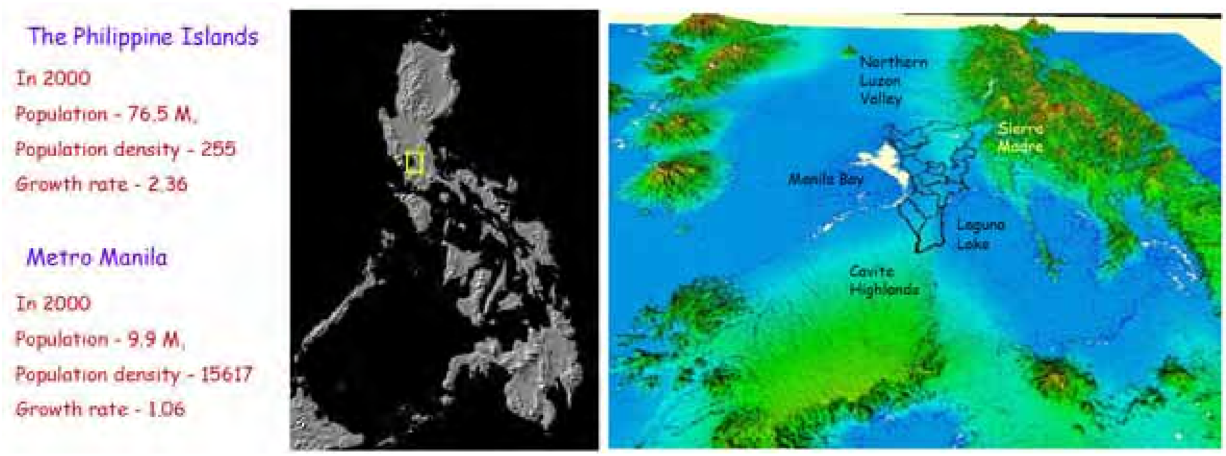
Metro Manila, also known as the National Capital Region of the Philippines, is comprised by 14 cities and 3 municipalities. It covers a total land area of 636 km^2 or 0.2 % of the Philippines total land area but it hosts 7.7% of the country population. As of 2000, Metro Manila had a population of 9.9 million and a population density of 15,617.

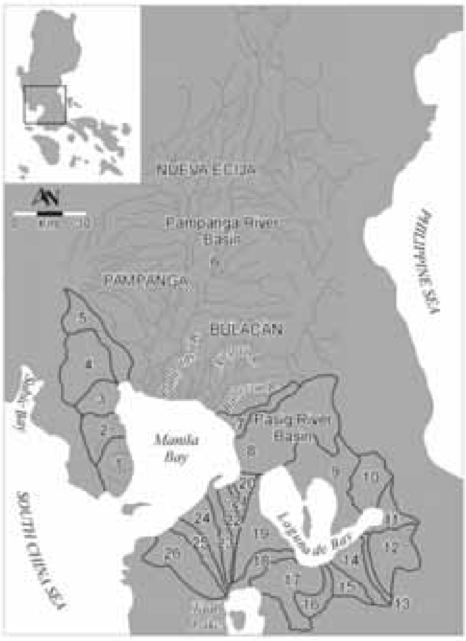
Historically, the water supply in Metro Manila as well as in most areas in the country has greatly depended on groundwater sources. In 2003, Metro Manila had 131 wells by water utilities and more than 3,000 private wells with an annual output of 33 million cubic meters (MCM) and 310 MCM, respectively. In addition, about 20,000 shallow wells (1990 figure) were pumping around 14 MCM. Most of the groundwater is being extracted from Plio-Pleistocene volcanics with clastic interbeds.

For the period 1982-1990, average annual groundwater withdrawal, was estimated to be about 235 MCM while the average annual recharge for the same period was only 206 MCM resulting in the lowering of the water table by 2.5 meters annually. For the period 1990-96, groundwater level declined at an estimated rate of 6-12m per year.

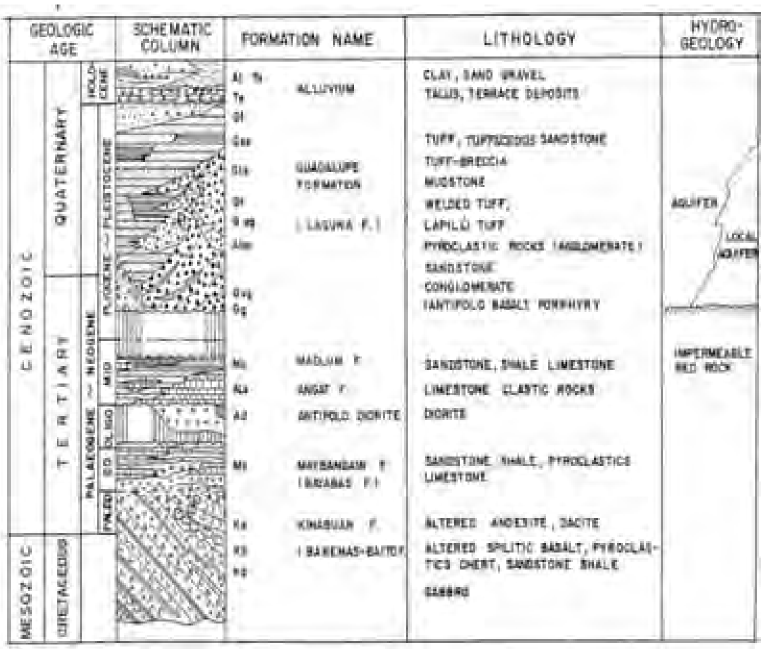
A considerable number of deep wells were affected by regional salinization, especially those in the coastal areas. Deep cones of depression also caused the upconing of connate or fossilized water in the inland aquifer, and seepage of brackish water along the rivers. Subsidence, induced by over extraction of groundwater, occurs at rates typically within a few centimeters per year but exceeds 9 cm/year in several coastal places. Differential compaction has caused remobilization of faults resulting in ground fissuring and damage to infrastructure. Subsidence has also led to the worsening of floods in Metro Manila – the floods have become more frequent, higher, stay longer, and occur in more areas.



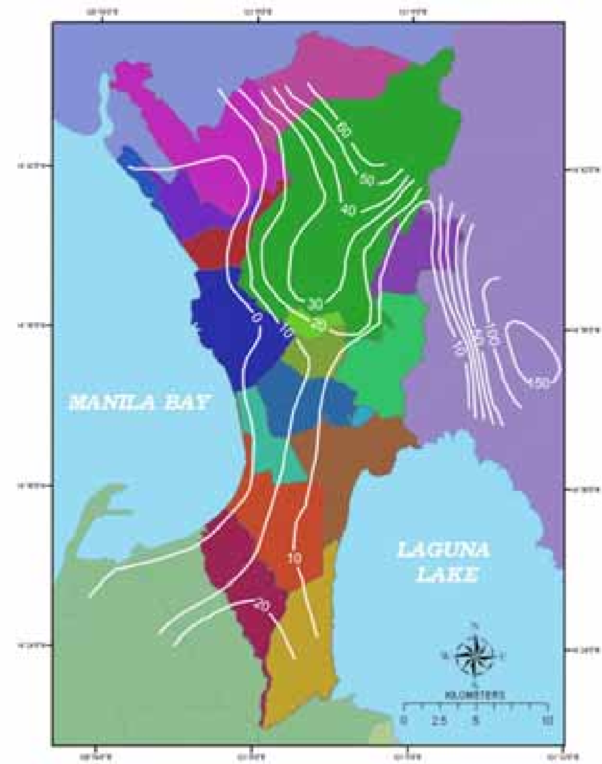
Over view of the Philippine Islands



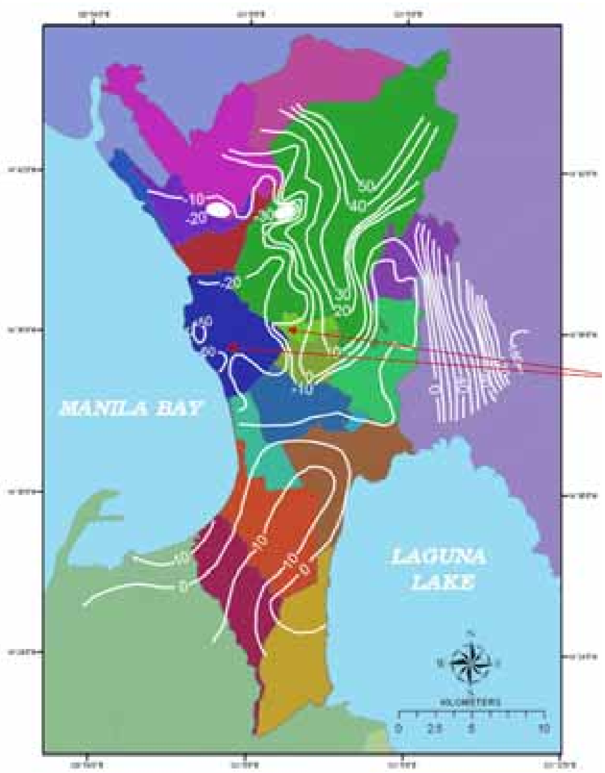
Rivers near the Metro Manila



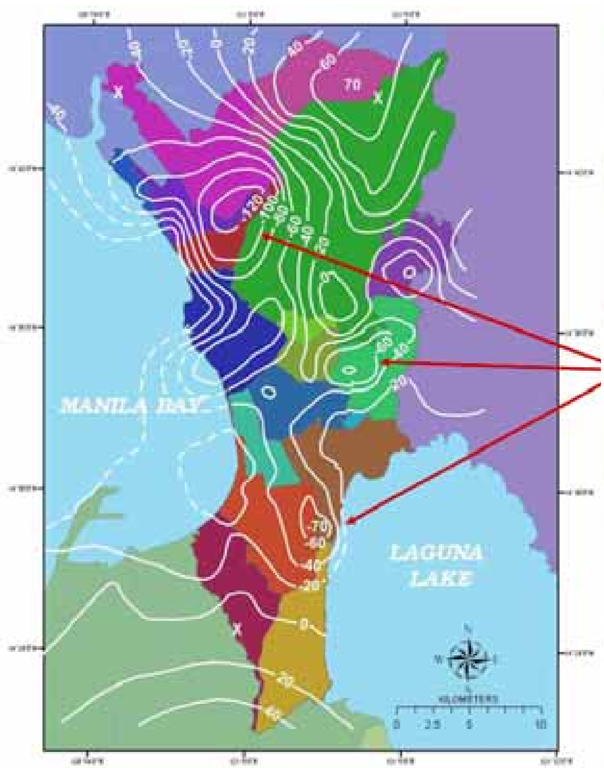
Aquifers in Metro Manila

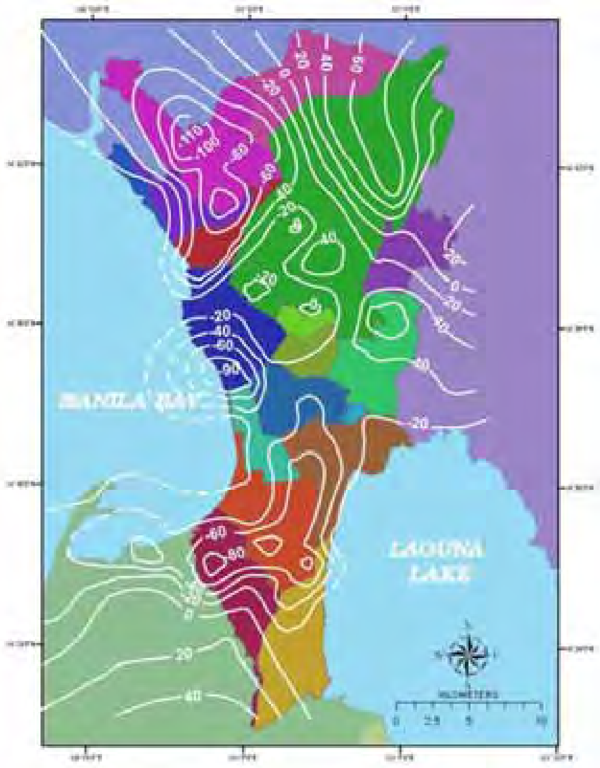


Piezometric level on 1951 (NHRC, 1991)

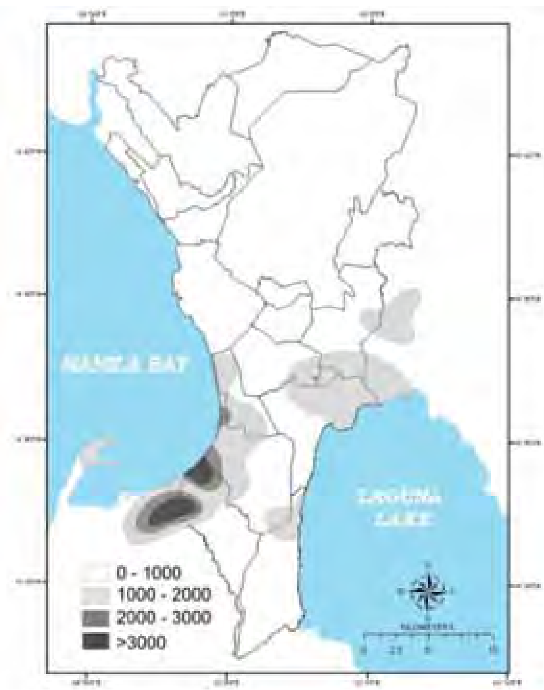


Piezometric level on 1967 (NHRC, 1991)

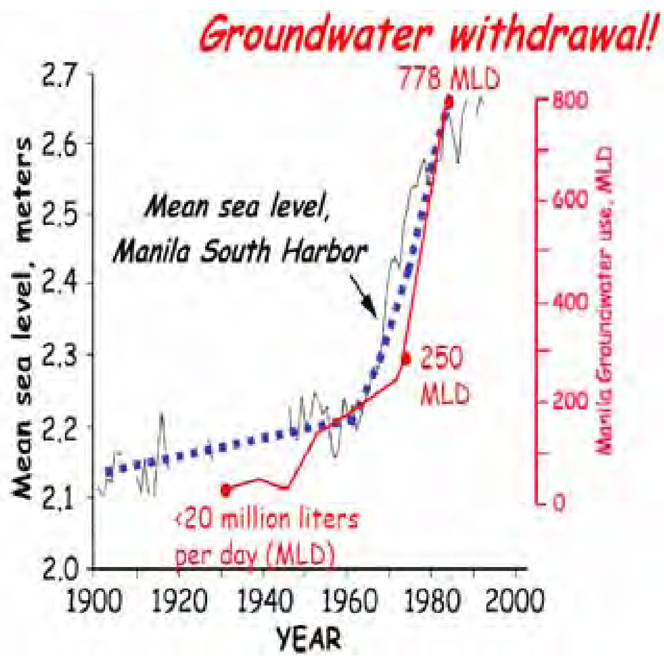




Piezometric level on 1981 (JICA, 1992) **Piezometric level on 1991 (JICA, 1992)**



Electric conductivity of groundwater on 1991 (JICA, 1992)



Sea level rise and groundwater withdrawal at Metro Manila

SUBSURFACE ENVIRONMENT OF JAKARTA AREA

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Abstract

Jakarta is located on the Java Island, Indonesia. Nowadays, around 12 millions inhabitants live in this city and its surrounding area. It occupies the northern zone that comprises low hilly areas of folded Tertiary strata, and Quaternary coastal lowlands bordering the Java Sea. Two quaternary formations and three young tertiary formations act as groundwater aquifers zone and one quaternary formation act as an aquitard. Some older formations present as basement of the basin. Based on lateral and vertical distribution of the formation forming aquifer-aquitards, the basin can be divided in to four zones.

Since the beginning of the 20th century, groundwater from the Basin has been used for drinking water and other water resources purposes. Unfortunately, groundwater use is increasing year by year and some problems are threatening this fragile aquifer system. It has influenced either quality or quantity of groundwater, and land subsidence within the basin. It is showed on the groundwater level decline, water intrusion, and cracked building in some parts of the basin.

The most recent investigation that had been done in this basin is to generate the groundwater model using the groundwater temperature, analyzing hydro-chemical condition, isotope stable content and basin geological condition. The result showed that 4 existing aquifers in this basin were supplied by 3 different recharge areas that flowed southerly and easterly. The Jakarta land subsidence was first recognized when one fly-over bridge near Sarinah Supermarket at M.H. Thamrin Avenue in Central Jakarta was cracked.

Keyword: *Jakarta Groundwater Basin, Quaternary formation, Tertiary formation, aquifer, aquitard, water quality, water quantity, land subsidence*

Introduction

The City of Jakarta is the capital city of Republic of Indonesia and it is occupied the coastal plain area that bordered by the Java Sea with elevation varied from 0 to 1,000 m above sea level.. It is one of the most developed basin in Indonesia which located between 106° 33’ - 107° E longitude and 5° 48’ 30” - 6° 10’ 30” S latitude covered area about 652 km². It has a humid tropical climate with annual rainfall varied between 1,500 – 2,500 mm due to influence of monsoon.

The population of Jakarta was about 800,000 people when Indonesia proclaimed its independence in August, 1945 and it has increased to 8.2 millions in 1990. An annual increase of 2.4 % was calculated during the period of 1980 to 1990. In year of 2005, the population of Jakarta is estimated to be 12 millions (Bappedalda, 2005). It will increase in the near future as many people have been attracted to come to this city to pursue a better life. Unlike other regions, over 75% of the population of Jakarta is in an urban setting. Most people who are working in

Jakarta during the day are commuters and live in three neighboring cities i.e., Bogor and Bekasi (west Java Province) and Tanggerang (Banten Province). Actual land use in The Greater Jakarta is mostly occupied by housing, industry and commerce whilst some agriculture is practiced in the urban fringe areas.

The urbanization activity has increased the water demand in this area. As the drinking water that supplied by surface water only 30% of water demands, people are harvesting the available groundwater in the basin. In Jakarta Groundwater Basin, the use of groundwater has greatly accelerated conforming to the rise in its population and the development of industrial sector, which consume a relatively huge amount of water. The increase of groundwater exploitation in Jakarta Groundwater Basin has already caused a negative impact on these resources itself both quantity and quality, and land subsidence.

The land subsidence in Jakarta firstly recognized in 1978 when the so called Sarinah fly over bridge at M.H. Thamrin Avenue in the Central of Jakarta was collapsed. And the flooding area in Jakarta in the same period was covered a wider area as topographic position has changed. Actually, land subsidence in Jakarta was observed at the first time in 1926, when a Dutch surveyor conducted re-measurements of the leveling network from Jati Negara to Tanjung Priok harbor. Unfortunately, these measurement data were lost and remained unknown until present time (Suharto, P., 1971)

Figure 1.The study area location

Geological Setting

According to Engelen and Koosterman (1996), structurally, the Jakarta groundwater basin is part of the so called a Northern Zone that comprising low hilly areas of folded Tertiary strata, and coastal lowlands bordering the Java Sea. The base of the aquifer system is formed by impermeable Miocene sediments which are cropping out at the southern boundary of the basin. The basin fill, which consist of marine Pliocene and quaternary sand and delta sediments, is up to 300 m thick. Individual sand horizons are typically 1 - 5 m thick and comprise only 20% of the total fill deposits. Silts and clays separate these horizons. Fine sand and silt is very frequent component of these aquifers

Based on an assessment of the lithological logs of some deep production boreholes, it can be stated the identification of formations that have considerable lateral extent and that also form a geologic framework for a reasonably distinct hydro geological system or called hydro-stratigraphy on Table 1 .

Table1. Hydrostratigraphy of Jakarta Groundwater Basin (after Fachry et al, 2003).

<table>
<tr><th>Seq. No</th><th>Stratygraphy</th><th>Description</th><th>Depositional Environtment</th><th>Layer Type</th><th>Thickness (meter)</th><th>Remarks</th></tr>
<tr><td>1</td><td>Quaternary Volcanic Deposit</td><td rowspan="3">Sandstone, Conglomerate, breccias intercalated with clay stone</td><td rowspan="2">Fluvial</td><td>Aquifer Unit 1</td><td>55</td><td></td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Citalang Fm</td><td>Soft Aquitard</td><td>2-3</td><td>Boundary for unconfined aquifer (± 40 m)</td></tr>
<tr><td>Braded Stream</td><td>Aquifer Unit 1</td><td>31.5 – 53</td><td></td></tr>
<tr><td>3</td><td>Upper Kaliwangu Fm</td><td>clay stone</td><td>Braided Stream</td><td>Aquitard Unit 1</td><td>3 - 42</td><td>Boundary for aquifer unit 1 (± 90 m)</td></tr>
<tr><td>4</td><td>Genteng Fm</td><td rowspan="3">Sandstone, Conglomerate, breccias intercalated with clay stone</td><td>Fluvial</td><td rowspan="3">Aquifer Unit 2 (Main Aquifer for Groundwater Exploitation)</td><td rowspan="3">30 - 277</td><td></td></tr>
<tr><td>5</td><td>Middle Kaliwangu Fm</td><td>Marsh</td><td>Soft Aquitard founded (± 140 m)</td></tr>
<tr><td>6</td><td>Serpong Fm.</td><td>Braided Stream and swamp</td><td></td></tr>
<tr><td>7</td><td>Lower Kaliwangu Fm</td><td>clay stone</td><td>Offshore Bar</td><td>Aquitard Unit 2</td><td>12 – 20</td><td>Boundary for aquifer unit 2 (± 190 - 300 m)</td></tr>
<tr><td>8</td><td>Subang Fm</td><td>Clay stone, Silt intercalated with limestone</td><td>Lagoon and Batial</td><td rowspan="3">Groundwater Basin Basement</td><td>422</td><td rowspan="3"></td></tr>
<tr><td>9</td><td>Klapanunggal Fm / Parigi Fm</td><td>Limestone and clay stone</td><td>Transitional and Lagoon</td><td>40 - 173</td></tr>
<tr><td>10</td><td>Bojongmanik Fm / Cibulakan Fm</td><td>Limestone and clay stone</td><td>Transitional and lagoon</td><td>91-138</td></tr>
</table>

The Groundwater Flow

The most recent study that was carried out in Jakarta Basin was measurement of subsurface temperature and hydraulic head in some observation wells, which are assumed to be in thermal equilibrium with the surrounding aquifer. Temperature measurements were carried out in 51 observation wells (40 – 200 m deep), in July, 2004. The equipment used for the measurement was a sophisticated digital thermister thermometer (resolution of 0.01 ^{o} C) attached to a 300m long cable. Data were recorded from water table to the bottom of the hole in 2 m intervals in the downward direction. The observation wells are constructed of steel casing. The diameter of the observation wells ranges from 4 – 6 inch.

By analyzing the isotherms, it has been recognized that:

1. the recharge area of aquifer at depth 40 m below surface (Fig. 2.a.) is located at the southern part of Jakarta Basin itself, and the water from Bogor area is discharged at the south boundary of Jakarta basin as it is blocked by Bojongmanik Formation,
2. the recharge water to aquifer at depth 95 m below surface (Fig. 2.b.) comes from S-E and S-W area of the basin,
3. the recharge area of 140 m below surface aquifer (Fig. 2.c.) is located at the S-E area, while
4. the deepest aquifer (Fig. 2.d.) is supplied by water from the east.

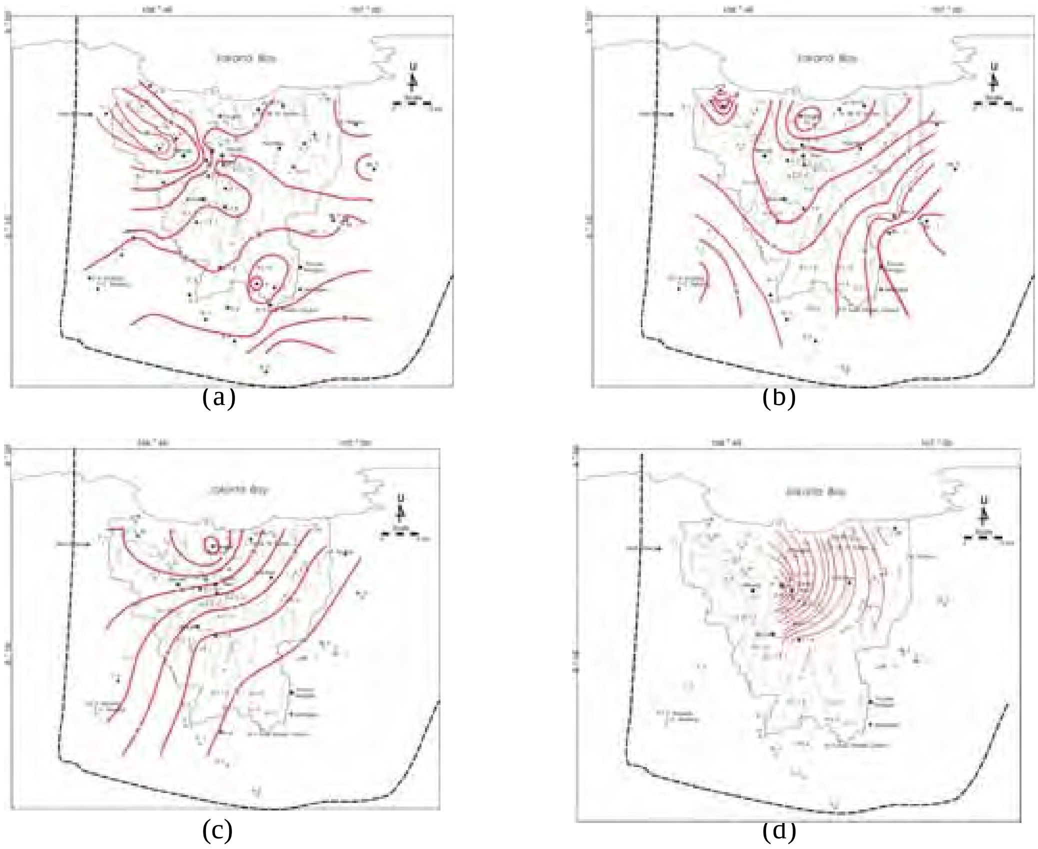

Figure 2.
Isotherms of subsurface temperature at (a) 40 m (b) 95 m (c) 140 m and (d) 190 m below sea level.

The hydrogeology of the Jakarta Basin is complex phenomenon. Until now, a good understanding of the hydrogeology of the basin on a regional scale is still not possible, due to lack of systematically sufficient drilling, testing and monitoring data. As a part of this investigation, collect the drilling data of additional monitoring boreholes, to establish a closer monitoring network, has made it possible to develop a better understanding of the shallow groundwater flow systems. Water level monitoring of boreholes has helped in developing an improved understanding of the water table fluctuations, regional and local impacts of groundwater abstraction and dewatering related to mining and water balance.

In this study, a groundwater flow analysis that is suggested by borehole temperature measurement in Jakarta groundwater basin is presented. This study examines cause of both horizontal variation in heat flow and the contrast between thermal properties of shallow and deep structures in Jakarta groundwater basin. The main objective of this study is to identify the Jakarta groundwater recharge area and direction of water flow inferred from the thermal properties. The horizontal and vertical distribution of subsurface temperature suggests that the effect of groundwater flow movements controlled by geological condition.

The Land Subsidence in Jakarta

Considering the detrimental impact of land subsidence on building and other infrastructures, a number of researchers carried out investigation in the cause and the rate of subsidence. Most of the land subsidence investigation conducted over part of Jakarta territory. The trend and rate of subsidence is characterized by the condition of the point where the equipments are located. Generally, in the northern part of Jakarta, the trend of elevation is decreasing, which means a downward movement if it is compared to southern part of the city. From the observation of period 1982 – 1991, the highest subsidence occurred at Cengkareng (North Jakarta) with rate of 8.5 cm/year. In the period of 1997 -1999, the highest subsidence occurred at Daan Mogot (North-west Jakarta) with a rate of 31.9 cm/year. The increasing of the rate shows that the land subsidence in Jakarta is continuing. Therefore, planners and engineers should take into account this condition for their planning and construction works.

In 1998, the method of GPS measurement was introduced in investigating land subsidence in Jakarta. (Abidin et.al. 2001), and the GPS land subsidence monitoring network was established. The network, radial to the fixed national GPS station at Cibinong, was extended by adding some monitoring points to establish the network. As we know, the land subsidence investigation deals with small movement within cm or mm range of height differences. Therefore, it would not give any differences whether traditional leveling or GPS observation were used.

Conclusion

It is very clear that he human activities have influenced the Jakarta subsurface environment condition. So far, not many subsurface environment studies have been carried out in this area. Therefore, the chance for detecting new phenomena in this basin is quite plausible.

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"Human Impacts on Land-Ocean Interaction"

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Abstract

Most megacities of the world are in Asia and most of these are on or near the coast. Rapidly increasing populations and resulting contamination on the underlying groundwater with nutrients (sewage, fertilizers) and other contaminants raises the question about the current and future effects on the associated coastal waters. We are now beginning to look at the megacity groundwater environment as a pathway to the ocean. Preliminary studies performed in 2004-5 in areas near Bangkok and Manila indicate that loads of dissolved inorganic nitrogen (DIN) from these subterranean pathways may be comparable to the discharges from the principal rivers draining into the Upper Gulf of Thailand and Manila Bay.

1. Introduction

RIHN Project 2-4PR "Human Impacts on Urban Subsurface Environments" aims to evaluate the relationships between the developmental stage of Asian megacities and their subsurface environments. Further, the project will explore the pathways and effects of the fluid subsurface (groundwater) with the coastal ocean. This is a very timely endeavor as the chemical and ecological significance of the interactions between groundwater and coastal ocean waters has only recently become appreciated (Moore, 1999; Taniguchi et al., 2002; Burnett et al., 2003).

In 1950, New York City was the planet's only "megacity," defined as a city with more than 10 million people (**Table 1**). By 1975, there were 5 megacities. Now there are 17 such cities around the globe, 14 located in coastal areas, and 11 in Asia. By 2030, two out of three people will live in an urban world, with most of the explosive growth occurring in developing countries. By 2015 there will be 21 megacities, 12 of them is Asia. Today the five largest cities in the world are Tokyo, Mexico City, São Paulo, New York City, and Mumbai (Bombay), and in 2015 they will probably be Tokyo, Dhaka, Mumbai, São Paulo, and Delhi – all with greater than 20 million people (UN Population Division, 2001).

Table 1. Population of the world's 10 largest metropolitan areas at four different points in human history. Data from the Worldwatch Institute (Washington, DC).

Metropolitan Area	1000 (million)		1800 (million)		1900 (million)		2000 (million)
Cordova	0.45	Peking	1.10	London	6.50	Tokyo	28.00
Kaifeng	0.40	London	0.86	New York	4.20	Mexico City	18.10
Constantinople	0.30	Canton	0.80	Paris	3.30	Bombay	18.00
Angkor	0.20	Edo (Tokyo)	0.69	Berlin	2.70	São Paulo	17.70
Kyoto	0.18	Constantinople	0.57	Chicago	1.70	New York	16.60
Cairo	0.14	Paris	0.55	Vienna	1.70	Shanghai	14.20
Baghdad	0.13	Naples	0.43	Tokyo	1.50	Lagos	13.50
Nishapur	0.13	Hangchow	0.39	St. Petersburg	1.40	Los Angeles	13.10
Hasa	0.11	Osaka	0.38	Manchester	1.40	Seoul	12.90
Anhilvada	0.10	Kyoto	0.38	Philadelphia	1.40	Beijing	12.40

Compiled by Worldwatch from: 1000–1900 from Tertius Chandler, Four Thousand Years of Urban Growth: An Historical Census (Lewiston, NY: Edwin Mellen Press, 1987); 2000 from United Nations, World Urbanization Prospects: The 1996 Revision (New York: 1998).

Since population growth is highest in urban areas (about half the world's population already lives in cities; see urban growth curve, **Fig. 1**) and most cities are on the coast, there is a need to explore how this growth is affecting water quality both above and below ground. It is well known that many coastal cities are growing rapidly across river deltas, draining wetlands, building on floodplains, cutting coastal forests, and increasing sediment loads into estuaries (Zwingle, 2002). Sprawling urbanization across watersheds, which can include areas hundreds of miles inland, damages the water quality of streams, creeks, and rivers that flow into coastal waters. Rainfall washes pesticides, fertilizers, oil, and other nonpoint-source pollutants off lawns, roads, and parking lots into waterways that flow to the ocean. But there are underground pathways as well. Do these play an important role? Contamination of groundwater resulting from human activities in urban areas can also result in coastal loading issues as groundwater will eventually discharge at the shoreline.

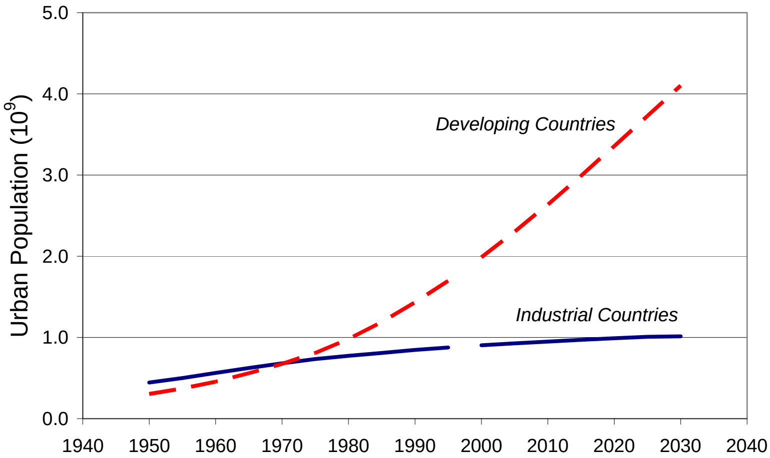

Fig. 1 Urban population in industrial and developing countries, 1950-1995, with projections to 2050. Data from Worldwatch Institute (Washington, DC).

In coastal waters, nitrogen is the principal cause of eutrophication and excess nutrient loading is thought to be related to outbreaks of harmful algal blooms. Nitrogen loading to coastal waters is known to have gone up exponentially with population growth (Smith et al., 2003). What is not well known is whether or not the groundwater pathway plays an important role in this delivery of nitrogen species and other nutrients to the coast. That is the goal of subject 2 of the RIHN Subsurface Environment Project "subsurface contamination and transport of contaminant loads to the coast."

2. Preliminary Results

We had the opportunity to perform some preliminary investigations on this subject near two Southeast Asian megacities, Bangkok and Manila. In 2004, we conducted two surveys (wet and dry seasons) on the Chao Phraya ("River of Kings") and Upper Gulf of Thailand. During January 2005 (dry season) we ran an expedition to the southeast Bataan Peninsula (Manila Bay). In both Thailand and The Philippines, we made estimates of submarine groundwater discharge (SGD) based on seepage meter deployments and isotopic studies. Biogeochemical measurements (inorganic and organic nutrients and carbon) and standard oceanographic parameters were also collected.

Seepage rates at all the sites investigated were relatively high and were characterized by mainly recirculated seawater in Thailand and a mixture of fresh and saline water discharge in Manila Bay. The nutrient concentrations in waters collected directly from seepage meters at the sites in both Manila Bay and Upper Gulf of Thailand were consistently higher in ammonia (NH_4), phosphate (PO_4), and silica (SiO_2) than ambient seawater from the same sites. Concentrations of organic nitrogen were higher in the groundwater than seawater at one site in Thailand as well as Manila Bay. The percent nitrogen occurring as dissolved organic nitrogen (DON), however, was consistently higher in the seawater at all sites investigated (**Fig. 2**).

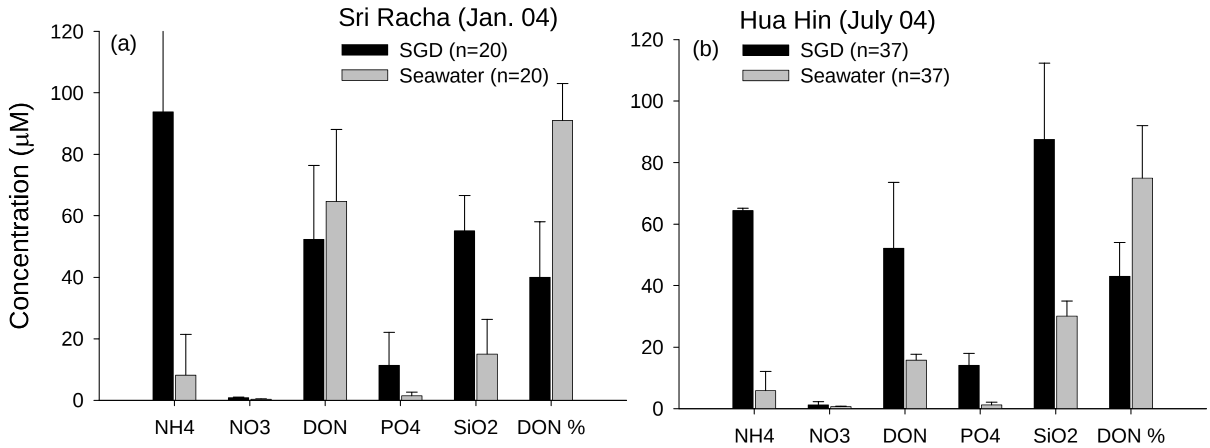

Fig. 2 Means and standard deviations of nutrient concentrations in waters collected from seepage meters and ambient seawater off the coast of Sri Racha (dry season, Jan., 2004) and Hua Hin (wet season, July 2004), Upper Gulf of Thailand. DON % refers to the percent of the total nitrogen that is dissolved organic nitrogen. The results for Manila Bay (not shown) were similar with much higher NH_4, DON, and SiO_2 concentrations compared to the ambient seawater.

Groundwater fluxes per unit width of shoreline were estimated by integrating seepage meter measurements along lines deployed normal to shore. Nutrient fluxes to the nearshore environment were then calculated by multiplying these integrated flows by measured nutrient concentrations in the seepage waters. By extrapolating the fluxes from the two seepage meter sites in the Gulf of Thailand (Sri Racha and Hua Hin) and the one study site in Manila Bay to the entire shoreline length of the respective embayments, we were able to compare the estimated nutrient fluxes via SGD to measured or reported riverine fluxes. We used 190 km and 330 km for the shoreline lengths of Manila Bay and the Upper Gulf of Thailand, respectively. In the case of the Thailand data, the estimated fluxes via SGD compared to those from the Chao Phraya River for NH_4 and PO_4 are ~40-50% and ~60-70%, respectively (**Fig. 3**). This is remarkable if one considers that this river is very contaminated and a major source of nutrients to the Gulf. The results from Manila Bay were similar with estimated SGD fluxes of dissolved inorganic nitrogen (DIN) of ~40% of the Pampanga River and ~90% of the Pasig River, the two largest rivers flowing into the bay.

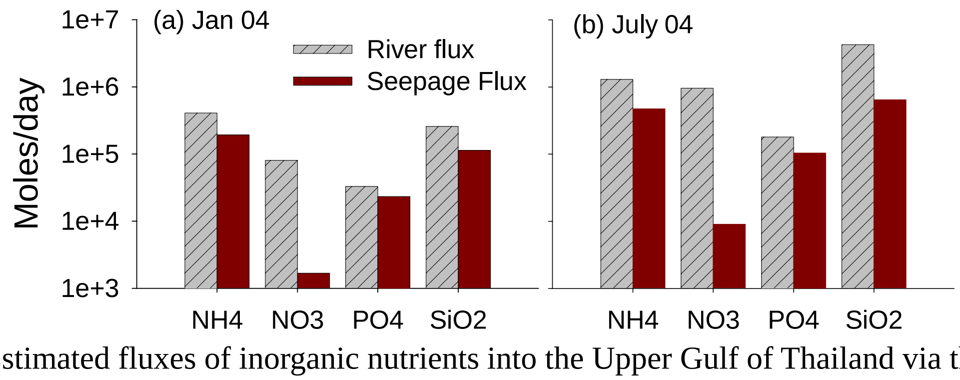

Fig. 3 Estimated fluxes of inorganic nutrients into the Upper Gulf of Thailand via the Chao Phraya River and SGD. Note that the vertical axis is a log scale. These preliminary results indicate that groundwater discharge may account for ~40-50% as much DIN and 60-70% as much PO_4 as the most important river entering the Upper Gulf of Thailand. The results from Manila Bay (not shown) were similar at ~40-90% DIN and 10-20% PO_4 as the two largest river systems entering the bay.

These estimates, while very crude and need of verification by additional measurements present compelling evidence for the importance of SGD as a pathway for nutrients to the coastal ocean. The RIHN project thus offers an excellent opportunity to advance our knowledge of the linkages between development of megacities, the changing groundwater environment, and the coastal ocean.

3. Acknowledgments

The investigators thank SARCS, the Southeast Asia Regional Committee for START (SyStem for Analysis, Research, and Training) and the Asia-Pacific Network (APN) for the financial assistance that made this preliminary research possible. We also thank the crew of the R/V Chula Vijai (Chulalongkorn University) for their helpful assistance during the river-estuary cruises in Thailand. Personnel from the National Institute of Geological Sciences (University of the Philippines) were instrumental in setting up the necessary logistics for the fieldwork in Manila Bay. W. Burnett thanks Henrieta Dulaiova for her assistance in the field and acknowledges the financial support from the National Science Foundation (Award No. OCE-0350514). Makoto Taniguchi acknowledges the additional support from Japan Society for the Promotion of Science (Award No. 13304036).

4. Recommendations

Our preliminary studies indicate that biogeochemical inputs via subterranean pathways may be comparable to river inputs. Yet, these inputs are being largely ignored by many scientists, coastal planners, and managers. The RIHN Project "Human Impacts on Urban Subsurface Environments" offers a unique opportunity to evaluate these flows more precisely and to identify the sources of the contaminants. Specifically, we recommend the following:

1. More field sites are needed for each environment studied so that the extrapolations are not so large (e.g., hundreds of kilometers in preliminary results shown above).
2. Seasonal assessments of groundwater seepage should be made at selected sites. In this initial work, we were unable to measure seepage rates at the same sites during both wet and dry seasons. We were thus unable to determine, for example, if the higher seepage rates measured at Hua Hin relative to Sri Racha are due to site specific or seasonal variations.
3. We should evaluate potential artifacts that may be associated with collection of nutrient samples from seepage meters. For example, the standing water inside such a chamber may become anoxic thus changing the biogeochemical environment. Parallel sampling via collection from seepage meters and shallow pore waters can address this question.
4. The Project team would likely have more success in defining the problem if a limited number of study environments were selected for detailed investigations. The coastal and groundwater evaluations are very time consuming and it is unlikely that well-constrained estimates could be made for more than about two megacity coastal environments, even with a 5-year project.
5. The preliminary results presented here and the available of good facilities and collaborations suggest that Bangkok and Manila would be attractive for the additional investigations.
6. Future studies should include source tracer studies (N, S, Pb isotopes, etc.) as reviewed by Onodera (2005) and Nakano (2005). This will enable identification of the source(s) of the contamination (agricultural, sewage, industrial, etc.), which cannot be discerned by the SGD evaluations alone.

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Penetration of human induced warming in the continental landmasses

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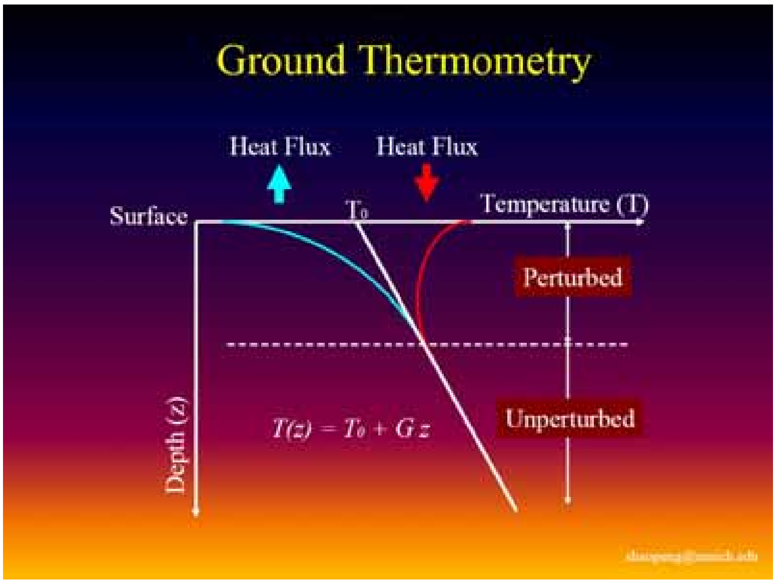
Changing climate is accompanied by changing energy in various climate system components including the continental landmasses. The heat content (thermal energy) of a rock is proportional to its temperature. At the annual to centennial time scales, the temperature and, therefore, the heat content of the uppermost layer of the crust are dominantly controlled by the temperature at the ground surface. When ground surface temperature rises, more heat will be deposited to the rocks, whereas when ground surface temperature falls, certain amount of heat will escape from the ground into the atmosphere. Based on global meteorological records, I analyze the annual heat budget of the world continents except for Antarctica. I assemble continental surface temperature anomaly time series from the variance adjusted version of the 5° × 5° grid-box basis land-only air temperature anomaly dataset of the Climate Research Unit of the University of East Anglia. Although there is regional variability in the continental surface air temperature, all six continents demonstrate a strong warming trend in the second half of the 20th century. With no exception, the mean 1951-2000 surface heat fluxes in all six continents are downward into the lithosphere. I estimate that between the period from 1851 to 2000 a total of 10.4 10^{21} J of thermal energy had been absorbed by Africa, Asia, Australia, Europe, North America, and South America landmasses, over 65 percent of which was acquired during the second half of the 20th century. The build up of the landmass heat content has been intensified recently. In just four years from 2000 to 2004, another 1.34 10^{21} J energy had penetrated beneath the ground surface of these continents. The human induced global warming has speeded up the heating of the continental landmasses.



Subsurface thermal anomaly due to surface temperature changes

Concept of urban environmental islands

Three aspects for the RIHN project

Database of subsurface urban heat island

Observations

Gayl D. Ness
University of Michigan

It was a great pleasure for me to attend the RIHN conference on Human Impacts on Urban Subsurface Environments. The conference reflects a significant attempt at the kind of interdisciplinary research that is vitally needed if we are to further our understanding of global environmental change, and especially if we are to make any progress in promoting sustainable development. As a sociologist who has worked for more interdisciplinary research on global change for the past two decades, it is especially welcome for me to see the work reflected in this conference. As an outside sociologist, as it were, let me make a few observations on what I have seen here.

First is the delight in learning something new. I was impressed with the high quality of scientific work done on subsurface urban environments and was happy to learn something of the natural science measurement techniques and theories that sociologists usually do not hear much about. I was also pleased to learn more about urban subsidence, caused by over pumping groundwater for urban development, which I have known to be a problem in many Asian cities for some time. I have seen the results in Bangkok, and shared many people's concern for the near and long term future of many cities. I have also seen the problems such as those in The Philippines' Cebu City (Flieger 2000), where uncontrolled well digging is depleting the city's aquifer with no discernible solution for the near future. It was therefore especially interesting to see from the research on Bangkok, how quickly a riverine urban water table can recover when pumping is controlled. The great natural force of river flows, especially in areas of good rainfall, is a natural ally that urban policy makers can rely upon for support if the right policies are adopted.

I was also concerned, however, that natural scientists may miss some of the historical processes that social scientists rely upon for much of their understanding. There are two points to be made here. One concerns the distinctive history of Asian cities; the other concerns the special character of the current urbanization process.

First, the recent history of world and regional urbanization is especially salient. World urbanization as we know it today is a relatively recent phenomenon. Cities and small villages emerged after the agricultural revolution some three to four thousand years ago. We know that they emerged first in the Middle East, but soon after in South and East Asia. We know, too, that for the past roughly two thousand years Asia has had an extensive and distinctive form of urbanization. For much of this time, the majority of the world's 25 largest cities have been in Asia. But historic Asian cities have a distinctive character. The cities of modern Europe and North America, which arose with the industrial revolution three centuries ago, were most often coastal cities. Their wealth lay largely in world wide water borne trade, and they derived their wealth from the resources of the rest of the world. Historic Asian cities were, by contrast, inland cities. They lived in part by trade, to be sure, but far more important is that they were administrative centers that organized a rich and productive hinterland for their wealth. This has given Asian urban administrators a long history of experience in organizing the hinterland for sustainable development.

Second, world urbanization, which is now proceeding very rapidly, has come in two major transitions. From roughly 1750 to 1950 Europe and North America (plus Japan and Oceania) became urbanized in the process of the industrial revolution. Africa, Asia and Latin America were left behind. Thus in 1950 the world was divided into two major blocks: the North Atlantic and Japanese wealthy urban-industrial block and the African-Asian-Latin-American poor rural-agrarian block. In the past half century the modern urban revolution is occurring in the block left behind in the past. Today throughout Asia we find the urban population growth rates are greater than total population growth rates everywhere. In many places we are even seeing negative growth rates in rural areas while cities continue to grow (Ness and Talwar 2004).

There are, however, two radical differences between the past and present urban transitions. The current is occurring much faster. What took two centuries in the past will now be complete in a century or less. Second, the absolute numbers today are many times larger than they were in the past. The North Atlantic urban transition involved a few hundred million people; the transition toady, especially in Asia, involves billions of people. The greater speed and greater numbers of this transition impose on Asian urbanization a much greater sense of urgency to identify and address the problems the transition is bringing. I hope the natural scientists dealing with current Asian urban problems are fully aware of the urgency with which solutions are needed today.

There is just one other observation I should like to make concerning the paper on Tamil Nadhu's systems of "tank" irrigation, which the author notes is now giving way to deep wells pumping out underground water for irrigation. The author seems to see some advantage in the tank system, which she notes in falling into disrepair and giving way to the increase of the deep wells. It is important to note that the tank system reflects two important conditions. One is the decentralized political system of India. Local Rajas had the power to call on villagers to provide courvee labor to dig the tanks. These were filled with monsoon rains and they then provided water for irrigation during the long dry season. Here was a political system that could mobilize labor for digging and maintenance. But it was also a system without the technical capacity to tap underground water sources. Today we have a more centralized political system and a technology fully capable of tapping underground water sources. Now the central government subsidizes the purchase of irrigation pumps and the electricity to run them. As the author notes, pump irrigation is increasing substantially. There is a good question of which system – tanks or wells – is the most effective and efficient for storage and retrieval of water. In the arid land of South India, the tanks must loose a great deal of water to evaporation. Underground water storage may well be much more efficient, so long as we have the technology to extract the water. But of course there is another problem, which we see in the north of China where heavy pumping for agriculture, industry and the new urbanism is drawing down the traditional water table at an unsustainable rate. Pumping for irrigation, industry and urbanization in South India could well pose the same problem. Here it is useful to call attention to a new strategy of water harvesting developed in Chennai (formerly Madras). Buildings and road surfaces are now used to catch rainwater and direct it into traps to direct the flow into the ground rather than allowing it to runoff into the river and sea. This has already had a positive impact in raising the urban underground water table. Tamil Nadhu's traditional tank system was suited to the political organization and technology of the past, with its much lower population densities and slower growth. Given the rapid growth of population and urban systems in modern Asia, new strategies for water management are needed, and the need is urgent and desperate.

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The Relationship between Urban Residents' Lives and Water Environment - Analyses on Watershed Scale and Community Scale -

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Abstract

In this article, the relationship between urban residents' lives and water environment is discussed through the two case studies. Firstly, a watershed scale study is intended to clarify the spatial structure of the urban residential water supply system and its historical changes, and to analyze the physical and socio-economic conditions of the residential water supply system on watershed scale by using GIS. Secondly, as a community scale study, the relationship between canal environment in urban area and urban residents' lives is analyzed through the case of central Kanazawa city. Both the watershed scale and the community scale studies indicate that it is important to consider relative positional relationships between the study areas and water environmental features such as rivers and canals around them, when we analyze human impacts on water environment in an urbanized area.

1. Introduction

In this article, the relationship between urban residents' lives and water environment is discussed through the two different scale studies.

Firstly, a watershed scale study is intended to clarify the spatial structure of the urban residential water supply system and its historical changes, and to analyze the physical and socio-economic conditions of the residential water supply system on watershed scale by using GIS. The cities of Mito and Mitsukaido are selected as study areas for comparative discussion. Mito is the capital of Ibaraki Prefecture, and is the most populous city in the prefecture. On the other hand, cities in the downstream of the Kinu-Kokai River basin – including Mitsukaido – are commuter cities of the Tokyo Metropolitan Area, Mitsukaido is also in Ibaraki Prefecture near Tokyo and both are located in the most downstream portions of the Naka River basin and the Kinu-Kokai River basin, respectively. In terms of methodology, to clarify the urban residential water supply systems in Mito and Mitsukaido definitively, the following will be examined: current location of water sources and intakes; quantity of water taken by each water source; population served by the water supplied; water supply system; and any historical changes to those water supply systems. How downstream municipalities deal with increases in water demand as a result of urbanization and population growth is compared with that of two downstream cities. Second, regional conditions on the watershed scale will be analyzed. In this study, four factors such as landform, land use, population and water rights are examined.

Secondly, the purpose of a community scale study is to analyze the actual use of canals and to investigate the conscious and practical canal maintenance by urban residents in Kanazawa, where there are many historical canals within the urbanized area. It is discussed here how canals in the urbanized area are utilized and managed through urban governance and community and individual activities. The methodology of this study makes use of a questionnaire survey to residents of central Kanazawa about the experiences of canal use and the conscious and practical canal maintenance; hearing investigations to some residents about the transition of canal use and how to use the canals; and hearing investigations to some local associations and voluntary organizations about their canal use and maintenance. Kanazawa city, which is one of Japanese historical cities, is located along the Sea of Japan. The city is the economic and political center of the Hokuriku region. The study areas of this survey are the Nagamachi school area and the Kodatsuno school area, both of which are near the civic center of Kanazawa. The Nagamachi school area has two historical canals, named the Ohnosho canal and the Kuratsuki canal. The Ohnosho canal was improved along with the historical landscape recreation work by Kanazawa city, which occured from 1985 to 1990. The Kuratsuki canal was largely covered until 1985, when a shopping center was constructed beside the canal. At the time, the canal was opened and an avenue with willow trees and benches was created across the canal. Meanwhile, the Kodatsuno school area has one major canal called the Tatsumi canal, which was historically landscaped by prefectural work in 1983. This was the first public work for canal landscape renovations in Kanazawa city.

2. A Watershed Scale Study

The municipal waterworks in Mito city continued to increase the quantity of taken water from the Naka River, along with the enhancement of water rights through the five expansion projects. The coverage of the waterworks was over 90% in 1974, and reached 99% in 1986. In 1992, with the merger of the two municipalities, the waterworks of former Tsunezumi village became part of the waterworks of Mito city. The Ashiyama and Edauchi water treatment plants were abolished in 1993. Water supplies from the prefectural extensive water supply project to parts of the Tsunezumi district started moving in 1998, and these processes formed the present-day residential water supply system of Mito city (Fig.1).

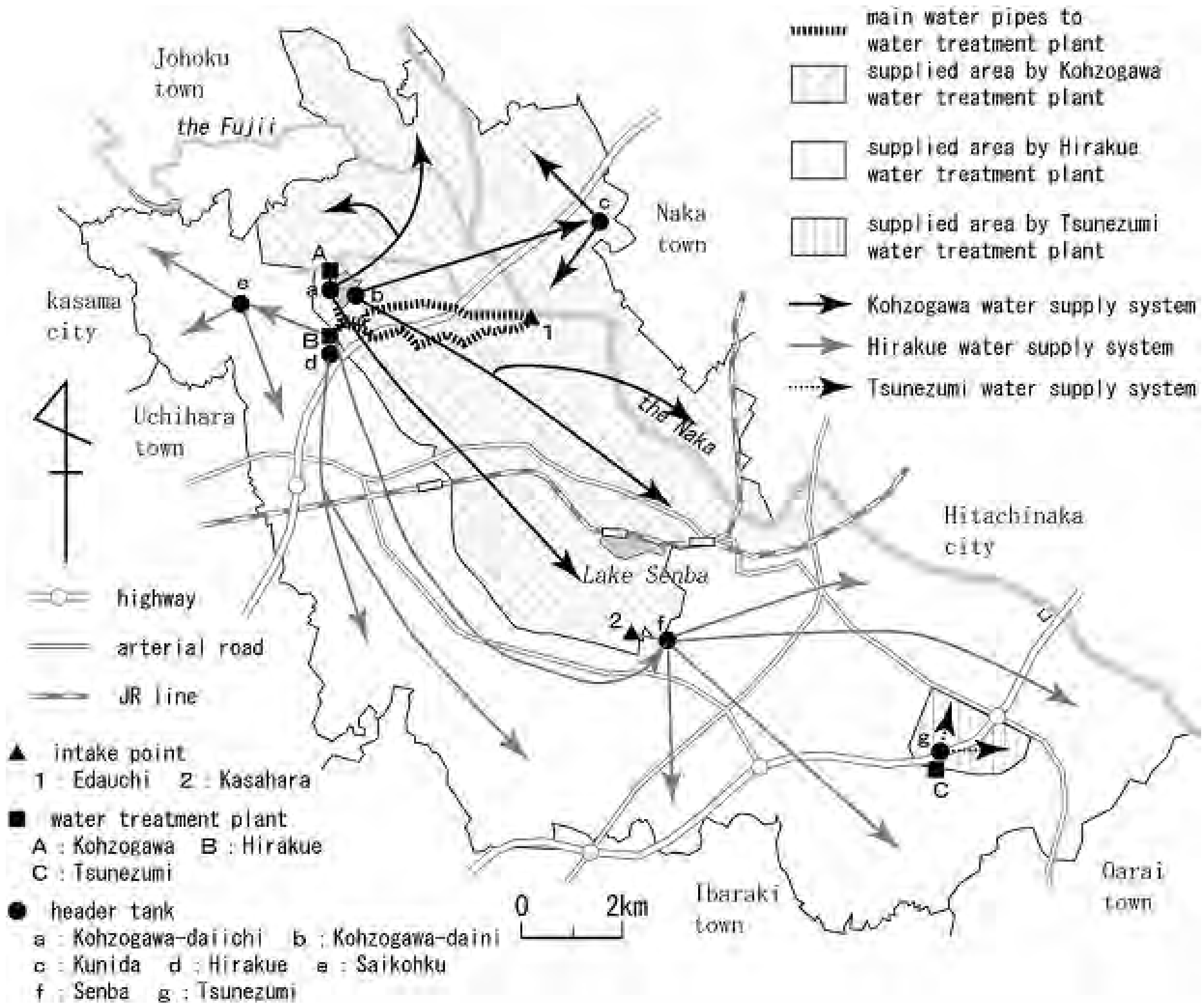

Fig.1 Municipal water supply system in Mito city (2002)

Currently, the river water from two intakes at Edauchi on the Naka River is pumped to the Kohzogawa dam and the Hirakue water treatment plant through the conducting water pipes. Water supply from Kohzogawa water treatment plant covers the central to northwestern sections of Mito city; on the other hand, the area supplied with water from the Hirakue water treatment plant includes the Shimoichi district, the area across the Route 50 bypass, and the former Tsunezumi village. With these two water supply systems and the Tsunezumi water treatment plant depending on an extensive prefectural water supply project, adequate residential water is supplied to entire Mito city efficiently.

On the other hand, the waterworks in Mitsukaido city started their service in 1964. Prior to that year, the residential water supply came solely from well-supplied groundwater. The wells are still being used in those areas where waterworks are not supplied. Fig.2 shows the transition of the residential water-supplied area and the current water supply system in Mitsukaido city. The area where water was supplied in the first several years was limited to the center of the city; the water source at the time was the groundwater from deep well No.1 and the residential water was supplied through the Hashimoto water treatment plant. Because the water source of municipal waterworks in Mitsukaido City before 1989 was all groundwater taken from deep wells, quantity of water was limited; waterworks supply coverage at the time was less than 40%.

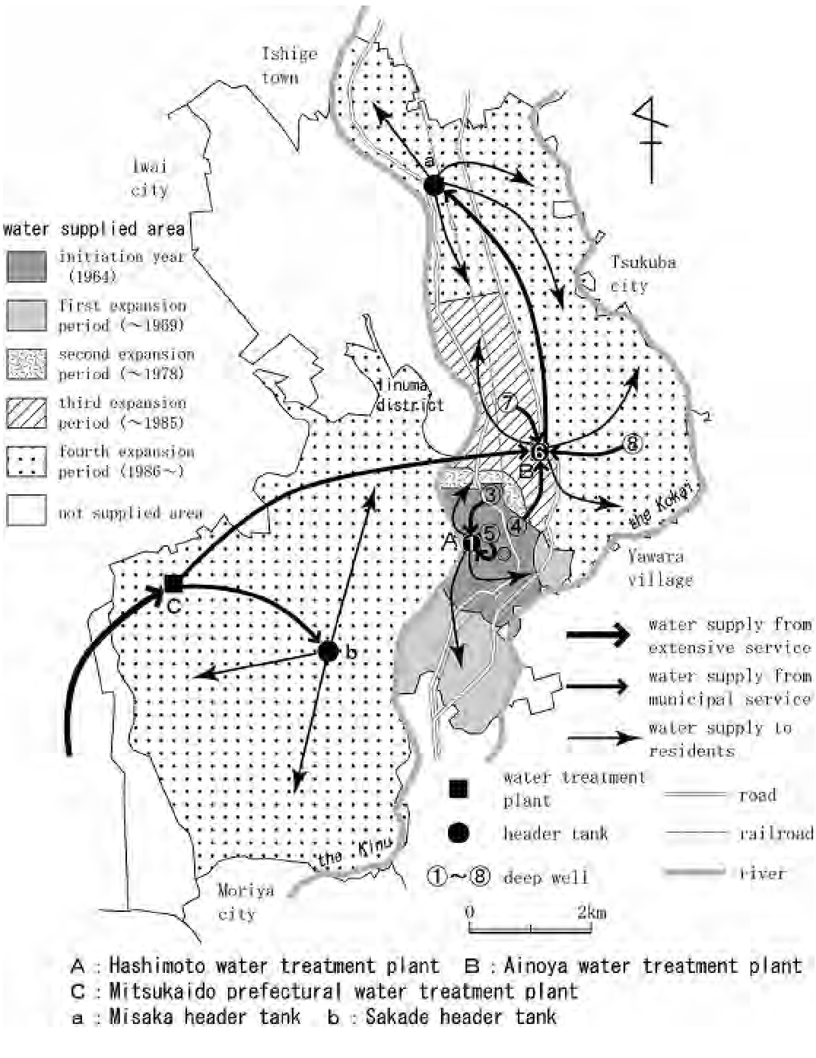

Fig.2 Transition of the residential water-supplied area and current water supply system in Mitsukaido city (2002)

In the fourth expansion project – which began in 1991 – the adoption of an extensive water supply service was planned. It started accepting residential water from the Kensei Prefectural Extensive Water Supply Project on July 1, 1995. With the adoption of an extensive water supply service, the water-supplied area was extended. The current residential water supply system in Mitsukaido city is as follows: the groundwater from deep wells No.3 and 5 is transported to the Hashimoto water treatment plant; and the groundwater from deep wells Nos.4, 6, 7 and 8 is delivered to the Ainoya water treatment plant, with a portion of that water being delivered to the Misaka header tank. On the other hand, river water from the Tone River is supplied to Ainoya water treatment plant and the Sakade header tank through the Mitsukaido prefectural water treatment plant. Residential water collected by the four water supply facilities is supplied to the surrounding areas.

Then, this study examines the spatial characteristics of landform, land use, population and water rights on watershed scale as the regional conditions that influence the residential water supply systems in the two downstream cities. In conclusion, the residential water supply system in a city is determined not only by the absolute water demand and that city's surrounding area, but also the quantitative and spatial balances between river water supply and demand on watershed scale that the city is in. Such a watershed scale river water supply-demand balance is closely related to such physical and socio-economic conditions on watershed scale as landform, land use, population and water rights.

3. A Community Scale Study

Fig.3 indicates the transition of canal use in both school areas. Until the 1960s, canals had

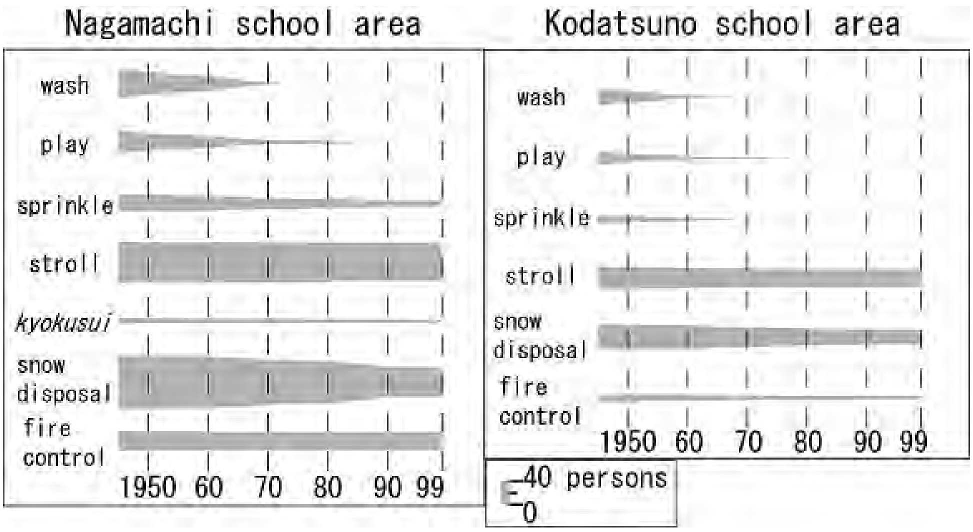

Fig.3 Transition of canal use in Nagamachi and Kodatsuno school areas
near the civic center of Kanazawa city

multiple functions in the daily lives of residents, such as helping them wash vegetables, clothes and shoes, providing for playing spaces for children, allowing them to water plants and roads, and so on. There were many open spaces at that time containing stairs by which one could enter the canals and use the canal water. However, since the 1960s, these open spaces have gradually disappeared: with the progress of motorization has come the need to widen roads and providing parking spaces, and to fulfill these needs, the canals needed to be covered. Today, the role of the canals is limited to strolling spaces and disaster prevention against in cases of heavy snowfall and fire. Since the 1980s, landscape and footpath creation works for recreational use - as well as canal improvement works for disaster prevention by the governance - have promoted the transition of canals' functions from essential roles in daily life to the somewhat secondary roles of landscaping and disaster preparedness. Additionally, some residences in the Nagamachi school area installed gardens with canal water, according to the traditional "feng shui" school of thought.

The consciousness of residents in the self-maintenance of canals is at variance with their actual practice. The practices of regional associations play a very important role in prompting residents to maintain the canals in their neighborhood, with most of those participants being nearly-middle-aged people in the Nagamachi school area and elderly people in the Kodatsuno school area.

On the whole, the residents of the Nagamachi school area utilize the canals more, are more cognizant of the need for canal maintenance and are more active in corresponding cleanup activities than those in the Kodatsuno school area. The main reason for this difference is as follows. The water of the Tatsumi canal in the Kodatsuno school area is poorer (in terms of quality and quantity) than the water of the Kuratsuki and Ohnosho canals in the Nagamachi school area. Consequently, in the Kodatsuno school area, the Tatsumi canal was largely covered and the residents become relatively negative about both canal use and maintenance.

By examining the results of this study in central Kanazawa, it has been revealed that there are two types of motivation among urban residents in conserving such urban nature areas as canals: "egocentric motivation" and "sociocentric motivation."

Firstly, "egocentric motivation" relates to the reasons behind personal experiences with canal use in their own lives. If a canal was essential in daily life for drinking, washing, cooking and so on, or if a canal was a popular playing space in childhood, for example, people will feel more compelled to conserve the canal. In a way, one could say that the canal has a special place in the lives of these people, and they therefore have a vested interest in preserving that area. In view of this logic, it is important to create opportunities for urban residents, by which they might have contact with their immediate natural environment (however contrived). These experiences cultivate an "egocentric motivation" in today's urban residents who would never otherwise feel the need for these environments in their daily lives.

Secondly, "sociocentric motivation" relates to the social concerns of the communities that people belong to. A typical phenomenon is switching a "purpose" behind environmental conservation to a "method." For urban residents, the purpose of participating in environmental conservation activities is not always for environmental conservation itself, but for maintaining good relations with neighbors and revitalizing their community. In short, the environmental conservation activities become a means to accomplishing different purposes. However, this "switching" can be interpreted in a positive light, because it indicates positive feedback between the environment and society, especially in the Nagamachi school area. Concretely speaking, the creation of an attractive canal environment raises the consciousness for the environment in residents and promotes the vividness of the community. At the same time, having a revitalized community brings about the more effective use and maintenance of the environment.

4. Conclusion

Both the watershed scale and the community scale studies indicate that it is important to consider relative positional relationships between the study areas and water environmental features such as rivers and canals around them, when we analyze human impacts on water environment in an urbanized area.

A geographical approach to the restoration of historical water environment in historical materials and topographical maps

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Abstract

This study is intending to reconstruct post water environment by the historical materials and topographical maps. I have focuses on the descriptions and landscape in this research. And a geographical approach to hydrological environment discusses a possibility of an analysis method in the analog type. As the result, it had been clear that the change of water environment is largely influenced by human activity. As a result, this method for the reconstruction water environment in the past can afford good result.

1. Introduction

The human activities have concentrated on cities; the rapid growth of population and developed infrastructure caused a dramatic shift in the nature within cities and surrounding areas. The water environment of cities can be understood based both on present and past natural environments, as well as the formation process of present situation.

In Japan, various researches have been carried out to investigate of water environment in the city. However, many of these studies were begun after 1960's when hydrological observation sites were set up. It is important to assess the historical changes in the water quality, discharge, ground water level and water use etc., because the water environment has been influenced by the human activity (Fig.1). Because of this, I have tried historical reconstruction of the water environment in the part of twentieth century.

To reconstruct the historical water environment, it is necessary to get the different kinds of information from the present. Although the quantitative data can not be obtained, descriptions of water space, maps, statistics books in the year and pictures etc. are valuable resources on the information of water environment. The historical materials and topographical maps are specially assessed and analyze the water environment in the past.

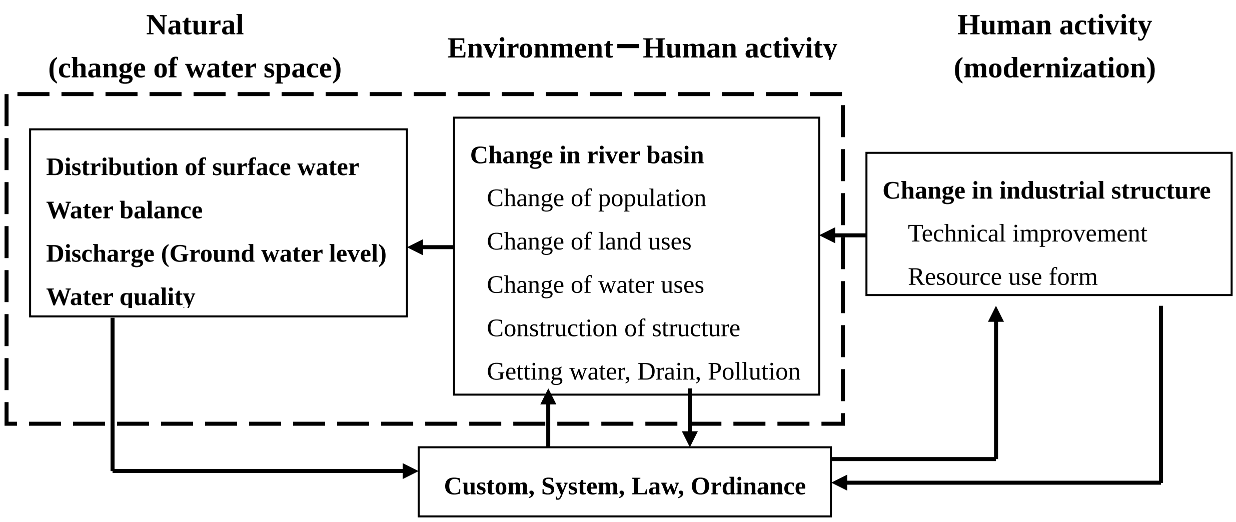

Fig.1 Framework of man-environment system for water (Arai 1992)

2. Research Objectives

It is important to assess the change of aquatic environment in the present and past for the better understanding of the water environment in city. It had been clear that the change of water environment is largely influenced by human activity. Therefore, it is necessary to clarify hydrological environment and the influence on water environment by the human activity in the city background of nature in the past.

In this study, it report on the restoration of historical water environment in historical materials and maps and a geographical approach to hydrological environment discusses a possibility of the analysis method in the analog type. I have focuses on the descriptions and landscape in this research in the last 100 years in Tokyo.

The methodology and purpose of this research is as follows. This research uses topographical map, land condition map, aero photograph. At the same time, historical reconstruction of water environment focuses on historical data, such as old documents, old maps, art pictures and photographs (Photo 1). And, I will reconstruct historical water environment in the city. Mapping of the historical changes in the land-uses and human activity is analyzed on the statistical data, old map and so on. Relations between human activity and water environment each other will be summarized by data and the analytical results.

The Expected Results of this research are shown as follows.

(1) Mapping of the historical changes in the land-uses and human activity and its analyses.

(2) Mapping of historical water environment and construction of database on the historical water environment.

(3) Relations between human activity and water environment in present and the past are the presented.

Photo 1 Art pictures (Ukiyoe) and photographs in river at Tokyo

3. Changes of water space in Tokyo

Tokyo was abundant in rivers, irrigation canals and these water spaces have been used for aqueducts, municipal water, irrigation, ship transportation and recreational park. Not only these water spaces have contributed to the development of Tokyo, but also had an important significance for the daily life of the citizen. According to the enlargement of city area of Tokyo since 1950's, water spaces have been much reduced by the construction of under-ground aqueducts and reclamation. 1960's was the time of sewer water pollution, after then, these pollution level decreased by the construction of sewerage. At present, water spaces such as rivers and ponds in Tokyo are recognized as park.

The regional aquatic environment is reflecting the nature of the area. Therefore, it is necessary to understand the change of water environment in the present and past.

Changes in the rivers and canals in Tokyo during the recent 100 years were traced from topographical map. Based on this procedure, the distribution of the water space and land use along riverside in Tokyo around 1920, 1940, 1960 and 1990 was reconstructed as grid map. As seen from Figure 2, numbers of grid of water space were 698 in 748 at 1920, but decreased to 575 in 831 at 1990. Numbers of grid of no water space were 50 in 748 at 1920, but decreased to 256 in 831 at 1990.

Rivers and canals have disappeared during the 20th century, since the rivers and canals lost their functions by urbanization, development of sewerage, railway and road. It is not easy to restore the river and channel that have been much reduced by the construction of under-ground aqueducts. Moreover, it is difficult to clear the water quality of the river and channel has once polluted, although the situation has been recovering in Tokyo by the spreading of the municipal sewerage service. Tokyo had been a large city even in the 20th century, and reconstruction of landscape and waterscape has been matter of interest.

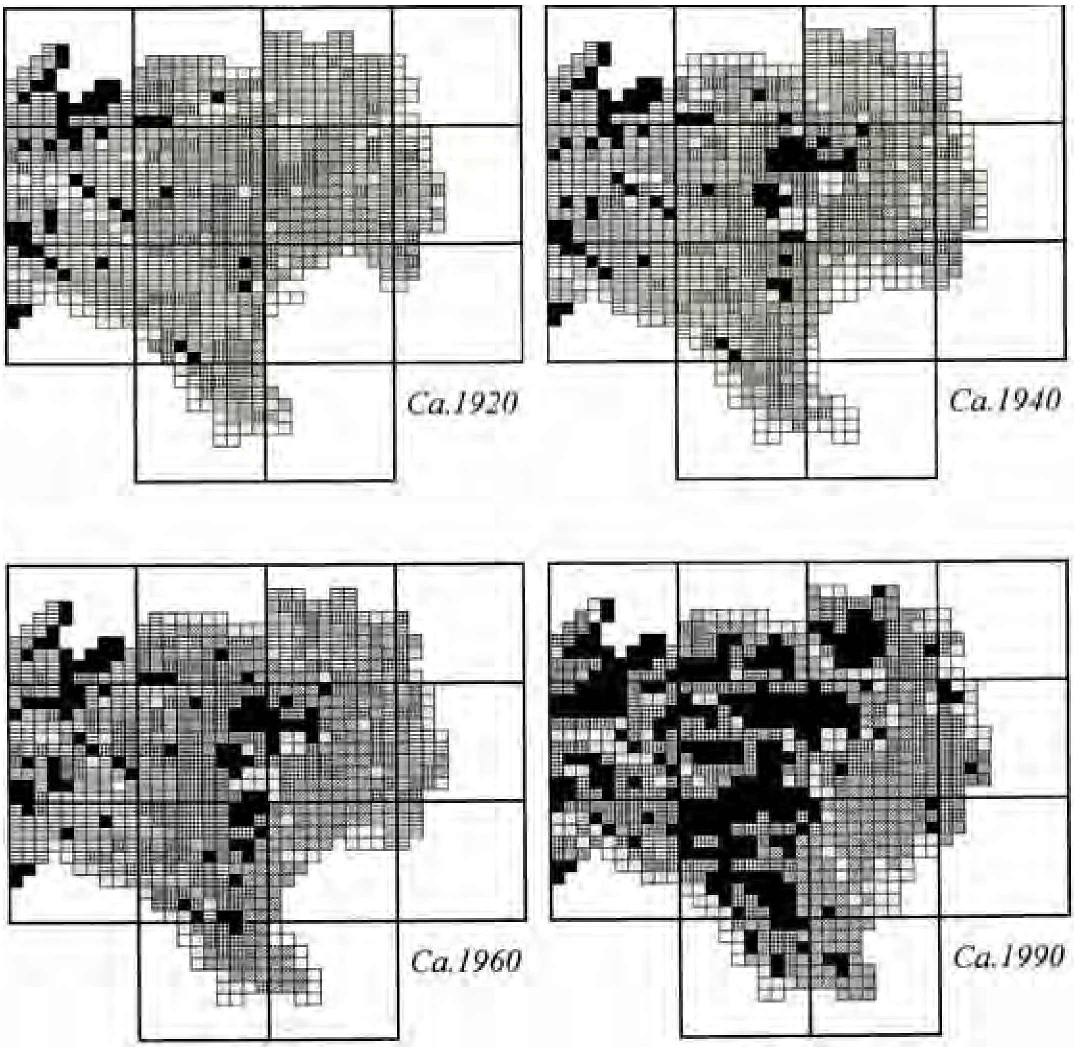

Fig.2 Distribution of the water space and land use along riverside in Tokyo (Taniguchi 2003)

4. Discussion

Geography has traditionally analyzed the natural and human activity, as well as their relationship to understand each region; however in recent years, "integration of the humanities and natural science", "environment", "nature" and "human" have been emphasized from the viewpoints of environment conservation and sustainable utilization. To understand each area, we should recognize our methods, documents, and analytical forms, in addition to the study on natural environment including cultural elements, or the one on cultural and social environments including natural elements. The water environment has its original practice and landscape; recent waterfront renovations, urban planning and urban development have been required to utilize the history and tradition of the place. There will lead to the recognition of immediate natural environment in the city. Such tendency also confirms the needs for a new method and analysis on urban water environment.

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A Study of the Formation Process of Inner Area in Modern City: Focusing on the Transformation of Land use

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Introduction

The aim of this study is to propound change models for urban hydro-environment in Asian cities through modernization, but here I limit the discussion to the relationship between the transformation of land use and the configuration of urban space in modern city of Japan.

The histories of cities have been intertwined with stages of colonialism, imperialism, and industrial capitalism. Each stage has provided the urban form with various built environment for social life at large. If one feels comfortable with the historical-geographical model used by Soja (1989) to illustrate the evolution of urban form (the internal spatial structure of capitalist city), the configuration of urban space in a certain time can be seen as 'representations as the past as well as the context for the next round of restructuring.' Soja, summarizing the urban metamorphosis in North America, provides an evolution model of urban form. It constitutes of four stages: mercantile city, competitive industrial capitalist city, corporate-monopoly capitalist city, and Fordist city under the state-managed urban system.

The governing principle of industrial capitalism, for example, produced the urban space composed of central business districts, manufacturing quarters, residential districts, stations, ports, and streets, railway, and canals which connect these locations. Accommodative technologies of transport accelerated the intensification of land use in the urban center, which redefined the form of the city. This intensification resulted in the formation of Central Business District (CBD). Rippling out the CBD and employment nucleus was a zoned build environment of residential rings, and its concentric zonation was not only a physical appearance of land uses, but also largely a matter of social class and division of labor.

In Japan, the modernization of urban structure started following the *Meiji* Restoration of 1868, which involved large historical changes in political and social systems and the opening of the country to foreign commerce. Then, the hydro-environment of modern city has been greatly influenced by the modernization and drastic transformation of urban space. In short, Hydro-environment has changed along with modernization of urban space. So, we will begin by considering characteristics of urban land use through the early *Meiji* era. Although urban land use or urban form has been an object of urban studies such as urban planning, urban history, historical or urban geography, and so on, for a long time, little attention has been given to the formation process of inner "transitional" area —using the term by Burgess, a famous sociologist of the Chicago School— and its geographical (not social) characteristics.

Urban Form in Modern Japan

Many Japanese cities developed from feudal castle towns, and the CBDs of such cities have mainly grown up around the nucleus of the former castle, because castle sites were the center of military and administrative functions and were easy to convert the function till then for the absence of the Lord with the *Meiji* Restoration. Areas with such functions became the points where the public facilities of the city accumulated and the former merchant dwelling areas have become the present central business districts and shopping streets. Thus in Many cases the CBD is formed of these two types of area.

Many of these cities experienced the rapid increase of inflowing population and the expansion of the built-up area through *Meiji* to early *Showa* era. In this process, inner “transitional” zone was formed around the built-up area of castle town, and the outer residential zone was formed around the inner area further. First of all, to consider the formation of inner area of Japanese city, it is useful to quote from *30 years of Tokyo* by Tayama Katai, a famous writer in Japan. He described the expansion of built up area in the famous paragraph entitled "Development of Tokyo" as follows:

> Generally, the outerzone of Tokyo was developed newly. It is the new development. That is a town in which labors and students live. Old atmosphere does not remain there. The air of *Edo* overwhelmed by civilization, and it is just seen the remainder faintly at the center of the city, in shot the bottom.

It was inevitable to expand the urban area to suburbs along with the process of modernization, which include an increase of population and industrialization. It is in this processes that the inner area ―more generally, inner city― was formed. As Engels, nearly a century and a half ago, acutely pointed out taking the case of Manchester, or as shown in the concentric zone model of the Chicago School in 1920’s and in the contemporary studies of urban restructuring in critical geography, this spatial form can be seen as landscape to reflect the division of labor. The surrounding area of modern city was, as Tayama also put it, a zone that had been newly developed. Many of residential districts for increasing working population was prepared by public-private partnership in this area, and, on the other hand, the villa area and the residential quarter for affluent come to be supplied by private sector such as the electric railroad company and the developer in a more outside part. Thus, that Tayama called ‘outerzone’ was former rural area around the castle town, where is the inner area in contemporary urban form.

We can see from several observations in the last few paragraphs what urban form of modern city was zonational composed of three zones. The first is Urban Core (the area of castle town) which includes CBD. The second is Inner Area of mixed land-use for working-class residential and industrial which has been formed around the first zone. The third is Outer Area for elite residential and is located in the outside of the second zone.

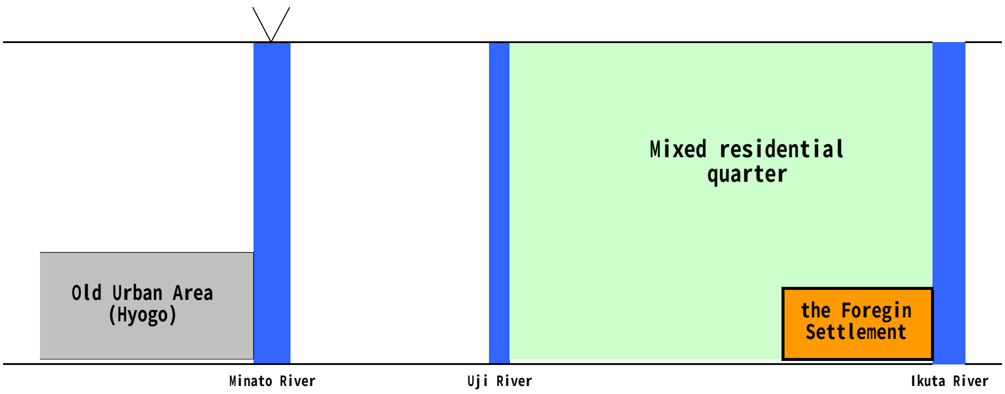
The Formation Process of Inner Area of Kobe City

Kobe is a city that has pursued capitalist urban development most explicitly in Japan. Kobe is the fifth largest city in Japan with a population of 0.76 million (1933) and lies on a compound alluvial fan at the foot of the Rokko mountain range. The built-up area forms a belt-like zone between the shore and the mountain. As for this city, however, historical-geographical assumption is very different from many of other cities. Because Kobe is not a castle town, although many cities of Japan had Castles, which were the living place of feudal lords. Kobe is a typical port city of Japan that has developed since Meiji Restoration and the construction of the Foreign Settlement in the same year (1868). Thus, Kobe experienced a contrasting and unique course of urbanization, and I think this city provides a starting point.

Generally central business districts of Japanese city developed in and around castle sites, but in Kobe, the Foreign Settlement was located in the land of an unfavorable condition, far from the old town, and was a substantial influence on the process of urbanization there. In short, the nucleus of the city was originally in old port town which called Hyogo, but the focal point of formation and modernization of urban space in Kobe had moved in and around the Foreign Settlement.

The Foreign Settlement was established in 1868, according to the request of foreign traders who were to come to live in Kobe. After the termination of this special self-governing system, this area attracted import-export offices and related businesses. Retail and dining-amusement functions concentrated around the area of these international businesses. In spite of being an historical central district with a small castle and a port in the feudal middle age, the Hyogo district could not attract the central urban functions as the Foreign Settlement area did and is now on the periphery of the central business district. Thus the Foreign Settlement area played as essential role in the formation of the present urban structure of Kobe (see photograph 1).

In addition to this, there is one father thing. It is the definition of 'mixed residential quarter' in which the foreigners were able to live freely though there were Japanese houses. By this definition, the direction of land uses was decided unexpectedly. It could be considered that this is the prototype of land use control, because the ideal way of the land use as shown in figure below became clear as a result. The term 'land use control' is defined in generally as a method to make rational land use of inducing proper land use through restrictions. It is the small rivers that played the important role in the delineation of areas.



Land-Use Control of Kobe in early Meiji

Thus, three rivers are used as a boundary, which means it had symbolic meanings as marginality, and the feature of each district divided by them becomes clear. They may be divided into five categories (or six areas): the Foreign Settlement built on the right bank of and the mouth of Ikuta River（①）; Mixed residential quarter set up between Ikuta River and Uji River（②）; and Hyogo which was the main port of old urban area（③）. In addition to these, there is a blank area between Minato River and Uji River（④）. Moreover, the west area which is located from Minato River to the west without Hyogo and the east area which is located from Ikuta Rive to the east can be regarded as the near suburbs (⑤). Thus, we may consider the process of inner area of Kobe through each type of land use. ① and ② can be left outside the consideration here, because both has been composing the urban core or CBD.

Hyogo（*③*）　Hyogo, now a part of Kobe city and lying about 4km from old Kobe, was a transit harbor. There was also a small castle there during feudal Edo era. At the beginning of the Meiji era, the new prefecture office was located on the former castle site. But, land use in Hyogo changed gradually to such transitional land uses as match factories, small iron factories, or cheap lodging houses. Central commercial functions did not accumulate here, bur surrounding the former Foreign Settlement in new Kobe along with administrative and cultural functions.

Blank area (④) This area played the quite important role as well as the Foreign Settlement and the mixed residential quarter. in the initial stage of formation process of urban space. This area was a zone of the blank in the land use control so that large-scale, public development was possible, and it was actually promoted. For example, *Fukuhara-Yukaku* (red-light district), the Prefectural government, Minatogawa Shrine, local court, and Kobe Station on a vast site were constructed. And also, large arable land was rezoned for the residents who had forced removal from those sites in order to promote those constructions, and a lot of houses were supplied for them.

Suburbs (⑤) Sooner or later, both suburbs where underdeveloped land spreads out serve as the fronts of built-upping area where it goes. Especially in the case of Kobe, it is remarkable that rezoning of arable land around the built-up area was executed in premeditation at a considerably early stage of the formation of urban space in early Meiji era (see figure2). It became the geographical base to which the land division developed at this time supplying a lot of cheap houses for the laborers, and also became the sites of small-scale factories. Heavy industries such as shipbuilding and steel mills are located along the coast in both sides.

There is one further development that we must ignore. It is the rezoning of reclaimed land of two rivers: Ikuta River and Minato River (see figure2). The Ikuta Rive where the passage was changed in 1872, and then it was redeveloped as town districts and a road. On the other hand, Minato River has changed in late 1890’s, and the site had developed into the most famous amusement quarter in Kobe.

The inner area of Kobe had been produced through those developments including the rezoning of arable lands and the reclaimant of rivers, on which the social spaces had been constituted along with the progress of industrialization, division of labor, residential segregation. This “Inner Transitional Area” had become built-up city by about 1920, and now, the area have many functions which complemented the commercial activities of the CBD diffused out from the central area.

Industrial urbanization on the periphery of Tokyo and change of hydrological environment

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1. Introduction

The location of factory and the development of residential area in the urbanization process have concerned with the change of hydrological environment. The reclamation land and the former river basin have influenced to the land use of urban area and they show remarkable internal structure on the each situation of the urbanization. These changes of industrial urbanization will be analyzed with collecting of maps and utilization of GIS. Especially the expansion of residential area is historically clarified with dating from the urbanization of modern age. In the view of hydrological environment, the formation process of urban internal structure which arose from the subsurface environments will be tried to get a solution. In this study, I will introduce a case of industrial urbanization on the periphery of Tokyo. There is a Keihin (which means Tokyo and Yokohama) coastal industrial zone around Tokyo bay (Figure 1).

2. Data & Methods

2.1. Data

Some maps are investigated for confirming the changes of the study area. They are topographical maps about historical changes in industrial urbanization. The geological maps are utilized in the comparison to the urban internal structure. In relation to industrial urbanization, the distribution map about the population density and the victims of environmental pollutions are drawn with GIS

2.2. Methods

From the historical view points, the process of industrial urbanization is clarified with the changes of topographical maps. One of the local differentiation illustrated with the geological subsurface environment.

With making a GIS map about the urban internal structure and the environmental pollutions, it will be find a hypothesis. One of spatial character at the industrial urbanization is caused by the subsurface environments. GIS map is made with ArcView 3.3 by ESRI.

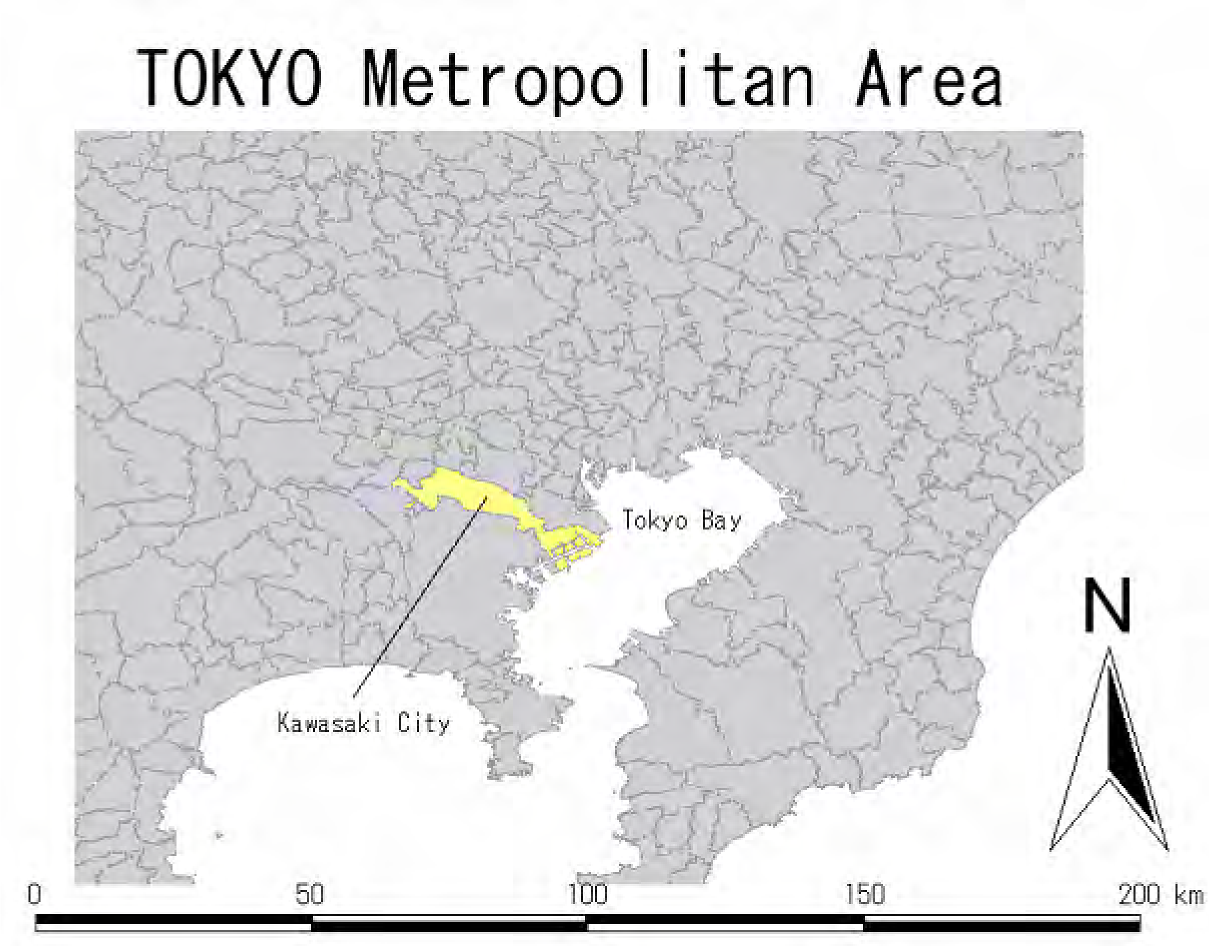

Figure 1 Study area

3. Results & Discussion

3.1. Industrial Urbanization on the Periphery of Tokyo-the Coastal Area of Kawasaki City-

In the beginning of the 20th century, large factories were constructed one after another. Some industrial sites were the reclaimed land and others were on the riverside of Tama River. Before the industrialization it was post town and farmers or fishers village where the name of place is Kawasaki (Figure 2; Figure 3). At the present time, Kawasaki city has over one hundred person and mainly it has become urbanized area as the landscape. But the subsurface environments of the Kawasaki city affected to the process of industrial urbanization.

3.2. The Subsurface Environment of the Residential Area

As far as seeing the land use pattern, some characters about the details of topography related with urbanization. It means that the residential area has changed the bottom of the land by the age. Early village occupied the better land condition. So many

Figure 2 Before the industrialization in the coastal area of Kawasaki (19c)

Source: 1:20,000 Jinsoku-zu: Kawasaki-eki and Haneda-mura

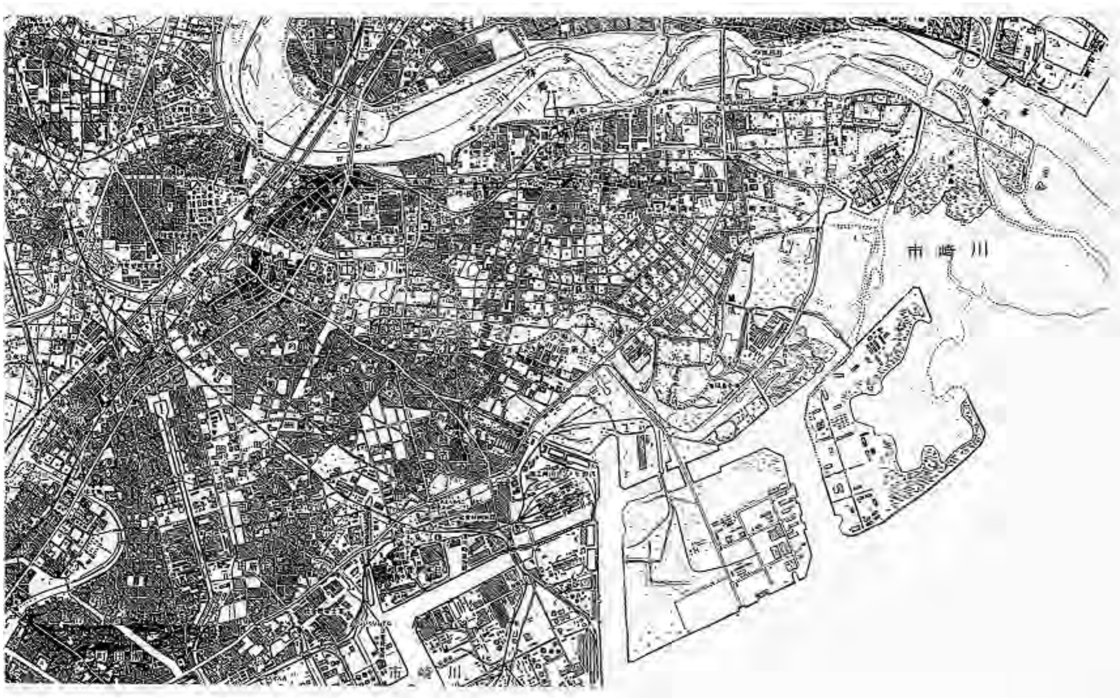

Figure 3 Under the industrialization in the coastal area of Kawasaki (1945)

Source: 1:25,000 Topographical map: Kawasaki and Anamori

residential areas developed after industrialization, but its sites were the former farmland or the reclaimed land. After World war Ⅱ, Kawasaki city has changed into not only worker’s town but also residential town for commuters. The construction of the residence is in succession. From the geological map (Figure 4), it will be find that the subsurface environment might influenced to the urbanization.

Figure 4 The geological map of the coastal area of Kawasaki

Sb: sandbar, Nl: natural levee, Bm: back marsh, Ac: ancient channel, Rc: reclamation of the coastal area, －10－ : contour line based alluvium, --10-- : contour line of the upper limit by Kazusa strata
Source: Kawasaki city (1981) “Environmental and geological map in Kawasaki city”

3.3. The Distribution Map about the Population Density and the Victims of Environmental Pollutions.

Distribution map is as follows (Figure 5). The point of blue shows the deceased of environmental pollutions and that of purple shows the complainants for the trial about environmental pollution. The point of green shows the factories were complained in the trial. Concerning to the population density in 1975, some area are overlapped in many people who were deceased and complained. It will be suggested that the land use pattern and the residential in the urban internal structure has related with the subsurface and hydrological environment.

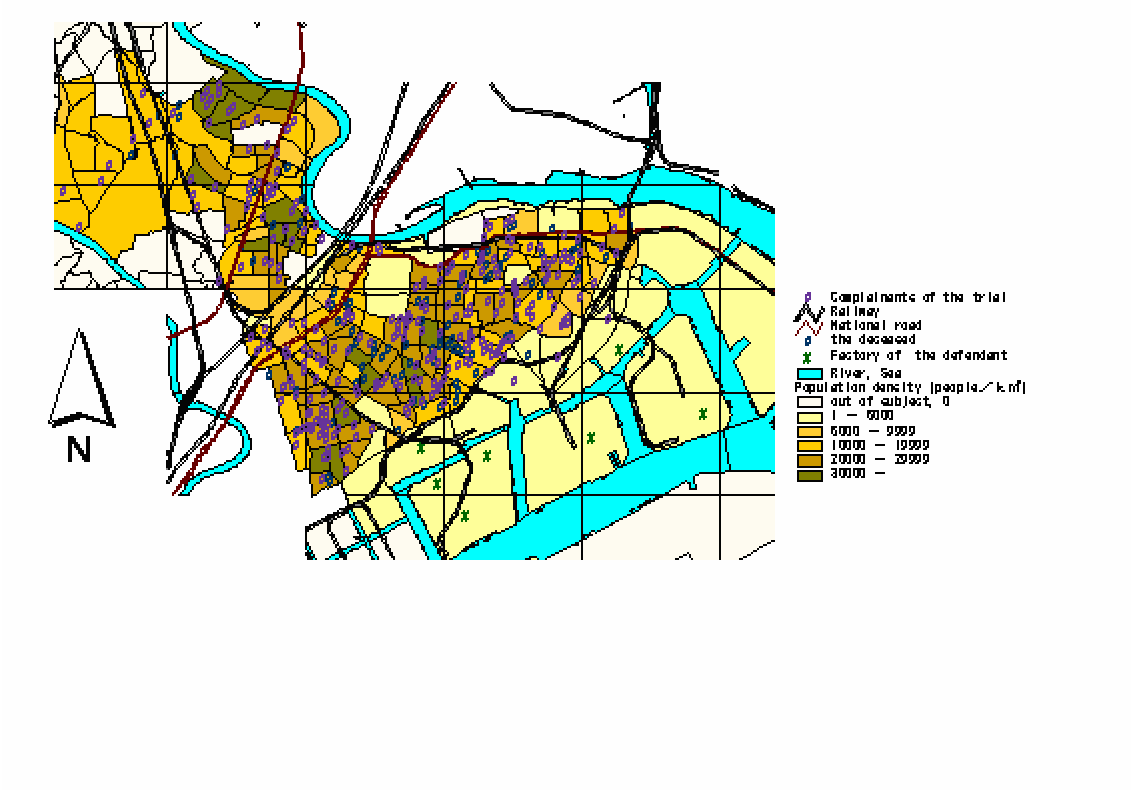

Figure 5 Distribution map about urbanization and environmental pollutions

3.4. Residential History of the Victims in Kawasaki

I prepared more attribute data about complainants (Figure 6). The green graph indicates the birth year of complainants. Many of them was born before world war Ⅱ. Most frequent year is 1916 and 1932. After world war Ⅱ, It owed baby boom that there are much born in 1948. On the other point of view, the yellow graph indicated beginning year of as a resident of complainants. There is a clear difference from birth year. Many of them began to live after world war Ⅱ. Most frequent year is 1950 and 1959. It is seemed that industrialization and urbanization of Kawasaki is concerned with the trend of complainants.

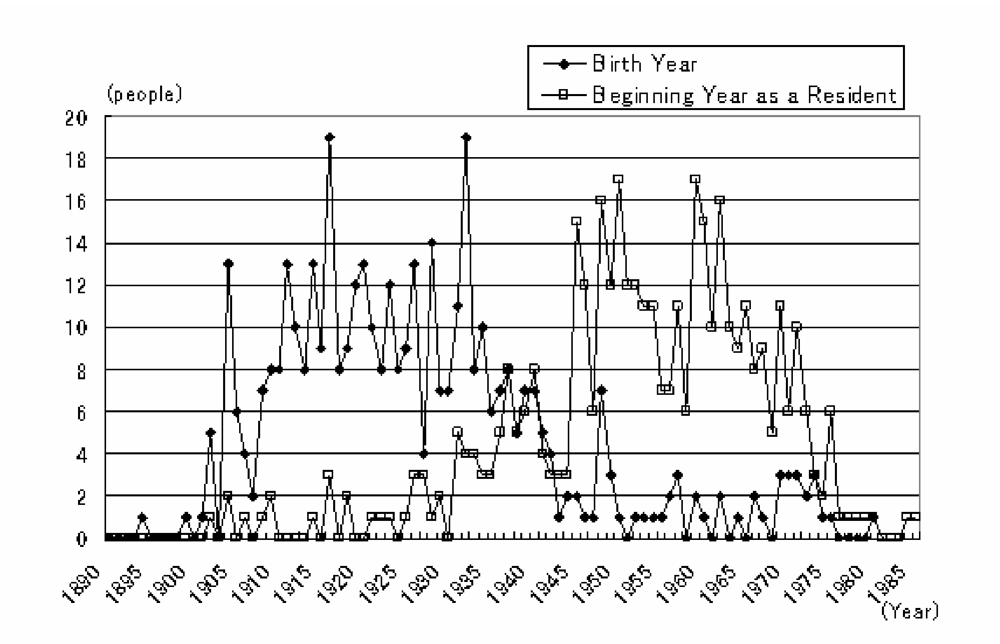

Figure 6 Birth year and beginning year as residents of the victims

Source: The record of the trial about pollution in Kawasaki (2001)

Conclusion

I have tried to demonstrate the processes of industrial urbanization in the periphery of Tokyo with historical maps and GIS. Probably residential pattern was caused by subsurface environments. I will illustrate the relation between urbanization and subsurface environments at the metropolitan area of Asia. There are some important suggestions for the urban internal structure of Asian cities.

Lifestyles and Substance Balance in Households of Asian Mega-cities

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Abstract:
The primary objective of the socio-economic group is to identify the factors in human dimension causing the environmental stresses on the subsurface environments in the urban different development stages and describe the major causalities between urbanization and the changes in subsurface environment from a long-term perspective. Our group's objective is to analyze the influence of long-term life style changes to the material and substance balance in household, industry, and business sections. Six cities were chosen for the case study, they are all mega-cities at coastal area but in different economic development stage and had suffered or is suffering severe subsurface environmental problems. Dynamic Material Flow analysis (MFA) and Substance Flow Analysis (SFA) will be used for the analysis of C, N, P in a long-term perceptive (50 years).

1. Introduction

The rapid urbanization and population increase has modified land use patterns and increased water demands. The sustainability of groundwater resources in coastal zones bounded by freshwater and saltwater bodies is affected by human activities as the result of residential, commercial, agricultural and industrial land use, which has resulted in overuse as well as microbial, chemical contamination, subsidence and subsurface thermal anomalies[1].
As a part of a project aimed to evaluate the relationships between the developmental stage of cities and various subsurface environmental problems, the objective of this research is to analyze the influence of long-term life style changes to the material and substance balance in household, industry, and business sections.
Six cities (Tokyo, Seoul, Taipei, Bangkok, Manila and Jakarta) in different development level were chosen for the case study, Material Flow Analysis (MFA) and Substance Flow Analysis (SFA) will be used for the analyze material balance as well as substance (C, N, P) balance in the past 50 years.

2. Methodology

2.1 Selected case study cities

Six cities were chosen for the case study, they are all mega-cities at coastal area but in different economic development stage and had suffered or is suffering severe subsurface environmental problems. For example, Tokyo and Taipei had suffered severest subsurface environmental problems in the 1960's and 1970's, respectively, with groundwater level decrease, land subsidence, and groundwater contamination. But since then with the restriction of groundwater use, the ground waste level and quality recovered gradually. On the contrast, Bangkok, Manila and Jakarta are suffering these problems now, and the subsurface situation getting worse and

worse.
Choosing these six cities as case study would be helpful for evaluation of the relationship between the developmental stage of cities and various subsurface environmental problems.

2.2 Methodology

SFA is a technique for tracking and assessing the inputs, stocks and outputs of a particular substance in a particular region. Based on the law of mass conservation, the method involves establishing a mass balance of goods and selected substances for defined system[2]. It is widely established method that has been used to support decision making in various fields such as waste management, nutrient management, and urban metabolism analysis. At the same time, SFA is more comprehensive than the conventional mass balance approaches since it relates substance flows to economic process, and it can help trace the origins of pollution problems[3].
In this research the objective is to analyze the influence of long-term life style changes to the material and substance balance in household, industry, and business sections. Therefore besides the typical steps involved in SFA, the relationship between the urbanization and changes of human activities (increasing of water demand, energy consumption, and material consumption) will be analyzed too. The analysis steps are as follows:

1) Selection of substances for analysis;
2) Define the study region and year;
3) List most significant goods and processes that are important for the selected substance;
4) Collect all the written information on flows and stocks of selected goods or substance for a given year;
5) Collect all socio-economic data related to urbanization and change in consumption level, analyze the relation between urbanization and consumption.
6) Establish a material balance for the significant goods and processes in a given year.
7) Determine the concentrations of the selected substance in the goods (c_{ij}) where i=1,….,k is the index for goods, and i=1,….,n is the index for substances;
8) Determine substance flows (X) that induced by the flows of goods (M) and the substance concentrations (c) in these goods using the formula:

$$X = M \times c_{ij}$$

9) Calculate the magnitude of the stock by the difference between in and output over an appropriate time span [t_0-t] following the formula:

$$M_{stock}(t) = \int_{[t_0-t]} M_{input}(\tau)d\tau - \int_{[t_0-t]} M_{output}(\tau)d\tau + M_{stock}(t_0)$$

10) Establish a substance balance for the selected substance fluxes and stocks;
11) Present the results appropriately.

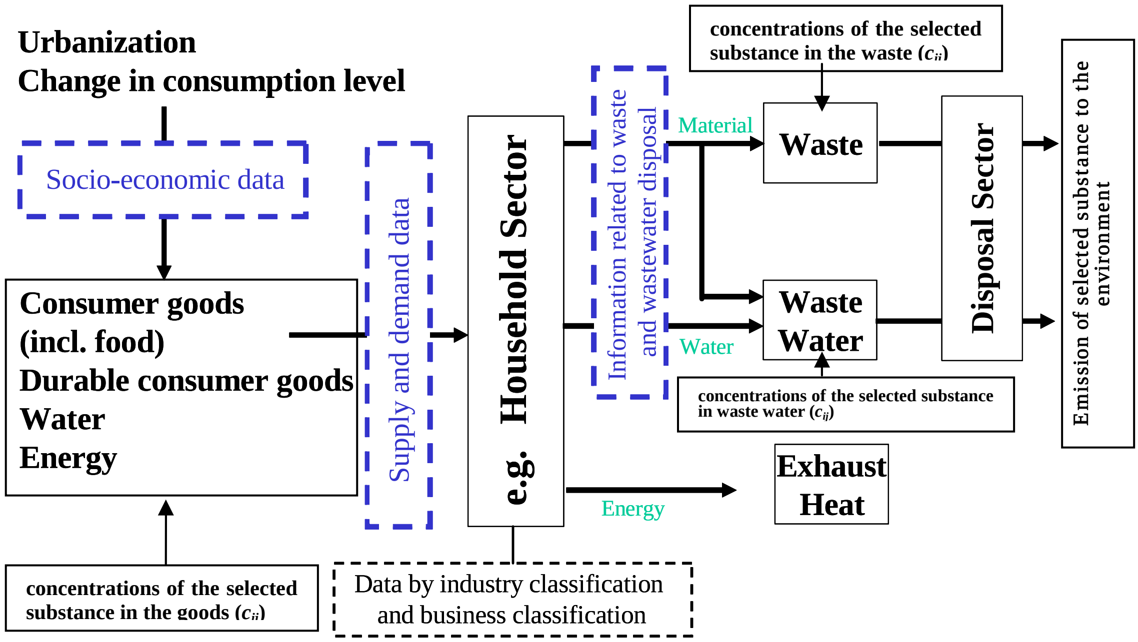

Fig. 1 Material and Substance Balance of each sectors

2.3 Study concerns

The most common sources of human-induced groundwater contamination can be grouped into four categories: waste disposal practices; storage and handling of materials and wastes; agricultural activities; and saline water intrusion. Because this research is aimed of analysis the groundwater contamination induced by human activities with urbanization, the analysis will concentrate on emission from waste disposal practices.

C, N, P were selected for investigation in this study because (1) these substances are included in the main emissions of human activities, (2) the consumption of goods containing these substance is greatly influenced by the urbanization level of cities, (3) the data related these substances are easy available. For the other substances which induced contaminations to groundwater such as heavy metals, whether it would be investigated in this study depends on the data availability.

3. Conclusions and discussions

The objective of this research is to analyze the influence of long-term life style changes to the material and substance balance in household, industry, and business sections from a long-term perspective. Therefore the main points of the research are as followings:

- Six Asia mega-cities were chosen for case study;
- Dynamic MFA and SFA will be used for the analysis of C, N, P;
- The research concerns on the changes in the past 50 years.

At present, the research is at the beginning period, with the data collection and formation of analysis model based on former research and available data. The possible difficulty for the research is mainly lie in data, for the collection of data in the past 50 years from developing countries, such as Bangkok, Manila, it would be very difficult. At the same time, the discrepancy of data from 6 cities makes it difficult for comparing and analyzing.

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The historical analysis for long term development of sewerage and water supply system infrastructure in developing country

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Abstract

It is possible to analyze the variation of environmental improvements about its water resource (surface water and ground water) in one urbanized city, if we know the history of sewage development. Moreover, the history of sewage development is one of the most important data for the circumstance of groundwater contamination in subsurface. In this study, technology and institutional assessment for the long-term development (50-100 years) of sewerage system and water supply system infrastructures in the urbanized city will be conducted. The target cities are Tokyo, Seoul, Bangkok and Taipei.

1. Introduction

For achievement of sustainable development in human society, there is a need for solutions for environmental problem. Urbanization is mainly ascribed to population growth, its concentration and spatial expansion with many related factors such as economic activities, social services, infrastructure, transportation, governance, etc. Many environmental problems in urban areas happen simultaneously with the stages in development.

Environmental problems of subsurface in urban area have to be paid much more attention. However, in the past, there were not enough studies about the environmental issues in of subsurface in urban area. Especially, groundwater plays an important role in urban area, thus, in this study focused on the ground water from a viewpoint of sewerage development in urban area. It is possible to analyze the variation of environmental improvements about its water resource (surface water and ground water) in one urbanized city, if we know the history of sewage development. Moreover, the history of sewage development is one of the most important data for the circumstance of groundwater contamination in subsurface.

2. Method

In this study, technology and institutional assessment for the long-term development (50-100 years) of sewerage system and water supply system infrastructures in the urbanized city will be conducted. The target cities are Tokyo, Seoul, Bangkok and Taipei.

Generally, "percent of sewered population" is used as an index of sewage development in urban area. However it is very difficult to check the precise population of the city in developing country. So, it is better to propose the new index of "percentage of sewered area" in this study. This index of "percentage of sewered area" is the percentage of sewerage construction as urbanized area of a city. The reason of this new index is needed is that it is quite difficult to comprehend the exact population of each big city in developing country.

In case of water supply system, the same new index "percentage of water supplied area" will be used.

3. Evaluation

There are many types of wastewater treatment system in each country as shown in **Figure 1** and **Figure 2**.

Figure 1 Sewerage system (Separate system) (Ohuchi, H., 1987)

It is need to investigate what types of wastewater treatment system (sewerage system: combined system and separate system, small wastewater treatment system: oxidation ditch activated sludge, oxidation ponds and lagoons, etc., individual wastewater treatment system: septic tank and “jokaso system ()” etc.) are/were existed in each country. As shown in **Figure 3**, it must be understood the deference/characteristics of each wastewater treatment system. For example[23)], most sewer systems in developed countries are combined system. During periods of high rainfall, sewer systems cannot transport the rate and volume of runoff from the urban catchment to the treatment plants and are therefore designed to discharge excess storm flows via overflows (Combined sewer overflow: CSO) to natural watercourses. Pollutants within these

Figure 2 Septic tank (Individual system) (Ohuhi, H., 1987)

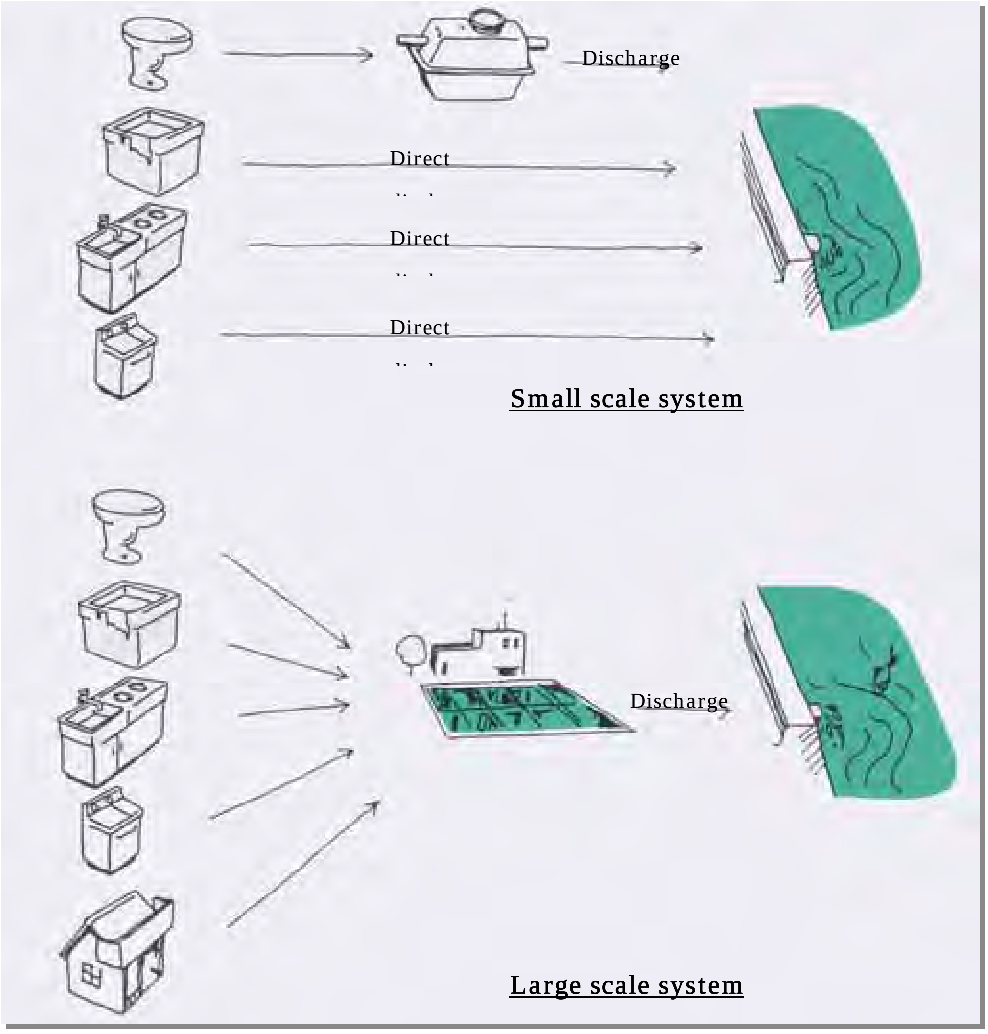

Figure 3 Comparison the deference of these two systems (Ohuchi, H., 1987)

discharges can have a significant environmental impact on the receiving waters. High suspended solids concentrations have been commonly observed in these overflows during the initial periodof storms and have been termed "first foul flushes". Furthermore, as shown in **Figure 3**, in case of small scale system (individual system), only black water (night soil) is treated before discharging to natural watercourses, i.e., another wastewater (gray water; wastewater from bath, kitchen and laundry) is discharged to natural watercourses directly. These pollutants within the discharges can have a considerable environmental impact on the receiving waters.

It is also needed to investigate the historical and political circumstance about the wastewater treatment system.

4. Future work

It is necessary to get the data of each city (Tokyo, Seoul, Bangkok and Taipei) and analyze the data by the method shown above.

Present condition is as below.

(1) It is possible to get the data of Tokyo and Seoul.

(2) Now, it has been to research about the data of Bangkok and Taipei.

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Using the DPSIR Framework for Multi-dimensional Issues
- Literature review for the application to urban subsurface environments -

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Abstract

The present study reviewed the literature and investigated the possibility of extended use of the DPSIR (*driving forces, pressure, state, impact, and responses*) framework for urban environmental issues with a focus on multi-dimensional issues including subsurface environments. A descriptive meta-analysis of 17 studies was conducted by four criteria: formulation of DPSIR, level or scale of the issue (global, national, city), cause-effect complexity of the issue (single-/multi-/super-dimensional), and indicators used in DPSIR, and the following were found. First, the semi R-oriented DPSIR which regards D, P, S, and I in a causal chain and *responses* as affecting only *driving forces* and *pressure* is the most popular formation in multi-dimensional issues. Second, indicators related to urbanization appear mostly in d*riving forces* in all issues and several in state in super-dimensional issues. Third, DPSIRs of single-/multi-/super-dimensional issues can be described as gearwheels as a multi-dimensional issue is geared by environmental changes in a single-dimensional issue and its consequences give effects on the transformation in a super-dimensional issue. Based on these findings of the inherent cause-effect relations of urbanization and environmental changes and between environmental issues, the present study proposed the comprehensive DPSIR framework. This is to be further developed and applied in empirical analysis in Asian and European cities.

1. Introduction --- Urbanization, environmental changes, and DPSIR

The world is drastically urbanizing during the last few decades (Table 1, UN-HABITAT 2002). Urbanization has inherent cause-effect relations with various issues such as infrastructure and welfare services. When urban sustainability being discussed, environmental changes are those of the most important issues (Alberti 1996, White 1994). Difficulties always arise, however, in analyzing the mechanism since it is so complex. Due to the aspect of interdependency, one cannot disregard other environmental issues even when a single issue is in question. A comprehensive framework is needed.

Table 1: Trend of urbanization and environmental changes

	Urbanization	Urban population share	Environmental problems	Underlying issues
Europe and North America	Long history since Industrial Revolution in the 16th century	70-77% in 2000. 4% increase during 2000-2015 (Europe)	CO_2 emissions from fossil fuel use	Consumption
Asia and Africa	Drastic population growth since 1980s	37% and 38% in 2000. 69% and 44% increase during 2000-2015	Fuel-burning, industrial pollution (SOx), vehicles (NO_2 and PM), CO_2	Immature infrastructure and health care, industrialization

Source: UN-HABITAT (2002), White (1994)

The DPSIR framework, further developed from OECD's DSR (OECD 1993), basically reflects a systems analysis view of the relations between environmental systems and human systems. A strong emphasis is placed on interdependent relations of the five elements of *driving forces (D), pressures (P), state (S), impact (I), and responses (R)* (Figure 1, EEA 1999). For its simplicity and flexibility, the approach has been widely used for almost any kind of issues and areas.

The present study investigated the possibility of extended use of DPSIR for urban environmental issues with a special focus on multi-dimensional issues including subsurface environments. The research questions were (1) Can DSPIR explain the cause-effect relations of urbanization and environmental changes? and (2) How can environmental issues be linked in the framework?

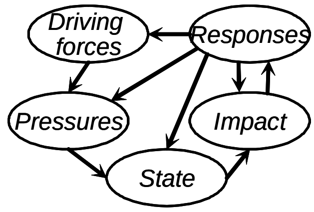

Figure 1: The DPSIR framework by EEA (1999)

2. Analysis approach and criteria

A descriptive meta-analysis of the literature was conducted. The following analysis criteria were carefully selected.

DPSIR:	Formation of DPSIR
LEVEL:	Global/regional/national/city
DIMENSION:	Single/multi/super (environmental issue)
INDICATOR:	Indicators used in the DPSIR elements

To compare the DPSIR formation and indicator use, environmental issues were classified by three groups (Table 2). This is important especially for multi-dimensional issues to be effectively compared and linked with other issues. The classification places subsurface environments in multi-dimensional issues together with climate change and groundwater management, etc..

Table 2: Environmental issues by dimension

Single-dimension	Relatively simple cause-effect relations (air and water pollution, etc.)
Multi-dimension	Comprise several issues and both be affected by and give impacts on other environmental issues (climate change, groundwater, subsurface environments, ecosystems, etc.)
Super-dimension	Integrate all issues to one overall goal (sustainable development)

3. Analysis and discussion

Out of 17 reviewed studies, 13 studies use DPSIR and the rest use DSR. Although they basically follow EEA's idea (Figure 1), more studies employ semi R-oriented DPSIR which regards *responses* as affecting only *driving forces* and *pressure*. This trend is typical in the studies on multi-dimensional issues (Luiten 1999; Cave et al. 2003; Danielopol et al. 2003; Mysiak et al. 2005) and has no clear difference between the levels of global, national, or city.

Most indicators related to urbanization (underlined in Table 3) are, not surprisingly, listed in *D (driving forces)* except for super-dimensional issues which include many of them in *S (state)*. This may be due to its extremely broad concept and cause-effect relations with other individual issues. Urbanization can mainly affect *driving forces* of environmental changes, and these changes in the environment and consequently in human systems can have effects on urban conditions, which appear again as *driving forces*.

The arrangement of indicators among the DPSIR elements is different across the dimensions to some extent. The *state (S)* of a single-dimensional issue (squared in Table 3) is found in *driving forces (D)* and *pressure (P)* in multi-dimensional issues. On the other hand, as one can say for the case of climate change, a multi-dimensional issue's *state (S)* (dot-squared) appears in *impact (I)* in a single-dimensional issue (Yoon and Lee 2003) and also in *driving forces (D)* in another multi-dimensional issue (Danielopol et al. 2003). A super-dimensional issue comprises *state* of both single- and multi- dimensional issues in *driving forces* and *state* itself.

From the above findings, the cause-effect relations of urbanization and environmental changes and between environmental issues at the different dimensions can be described as shown in Figure 2. Urbanization has substantial effects on all dimensions and can be also affected by the environmental conditions. In this comprehensive framework, the DPSIRs as a linkage between the dimensions can be well compared to *gearwheels*, i.e., a multi-dimensional issue is geared by environmental changes at the first wheel (single-dimension) and its consequences give effects on the transformation in the bigger wheel of overall sustainability (super-dimension).

Table 3: DPSIR indicators in selected studies

	Single-dimensional	Multi-dimensional		Super-dimensional
Study	Yoon & Lee (2003)	Chen et al. (2005)	Danielopol et al. (2003)	UNCSD (2001)
Issue	Air pollution and climate change	River basin land use management	Groundwater ecosystems	Sustainable development
Level	City	City	National/Global	National/Global
Area	South Korea	Taoyuan, Taiwan	-	-
DPSIR	Interdependent DPSIR	Interdependent DSR	Semi R-oriented DPSIR	DSR
D	Population	Population		Population
			Urban activities	Economy & investment
	Transport		Infrastructure	
	Land use (building)	Land use		
				Energy consumption
		Water pollution	Water extraction	Water availability
			Waste	Waste
			Climate changes	Climate change
		Air pollution		
			Mining	
			Agriculture	Agriculture
			Tourism	
				Natural disasters
				Education & literacy
P	Emissions	-	Water & soil pollution	-
			Groundwater withdrawal	
			Water DS balance	
	Energy consumption			
S	Pollution concentration	Q&Q of air & water	Q&Q of groundwater	Air & water quality
			Local biodiversity loss	Ecosystem
	Land use change			Land use change
				Poverty & gender
				Health
				Housing & security
				Urban population
				Energy & material use
				Transportation
				Information
				Trade & finance
I	Climate change	-	Global biodiversity loss	-
			Vegetation changes	
			Reduction of global GW	
R	Reforestation	Pollution control	Regulation	Institutional framework
			Protection zones	Ecosystem protection
			Technological & mng. improvement	Improvement in science & technology
			Education	Health care

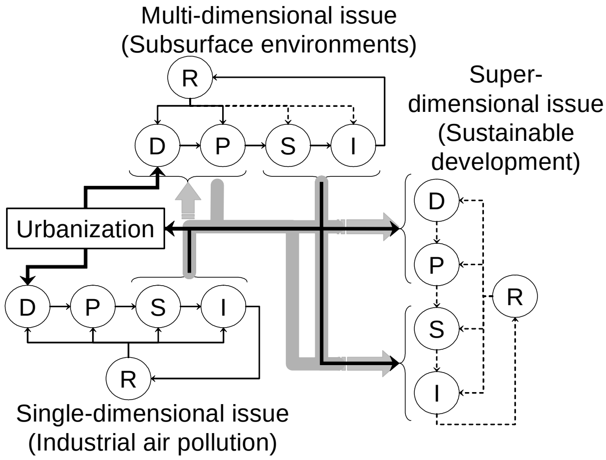

Figure 2: The comprehensive DPSIR framework

4. Conclusions

The present study analyzed the literature on DPSIR and derived the important implications for the inherent cause-effect relations of urbanization and environmental changes and between environmental issues. In analyzing socio-economic factors of multi-dimensional issues such as subsurface environments, it is crucial to develop an effective linkage between the relations. The comprehensive DPSIR framework proposed in the present study can be a useful tool for this purpose. After thorough indicator selection, an empirical analysis with this new framework is to be carried out (Japan, China, Korea, and Europe).

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Analysis of groundwater quality trend for 20 years in Bangkok, Thailand

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Abstract

A report presents some chemical analyses of the groundwater in monitoring well network of the MGL Project in Bangkok and adjacent provinces in Thailand during 1978-1998. No significant long-term change was observed, however the increases in some ion were found during 1989-1992, then recovered to the previous level. The higher concentration of each ion was observed in the area from northwest to southeast. The higher concentration in the shallower aquifer may be recharged to the deeper aquifer in future. Higher Na and Cl concentrations were also found near the coastal area, indicating the effects of sea water intrusion.

1. Introduction

A report was published in 1999, presents chemical analyses (pH, electric conductivity and concentration of Ca, Mg, Na, K, Fe, Mn, Cl, SO_4, CO_3, HCO_3 and F and TDS) of the groundwater in monitoring well network of the MGL (Mitigation of Groundwater Crisis and Land Subsidence in Bangkok) Project in Thailand for 20 years (1978-1998). However long-term (for 20 years) change and spatial variation of the some chemical analyses had not been evaluated.

In this study, to clarify the long-term change and spatial variation of some dissolved ion in groundwater, analyses of above-mentioned ions were conducted.

2. Location

The study area is the southern part of the Lower Chao Phraya River Basin, bounded on the south by the Gulf of Thailand. This area comprises six administrative provinces of Bangkok in Thailand; Metropolis, Nonthaburi, Samut Prakan, Pathum Thani, some part of Samut Sakhon and Nakhon Pathom (Fig. 1). A complete groundwater monitoring station consists of three monitoring wells penetrating three different aquifers: (1) Phra Pradacng (PD: 100-meter depth zone), (2) Nakhon Luang (NL: 150-meter depth zone), and (3) Nonthaburi (NB: 200-meter depth zone). In the report, data of 275 monitoring wells (PD: 93 well, NL: 94 wells, MB: 88 wells) in 110 groundwater stations are presented during 1878-1998.

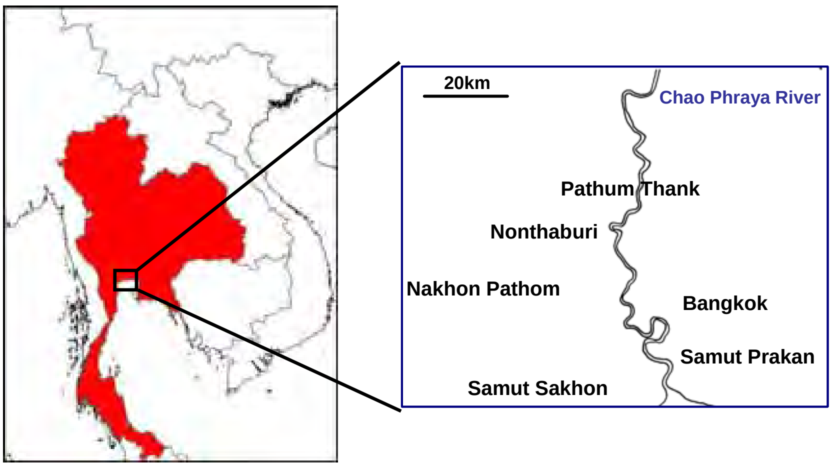

Fig.1 Location of study area

Table 1 Average of chemical analyses of groundwater from all monitoring wells in three aquifers

Aquifer	PD	NL	NB	Average
pH	7.9	8.1	8.2	8.0
E.C.	5651	6997	3826	5491
Ca (mg/l)	254	236	143	211
Mg (mg/l)	133	152	60.4	115
Na (mg/l)	605	990	439	678
K (mg/l)	13.7	14.3	9.02	12.3
Fe (mg/l)	4.89	4.68	4.07	4.55
Mn (mg/l)	0.99	0.65	8.60	3.41
Cl (mg/l)	1749	2070	1143	1654
SO_4 (mg/l)	105	223	50.9	126
CO_3 (mg/l)	6.64	59.4	15.0	27.0
HCO_3 (mg/l)	171	193	213	192
NO_3 (mg/l)	2.36	7.40	1.34	3.70
F (mg/l)	0.18	0.24	365	122
TDS	3762	4548	2533	3614

3. Results and discussion

The values in the first observation every year were extracted from the report. Averages of pH, E.C. and some ion concentrations of groundwater from all monitoring wells in three aquifers are shown in Table 1. From the results to the analysis of groundwater quality trends for 20 years, no significant long-term change was obtained for each parameter. However, in period 1989-1992, the increases in concentration of Ca, Mg, Na, Cl and SO_4 were found in some well, then the concentration recovered to the previous level.

For spatial variation, Figs. 2-6 show average of pH (Fig. 2), E.C. (Fig. 3) and concentrations of Ca ion (Fig. 4), Na ion (Fig. 5) and Cl ion (Fig. 6) at each aquifer. In order to analyze the spatial variation of the groundwater quality, average of pH, E.C. and other ion concentrations at each aquifer (PD, NL and NB) during 1978-1998 were analyzed. From the results, the distribution of pH (Fig. 2) was difference from that of ion concentration (Figs. 3-6). Groundwater with pH 7.0-7.9 is distributed along a river, on the other hand, groundwater with the value pH > 8.0 located in the far from the river, and groundwater with pH > 9.0 exists in the eastern area. The area with pH = 7.0-7.9 in deeper aquifer was smaller than that in shallower aquifer, whereas the area showed pH > 8.0 was larger in deeper aquifer. On the other hand, ion concentrations show significant differences from each ion (Table 1). For Fig. 4, these show typical spatial variations of other ion concentrations. Higher concentration of groundwater showed approximately 1000ppm. The area with lower concentration (<1000ppm) in deeper aquifer was larger than in shallower aquifer. The higher concentration of each ion was observed in the area from northwest to southeast. The area with higher concentration in deeper aquifer was smaller than that in shallower aquifer. The higher concentration in the shallower aquifer may be recharged to the deeper aquifer in future. In the case of Na (Fig. 5) and Cl (Fig. 6), higher Na and Cl concentrations were also found near the coastal area, indicating the effects of sea water intrusion.

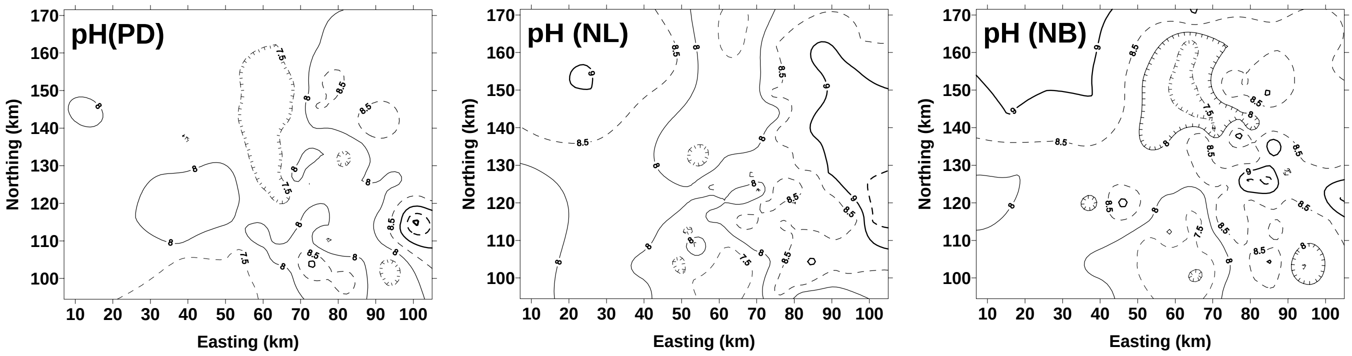

Fig. 2 Distribution of pH in different three aquifers

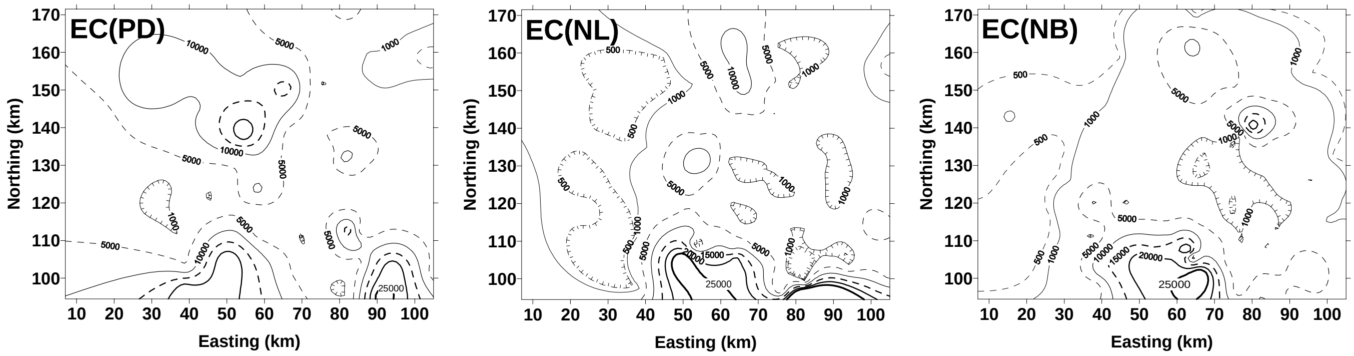

Fig. 3 Distribution of Electric conductivity in different three aquifers

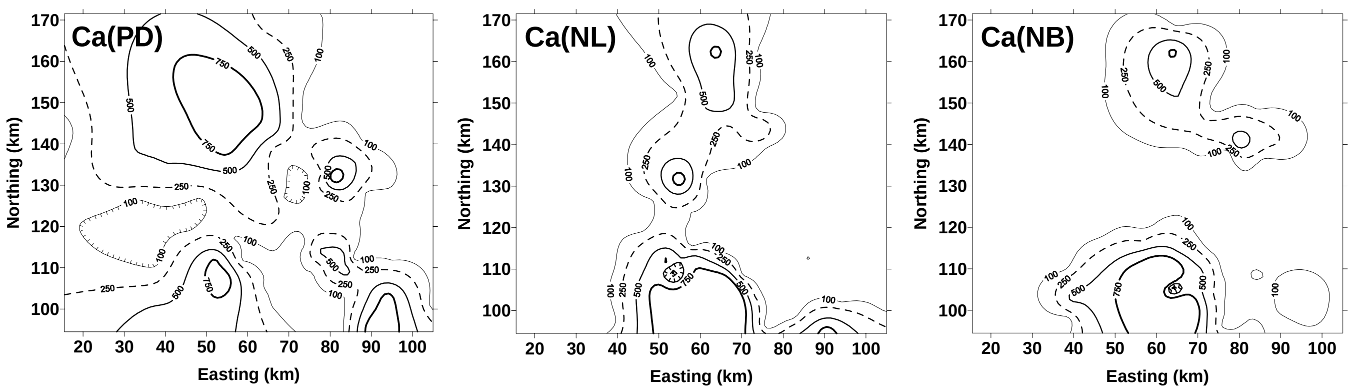

Fig. 4 Distribution of Ca ion concentration in different three aquifers

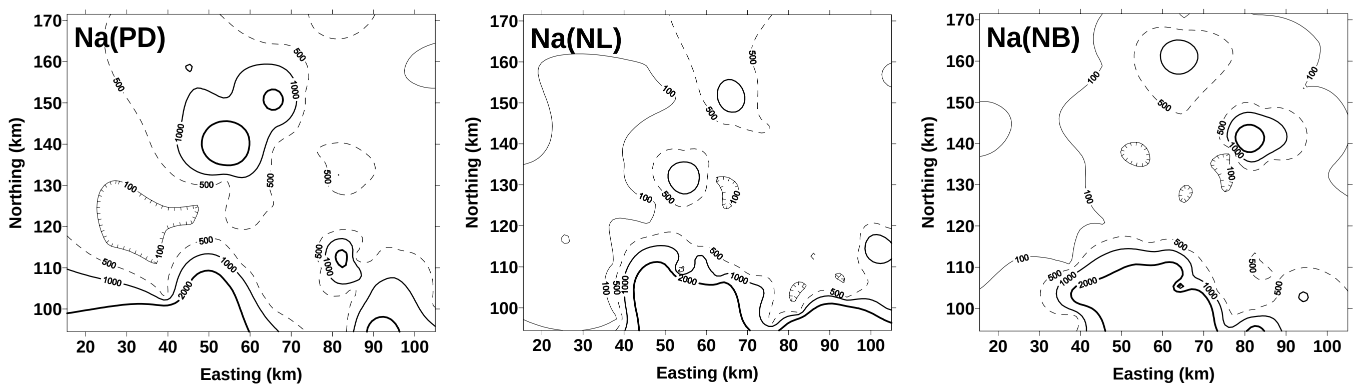

Fig. 5 Distribution of Na ion concentration in different three aquifers

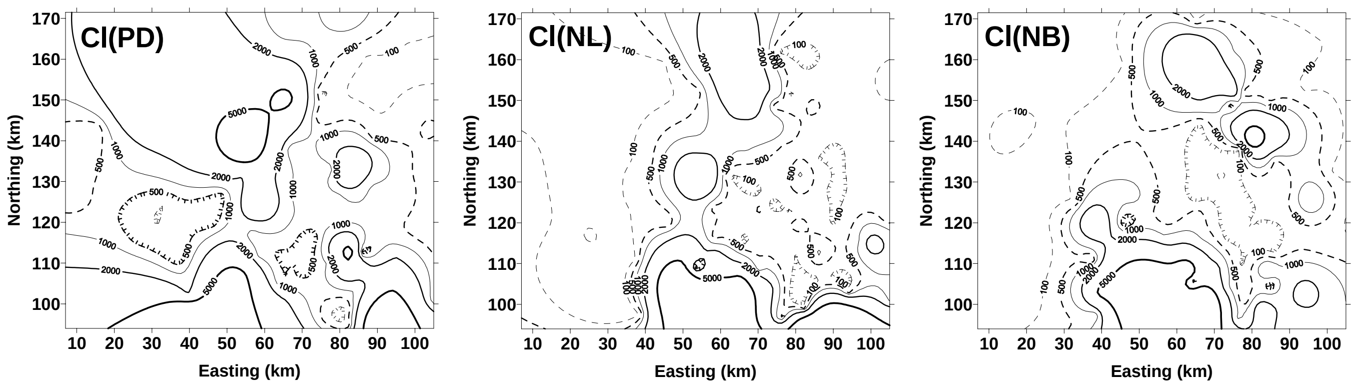

Fig. 6 Distribution of Cl ion concentration in different three aquifers

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Preliminary results on submarine groundwater discharge in South Korea, The Philippines, Thailand and Japan

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Abstract

Submarine groundwater discharge (SGD) is recently recognized as a potentially significant water and material pathway from the land to the ocean. The features of SGD, such as relationship to tidal change, are evaluated from the results on SGD in Asian cities and Japan. Moreover, dynamics of fresh / salt water interface related with tidal change are also clarified from resistivity measurement in the coastal zone. Quantitative evaluations of water and material transports in each city will be contributed to this RIHN Project.

1. Introduction

One of the subjects of RIHN Project "Human Impacts on Urban Subsurface Environments" is to evaluate water flux and transport of contaminant loads from land to ocean. Recently, submarine groundwater discharge (SGD) is recognized as a potentially significant water and material pathway from the land to the ocean (fig.1). While the amount of groundwater flow into the ocean is about six percent of the river flow on a global basis, some study estimated that the total dissolved salt contributed by SGD may be as much as 50 percent of that contributed by rivers. Therefore, evaluations of SGD are important to achieve this Project's subjects.

Fresh / salt water interface is located in the coast where terrestrial groundwater and seawater meet (fig.2). It is thought that SGD actively occur near this interface. However, research on relationship between SGD and fresh / salt water interface is very few. Fig 3 shows areas where SGD research has been done in all over the world. SGD measurements in east Asia that is research area of this Project are also very few. A lot of uncertain points exist about SGD because quantitative evaluations of SGD have not been done. This study shows preliminary results observed in some Asian cities.

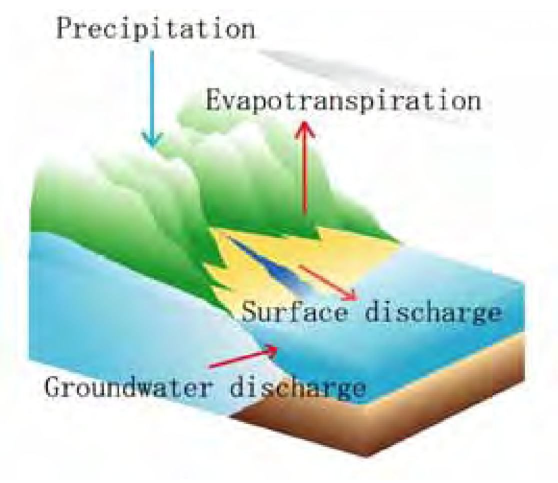


Fig.1 Water cycle

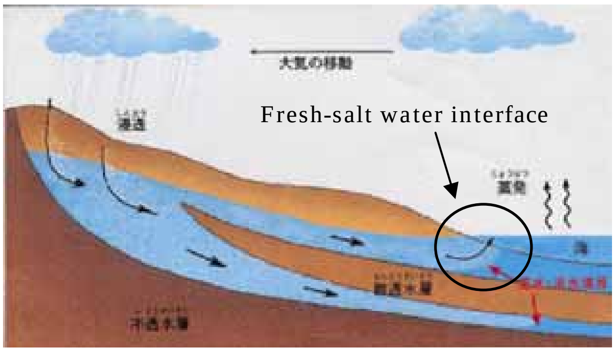


Fig.2 Fresh-salt water interface

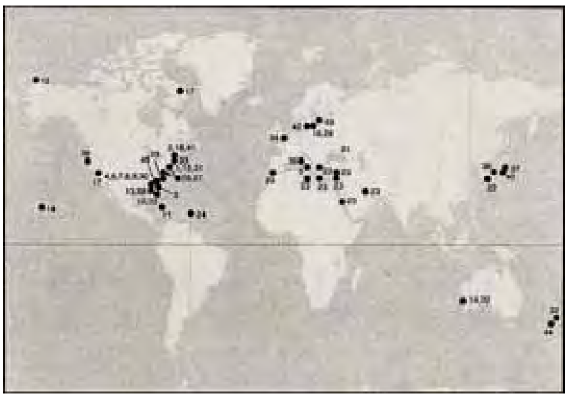


Fig.3 Location of published investigations of SGD (Taniguchi et al., 2002)

2. Study area and measuring method

Study areas are a coastal zones of (1) Chonburi, Thailand, (2) Hua Hin, Thailand, (3) Bataan Peninsula, The Philippines, (4) Inchon, South Korea, and (5) some cites in Japan. Continuous measurements of SGD rates, conductivity and temperature of SGD have been done by automated seepage meters and CT sensors in these study areas. Resistivity measurements also have been made across the coastal aquifer by resistivity cable in these study areas to evaluate fresh groundwater movement under the seabed. Figure 4 shows the setting map of measurement equipments as an example.

Fig. 4 Location of the study area in Asian cities

3. Results

An example result of SGD measurements using seepage meter is shown in. Fig 5 indicates temporal changes of SGD and tide in Hua Hin, Thailand. This figure shows SGD rates is larger during low tide and SGD rates is smaller during high tide. Relationship between tidal change and SGD is reported in other SGD studies. It is thought as this cause that difference of terrestrial groundwater level and seawater level is the largest during low tide and SGD rates are larger. Fig 6 shows variations of SGD according to distance from the land in Bataan Peninsula. SGD at 270m location from the land is the highest than other measurement locations.

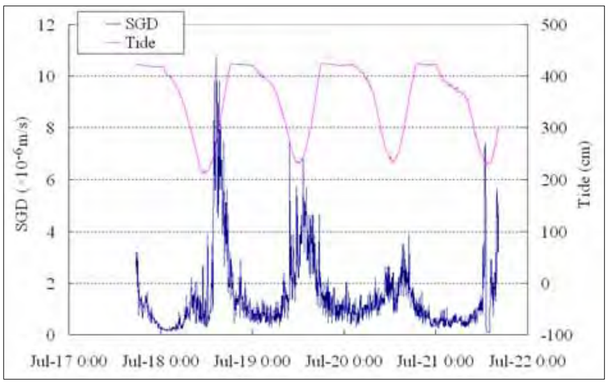


Fig.5 Relationship between SGD and tide (Chonburi)

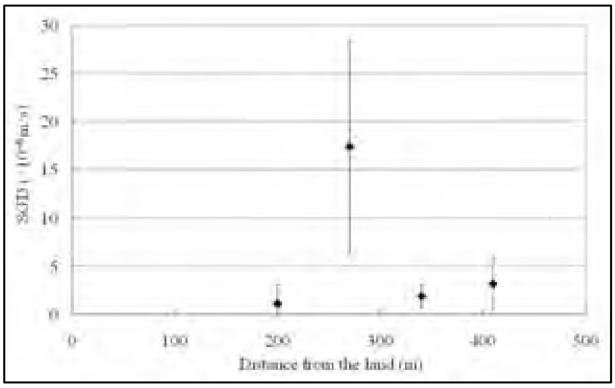
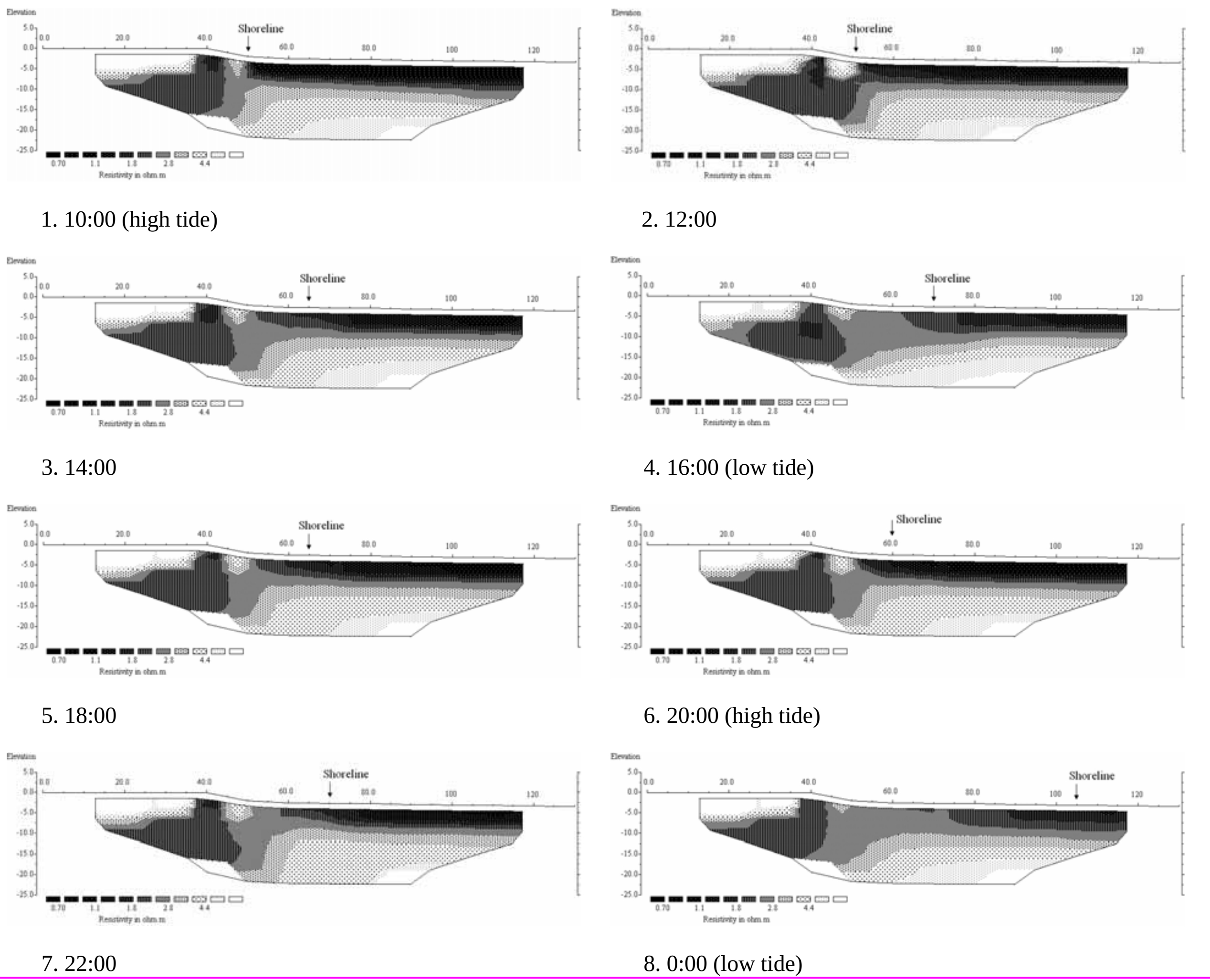


Fig.6 Spatial variation of SGD (Bataan Peninsula)

Fig 7 shows the result of resistivity measurement in Chonburi, Thailand. Resistivity measurements had been done from 10:00AM January 27 until 0:00AM January 28. Measurement location is shown in fig 4. In fig 7, the white color indicates high resistivity region and the black color indicates low resistivity region.

There is the region of low resistivity in the upper right and the region of high resistivity in the upper left and downward of cross section in fig 7. Time variations of resistivity rates indicate little change in high resistivity region. On the other hand, low resistivity region change with the change in the tide. Electric conductivity indicating the dissolved material in water, differs greatly in terrestrial groundwater and seawater. Therefore, low resistivity is the region where strongly influenced in seawater, and high resistivity is the region where strongly influenced in terrestrial groundwater, because resistivity rates and electric conductivity have the relation of the reciprocal. Time variations of resistivity rates show the change in the interaction of terrestrial groundwater and seawater due to tidal change.



1. 10:00 (high tide)
2. 12:00
3. 14:00
4. 16:00 (low tide)
5. 18:00
6. 20:00 (high tide)
7. 22:00
8. 0:00 (low tide)

fig.7 The result of resistivity measurements in Chonburi, Thailand.

4. Future works

Quantitative evaluations of SGD in each city such as fig 8 and fig 9 are expected as this study results. As the research plan in the future, (1) intensive field research, (2) scale-up to the basin scale, and (3) quantitative evaluations of water and material transports to the ocean from the land in each city will be made (fig.10). In addition to these, estimations of proportion of SGD in water cycle and material budget in the basin are also expected.

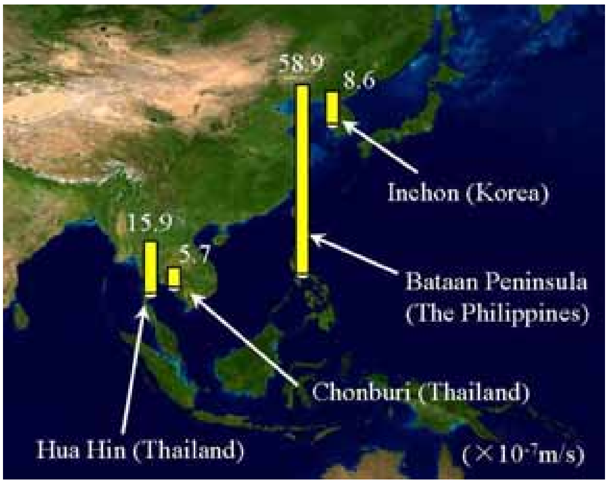


fig.8 Quantitative evaluations of SGD in each Asian city

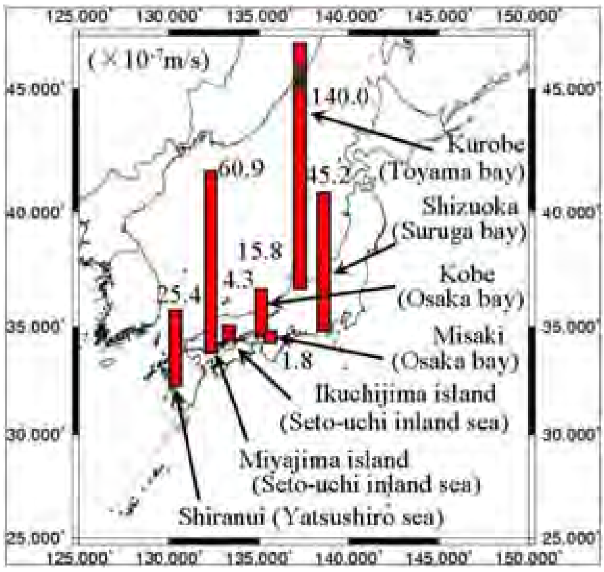


fig.9 Quantitative evaluations of SGD in cities in Japan

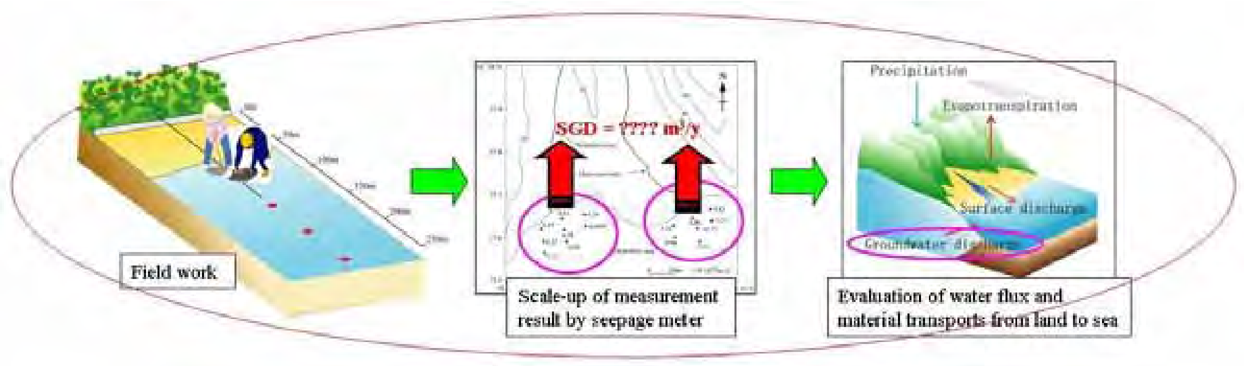


fig.10 the research plan in the future

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Heavy Metals in Tree Rings: Reviews and Results in Chugoku District, Japan.

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Abstract

Tree rings can be used as the sensitive biomonitors to record local and global environmental changes, especially for the heavy metal pollution of air and soil, and the effects of acidification of rain on forest soil. Many studies have presented good correlations between radial distributions of heavy metals in tree ring and temporal records of pollution. On the other hand, some reports pointed out the necessity of careful discussion for the relation between the radial distribution of elements and historical change of environments. In this presentation we will review the chronological distributions of heavy metals in tree rings. Results of heavy metal concentrations and lead stable isotope ratios of the Japanese red pine collected in Chugoku District, Japan are also presented.

1. Review: Chronological distribution of heavy metals accumulated in tree rings

The method of analyzing for radial distribution of heavy metals in tree ring is based on the assumption that element concentrations in the tree represent element availability in the environment in which the tree was grown, although the radial distributions of the elements are also affected by the wood structure, chemical nature of each elements, uptake pathway, uptake mechanism and the species of the tree. Many studies have presented good correlations between radial distributions of heavy metals in tree ring and temporal records of pollution. Suzuki [1] analyzed ring width and concentration of Cd, Zn and Pb in tree ring of Japanese cedar (*Cryptomeria japonica*) collected in Annaka, Gunma, Japan. The sampling area was beside a zinc refinery and was contaminated by Cd, Zn and Pb. The Cd concentrations in the tree ring were increased since 1950 and reached the highest in 1954-1958. Growth rates were also decreased in this period. He reported that the Cd and growth rate profiles of tree ring collected in contaminated area corresponded to the activity of the zinc refinery. Base and McLaughlin [2] determined the Zn, Al, Fe and Mo of short-leaf pine (*Pinus echinata*) in Tennessee, US. Their results showed suppressed growth and increased iron content between 1963-1912, a period of smelting activity and large SO_2 releases. Meisch *et al.* [3]analyzed 14 metals in annual rings of 140-160-years-old beeches (*Fagus sylvatica*) collected in Germany. They divided 14 elements in to three groups: 1) no chronological change (Na, K, Cu, Cr, Co, Ni, Pb and Cd), 2) recent decrease (Ca, Mg, Mn and Zn) and 3) resent increase (Fe and Al).They discussed chronological variation of these elements in connection with the industrial history of that area and indicated that the chronological change for Ca was associated with dust emission from the smelting. Tommasini *et al.* [4]determined lead isotope ratios of tree ring *(Celtis Australis*) and urban aerosols collected in Firenze, Italy. In their results, lead isotope ratios in tree rings from 1950 to 1995 were correlated with the temporal evolution of lead isotopes measured in air particles, suggesting that lead isotope composition of tree rings can be used successfully as a proxy of the atmospheric isotope composition. Bondietti *et al.* [5] investigated the anomalies in the radial concentration trends of Ca^{2+} and Mg^{2+} and other divalent cations in the stemwood of red spruce (*Picea rubens* Sarg.) collected in New England, Tennessee and North Carolina. They reported that the radial concentration trends of divalent cation may be interpreted as a signal of regional mobilization of cations in the rooting zone and the anomalous increase was coincident both with increases in SOx and NOx deposition and with increases in radial growth increment.

On the other hand, some reports pointed out the necessity of careful discussion for the relation between the radial distribution of elements and historical change of environments. Padilla and Anderson [6] analyzed for element concentration of tree rings of a 350+ year old mammoth ponderosa pine (*Pinus ponderosa*) and evaluated versus local and global historical events. They concluded that the largest temporal difference in element concentrations in the tree rings cannot be correlated with any known local events but can be associated to global environmental changes, specifically volcanic eruptions. Nabais *et al.* [7] indicated that some trace elements showed considerable radial mobility in the stem wood of trees, and concluded that radial distribution patterns of heavy metals in tree stems have only a limited value for retrospective biomonitoring of past pollution levels. Circular investigations of tree rings showed a variation of up to 60% of the elemental concentration depending on the geographical direction following the changing properties (e.g density) of wood.[8]

Negative reports also have been published. Watmough [9] reported that stable lead isotope ratios in tree-rings were used to show that sacred fir (*Abies religeosa*) is not a useful monitor of lead deposition because lead accumulates in the heartwood. Bindler *et al.* [10] analyzed lead isotopic composition of Scots pine (*Pinus sylvestris* L.) collected in southern and northern Sweden. They indicated that tree rings always contain a mixture of pollution lead and lead from the underlying mineral soil. In their results, a significant (10-30%) contribution of Pb derived from the soil. They conclude that dendrochemistry is not a useful means of reconstructing temporal trends in Pb pollution.

2. Concentrations of Heavy Metals and Lead Isotope Ratios in Tree Rings of Japanese Red Pine (*Pinus densiflora* Sieb. et Zucc.) [11, 12]

The Japanese red pines (*Pinus densiflora* Sieb. et Zucc.) were collected in 4 sites located in Chugoku District, the western parts of the Honshu Island of Japan; (T) Takehara, (K) Kure, (F) Fukutomi, and (M) Masuda (Fig.1).

Trees for samples were cut down in 1995. Tree ring samples sub-divided were dried at 80^{o}C. The sample was digested with a super-pure nitric acid in Teflon beaker at 180^{o}C on a hotplate. Heavy metal concentrations and lead isotope ratios were determined by inductively coupled plasma mass spectrometry (ICP-MS, Perkin-Elmer ELAN-5000A). A standard solution for the lead isotope ratio was prepared from National Institute of Standards and Technology, Standard Reference Material 981 (NIST, SRM-981).

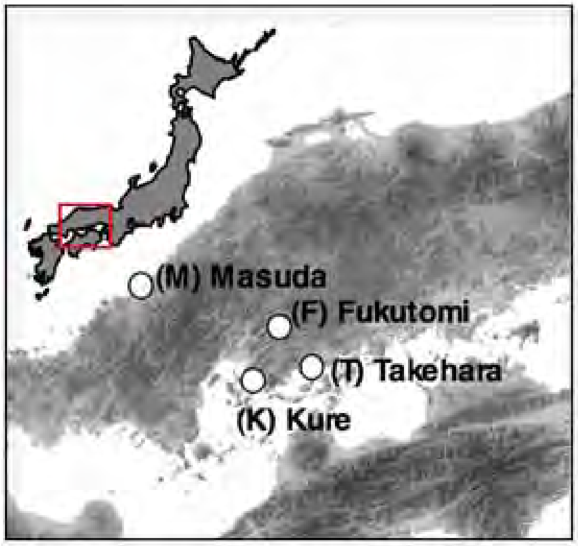

Fig. 1 Sampling sites of Japanese red pines. (T) Takehara is in industrial area with coal-burning power generator and refinery, (K) Kure is also in industrial area with iron manufacturing and ship yards, (F) Fukutomi is in mountain area without industrial plant, and (M) Masuda is in non industrial area beside the Sea of Japan.

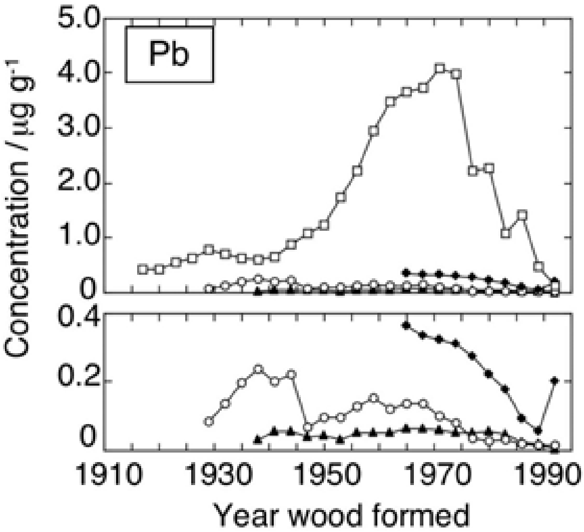

Fig. 2 Concentrations of lead in tree rings collected in T: Takehara (□), K: Kure (◆), F: Fukutomi(○), and M: Masuda (▲).

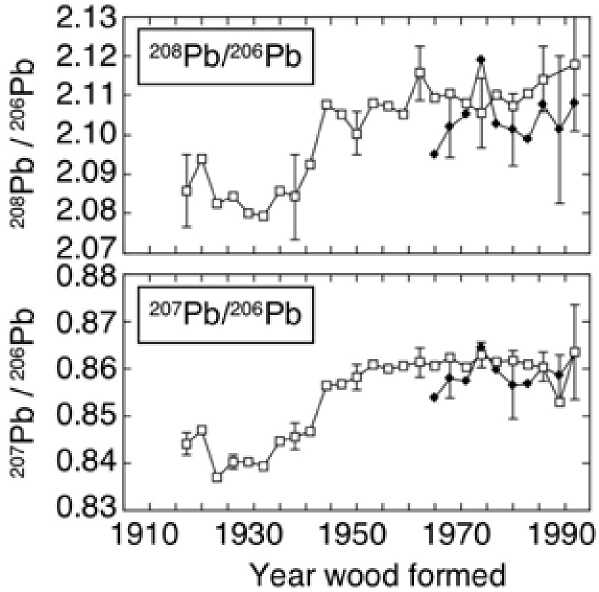

Fig. 3 Lead isotope ratios in tree rings collected in T: Takehara (□), K: Kure (◆).

Concentrations of lead and lead isotope ratios in tree rings were shown in Fig. 2 and Fig. 3, respectively. Concentrations of tree ring collected in the industrial areas (Takehara and Kure) were higher than those collected in the non-industrial areas (Fukutomi and Masuda). Concentrations of lead in tree rings increased since 1940s-1950s and lead isotope ratios also changed at the same period, suggesting that sources of lead in tree rings were changed at this period. Lead concentration reached the highest level in 1960s-1970s, and then began to decrease steeply, regardless of sampling sites. Lead isotope ratios were not affected by the decrease of lead concentration. Although the sources of anthropogenic lead were complicated, the gasoline additives and industrial air dusts would be one of the major sources for the lead pollution since 1940s-1950s. The lead isotope ratio of aerosol collected in Higashi-Hiroshima area in 1995-1997 were 0.85~0.87 for $^{207}Pb/^{206}Pb$ and 2.08~2.12 for $^{208}Pb/^{206}Pb$, suggesting that the recent lead isotope ratios in tree rings were similar to those in atmosphere.

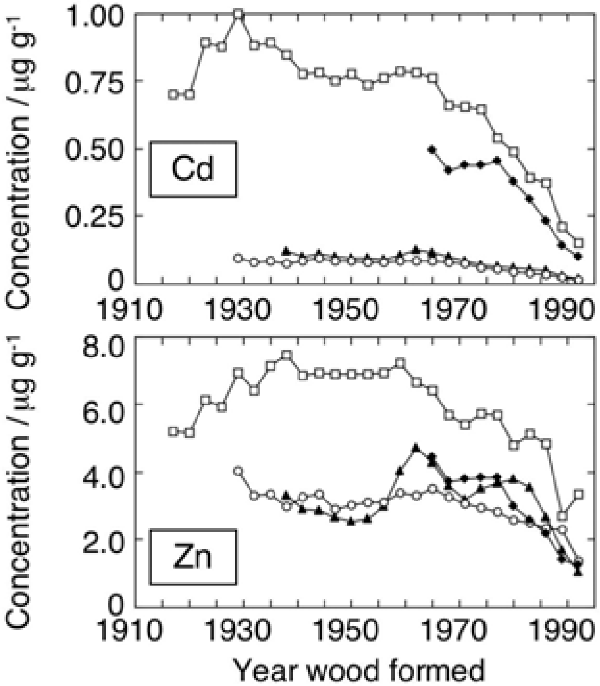

Fig. 4 Concentrations of cadmium and zinc in tree rings collected in T: Takehara (□), K: Kure (◆), F: Fukutomi(○), and M: Masuda (▲).

Concentrations of cadmium and zinc in tree rings were also higher concentration in the industrial areas and decreased since 1960s-1970s in the same manner as lead, as shown in Fig. 4. In other metals, such as manganese, calcium, aluminum and copper, characteristic changes of the chronological distribution found for cadmium and lead could not clearly seen and concentrations were independent of the sampling sites.

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Characteristics of surface and subsurface water chemistry at the river mouth area of Han-river, Seoul

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Abstract

The authors conducted the preliminary research of the RIHN (Research Institute for Humanity and Nature, Japan) project of "Human impact on urban subsurface environment" at the coastal area of South Korea in this August. Based on the results of this research, characteristics of surface and subsurface water chemistry were discussed in this paper. The results are summarized as follows: 1) the results about water chemistry showed that the ion compositions of water samples were divided into two main types, 2) some pore water samples were characterized by higher concentration of dissolved nitrogen (DN) and dissolved organic carbon (DOC) than that in local groundwater and river water. This result implies some kind of biological production of DN in the pore water at the coastal tidal flat area.

Keywords; water chemistry, nitrogen, surface and subsurface water, river mouth area, Seoul

1. Introduction

Nutrient flux from land to sea has been discussed in many studies of recent years (Tappin, 2002, Stephen et al., 2003; Jickells, 2005). Submarine groundwater discharge (SGD) has been recognized as an important pathway to the ocean for several chemical constituents such as nutrients (Zektser and Loaiciga, 1993; Burnett et al., 2003). Also in Korea, nutrient load by SGD has been estimated (Kim et al., 2003; Hwang et al., 2005). However, spatial distribution of nutrient discharge by SGD is indeed poorly understood. Thus, it is important to confirm the distributions of nutrient concentration in surface and subsurface water in the coastal area.

The objective of this paper is to confirm the characteristics of surface and subsurface water chemistry of the river mouth area of Han-river, Seoul.

2. Study area

Kwang-hwa tidal flat (solid square in Fig.1b) is located on the river mouth area of Han-river, Seoul (Fig.1a). Total area of the tidal flat is 105km^2 with 7.3m tidal depths.

The authors conducted field survey at the beach area of Kanghwa Island (solid circle in Fig.1b) and the edge of Kwang-hwa tidal flat (dotted circle in Fig.1b) from August 3 to 5. The distance between these two areas is about 7~8km (Fig.1b).

3. Sampling and analysis

We collected groundwater, river water, surface water, pore water and seepage water samples at the beach area (Fig.1b). Seepage water samples were collected using seepage meter. Pore water, surface water and seawater samples were collected at the edge of tidal flat (Fig.1b). Groundwater and Han-river water samples were also collected in the Seoul city.

All water samples were analyzed for DN (Dissolved Nitrogen) and DOC (Dissolved Organic Carbon) concentrations using TOC analyzer, major cation (Na^+, K^+, Mg^{2+}, Ca^{2+}) by ICP-AES and anion (NO_3^-, Cl^-, HCO_3^-, SO_4^{2-}) by ion chromatography.

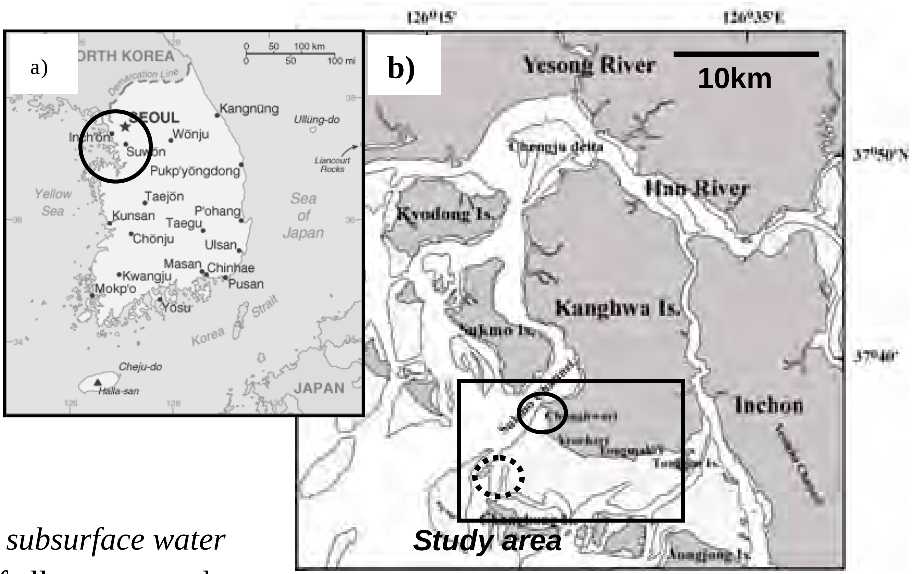

Fig.1 Location of the study site

4. Results and discussions

4-1. Chemistry of surface and subsurface water

Fig.2 is the piper diagram of all water samples.

This result indicates that the ion compositions of water samples are divided into two main types. Groundwater collected within the Seoul city (GW-Urban), River water collected at the downstream area of Han-river (Han-River) and groundwater collected near the beach area (GW-Local) are characterized by relatively low ratio of Na+K and SO_4+Cl. While, the other samples that are pore water collected at the beach area (PW-Beach) and the edge of tidal flat (PW-Tidal flat), river water collected at the beach (RW-Local), seawater collected near the tidal flat (Seawater), seepage water collected at the beach (Seepage-Beach), surface water collected at the beach (SW-Beach) and the tidal flat (SW-Tidal flat) are characterized by high ratio of Na+K and SO_4+Cl. This result suggests the large contribution of seawater to pore water, seepage water and surface water at both of the beach area and the edge of tidal flat.

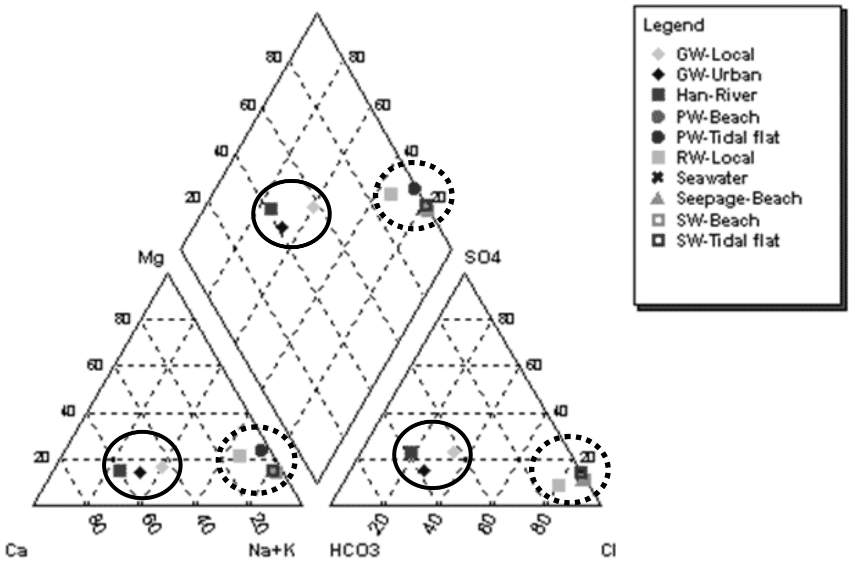

Fig.2 Piper diagram of all water samples.

4-2. Distribution of dissolved Nitrogen concentration and transport process

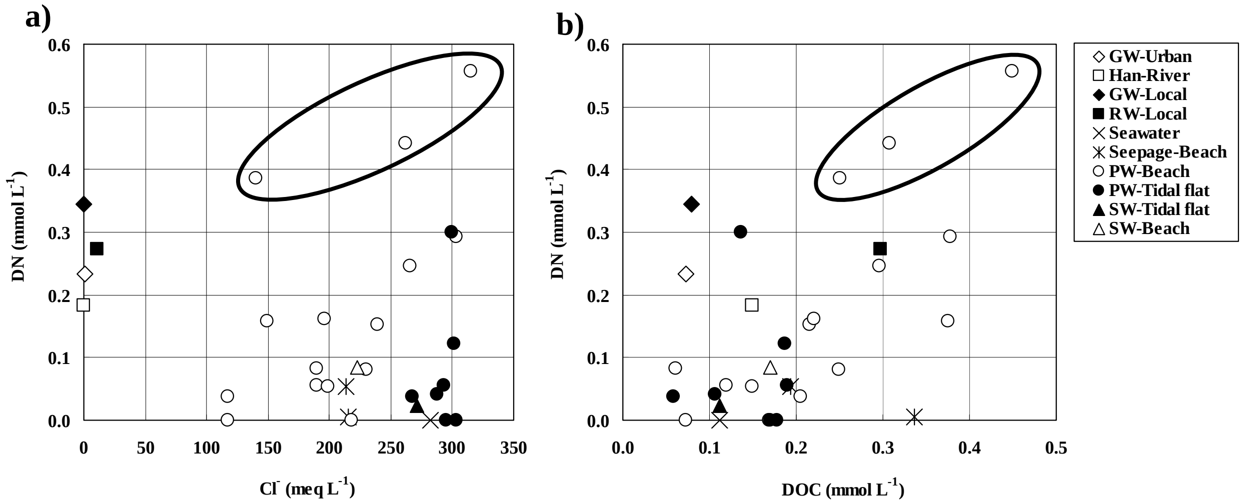

Fig.3 Relationships between a) Cl^- and DN concentrations, b) DOC and DN concentrations of all water samples.

Fig.3 shows the relationships between Cl^- and DN concentrations (Fig.3a), DOC and DN concentrations (Fig.3b) of all water samples. In spite of high contribution of seawater, most of pore water samples showed higher DN concentrations than that in seawater (Fig.3a). Furthermore, some pore water samples of the beach area showed higher DN concentration than that in local groundwater and river water. This result indicates that the DN in these pore water samples was not originated from local groundwater or river water. In addition, these samples were also characterized by relatively high concentration of DOC (Fig.3b). This result implies some effects of biological production of DN in pore water at the beach area.

Fig.4 shows the vertical profiles of DN concentration in pore water of the beach area and the edge of tidal flat. DN concentration increased from the shallower zone to the deeper zone. This result suggests that DN concentrations in deeper pore water samples are reflected on either discharge of groundwater with high concentration of DN or some type of biological production of DN.

Fig.5 shows the variations of DN and DOC concentrations in pore water at the beach area from river mouth to the sea. Pore water collected at a distance of 100m from the river mouth showed almost same concentration of DN and DOC with river water. From this result, pore water near the river mouth suggests to be influenced by infiltration of river water. While, pore water collected at a distance of 350m from the river mouth showed higher concentrations of DN and DOC than that in river water and local groundwater. This result suggests the biological production of DN in pore water at the beach area.

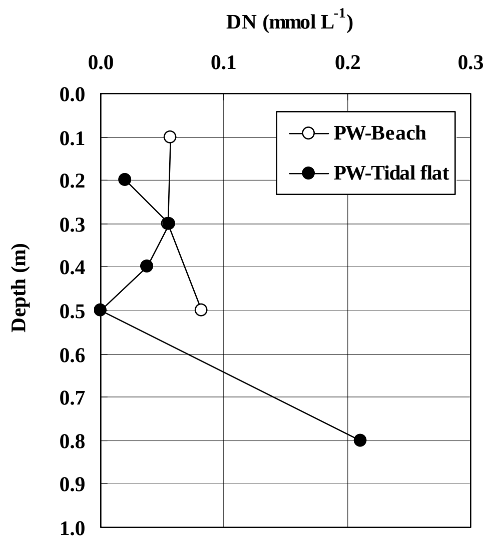

Fig.4 Vertical profiles of DN concentration in pore water of the beach area and the edge of tidal flat. (0m is ground surface)

5. Concluding remarks

To confirm the characteristics of surface and subsurface water chemistry at the coastal area of Seoul, several types of water samples were collected and analyzed for chemical component. The results showed that chemistry of surface and subsurface water samples were divided into two main types. From the distribution of DN and DOC concentrations, it is suggested that some biological production of DN occurred in the pore water at the coastal tidal flat area.

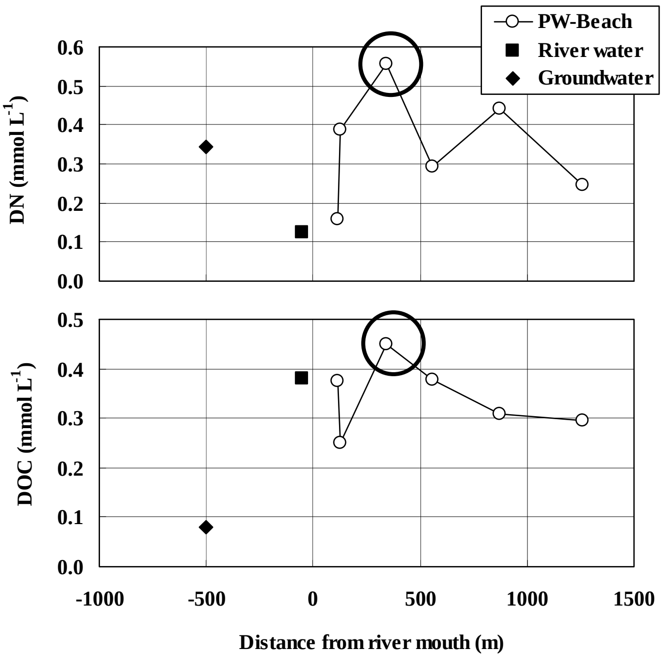

Fig.5 Variations of DN and DOC concentrations in pore water of the beach area from river mouth to the sea. (0m is river mouth)

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Research on groundwater quality in the Seoul City (*Ab initio*)

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1. Objective

The metropolitan underground pollution has become one of the apprehensive environmental problems of the world. The aim of our group (Material Environment Group, Project 2-4) is to elucidate the mechanism of such pollution in Asian area, by extracting the chemical information from the materials, such as groundwater and sediments, and to supply primary information which is directly related to the solution.

Our Group and Underground Heat Group carried out pilot study at the Seoul City, one of the research targets, for three days during 3rd to 5th, August, 2005. In this symposium, results of this research, especially focusing on general groundwater quality, are reported.

2. Outline of the Study Area

The Seoul City is located at northeast part of the South Korea (Fig. 1; left hand figure). It is about 600 km^2 in area and its total population is about 10 million. Geography of the city is characterized by typical basin structure, surrounded by mountains and hills around 500 m above sea level. The local geology is composed mainly of basement rocks, the Precambrian gneiss, and granitic rocks of Jurassic age. The climate is characterized by subarctic winter monsoon and a

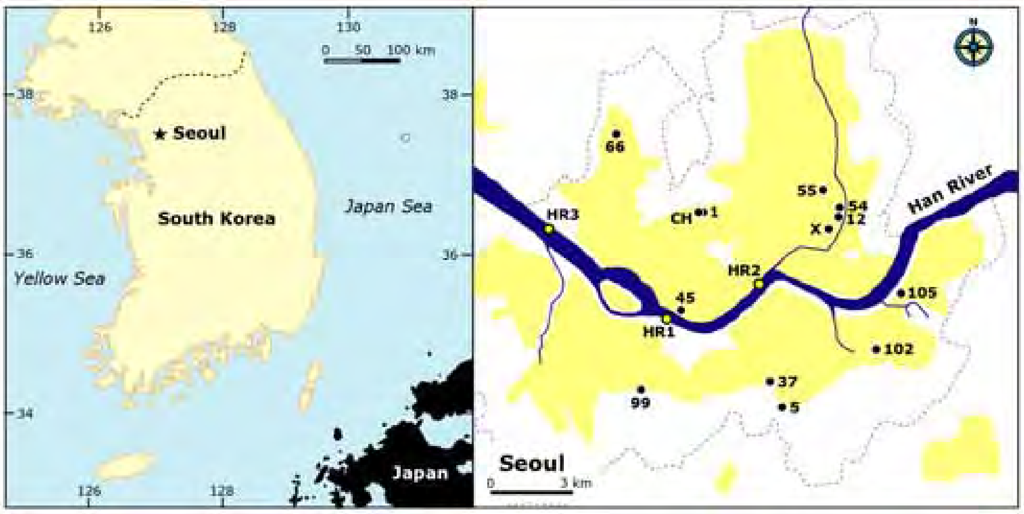

Fig. 1: Location of the Seoul City (left hand figure) and sampling sites (right hand figure). The border of Seoul City and urbanized area of the city are shown by doted line and yellow color, respectively.

small amount of precipitation. The Han River is across the central city (Fig. 1; right hand figure), dividing it into two areas, the Kangbuk, the historical and anciently developed area, and the Nambu, the modern area.

3. Samples and Methods

There are more than 200 drilling wells in the Seoul City. In this preliminary research, 13 representative well points were selected for the field measurements (electric conductivity (EC), pH, and temperature) and sampling of the groundwater (50 ml). Four river water samples and three tap water samples were also collected for comparison. Sample locality is shown in Fig. 1.

EC, pH, and temperature were measured by a HORIBA pH/COND METER D-54 in the field. For the analysis of the major dissolved ions concentrations (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}, and NO_3^{-}), Japan DIONEX Ion chromatography ICS–90, equipped at RIHN, were applied. The results of analysis are shown in Table 1.

Table 1: Major ion concentrations (meq/L) for water samples in the Seoul City, Korea

Sample No.	Point No.	Type	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3
					Groundwater					
1	5	A	1737	115	4407	642	821	5754	324	1
2	45		2107	115	3002	1736	1661	4597	590	111
3	105		1412	82	4147	2378	1014	6312	691	2
4	CH		328	191	1465	138	288	1527	306	2
5	37	B	702	93	1981	727	1459	1573	301	170
6	54		1979	58	1599	432	1306	1787	972	3
7	55		1225	222	3235	676	2107	2430	667	154
8	99		1448	142	2634	917	1892	975	727	1548
9	102		1389	40	1318	841	1607	1440	536	5
10	1	C	1415	45	1968	283	1130	2176	403	1
11	66		1130	90	2372	957	1551	2074	500	424
12	X		1442	467	2793	544	1259	2445	893	650
13	12	D	481	20	263	89	77	716	35	25
					River water					
14	CH		1623	301	2899	528	1238	3024	808	281
15	HR1		200	80	602	189	139	611	173	147
16	HR2		235	80	642	194	163	629	185	174
17	HR3		177	63	736	230	130	744	179	154
					Tap water					
18	5		250	74	661	205	337	530	181	142
19	66		231	71	668	208	314	540	180	144
20	55		229	78	817	227	375	613	205	159

4. Results and Discussion

4.1. Trilinear Diagram

In the trilinear diagram (Fig. 2), the samples of groundwater are divided into 4 types, A, B, C, and D. A type is characteristically high in proportion of Ca^{2+} and HCO_3^{-}. This type, excluding of sample-1, is also characterized by high EC values and high total ions concentrations. B type is relatively high in proportion of Na^{+} and Cl^{-}; and C type displays intermediate characteristics between A and B. On the Fig. 2, a plot of sample-13 is clearly deviated from another one, and it is defined as type D.

The samples of river water and tap water, which were collected for comparison, show different feature in terms of general water quality; tap water possess clearly higher Cl^{-} ratio than that of river water (Fig. 2), because of artificial addition of chlorine to the water. Compared to groundwater, in Fig. 2, river water samples plot on the intermediate field between A and C, whereas, tap water samples plot on the intermediate field between C and B.

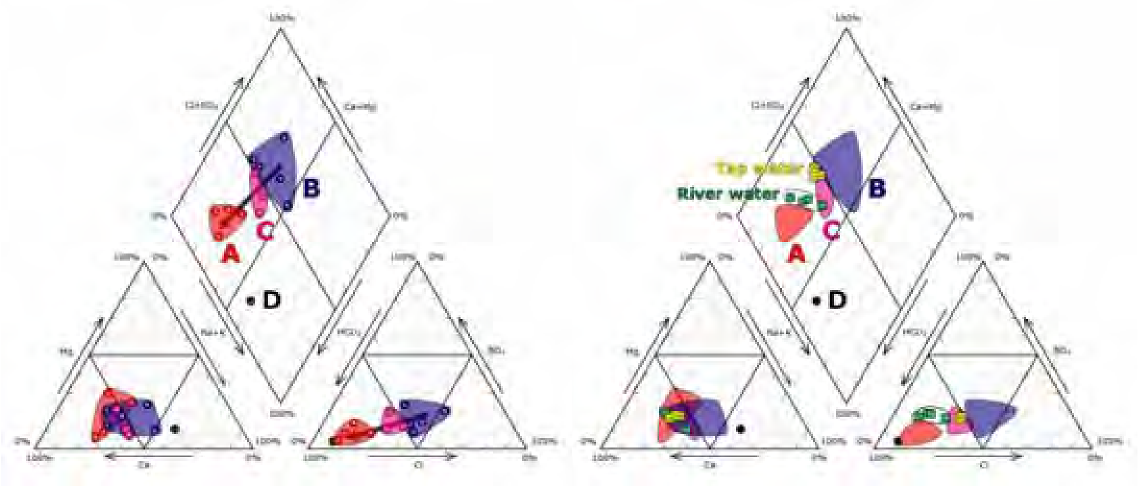

Fig. 2: The proportion of major ions concentrations for groundwater (left hand figure) and river water and tap water (right hand figure) of the Seoul City. The number in the plot is corresponding to the sample number.

4.2. Hexa Diagram Map

Above different types of water can also be characterized by Hexa diagram, which are displayed into the map of the Seoul City (Fig. 3). The first striking feature on these diagrams is that ions concentrations of groundwater are significantly higher than those of river and tap water, except of sample-14. Some groundwater samples show remarkably high NO_3^- concentrations (Fig. 3 and Table 1; up to 1548 meq/L), implying the occurrence of the groundwater pollution in local area due to the human activity.

The other important feature is that the type of groundwater tends to change from B to A, from surrounding to the central part of the city (Fig. 3). This water quality change, such as increasing of Ca^{2+} and HCO_3^-, occurred since it passes under the Seoul City.

5. Summary

In general, the groundwater of the Seoul City contains larger amounts of major ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, SO_4^{2}, and NO_3^-) than those of the water of Han River. The groundwater

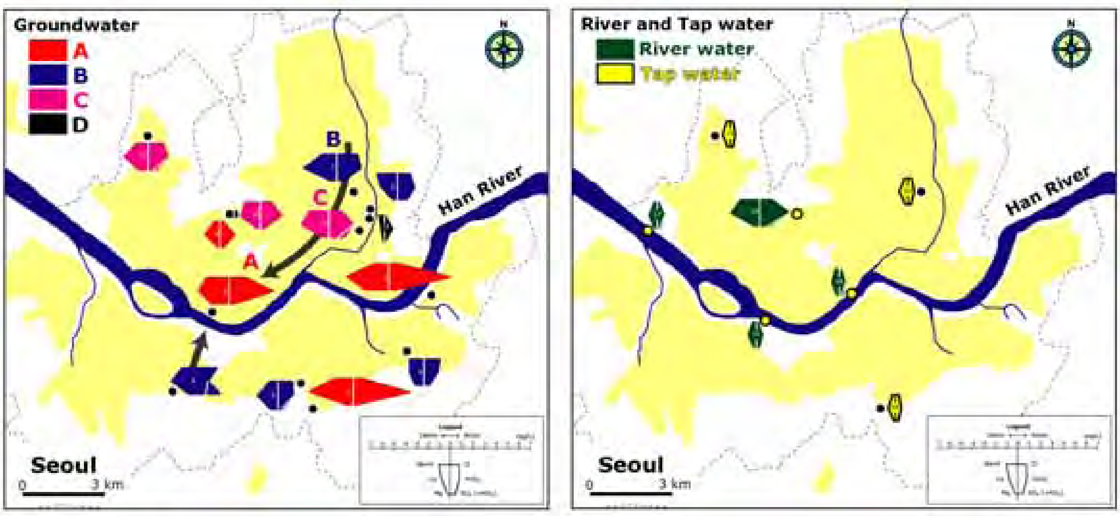

Fig. 3: The Hexa diagram map of the Seoul City for groundwater (left hand figure) and river water and tap water (right hand figure). The number in diagram is corresponding to the sample number.

assumed to have several stages depending on the degree of influence of human activity. In the preliminary research, it is indicated that detailed evolution of the groundwater would be revealed in the future full-scale sampling with analysis of groundwater flow and land use data.

6. Future Research Plan

For better understanding of the underground pollution mechanism in Asian metropolitan, it is indispensable to make an extensive research based on general water quality like shown in this preliminarily research. In addition, the data of heavy metal elements and trace elements which compose of pollutant materials and stable isotopic tracing methods (H, N, C, O, S, Sr, and Pb) will be used for analyzing the source(s) and evolution of the pollution. Attention will also be paid to the underground sediments pollutions with its relation to groundwater. These analyses methods will be applied for typical Asian metropolitan, situated at the deferent developing status, such as the Seoul, Osaka, Manila, Bangkok, and Jakarta, with an aim of solution of the underground pollution mechanism.

Gravity changes due to ground water level changes at Bangkok, Thailand -Report of preliminary survey-

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Abstract

The large amount of pumping up causes serious problems in urban area. It is necessary to assess the aquifer balance of discharge and recharge. These discharges of groundwater cause mass movement and redistributions. We can detect the effect of these mass movements using repeat gravity measurement. We started the preliminary survey at Bangkok since 2004 in order to establish the gravity station network. We will divide some areas using the pattern of the ground water level changes, and we will arrange the 5 or 6 gravity stations in each area. We established the reference station in the Thai Meteorological Department and measured the gravity using FG-5 absolute gravimeter in September 2005.

1. Introduction

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

Repeat gravity measurements have been applied at the geothermal power plant and the erupting volcano. In New Zealand, Gravity decreases of up to 1000μgal have been measured after 30 years of production from the Wairakei geothermal field (Allis and Hunt, 1986). In Japan, a strong qualitative correlation has been observed between the pressure change and gravity change at the Hatchobaru geothermal field, Oita prefecture (Tagomori et. al, 1996), but quantitative correlation are poor. The observed gravity changes depend significantly on changes in shallow groundwater level change (Ehara et. al, 1995). We estimated the background gravity change that is caused by the seasonal changes of the shallow groundwater level using statistical methods. We applied a multivariate regression model and eliminated the effect of shallow groundwater level change in order to extract the gravity change associated with the production and injection of geothermal fluid (Nishijima, 1999). These studies suggest that repeat gravity measurements are an effective method to monitor underground water flow. But there is no study for the application of the repeat gravity measurements for urban water resources problems. We are planning to make a repeat gravity and GPS survey at Bangkok and Jakarta to monitor the aquifer balance changes.

2. Gravity measurement

Fig 1 shows the area of repeat gravity and GPS survey. We will survey at about 25 points. There are two methods to measure the gravity. We will combine the Absolute gravity measurement and the relative gravity measurement. The instruments are CG-3M relative gravimeter (Scintrex Ltd.) and A-10 absolute gravimeter (Micro-g solutions, Inc.). Recently there are some satellite gravimetry missions. GRACE mission is one of them. GRACE data can evaluate the global mass movement include ground water flow. We will also use the satellite GRACE mission data to evaluate the wide area ground water flow, because the spatial resolution is not enough (about several hundred km).

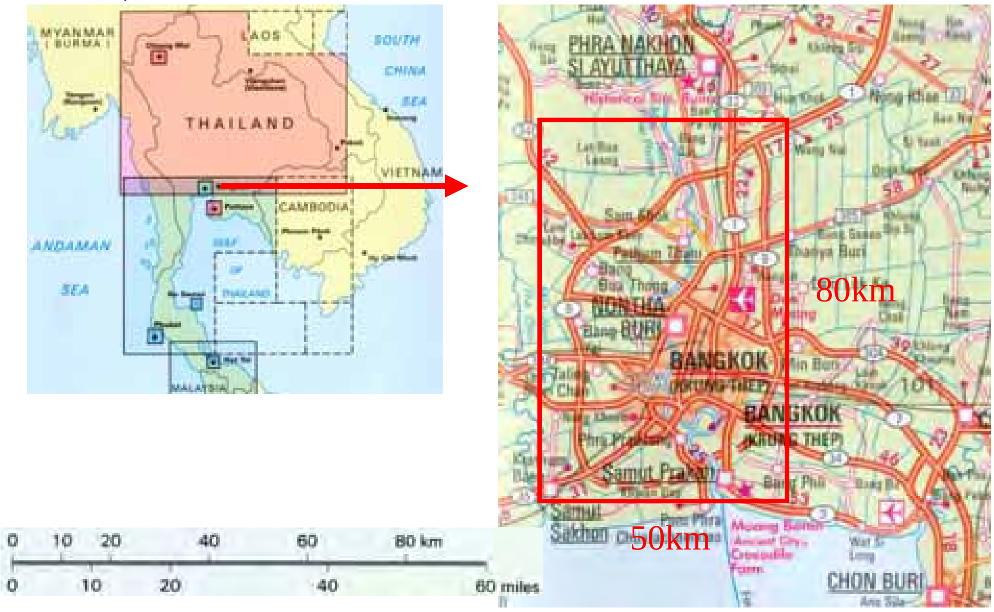

Fig.1 Survey area of Bangkok.

Figure 2 shows the concept of repeat gravity measurements. In discharge area, if the discharge is more than recharges, the ground water level will drop. And this water level changes causes the measurable gravity decrease (Red line). In recharge or injection area, the water level will be rise. And this water level changes causes the measurable gravity increase (Blue line). We can measure the sum of gravity increase and decrease (Black line). A large amount of water discharge also causes the ground subsidence. The subsidence causes the gravity increase (+308.6μgal/m). We can't neglect this effect; we will measure the station height changes using dual frequency type GPS receiver at the same time.

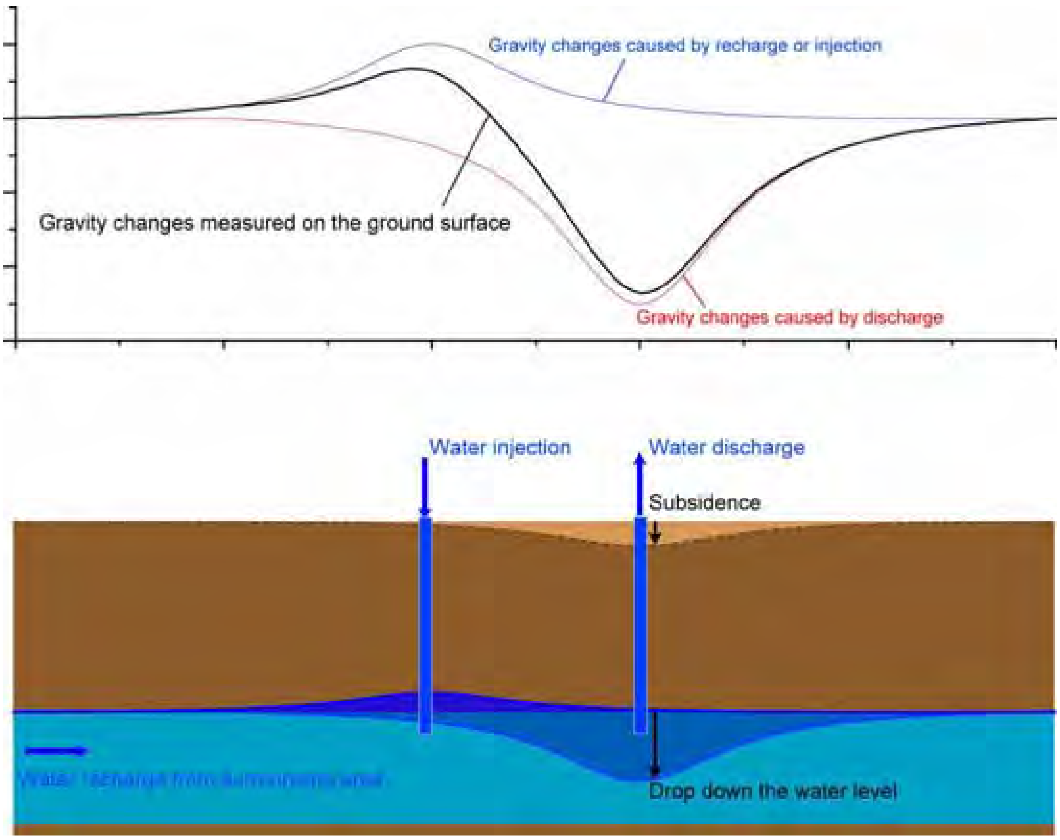

Fig.2 Concept of repeat gravity measurements.

Figure 3 shows the concept of measurement loop. The repeat gravity measurements will be conducted once a year at the same season. The two-way measurements method was taken to evaluate the instrumental drift and precision. We estimate the errors of observation as ±10 μgal. Each loop has the reference station (red cross) and we will measure using absolute gravimeter.

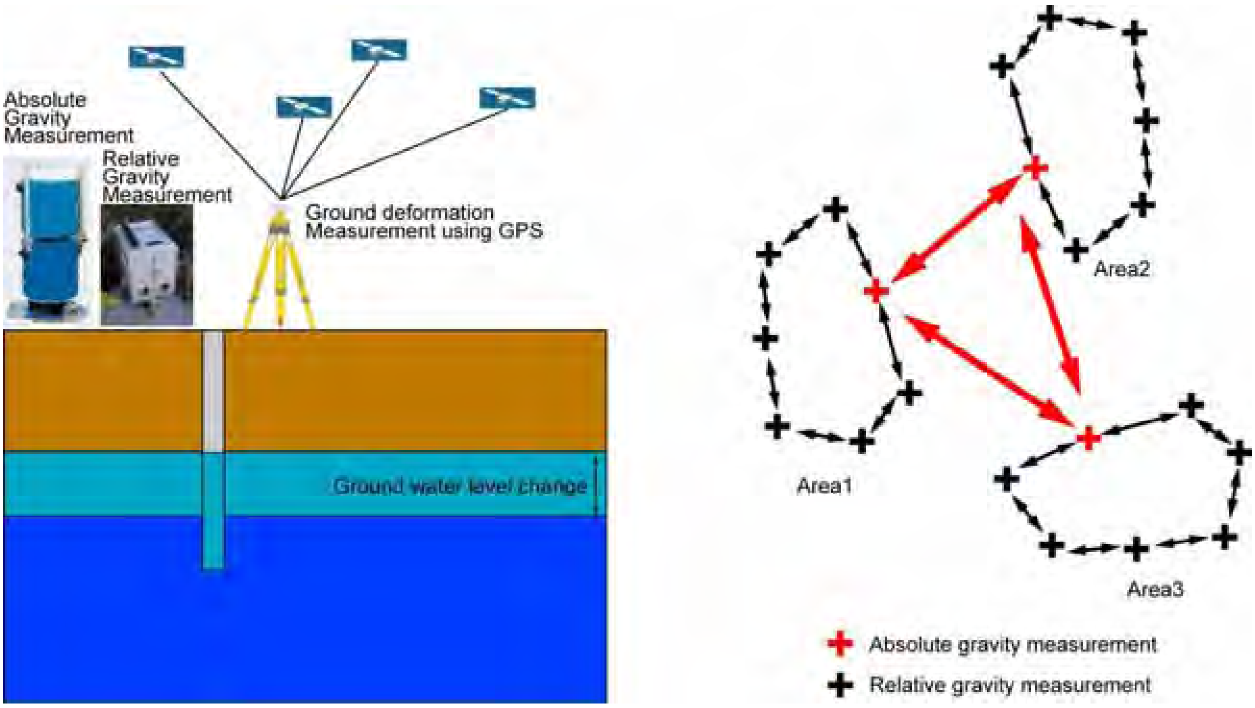

Fig.3 Concept of repeat gravity measurements loop.

3. Preliminary survey at Bangkok

We carried out the preliminary survey at Bangkok since 2004, and we checked the observation wells to plan the repeat gravity and GPS survey. Each observation wells drilled to the 2 or 3 aquifer called PD, NL and NB (Figure 4), and the depth of aquifer is about 100m, 150m and 200m respectively. We will divide some areas using the pattern of the ground water level changes (For example, water dropping area, water recover area, and so on). We will establish the reference station and 5 or 6 gravity stations in each area. And we will check the gravity change between each reference stations using the absolute gravimeter.

We established the reference station in the Thai Meteorological Department and measured the gravity using FG-5 absolute gravimeter (Micro-g solutions, Inc.) in September 2005.

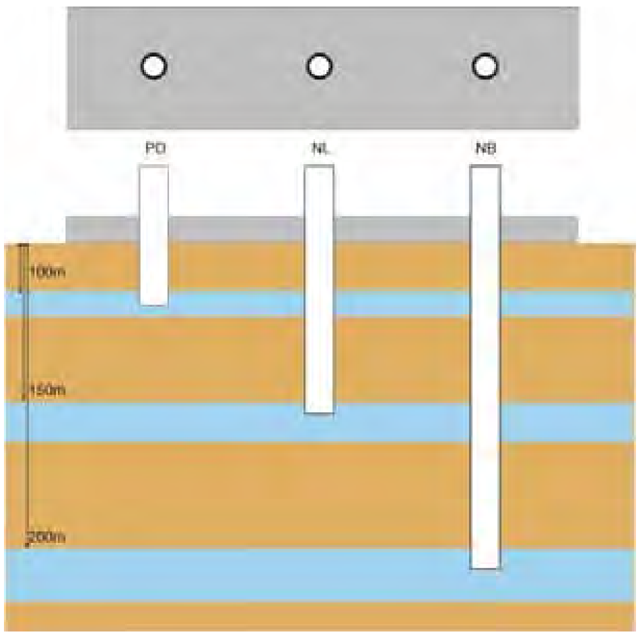

Fig.3 Typical observation well in Bangkok.

4. Summary

We carried out preliminary survey at Bangkok since 2004, and we checked the observation wells to plan the repeat gravity and GPS survey. We will decide the gravity stations as soon as possible and we will start the measurements from March 2007.

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Preliminary field survey on groundwater chemistry in Seoul city area.

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Abstract

The Seoul city is most urbanized area in Korea, and groundwater is used for various purposes. Recently, groundwater quality degradation caused by local pollution becomes a serious problem. This survey identifies groundwater flow in Seoul city and understands the hydrological characteristic of groundwater and Han River water. In the Seoul city area, the groundwater flow system can be classified as the northern and southern areas, and there exist clear difference between groundwater and Han River water both isotopic and chemical components. Recharge from riverwater to groundwater caused by subway tunnel pumping is occurred in northern side of Han River.

I. Introduction

The Seoul city is the largest urbanization area in Korea. The population has grown rapidly since 1965 to about 10.5 million, representing about 24% of the country's total population in 1996. The use of groundwater has increased along with growing population. And, by increasing subway tunnel pumping caused by expansion of subway line, groundwater level has decreased extremely in a part of region. In the previous studies, groundwater recharge and discharge in Seoul area have been balanced approximately, and it was pointed out that a more serious problem is not quantitative point but quality degradation of shallow groundwater by local pollution (Kim et al. 2001).

The purpose of this study is to understand the geochemical characteristic of groundwater in Seoul area, using stable isotopic components (deuterium and oxygen-18) and major inorganic ion chemistry.

II. Study area and Methodology

The Seoul city is located in the central part of Korean peninsula (Fig. 1). Two major aquifers composed by unconsolidated alluvium of Han River and by fractured rock existed in the city area. The alluvium aquifer is mainly composed by coarse-grained sediments interlayered with fine-grained sediment, while the fractured rock aquifer is comprised by granite, schist, and gneiss (Kim et al. 2001). Water sampling was conducted in 13 observation wells in the research area including 4 sampling points along Han River (upstream, midstream, downstream, and the branch). Those sampling points are shown in Fig. 1.

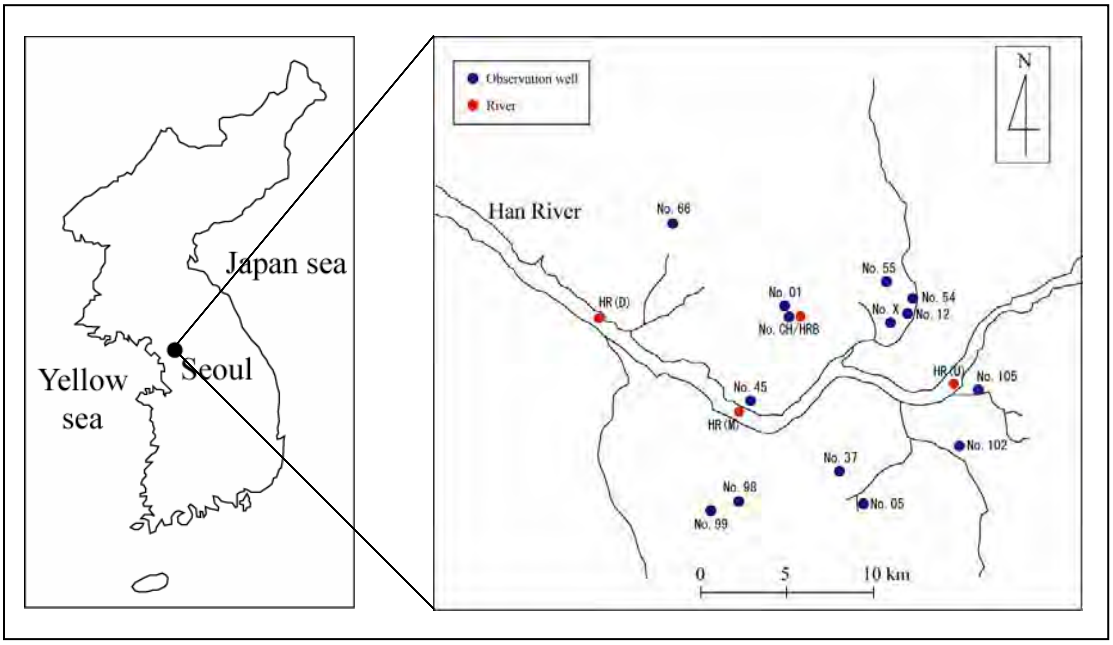

Fig. 1 Location of study area and sampling point of groundwater in Seoul city.

Deuterium and oxygen stable isotopes of these samples were analyzed by mass spectrometry (delta S; Thermo electron), with the preparations of CO_2-H_2O equilibration method for $\delta^{18}O$ and Cr reduction techniques for δD, at Kumamoto university. The isotopic ratios are shown by conventional δ-notation in per mil (‰). The measurements accuracies are ±0.1‰ for oxygen-18 and ±1‰ for deuterium, respectively. Major inorganic ion chemistries were measured by ICP-AES (HPLC; SHIMAZU) for cation and ion chromatography (Optima3000; Perkin Elmer) for anion, respectively, at Hiroshima University. Electric conductivity (EC), pH, and temperature of water samples were measured directly on site. Borehole data and the chemical result of these analyses are shown in Table 1 and 2, respectively.

Table 1 Borehole data in the Seoul city area.

Location	Altitude (m)	Groundwater table (m)	Well depth (m)	EC(μS/cm)	pH	Temp(℃)
98	62	61.4	100	228	8.1	15
99	55	48.7	100	579	6.5	15.3
55	52	49.9	43	547	6.7	16.4
54	19	12.0	150	434	6.8	16.7
12	20	14.1	36	92.8	7.0	15.9
X	17	10.0	15.5	535	6.3	16.4
5	27	22.3	unknown	638	6.8	15
37	27	18.6	unknown	368	7.0	15.6
CH	30	13.7	unknown	207	7.4	19.6
45	17	-	59	668	6.6	16
66	31	28.3	54	471	6.6	16.3
1	35	12.5	unknown	412	7.3	16.1
102	20	14.9	47	416	6.1	15.5
105	26	16.1	74	778	6.7	15.7
HR (Tributary)	30	-	-	519	8.3	27.4
HR (Upstream)	17	-	-	124.3	7.3	22.8
HR (Midstream)	15	-	-	119.8	7.1	24
HR (Downstream)	10	-	-	124.2	7.4	24.1

Table 2 Chemical analyses of water sample.

Location	δD (‰)	$\delta^{18}O$ (‰)	K^+ (mg/l)	Ca^{2+} (mg/l)	Na^+ (mg/l)	Mg^{2+} (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	HCO_3^- (mg/l)
98	-56	-8.5	0.816	34.405	23.531	1.482	17.157	73.231	0	76.564
99	-63	-9.0	4.097	43.304	32.371	8.6	59.902	37.992	88.443	65.314
55	-59	-8.5	5.753	54.913	26.283	5.707	62.941	35.79	11.018	137.955
54	-60	-8.7	1.667	27.455	43.465	4.129	45.196	49.555	0	108.964
12	-57	-8.2	0.819	7.64	15.578	1.401	11.176	4.955	2.68	55.25
X	-63	-9.1	14.174	47.667	32.007	5.022	44.118	45.701	40.797	142.414
5	-55	-7.9	3.008	68.287	37.211	5.526	33.137	17.62	0	335.254
37	-58	-8.5	2.582	32.704	15.31	6.385	49.216	16.518	9.529	89.735
CH	-71	-10.1	6.473	23.084	6.437	1.063	9.608	12.113	9.529	77.216
45	-64	-9.0	3.322	49.504	46.492	15.089	57.059	32.385	6.551	285.14
66	-58	-8.4	2.401	40.15	23.229	8.444	52.549	24.777	29.183	124.26
1	-62	-8.9	1.307	36.623	33.692	2.951	42.843	23.126	0	142.197
102	-62	-8.8	0.963	22.152	30.042	7.49	52.941	28.632	0	87.171
105	-64	-8.9	2.154	67.778	31.025	17.627	40	34.138	0	372.495
HR (Tributary)	-70	-9.8	8.9	48.298	35.93	4.509	43.431	40.745	17.867	170.245
HR (Upstream)	-70	-9.9	1.644	12.723	3.917	1.965	4.706	9.911	9.231	42.228
HR (Midstream)	-71	-10.0	2.134	10.208	4.445	1.572	5.49	9.36	9.231	35.193
HR (Downstream)	-70	-9.7	2.215	11.006	5.239	1.632	6.078	9.911	11.018	31.578

III. Result and Discussion

Groundwater level.

Groundwater levels were measured directly in each well on 3 to 5 August 2005. Fig. 2 shows the distribution of groundwater potential (m, a.m.s.l) in the study area. In this figure, the groundwater levels of southern side are relatively higher than those of northern side, and the lower levels are observed in northern side of Han River. The draw-down of groundwater levels may be caused by subway tunnel pumping. As a result, in the southern side of Han River, the groundwater is not recharged by Han River water, while in the northern side of Han River, groundwater is recharged by both the Han River water and the regional groundwater that is mainly recharged at surrounding mountain area.

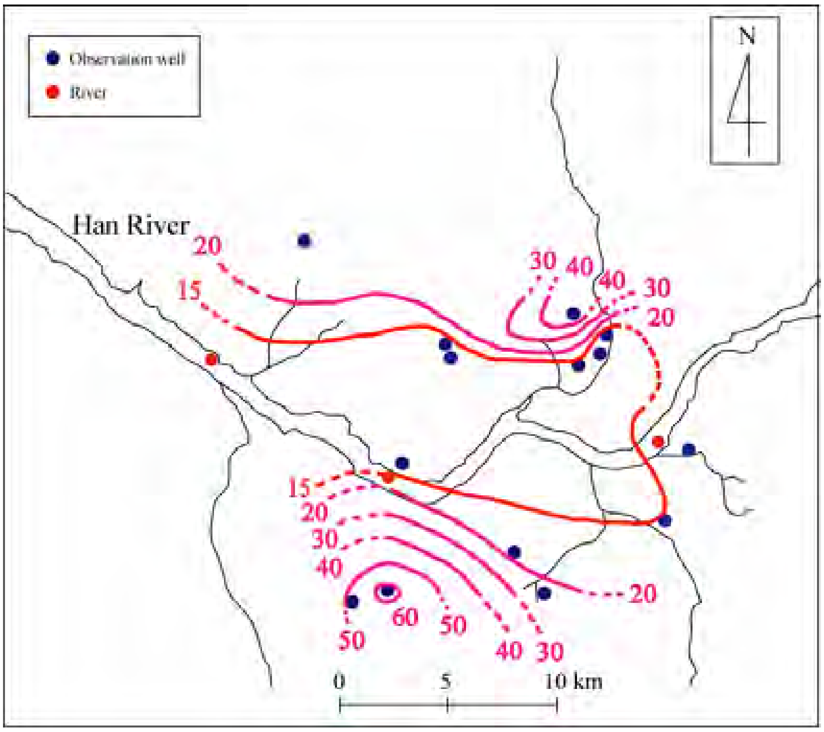

Fig. 2 Groundwater potential distribution (m, a.m.s.l.) in August, 2005.

Stable isotope.

Fig. 3 shows distribution of δD values (‰) in groundwater in Seoul city area. It shows relatively heavy value in the surrounding area, and it has gradually depleted toward the central part of Seoul city. Thus, isotopically, there are two potential recharge sources in the northern side of Han River; Han River water and higher altitude recharge water through regional large scale groundwater flow system.

Fig. 4 shows δD-$\delta^{18}O$ relationship for sampled water. Except No. CH, the isotopic ratio of groundwater has relatively heavy value compared to Han River water, and isotopic ratio of Han River water shows not much difference between upstream and downstream including the branch river which is mostly supplied by discharge water from Seoul city water. Thus, except No. CH groundwater, it is considered that most of groundwater in Seoul city has little contribution by the Han River.

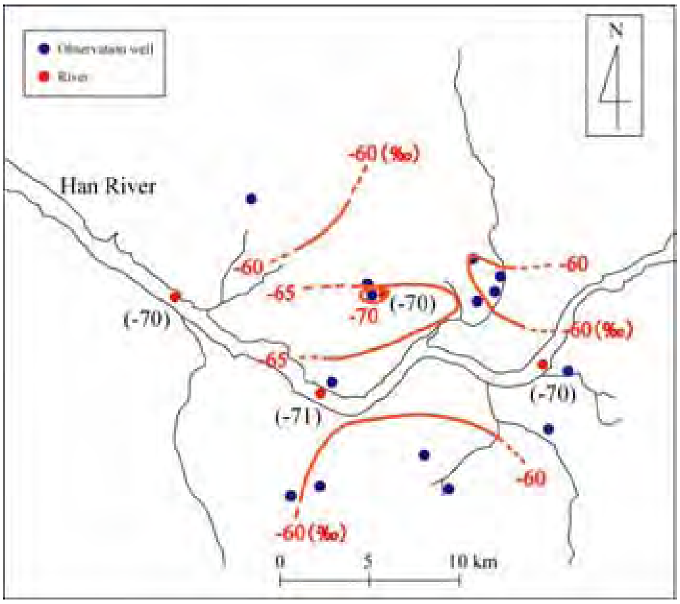

Fig. 3 Distribution of δD values (‰) in groundwater in Seoul city.

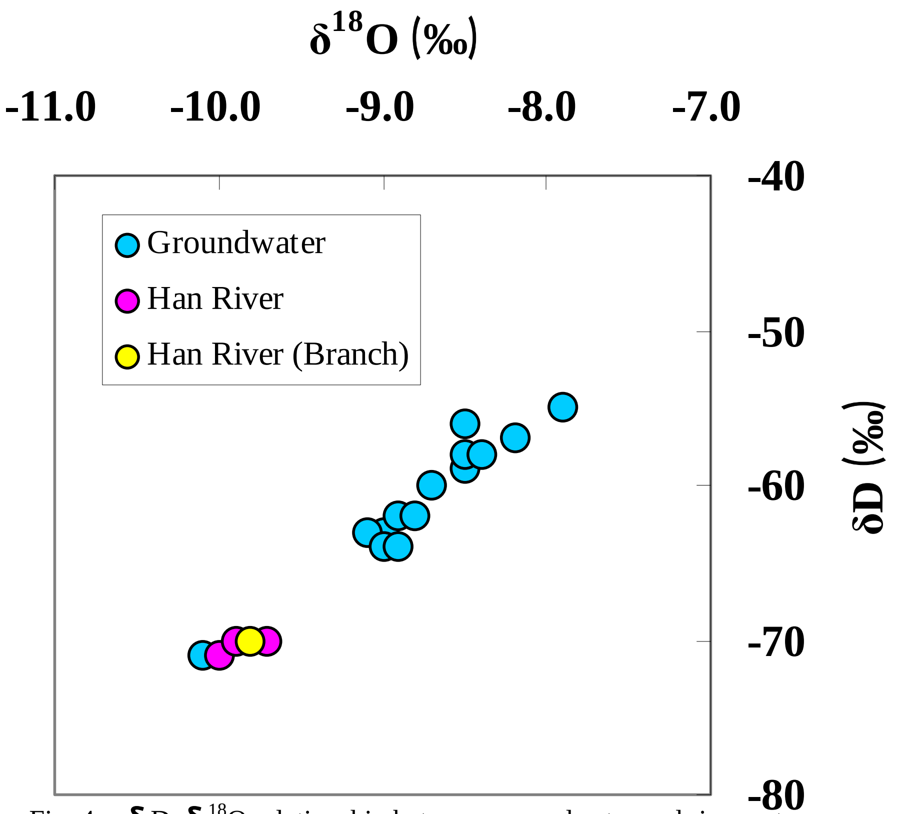

Fig. 4 δD-δ18O relationship between groundwater and riverwater.

Major inorganic ion chemistry.

Fig. 5 shows distribution of hexadiagram for major inorganic chemical components in groundwater and Han River water. It was clearly shown that dissolved component in groundwater is considerably higher than that is Han River water. Also it shows different chemical characteristics at each sampling point. Some groundwater samples shows high concentrations of chloride and nitrate, however, the relationship between these high ion concentrations and leakage from sewer system has not been cleared.

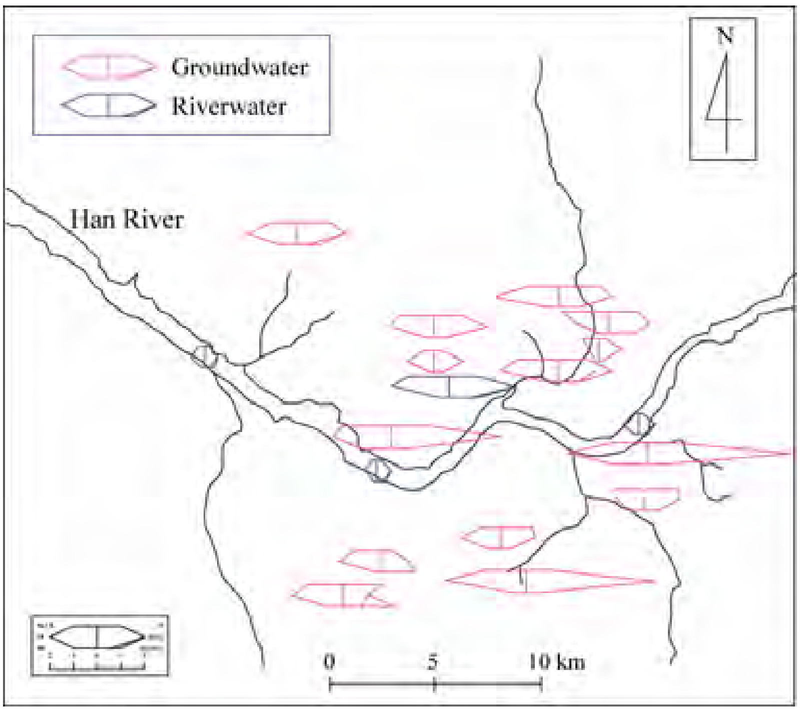

Fig. 5 Hexadiagram of major chemical components in the groundwater and riverwater.

IV. Conclusions

Major inorganic chemistry and stable isotope contents were measured to understand the geochemical characteristic of groundwater in Seoul city area, Korea.

The water samples were collected between 3 to 5 August 2005 in 13 observation wells and 4 points along Han River.

As a result, it is cleared that the groundwater in Seoul city has originally the effluents groundwater flow system toward Han River; this natural flow system has been much affected by the subway tunnel system and this caused the large groundwater depletion which create the intrusion of Han River water to the aquifer. This is quite evident in the northern side of Han River (Fig. 6).

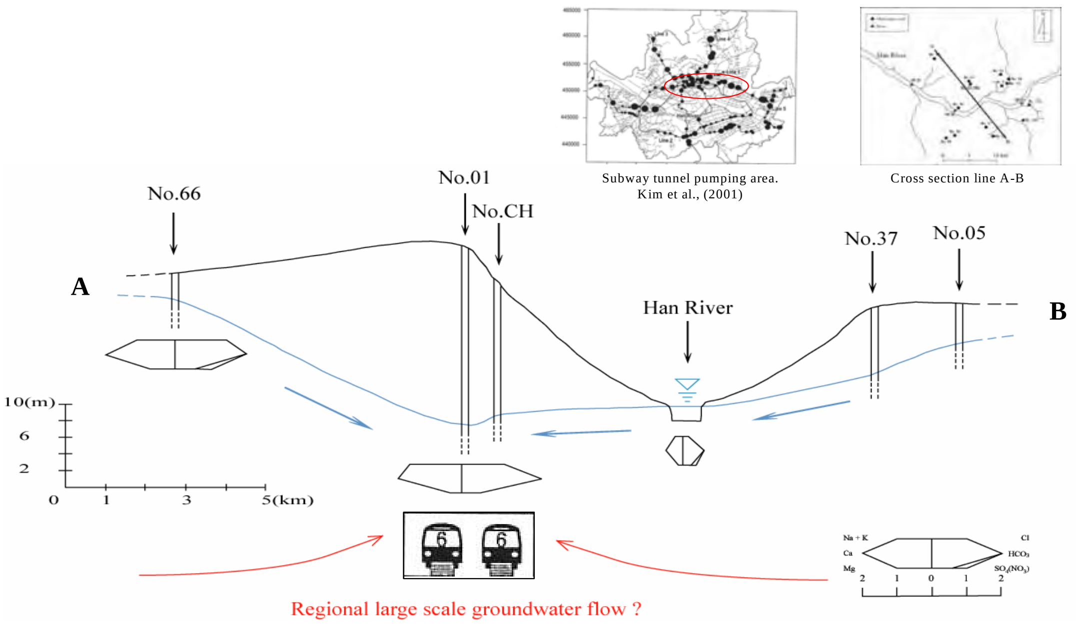

Fig. 6 Conceptual cross section view of groundwater in Seoul city.

Reference

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Human Impacts on Groundwater Environment in the Tokyo Lowland, the Kanto Plain, central Japan

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Abstract
Groundwater environment in the Tokyo lowland has been affected by human activity since 19th century (e. g. groundwater pumping, land subsidence). The purpose of this study is to clarify the trend and the process of quantitative and qualitative changes of groundwater in the lowland and surrounding areas. From the viewpoint of quantitative changes, hydraulic potentials in the lowland have recovered in recent years, but they still remain negative. As for the qualitative changes, groundwater quality has drastically changed in 1970s when land subsidence was most remarkable.

1. Introduction

The Kanto Plain located in the Pacific side of central Japan, is the largest sedimentary plain in Japan (Fig. 1). Tokyo metropolitan district is situated in this plain, and approximately 30 % of the whole population of Japan lives here. Center of politics and economics are most advanced in Tokyo lowland occupying south of the plain. Also, industries in the lowland have been developed since the latter half of the 19th century. Urbanization and various human activities have affected surface and subsurface environments of the lowland. For example, decreasing groundwater recharge, drying up of springs, and heat-island phenomenon have been increasingly become problematical. In subsurface part, depletion of hydraulic potential, land subsidence of alluvium and Pleistocene strata, leaking from water pipes and sewerages, and water quality deterioration have occurred. Warming of subsurface temperatures in depths shallower than 50 m has been induced. Additionally, recovery of hydraulic potentials by regulating groundwater pumping brought new problems, such as increase of buoyancy and groundwater leakage to underground structures (e.g. subway stations). That is, urban environment in the lowland became more complicated and more diversified. Therefore, it is necessary to make clear the trend and the process of environmental changes to maintain and manage urban environment. However, only few studies have been available in quantitative and qualitative change of groundwater in the lowland and surrounding areas. The purpose of this study is to fill this gap and clarify the tendency and the process of quantitative and qualitative changes of groundwater in the Tokyo lowland and surrounding areas.

2. Overview

Southern part of the Tokyo lowland is a reclaimed land that has been built up since 17th century (Fig. 1). The Musashino upland and the Shimousa upland are on the west and the east side of the lowland. Elevations of the uplands are approximately 50 and 30 m, respectively. The area between Sumida and Arakawa Rivers is lower than the sea level because of land subsidence. Fig. 2 shows stratigraphy of Quaternary System in the lowland and eastern part of the Musashino upland. Alluvium, buried terrace deposits, the Tokyo Group (middle to upper Pleistocene), and the Kazusa Group (lower to middle Pleistocene) consists of intercalated silt, sand, and gravel. Tokyo Group and Kazusa Group dip from the Musashino upland in the east toward the lowland. From the viewpoint of hydrogeology, the Kitatama Formation, over 400 m thick consolidated silt, defines lower hydraulic boundary of groundwater flow. Distribution of upper boundary of the Kitatama Formation (Fig. 3) shows that the groundwater recharged in western part of the Musashino upland cannot directly flow into the lowland.

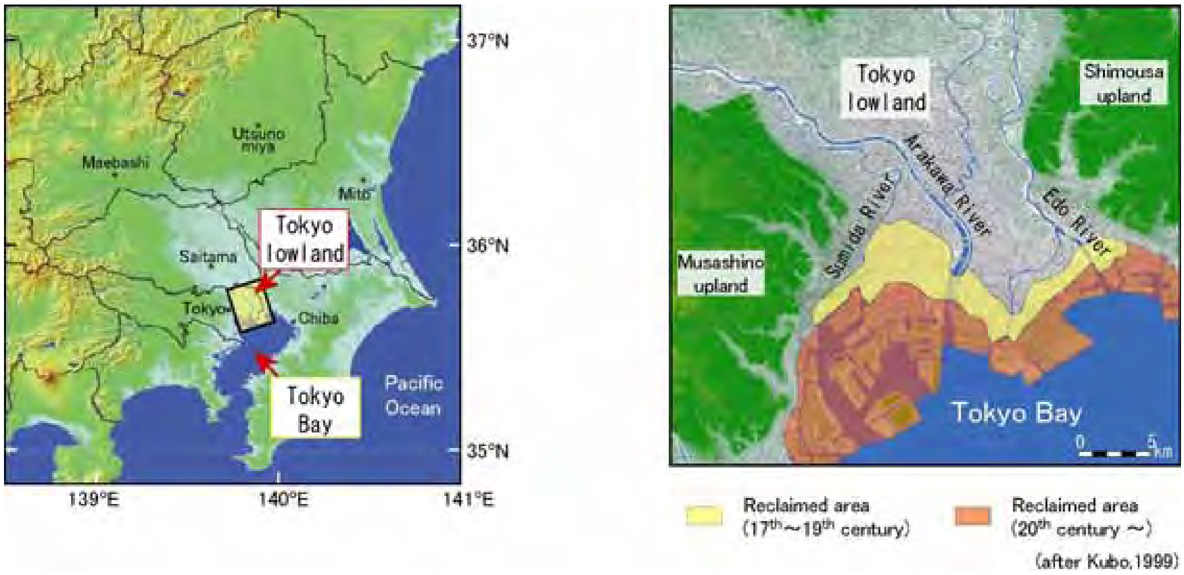

Fig. 1 Location map of Study area

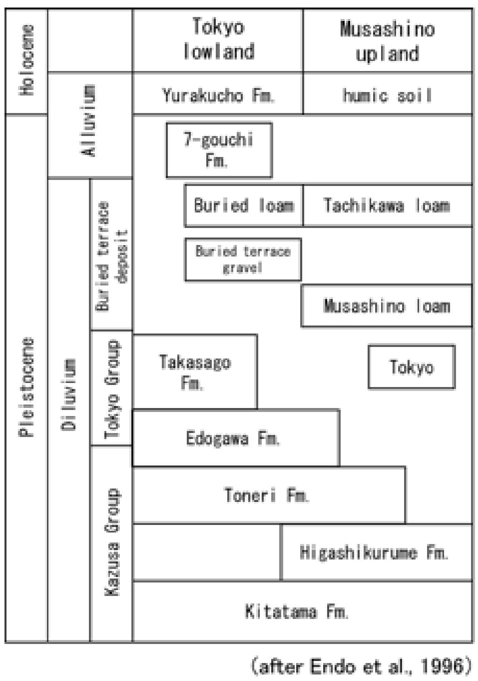

Fig. 2 Stratigraphy of Quaternary system

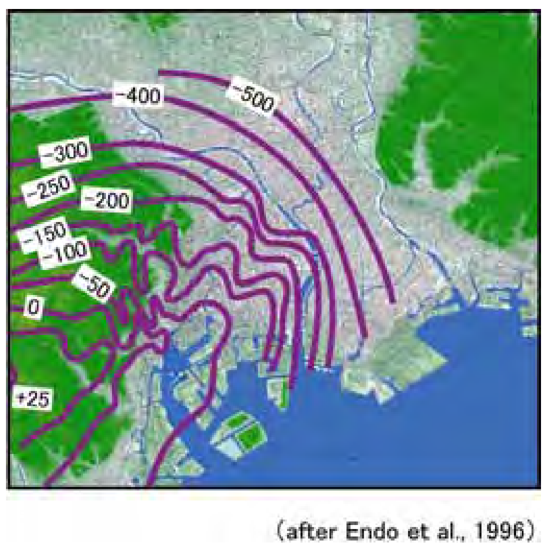

Fig. 3 Upper boundary of the Kitatama Fm.

3. Method of study

a: Groundwater samplings and analyses of pH, EC, major dissolved ions, and $\delta^{18}O$ and δD.

b: Measurements of subsurface temperatures using observation wells.

c: Data collected on groundwater levels, amounts of groundwater withdrawal, assessment of groundwater quality, and more.

4. Quantitative analyses

4-1. Changes in infiltration rates of precipitation

Urbanization and land cover causes decrease of groundwater recharge rates at the lowland and surrounding areas. Secular change of infiltration rates of precipitation from ground surface shows that the infiltration rates in the lowland and the eastern Musashino upland are only 10 % in recent years (Table 1). Also, groundwater recharge rates in this area were calculated to be from 140 to 224 mm using annual precipitation in Tokyo (approximately 1,400mm: average from 1961 to 2000).

Table 1 Secular change of infiltration rates of precipitation in Tokyo area

	1968	1976	1992
Tokyo lowland & Eastern part of Musashino upland	16%	13%	10%
Western part of Musashino upland	45%	32%	25%

(after Imai, 2002)

4-2. Change of groundwater withdrawal rates

Groundwater pumping for industrial use has been practiced since the end of 19th century, and increased rapidly in 1950s. However, rates of withdrawal has decreased from 1980s, because of restricting regulation was imposed in 1970s. Fig. 4 shows secular variation of groundwater withdrawal for each local authority in the lowland and the surrounding areas. In the lowland, withdrawal is much higher than groundwater recharge rate until 1970s, but it became lower than recharge rate after 1980s. On the contrary, withdrawals in the surrounding areas remained large after 1980s. Withdrawal in the surrounding areas probably delays the recovery of hydraulic potentials in the lowland.

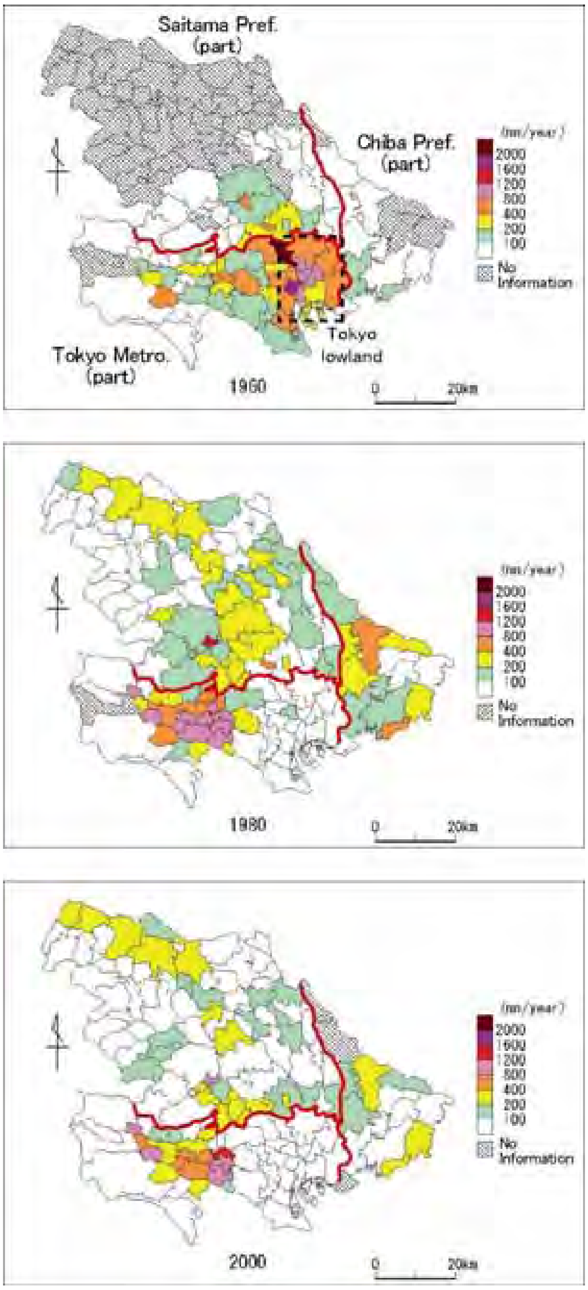

Fig. 4 Secular variation of groundwater withdrawal

4-3. Change of hydraulic potentials

Fig. 5 shows secular variations of the hydraulic potentials in Alluvium and Pleistocene strata. The hydraulic potentials have been recovering since the latter half of 1970s, but that still stays in negative. Fig. 6 indicates vertical distribution of the hydraulic potentials in north-south section. The hydraulic potential in the whole section has increased with time. It decreases from the south (Tokyo Bay area) toward the north (inland part). Especially, hydraulic potentials rapidly decrease at the central part of the section. This suggests the existence of hydraulic boundary in this area.

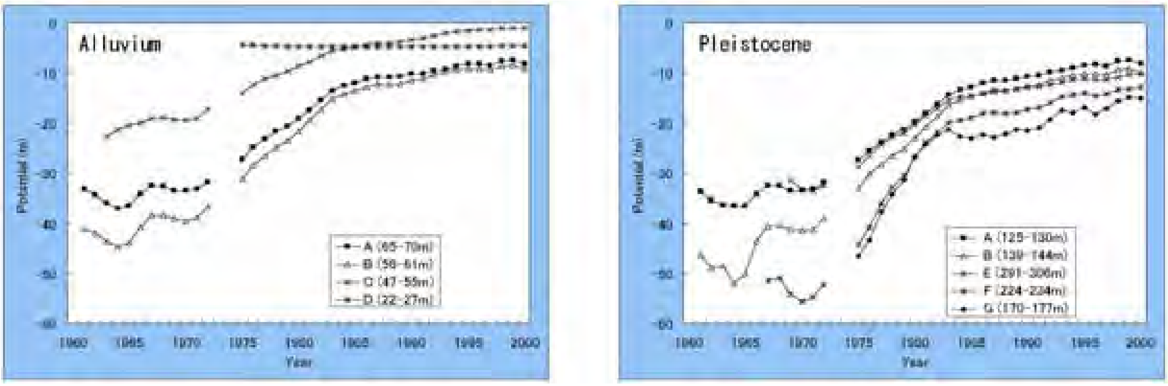

Fig. 5 Secular variations of the hydraulic potentials in Alluvium and Pleistocene strata

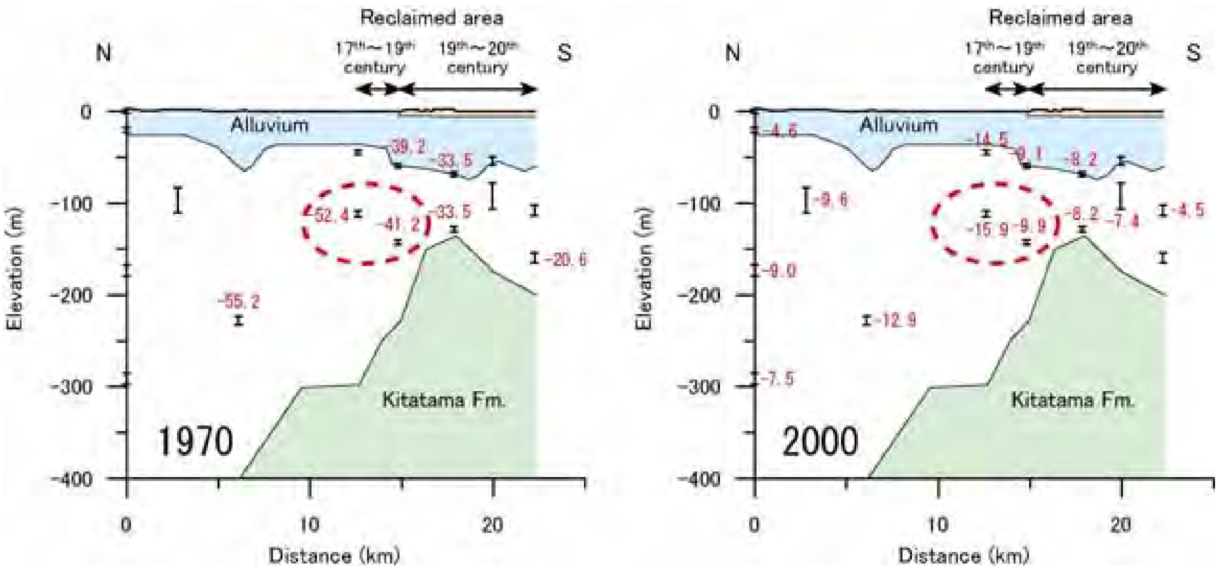

Fig. 6 Vertical distribution of the hydraulic potentials in north-south section

5. Qualitative changes

5-1. Changes in Cl concentrations

Fig. 7 shows changes in Cl concentrations of groundwater. Changes of concentrations occurred not only in Alluvium but also in deep parts (about 300 m in depth). However, clear trend has not been found in the areas and in depths yet. Fig. 8 indicates vertical distribution of Cl concentrations in the north-south section. In the area that hydraulic potential rapidly decreases, Cl concentration is quite different, too. In addition, this difference has probably existed since 1970s, from the change of Cl concentrations (Fig. 7). This chemical difference suggests the existence of hydraulic boundary, which is estimated from distribution of hydraulic potentials, in the central area.

5-2. $\delta^{18}O$ and δD

Fig. 9 shows correlation between $\delta^{18}O$ and δD of groundwater samples that were collected from the lowland and the eastern part of the Musashino upland. Isotopic ratio in the central part of the lowland west of the Arakawa River is lower than that of the upland. Therefore, the eastern part of the Musashino upland cannot recharge the groundwater into the central part of the lowland.

	1969	1970	2001～2003
A (108–115m)	5.9	8.4	16.9
B-1 (56–61m)	154.8	179.6	244.8
B-2 (139–144m)	15.7	26.3	251.6
C-1 (65–70m)	656.5	10290	588.8
C-2 (125–130m)	156.8	263.6	1085.8
D (47–55m)	198.9	682.5	2431.4
E-1 (129–150m)	58.8	80.9	79.9
E-2 (313–346m)	114.7	157.5	250.5
F-1 (60–70m)		157.5	349.6
F-2 (150–160m)		157.5	103.1
F-3 (291–306m)		2416	363.3

Fig. 7 Changes in Cl concentration of groundwater

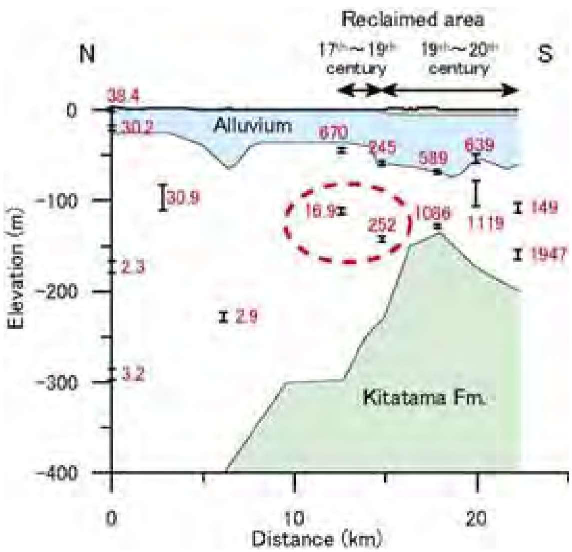

Fig. 8 Vertical distribution of Cl concentrations in the north-south section

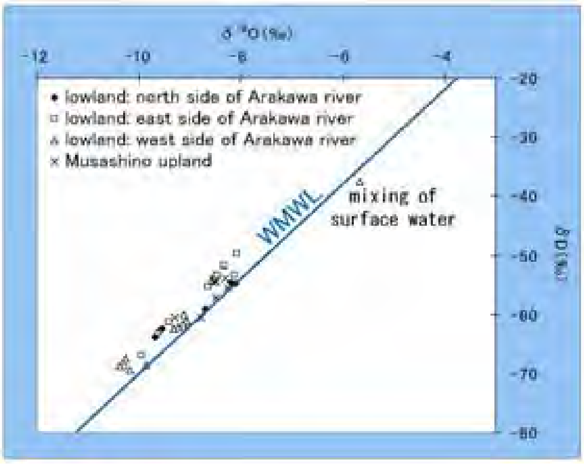

Fig. 9 Correlation between $\delta^{18}O$ and δD

6. Subsurface temperature changes

Urbanization affects not only surface temperatures but also subsurface temperatures. Fig. 10 shows vertical distribution of subsurface temperatures in an east-west section. Subsurface warming occurs in the depths shallower than 50 m, and it is remarkable to see the effect of warming in the center of Tokyo such as Shinjuku and Kasumigaseki.

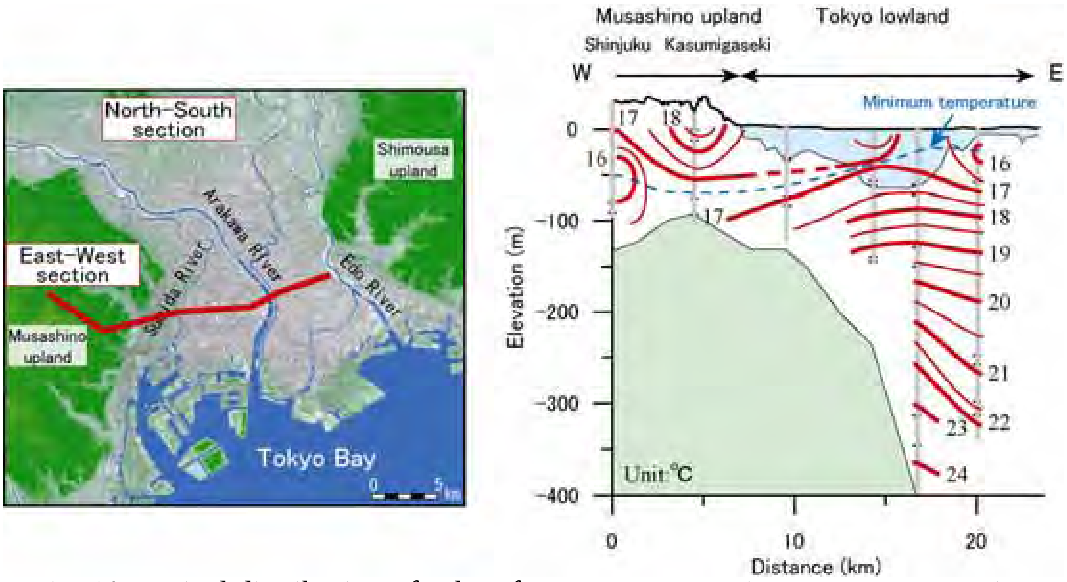

Fig. 10 Vertical distribution of subsurface temperatures in an east-west section

7. Conclusions

a: Hydraulic potentials in the Tokyo lowland have recovered in recent years, but they still remain negative.

b: Geochemical processes of groundwater change are not yet clear. Further studies are required.

c: Subsurface temperatures have increased by urbanization. The increase in the center of Tokyo is remarkable.

"An Estimation of Compressibility of Underground Formations from Groundwater level and Land Subsidence Data in the Kanto Plain, Japan"

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Abstract

To achieve the sustainable use of groundwater, it is necessary to evaluate the possibility of land subsidence which will be caused by groundwater extraction. A coupled numerical simulation of both groundwater flow and consolidation can be a strong tool for this purpose, and it is essential to obtain information on the spatial distribution of both elastic and plastic compressibility values of the underground formations. We tried to evaluate the bulk compressibility values from the temporal change of groundwater level and land subsidence. The deformation properties for the Shimosa and Kazusa groups were obtained at several locations. Both the C_e values for elastic deformation and λ values for plastic deformation of the Kazusa Group were about three times as small as those of the Shimosa Group. On the other hand, the spatial change of these properties within each Group was very small, suggesting that each Group can be modeled as one homogeneous material for deformation modeling.

1. Introduction

Sustainable groundwater usage is one of the important goals in urban cities which situates on the soft sedimentary formations, and hence, it is necessary to evaluate the possibility of land subsidence caused by groundwater extraction. For this purpose, we are planning to construct a coupled numerical model to analyze both groundwater flow and consolidation in the Kanto Plain. In this study, we tried to estimate compressibility of underground formations as one part of this approach (Fig. 1).

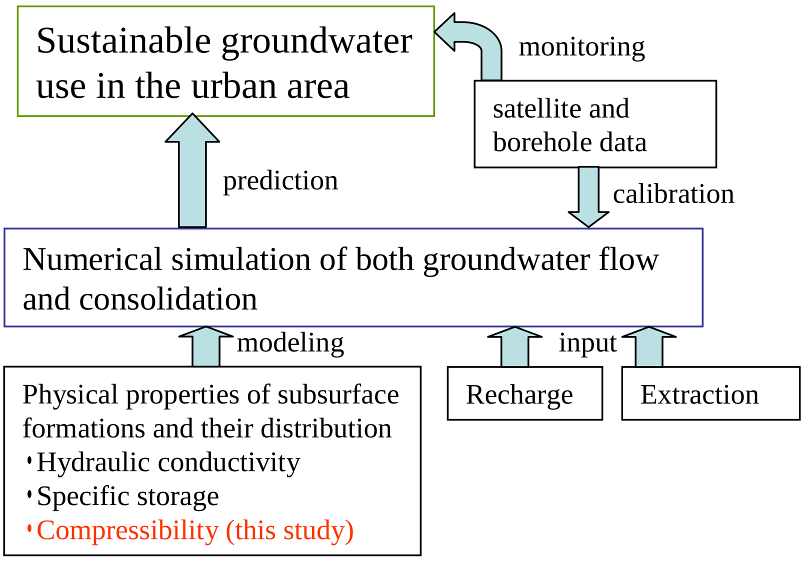
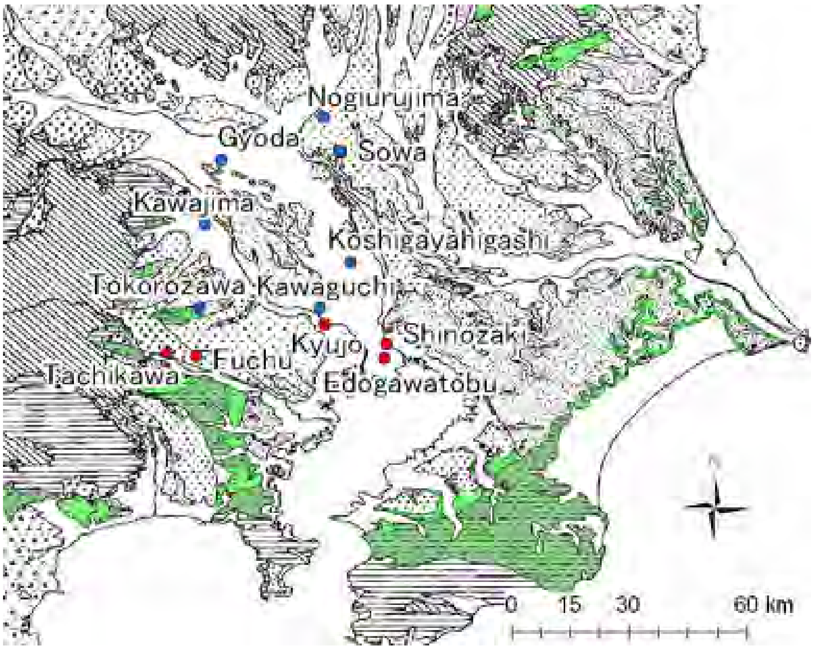


Fig. 1 Our strategy for sustainable groundwater use in the urban area from the simulation-based view point

In the Kanto Plain, the Shimosa Group and the Kazusa Group are the major aquifer systems and it is important to obtain information on the spatial distribution of both elastic and plastic compressibility values of these groups. Previous studies (i.e. Horiguchi, 1994; Suzuki, 2002) showed that these groups situate at the depth from about tens to hundreds of meters in the central part of the Kanto Plain while the groups are exposed to the surface in the northern, eastern and southern parts (Fig. 2).



Age (Ma)	Stratigraphy	Legend
～0.01	**Holocene**	
0.01～0.06	**Terrace deposit**	
0.06～0.4	**Shimosa Group**	
0.4～2.2?	**Kazusa Group**	
～24	**Miura Group**	
24～	**Pre-Neogene**	

Fig. 2 Surface geology and location of observation wells whose data are used for the present analysis (blue points are the locations analyzed in this study, and red points are those in Aichi and Tokunaga, 2005) (edited from Suzuki, 2002)

2. Measurement of groundwater level and land subsidence

In the Kanto plain, there are many wells that observe the groundwater level and land subsidence (Fig. 2, Fig. 3). We can obtain the deformation of interval “C” from the difference of the subsidence data of two wells (Fig. 3). Monthly data from the observation wells in Fig. 2 (Tochigi Prefecture, 1991-1998a,b; Ibaraki Prefecture, 1980-1998a,b; Saitama Prefecture, 1975-1998a,b) was used for analysis in this analysis (Fig. 4).

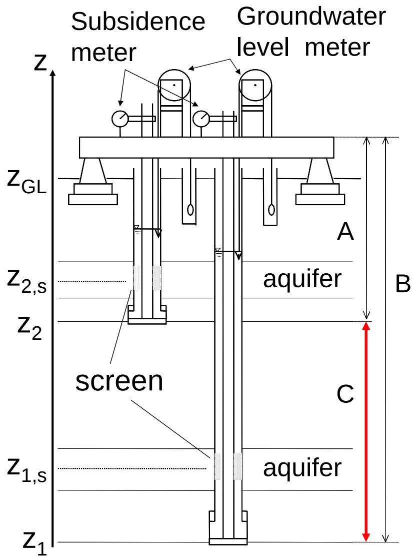


Fig. 3 Structure of observation well

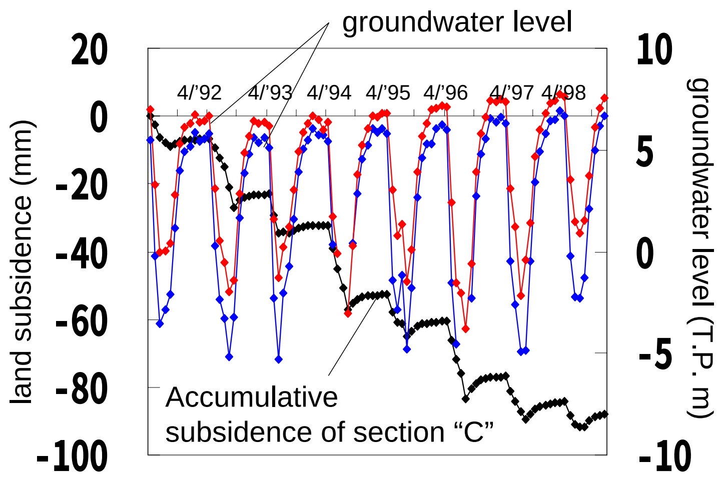


Fig. 4 An example of observed data (Nogiurujima 2)

3. Estimation of elastic compressibility

Elastic deformation occurs under overconsolidation condition (Fig. 5), and an elastic vertical strain increment ($\Delta \varepsilon_e$) is considered to be proportional to an effective stress increment ($\Delta \sigma_{eff}$)(Wood, 1991).

$$\Delta\varepsilon_e = -C_e \Delta\sigma_{eff} \quad \cdots\cdots(3\text{-}1)$$

where the constant C_e is the elastic deformation property.

By plotting effective stress increment due to groundwater level change versus land strain increment, we obtained the C_e value (Fig. 6).

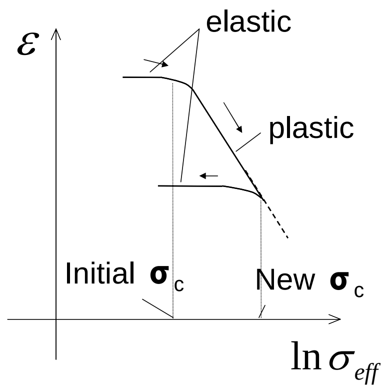


Fig. 5 Typical Elastic/plastic $\varepsilon - \ln\sigma_{eff}$ relation (σ_c: yield stress of consolidation)

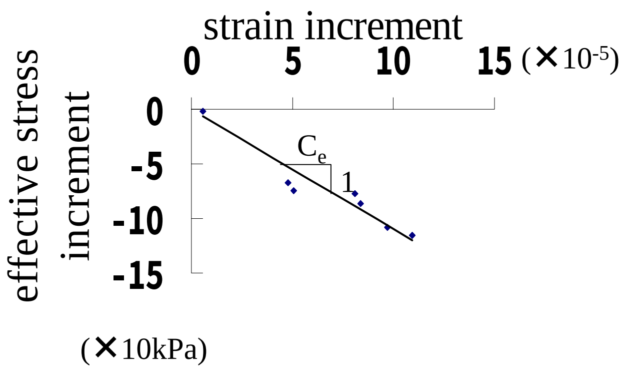


Fig. 6 An example of elastic deformation and its analysis (Nogiurujima 2)

4. Estimation of plastic compressibility

Plastic deformation occurs when effective stress exceeds yield stress of consolidation (σ_c: Fig. 5) and a plastic vertical strain increment ($\Delta\varepsilon_c$) is considered to be proportional to a logarithmic effective stress increment (Eq.4-1) (Wood ,1991).

$$\Delta\varepsilon_c = -\lambda\Delta(\ln\sigma_{eff}) \cdots\cdots (4\text{-}1)$$

where the constant λ is the plastic deformation property.

Because the effective stress is dependent on the depth, we used the integrated form of equation (4-1) throughout the evaluated interval as appeared in (Eq.4-2).

$$\int_{z_1}^{z_2}\varepsilon(z)dz = \int_{z_1}^{z_2} -\lambda\ln\sigma_{eff}(z)dz \cdots\cdots (4\text{-}2)$$

where

z_1: height of the bottom of deeper well (Fig. 3)(m)

z_2: height of the bottom of shallower well (Fig. 3)(m)

Here, we assumed that the effective stress is equal to the overburden pressure minus the pore pressure. The density of soil and water are assumed to be 1.9g/cm^3 and 1.0 g/cm^3 respectively. The pore pressure profile between upper and lower well is assumed to be linear (Eq.4-3).

$$\sigma_{eff}(z) = \rho g(z_{GL} - z) - \frac{p(z_{2,s}) - p(z_{1,s})}{z_{2,s} - z_{1,s}}(z - z_{1,s}) - p(z_{1,s}) \cdots\cdots (4\text{-}3)$$

where

ρ : wet density of soil (1.9g/cm3)

g: gravitational acceleration (9.8m/s^2)

p(z): pore pressure at z (Pa)

z_{GL}: height of ground level (Fig. 3)(m)

$z_{1,s}$: height of upper screen (Fig. 3)(m)

$z_{2,s}$: height of lower screen (Fig. 3)(m)

By plotting integrated logarithmic effective stress versus integrated strain values, the slope λ was obtained as shown in Fig. 7.

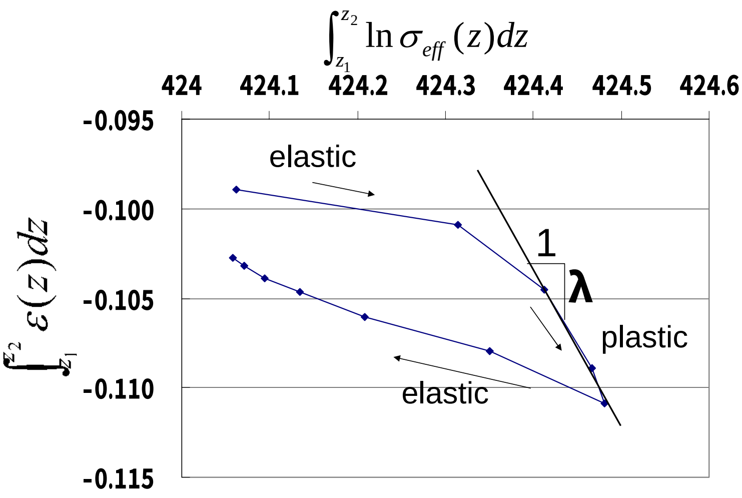


Fig. 7 An example of plastic deformation analysis (Nogiurujima 2)

4. Results and Discussion

The compressibility constants obtained in this study were very similar within each group, and the obtained plastic compressibility constant of the Shimosa Group was within the range of the general value of clay (David, 1991) and that of the Kazusa Group was lower (Table 1).

The obtained C_e values were consistent with those in the Tokyo area reported by Aichi and Tokunaga (2005) (Table 1). This result suggests that the spatial change of physical properties of the formations within the respective group is not significant and each formation can be modeled as one equivalent homogeneous material.

Table 1 Obtained compressibility and general value

Well	Depth (GL,m)	Group	Ce (/GPa)	λ	Reference
Nogiurujima 1	85-141	Shimosa	1.0-1.2	?-0.12	-
Nogiurujima 2	141-185	Shimosa	1.1-1.2	0.13-0.19	-
Gyoda	70-300	Shimosa:202m+ Kazusa:28m	0.6-0.9	-	-
Sowa	90-180	Shimosa	0.7-0.9	0.09-0.10	-
Kawajima	80-190	Shimosa	1.0-1.2	-	-
Koshigayahigashi	60-160	Shimosa	-	0.09-0.17	-
Kawaguchi	43-240	Shimosa	1.0-1.4	-	-
Kyujo	50-170	Shimosa	1.0-1.2	-	Aichi and Tokunaga (2005)
Shinozaki	65-265	Shimosa	1.0-1.4	-	
Edogawatobu	161-400	Shimosa	0.9-1.4	-	
Sowa	180-230	Kazusa	0.27-0.33	0.04-0.07	-
Tokorozawa	240-415	Kazusa	0.27-?	0.03-0.06	-
Fuchu	174-290	Kazusa	0.27-0.33	-	Aichi and Tokunaga (2005)
Tachikawa	108-210	Kazusa	0.27-0.33	-	
-	-	General clay	-	0.09-0.3	Wood (1991)

4. Perspectives

We are planning to construct a coupled numerical model for analyzing both groundwater flow and consolidation in the Kanto Plain. Based on the present study, each Group can be modeled as one homogeneous material (Fig. 8) for deformation analysis. By adding information on yield stress of consolidation, hydraulic conductivities, specific storage, groundwater recharge and extraction, this modeling is expected to reproduce the past groundwater flow and land subsidence due to the past groundwater extraction and to predict the future groundwater flow and land subsidence.

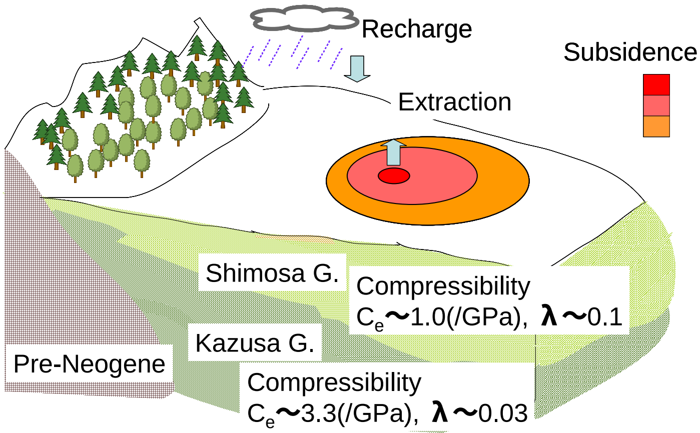


Fig. 8 An example of compressibility values modeling from our results and an image of a coupled simulation

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Tochigi Prefecture, 1991-1998b: *Tochigi-ken chikasuii nenpo.*

Ibaraki Prefecture, 1980-1998a: *Ibaraki-ken jibanchinka chosa hokokusho*.

Ibaraki Prefecture, 1980-1998b: *Ibaraki-ken chikasuii kansoku chosa hokokusho*.

Saitama Prefecture, 1975-1998a: *Saitama-ken jibanchinka chosa hokokusho*.

Saitama Prefecture, 1975-1998b: *Saitama-ken jibanchinka chikasuii kansoku nenpo*.

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Climate variations over Asia on decadal time scale

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Abstract
Precipitation, radiative flux and cloud properties were examined from a viewpoint of particulate and radiation studies in Bangkok, Jakarta and Chongqing. Trends of precipitation seemed gradual decreasing for these cities, although comprehensive analysis is needed. The phase contrasts of precipitation and radiative flux were inspected and different characteristics were reported. The importance of cloud properties was suggested for precipitation and radiation budget.

1. Introduction
To get further understanding of water cycles of both the Earth's surface and sub-surface, it is important to know better atmospheric situations like precipitation and radiation correctly. This is because these kinds of information serve as crucial constraints for the surface water behavior (e.g. water input and evaporation). Targeting Asian cities (Bangkok, Jakarta and Chongqing), this work shows long-term trends of precipitation and radiation variations. Moreover, the possibility of changing precipitation efficiency due to anthropogenic aerosols are mentioned. Data used here are described in the next section and analyzed results are summarized subsequently.

2. Data
Precipitation:
Precipitation datasets used in this study were as in Xie and Arkin (1996). Their merging algorithm takes the ground-based gauge observations, satellite estimates derived from infrared, outgoing longwave radiation and microwave sensors, precipitation distributions from the National Centers for Environmental Prediction (NCEP)-National Center for Atmospheric Research (NCAR) reanalysis. Using this algorithm, a globally monthly precipitation datasets, called the Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) has been created. Detailed treatments should be referred to Xie and Arkin (1996). Although they constricted datasets for precipitation amount on a global scale, we subtract data over only East Asia region for this study in 0.5-degree and monthly resolutions. The example of July in 1999 is shown in figure 1

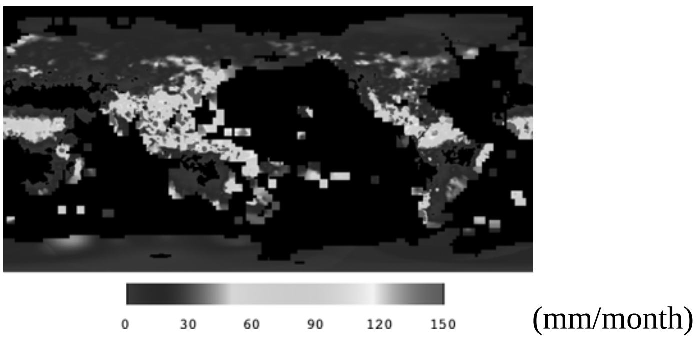

Figure 1. Global map of precipitation of July 1999.

Radiative Flux:

The International Satellite Cloud Climatology Project (ISCCP)'s FD datasets were used as downward shortwave flux (DSF) in this study. Cloud data from the ISCCP D1 and D2 datasets as well as ancillary datasets (Zhang et al., 1995, 2004) were applied to the radiative transfer codes of the NASA Goddard Institute for Space Studies global climate model (GISS GCM) to produce the ISCCP-FD. Compared with the ISCCP-FC version, the ISCCP-FD provided better treatments of ice clouds and aerosols. The ISCCP-FD data were based on monthly mean climatologies of aerosol vertical profiles with 18 different size and composition combinations. In contrast, FC data were based on the mean column optical thicknesses of the stratosphere and troposphere over land, ocean, and desert. Further, the FD data account for the effects of non-spherical ice particles. The FD data has a spatial resolution of 280 x 280 km (approximately 2.5-degree), an original temporal resolution of 3 hours, and have been available since July 1983. Figure 2 presents an example of July 1998.

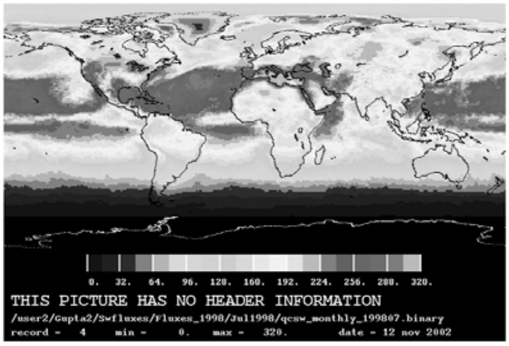

Figure 2. Global map of DSF of July 1998.

Cloud properties:

The ISCCP statistics were used to describe cloud amount data for three cloud types (low, middle and high cloud-tops) and total cloud (both water and ice) optical depth τ_{tot}, and were also used as inputs for radiative calculation. These parameters are determined at visible, near-infrared and infrared wavelengths assuming a water droplet effective radius of 10 micron and an ice crystal effective radius of 30 μicron. Water cloud properties were derived from Advanced Very High Resolution Radiometer (AVHRR) data from NOAA satellites using an algorithm proposed by Kawamoto et al. (2001). The optical depth at visible wavelength τ_{low}, effective particle radius *re* and cloud top temperature T_c were derived from data in three different channels, visible (0.64 micron), near-infrared (3.73 micron) and infrared (11 micron).

3. Analysis and results

Precipitation records in Bangkok, Jakarta and Chongqing (figures 1, 2 and 3, respectively) seem to show long-term decreasing trends with some spikes, but are not so simple variations. Many factors influence these processes such as large-scale air dynamics in addition to particle and radiation conditions mainly discussed here.

Comparisons between precipitation and DSF were performed also in Bangkok, Jakarta and Chongqing (figures 4, 5 and 6, respectively). As shown in the figures, precipitation and DSR have a negative correlation in Bangkok and Jakarta cases. Precipitation usually accompanies the frontal system and convection that are connected to thick clouds. Therefore, thick clouds prevent solar radiation from coming to the ground. However, Chongqing case is opposite. This would be due to cloud optical properties (optical depth, height and area extent). Further investigation is needed to elucidate this tendency together with dynamical aspects. Cloud particle size is an important parameter for precipitation and radiation budget. It can be used for an indicator of precipitation onset (for example, larger than 14 micron). Although raindrops (mm order) are much larger than cloud droplets (micron order) usually, cloud droplets larger than 14 micron are easy to occur the collision-coalescence process which generates larger droplets enough for precipitation. Moreover, clouds having smaller droplets with fixed optical depth reflect more solar radiation than those having larger droplets, since smaller and more droplets have larger surface area than larger and less droplets under a constant amount of water. Kawamoto and Nakajima (2003) reported that water cloud droplets became smaller both on global and East Asian scales with satellite remote sensing from 1985 to 1994. They attributed the reduction of cloud particle size to increasing aerosols due to enhanced industrial activities, admitting the large-scale dynamical effects. This trend is reasonable with decreasing of precipitation, though not simple variation as stated above. Rosenfeld (2000) gave an example that emitted aerosols could reduce rainfall in Indonesia, decreasing cloud droplet size though interaction. This effect should be examined in larger spatial scales.

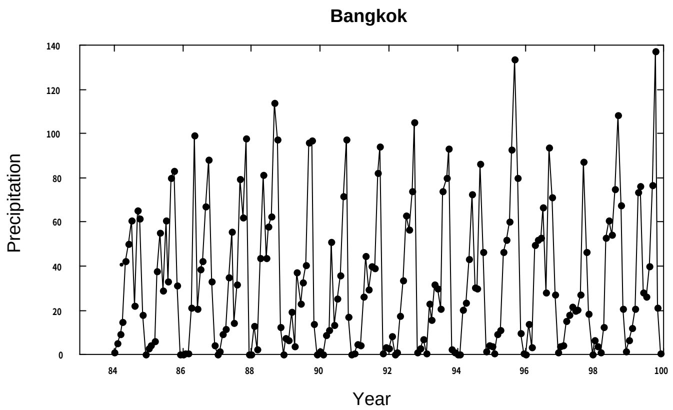

Figure 3 precipitation trend in Bangkok

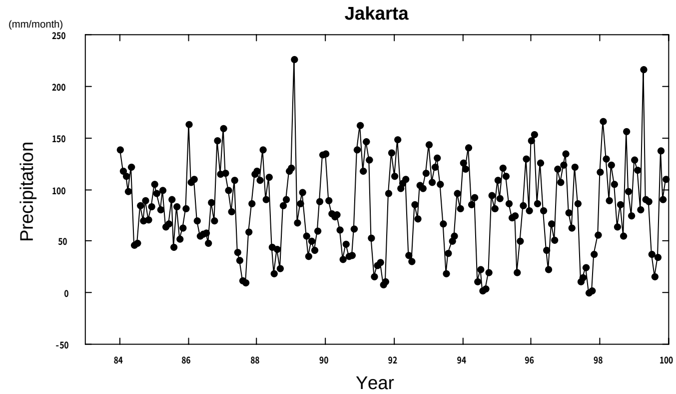

Figure 4 same as figure 3 except Jakarta

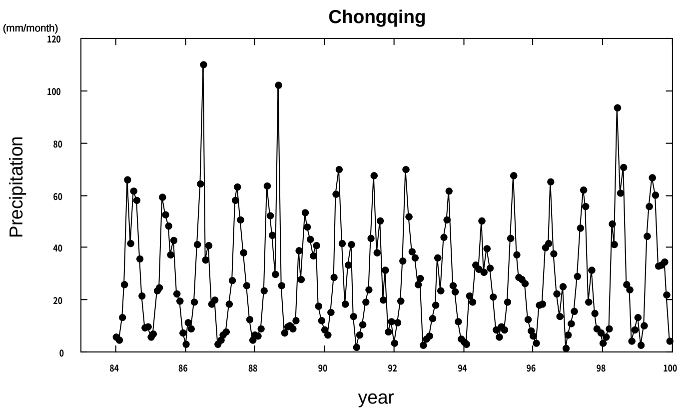

Figure 5 same as figure 3 except Chongqing

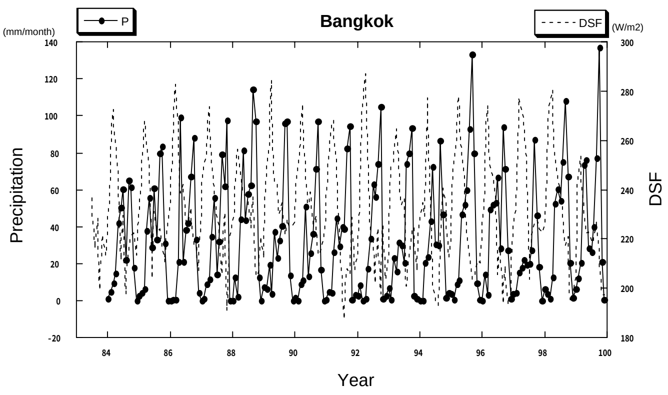

Figure 6 contrast of P and DSF in Bangkok

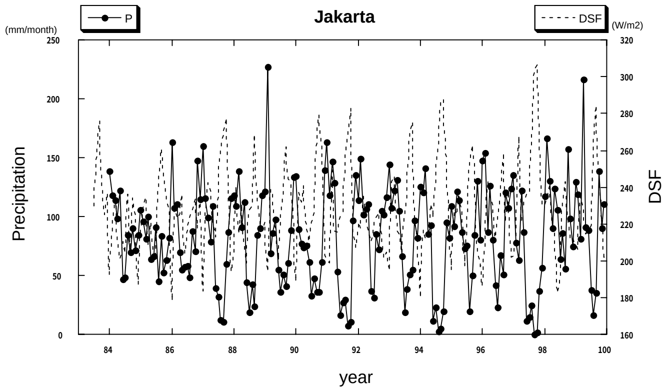

Figure 7 same as figure 6 except Jakarta

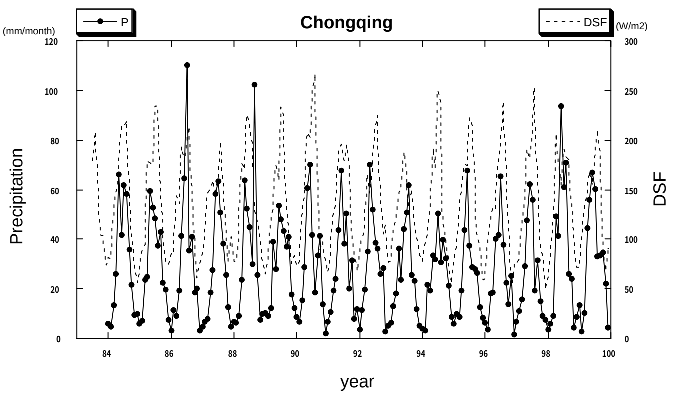

Figure 8 same as figure 6 except Chongqing

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Evolution of human-induced hazards in urban cities due to the temporal change of groundwater situation; the case study of Tokyo Metropolitan Area

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Abstract

Underground environments at the Tokyo Metropolitan Area have dramatically changed in accordance with the change of groundwater condition in the area. This paper summarizes the temporal changes of the underground environments at the Tokyo Metropolitan Area from 1920s until present, focusing on the change of groundwater level of the confined aquifers and associated change of human usage of urban geosphere. The evolution of hazards which have been caused mainly by the change of groundwater usage is also shown. Several new approaches to improve surface environments using “surplus” groundwater are also presented.

1. Introduction

Tokyo, the capital of Japan, is situated in the southwestern part of the Kanto plain, the largest flat plain in Japan (Fig. 1). The underground environments at the Tokyo Metropolitan Area have been changing dramatically in accordance with the change of groundwater condition and with the continuous increase and heavy usage of underground space. Because of the complex interaction between the change of groundwater environments and human activities, we have experienced a variety of human-induced hazards. This paper describes the temporal change of groundwater environments and associated hazards at the Tokyo Metropolitan Area. Several projects and approaches which try to simultaneously solve the presently faced problem of underground facilities and improve the urban environments are also presented.

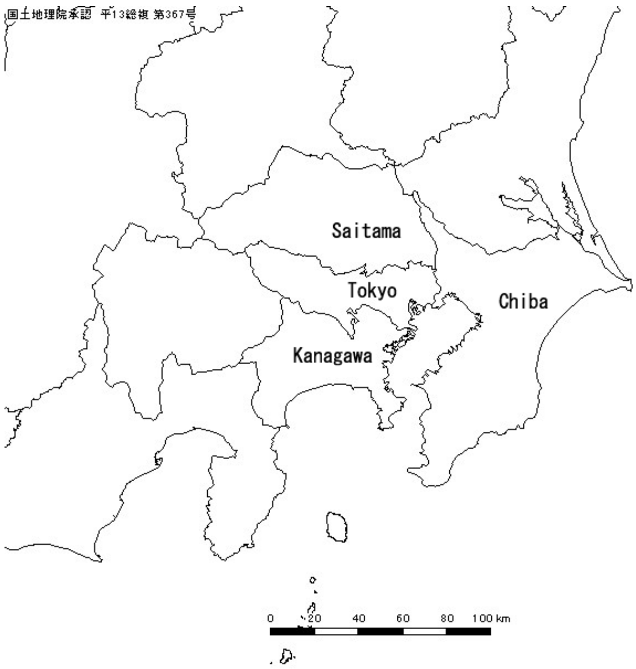

Fig.1 Index map of Tokyo Metropolis

2. Geology and groundwater system in the Tokyo Metropolitan Area

In Tokyo area, Late Pliocene and younger sediments and sedimentary rocks unconformably overlies the Miocene basement rocks. The shallower part of the sediments constitutes the confined aquifer-aquitard system. According to the Institute of Civil Engineering of Tokyo Metropolitan Government (ICE-TMG) [1], this confined aquifer-aquitard system is bounded at its bottom by relatively thick mudstone layer, and the top of this mudstone becomes shallower towards southwest (Fig. 2). Below the aquifer bottom, the Plio-Pleistocene sediments extend more than 2000 m thick and it mainly consists of alternating sandstones and mudstones, which comprises a reservoir system of methane gas dissolved in water.

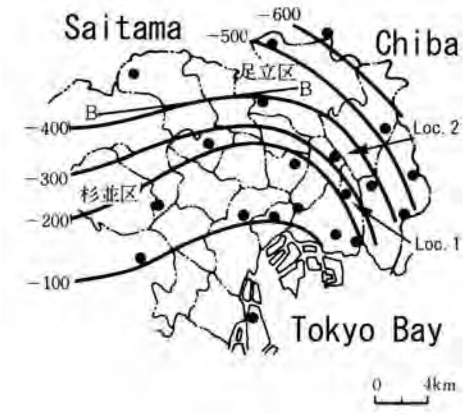

Fig.2 Contour map showing the depth of the bottom of the aquifer-aquitard system at Tokyo [1].

Fig. 3 shows the examples of the change of groundwater potentials of confined aquifers together with the extraction rate of fresh groundwater (white bars) and formation waters (black bars). The formation waters were extracted for mining methane gas dissolved in water and it had been one of the main causes for severe ground subsidence in this area [2].

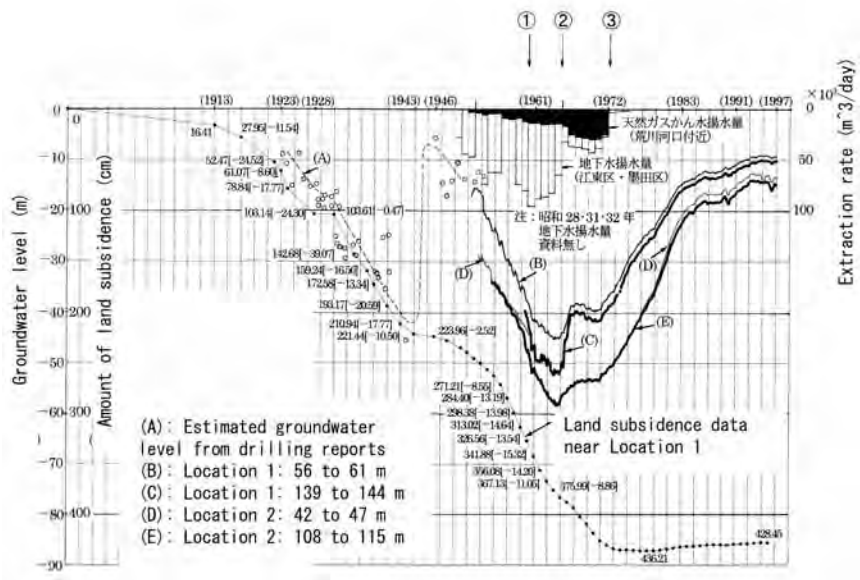

Fig.3 Examples of the change of confined groundwater potential in Tokyo from 1881 until 1997 [2]. Localities of the wells are shown in Fig.2. White bars indicate the extraction rate of groundwater and black bars that of formation waters. The events shown are: ① Southern part of the alluvial lowlands in Tokyo was designated by the Industrial Water Law (IWL) as a restricted area where no new wells were to be installed for industrial usage, ② Pumping of groundwater for industrial usage in southern part of the alluvial lowlands was restricted by IWL, and ③Extraction of methane gas dissolved in water was suspended in the southern part of the alluvial lowlands by means of purchasing the mining rights by Tokyo Metropolitan Government.

3. Hazards caused by the significant drop of groundwater potential

As shown in Fig. 3, the groundwater level of the confined aquifer had dropped to about 50 m below ground surface in the early 1970s. Because of the significant decline of the groundwater level, severe land subsidence appeared as a direct result of over-exploitation of groundwater (Fig. 4). Also, several confined aquifers had changed to become unconfined conditions and introduced the oxygen-deficient air mass under the ground. The oxygen-deficient air migrated along the aquifer during underground construction by pneumatic caisson method and caused deaths of people staying in basement floor (Fig. 5).

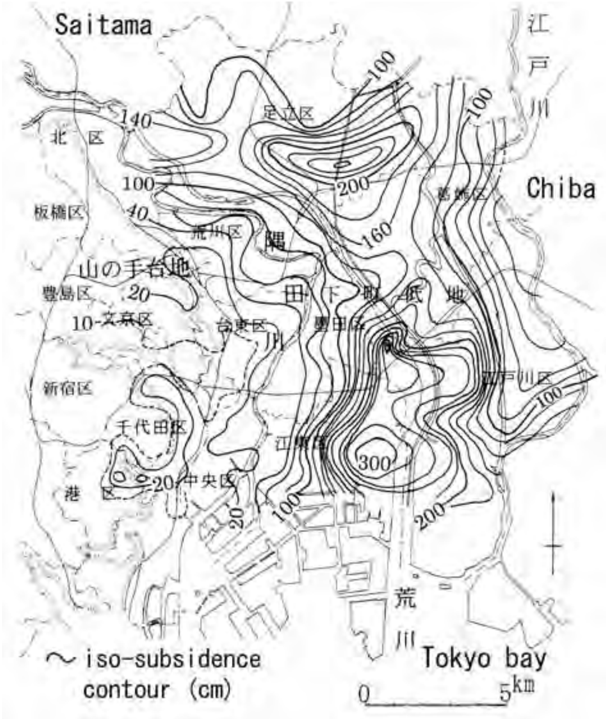

Fig.4 Contour map showing the subsidence between 1938 and 1977 at lowland Tokyo [2].

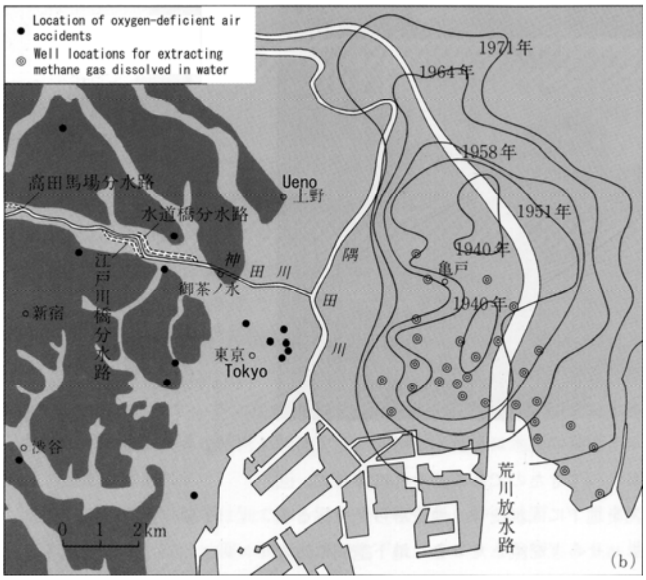

Fig.5 A map showing the distribution of the oxygen-deficient air accidents. Dots indicate the location of oxygen-deficient air accidents, and double circles the location of wells for extracting methane gas dissolved in water. Contour shows the extent of below zero meter region at 1940, 1951, 1958, 1964, and 1971 [3].

4. Regulation of groundwater use to cease land subsidence

Because of the serious problems related to the over-extraction of groundwater, the local government and Japanese national government decided to regulate the groundwater extraction to the absolute minimum. From January 1961 until April 1974, the Japanese national government and the Tokyo Metropolitan government with its surrounding three prefecture governments implemented the following groundwater regulation laws. The national government has restricted groundwater withdrawal for industrial use since 1961 by the Industrial Water Law (IWL) (in 1961, southern part of alluvial lowland was designated as a restricted area where no new wells were to be installed for industrial usage; in 1966, pumping of groundwater for industrial usage in southern part was restricted; in 1971, pumping of groundwater for industrial usage in the northern part was restricted), and for air conditional use since 1963 by the Law Controlling Pumping of Groundwater for Use in Building. In 1972, extraction of methane gas dissolved in water was suspended in the Tokyo area by means of purchase of the mining rights by Tokyo Metropolitan Government.

After implementing these regulations, groundwater potentials have recovered quickly, as shown in Fig. 3, far better than expected. The rapid recovery of groundwater levels have been considered to be due to the relatively high recharge rate (2 to 3 mm/day) in this region [4,5].

5. Problems of underground infrastructures due to the recovery of groundwater potential

Even though the land subsidence in Tokyo area has ceased and groundwater level has recovered, it has caused new types of damages to the underground infrastructures which have been constructed during the drawdown period of groundwater level in the region. The following shows an example of the problem.

Tokyo underground station was designed at 1965 and has been operated from 1972. At the time of its design, the groundwater level at the location was 35 m below the ground level, however, it has continuously recovered and reached to be 15 m below the ground level in 1998. The detailed investigation for the possible damage to the station revealed that the buoyant water pressure was quite high, and critical groundwater level for the severe damage was estimated to be 14.3 m below ground [6]. The East Japan Railway Company decided to conduct countermeasure construction work to the station by applying ground anchor technique (Fig. 6), which makes it possible to support the underground station until groundwater level be 12.8 m below ground [7]. Similar problems have been reported in Tokyo area (Ueno underground station [7]) and rebuilding operation close to Osaka station in Osaka prefecture [8]. Hirose et al. [9] summarized the published data on infrastructure damages caused by the recovery of groundwater level in Tokyo area.

Groundwater levels of confined aquifers have still been recovering (see Fig. 3), and accurate prediction of the rate of recovery and of the final groundwater level is necessary to plan the maintenance operations for the underground infrastructures.

6. Efficient usage of “surplus” groundwater to improve environments

Because of the recovery of groundwater level, the amount of leakage water into the underground structures has been increased. Usually, the leaked water is damped to the sewer. However, several plans for efficiently using the leakage water into the structures are presented to improve the surface water environments and some of them have been implemented.

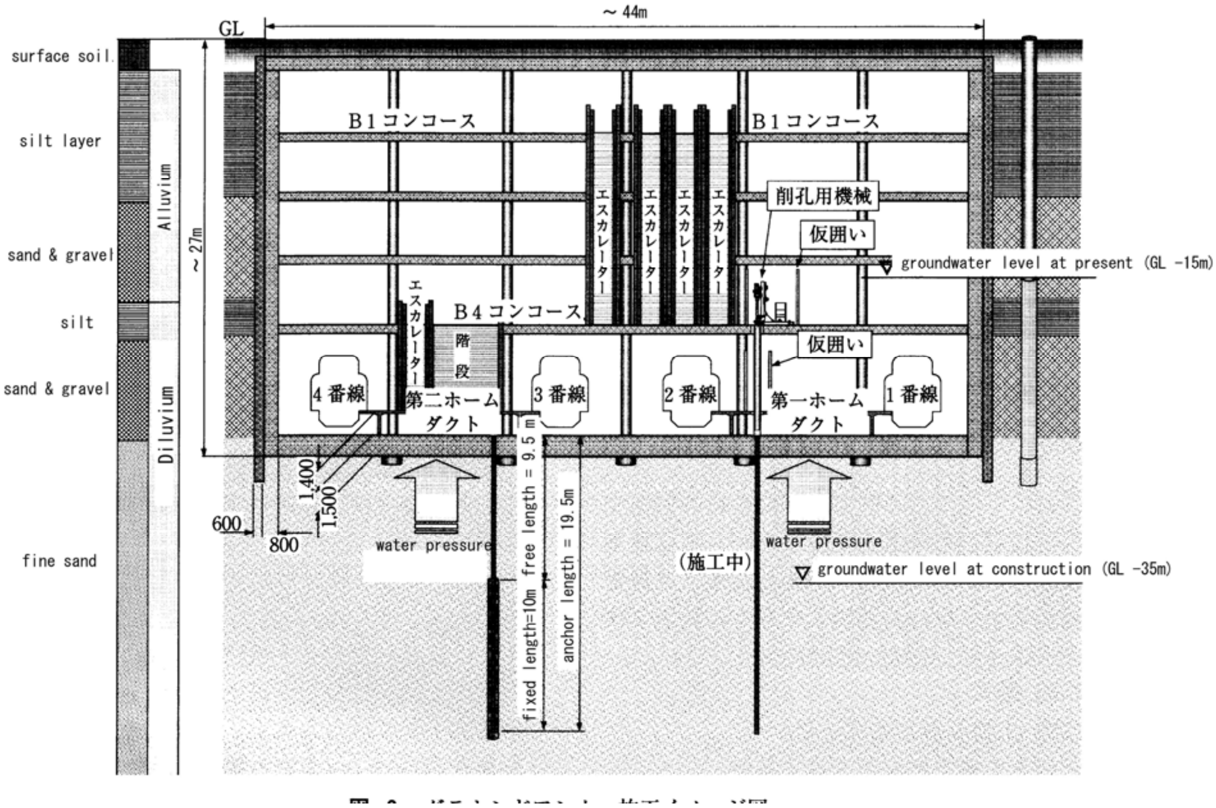

Fig.6 Schematic diagram showing the situation at the Tokyo underground station and the image of the countermeasure construction work to the recovery of groundwater level [7].

Here shows one example which has been done by the East Japan Railway Company, the Tokyo Metropolitan Government, and the Kokubunji City [6].

The Kokubunji tunnel of the Musashino line was constructed and has been operated since 1973. This tunnel is oriented perpendicular to the general groundwater flow direction of the area, and was experienced groundwater related problems at 1974 and 1991, respectively, due to the rapid increase of groundwater level and seepage by heavy rain. To prevent the rapid increase of groundwater level, twenty-four drain pipes were set and controlled the groundwater level. From 2002, the drained groundwater has been used to restore a local small pond and to increase the flow rate of the river to improve the local surface environments (Fig. 7).

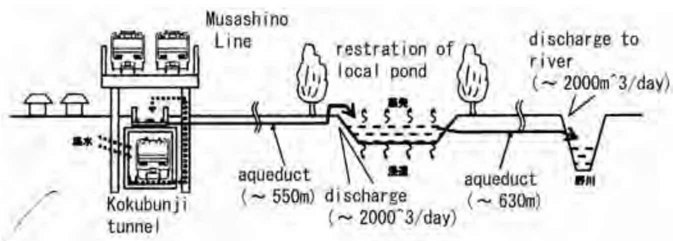

Fig.7 An example of efficient usage of leaked water into the tunnel (the Kokubunji tunnel) [6]

Recently, Kajino et al. [10] presented an idea to use “surplus” groundwater for cooling the pavement in the urban area to reduce heat-island phenomenon. Their idea comes from the fact that the groundwater temperature usually is very close to the annual mean temperature of the area and is much lower than the pavement temperature in summer. Considering that there exists “surplus” groundwater in the urban area and heat exchange can be done by applying cooler groundwater to the permeable pavement, it might be possible to control and improve the urban summer environments.

Similar and other ideas to efficiently use the groundwater to improve the urban environments and at the same time reduce the damage to the infrastructure are necessary to achieve the sustainable development of the urban areas.

7. Conclusions

This paper summarized the temporal changes of the underground environments and related hazards at the Tokyo Metropolitan Area. It is possible to divide the evolution into three stages, i.e., deterioration of underground and surface environments due to over exploitation of groundwater (first stage), regulation of groundwater extraction to the absolute minimum and the recovery of groundwater potentials (second stage), and damaging underground infrastructures by buoyant force and increase of groundwater seepage due to the recovery of groundwater potentials (third stage). Recent activities to use “surplus” water to improve the urban environments and to reduce the damage to underground infrastructures were shown. These activities should be expanded to achieve the sustainable development of the urban cities.

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Groundwater Dating Using Chlorofluorocarbons (CFCs) as a Tracer

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1. Dating of groundwater

Residence time of groundwater is essentially important factor to elucidate the hydrological processes in a certain region. The radio isotope of ^{3}H has been used for dating of groundwater and surface water since 1960's, however the ^{3}H is ineffective recently in Japan, because the ^{3}H concentration of precipitation has been approximately under 5 T.U. during recent 10 years (Fig. 1). Chlorofluorocarbons (CFCs) has been broadly used for dating of young groundwater instead of ^{3}H since 1990's, because (1) the atmospheric mixing ratios of these compounds are known and/or have been reconstructed over the past 50 years, (2) the Henry's law solubilities in water are known, and (3) concentrations in air and young water are relatively high and can be measured. Also, the CFCs have higher solubility and lower diffusion coefficient as compared with ^{3}He gas used in $^{3}H/^{3}He$ method, so the CFCs are useful especially for dating shallow groundwater (Plummers and Busenberg, 1999).

In Japan, however, the CFC's has been used only by oceanographic scientific community, whereas there has been previously no data on CFCs concentration of terrestrial water such as groundwater, soil water and surface water. An establishment of analytical and calibration scheme is highly required also in Japan.

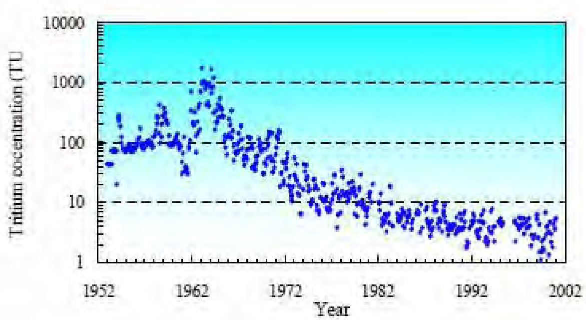

Fig. 1 Tritium concentration in precipitation observed in Japan (Shimada, et al., 1994; Yabusaki, et al., 2003).

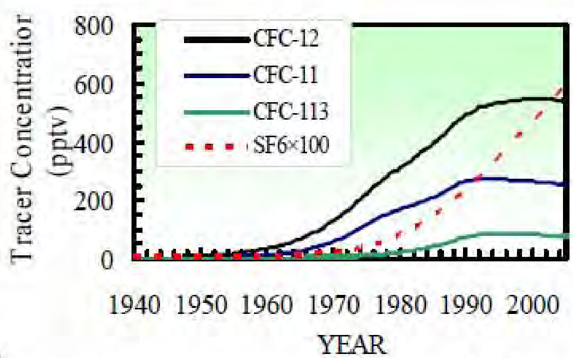

Fig. 2 Temporal change of CFCs concentration in the atmosphere (USGS, 2004).

2. Analysis of CFCs in groundwater

The CFCs concentration of the terrestrial water is generally analyzed using gas chromatograph and preparation system. Its feature includes a pulsed electron capture detecter, a sample handling system to remove CFCs from water and inject onto a chromatographic column (Fig. 3; Thompson and Hayes, 1979).

We are constructing a new simple analytical line of CFCs concentration of groundwater based on Thompson and Hayes (1979), and Bullister and Weiss (1988) as shown in Figs. 4 and 5. It is easy to handle and not crucial to proceed the purification of gas, and loss can be minimized during the process. A calibration will be performed soon using ^{3}H method.

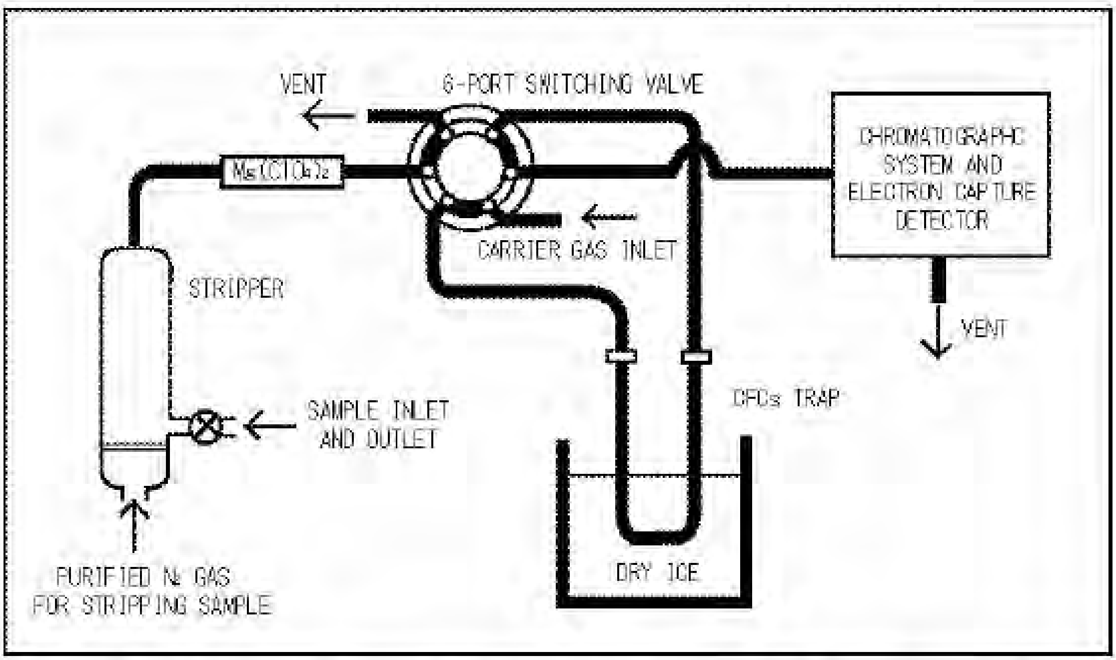

Fig. 3 Schematic drawing of the portion of the chromatographic system which isolates the sample (Thompson and Hayes, 1979).

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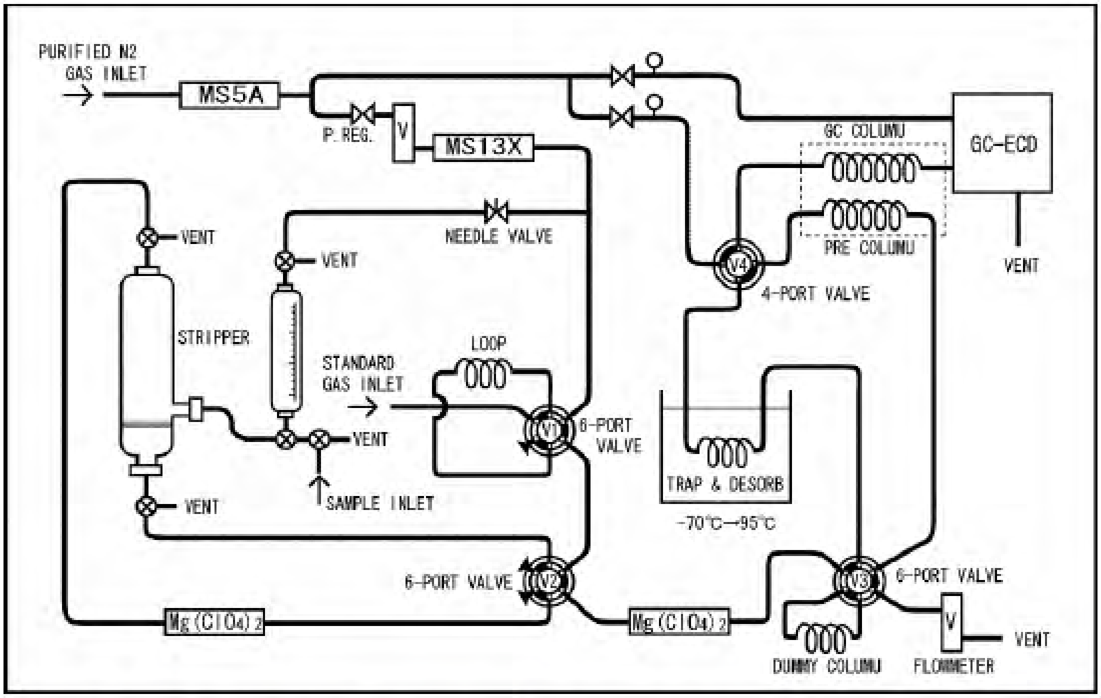

Fig. 4 Schematic diagram showing a new preparation line of groundwater for the analysis of CFCs concentration.

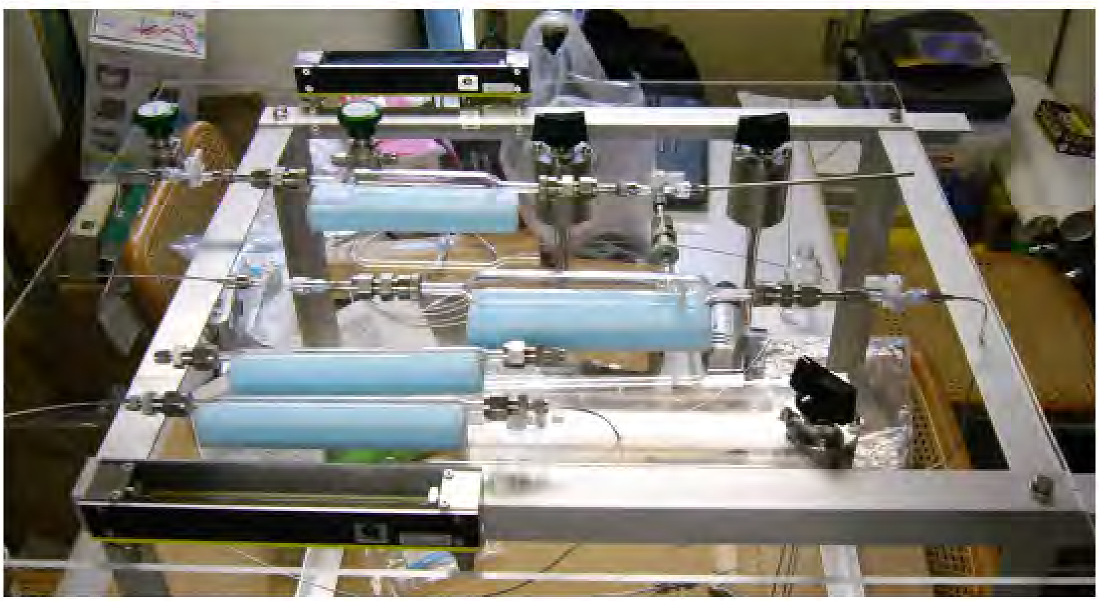

Fig. 5 Photograph showing a outline of the system illustrated in Fig. 4.

USE HEAT AS GROUNDWATER TRACER IN INDONESIA

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Abstract

It is well known that the distribution of subsurface temperature is affected by groundwater flow, and temperature data can be used to evaluate the direction and velocity of groundwater flow. Heat is transferred by ground water serves as a tracer to identify flow patterns in ground water basins. Temperature data are also used in formal solutions of the inverse problem to estimate groundwater flow and hydraulic conductivity. Temperature measurements can be analyzed for recharge, discharge rates and the effects of surface warming, interchanging with surface water, hydraulic conductivity of streambed sediments and basin-scale permeability.

This paper intends to provide some evidence of these effects on groundwater basin research in Indonesia. Temperatures measured in several monitoring wells, were used to estimate recharge and discharge area base on groundwater flow direction in Jakarta and Bandung Groundwater Basin. Groundwater flow system of the area was determined from borehole temperature profile classification, thermal gradient-temperature relationship and hydraulic head measurement.

As a result, subsurface temperature data showed a good relationship with geological condition of the area, groundwater flow condition and reflects good information of recharge and discharge area.

1. Introduction

Groundwater resources have always contributed substantially to the supply of water in Indonesia. In some groundwater basin, the use of groundwater has greatly accelerated conforming to the rise in its population and the development of industrial sector, which consume a relatively huge amount of water. The increase of groundwater exploitation in some Groundwater Basin has already caused a negative impact on these resources itself both quantity and quality. In addition the changing environment as consequence of the development has also brought undesirable effects to the quantity of groundwater. Therefore, protection of groundwater based on the resources management model in relation with regional planning and land use planning based on environmental geology aspects, is indispensable. To establish the management goal, determining recharge and discharge area for groundwater regional flow system became very important.

It is well known that the distribution of subsurface temperature is affected by groundwater flow, and temperature data can be used to evaluate the direction and velocity of groundwater flow (Smith & Chapman, 1983; Sakura et.all, 1978 & 2001). Heat is transferred by ground water serves as a tracer to identify flow patterns in ground water basins. Temperature data are also used in formal solutions of the inverse problem to estimate groundwater flow and hydraulic conductivity. Temperature measurements can be analyzed for recharge, discharge rates and the effects of surface warming, interchanging with surface water, hydraulic conductivity of streambed sediments and basin-scale permeability.

This paper intends to provide some evidence of these effects on groundwater basin research in Indonesia. Temperatures measured in several monitoring wells, were used to estimate recharge and discharge area base on groundwater flow direction in Jakarta and Bandung Groundwater Basin (Lubis et.all, 2005; Delinom et.all, 2003). Groundwater flow system of the area was determined from borehole temperature profile classification, thermal gradient-temperature relationship and hydraulic head measurement.

2. Methodology

Groundwater temperature can be measured easily and rapidly by lowering a thermometer down a borehole. In this study, subsurface temperature and hydraulic head measurements were generally made in some observation wells, which are assumed to be in thermal equilibrium with the surrounding aquifer. The thermal profiles and water levels were measured in several observation wells.

The thermal-profile measurements were made at 2-m intervals from the water level to the bottom of the hole with a digital thermister thermometer of 0.01 °C precision, attached to a 300 m long cable (figure 1). The boreholes selected are monitoring well, therefore ideal for thermal studies. Due to the time elapsed since their construction, they can be considered to have attained steady-state thermal conditions and not influenced by movement of water in the borehole (representative of water in the aquifer). The observation wells are constructed of steel casing. The diameter of the observation wells ranges from 4 – 6 inch. A temperature profile is plotting versus depth.

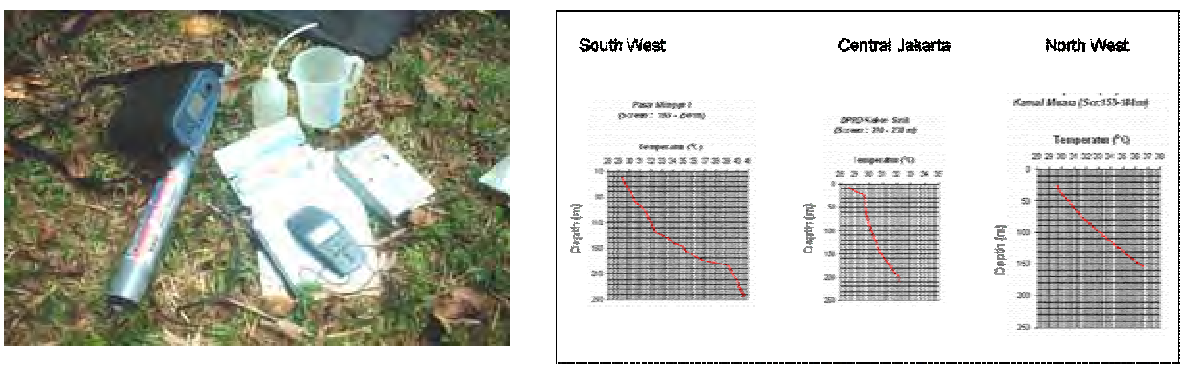

Fig.1. Thermister thermometer and thermal profile measurement

3. Study Area

In order to apply above method to the field, measurement groundwater temperature-depth profiles have been carried out. The study area is located in Bandung groundwater basin and Jakarta groundwater basin, Indonesia (figure 2)

3.1 Bandung Groundwater Basin

This basin is located in the West Java Province with an elevation which ranges between 660 – 2,750 m above sea level and it lies on the intra arc mountain of the West Java Province. It is located between 107°15' - 108°45' E Longitude and 6°50' - 7°50‘ S latitude with an area around 2670 km^2. Bandung Basin has a humid tropical climate (22.7^{o}C); annual rainfall is high between 2000 - 3500 mm due to influence of monsoon. 19 observation wells (20 – 200 m deep) were measured from June to July, 2002

3.2 Jakarta Groundwater Basin

It is one of the most developed basins in Indonesia as Jakarta City is located within the basin, with an elevation which ranges between 0 – 1000 m above sea level. Jakarta which is the capital of the Republic of Indonesia, lies on the coastal plain of the Java Sea (to the north) and is bordered by Jakarta Bay in the north, West Java province in the south, east and Banten province in the west. It is located between 106^o 33’ - 107^o ’E longitude and 5^o 48’ 30” - 6^o 10’ 30” S latitude with an area around 652 km^2. Greater Jakarta has a humid tropical climate (29^{o}C); annual rainfall is high between 1500 - 2500 mm due to influence of monsoon. 51 observation wells (40 – 200 m deep) were measured, on July, 2004.

Fig.2 Location of study site

4. Result

As a result in both groundwater basin, subsurface temperature data showed a good relationship with geological condition of the area, groundwater flow condition and reflects good information of recharge and discharge area.

4.1 Recharge and Discharge Area in Bandung Basin

All data showed that the recharge area is distributed in the hills and upland areas located along the periphery of the plain (figure 3). The highest recharge area was estimated to take place on the summits of the Southern Mountainous Complex. No indication was found of higher elevation water recharge in the northern part of the basin, which means the water recharged in the Northern Mount area did not reach the Bandung Plain. The recharge in the northern part of the basin mostly came from intermediate elevation and filled the intermediate flow system. Two local groundwater flow system discharged from foot -slope of the hills distributed along the periphery.

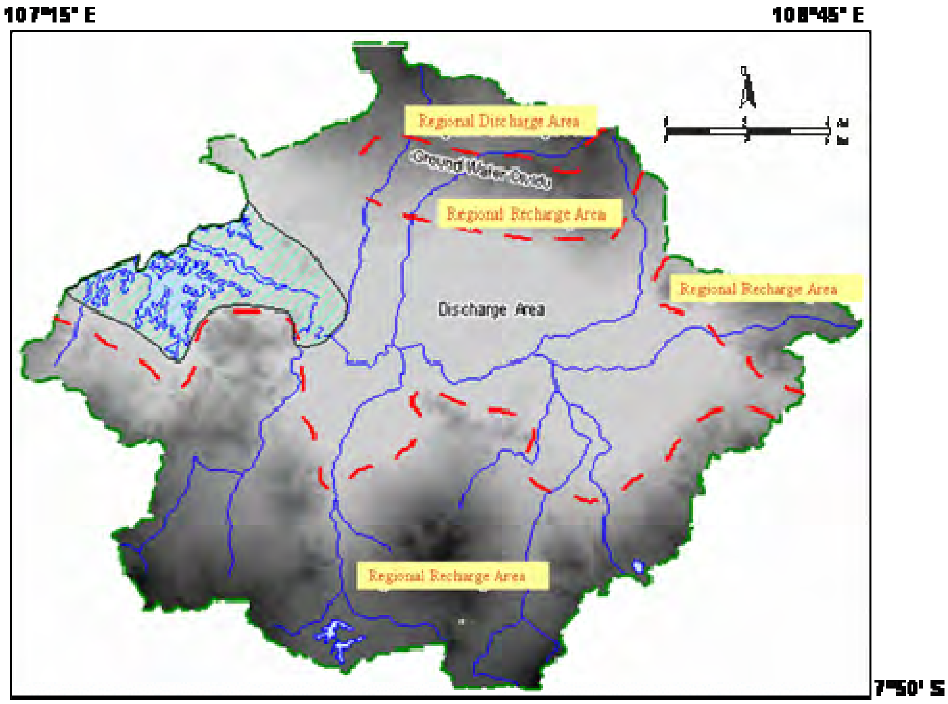

Fig.3 Distribution of the recharge type, intermediate type and discharge type using subsurface temperature profiles in Bandung Groundwater Basin

4.2 Recharge and Discharge Area in Jakarta Basin

Subsurface temperature distribution is strongly affected by heat advection due to groundwater flow. Under natural flow conditions, the recharge area of the deep aquifer system is located in the hilly area. Discharge area from the confined aquifer to the natural base level in the flat coastal area, occurred mainly by upward leakage and outflow to the surface water system (figure 4).

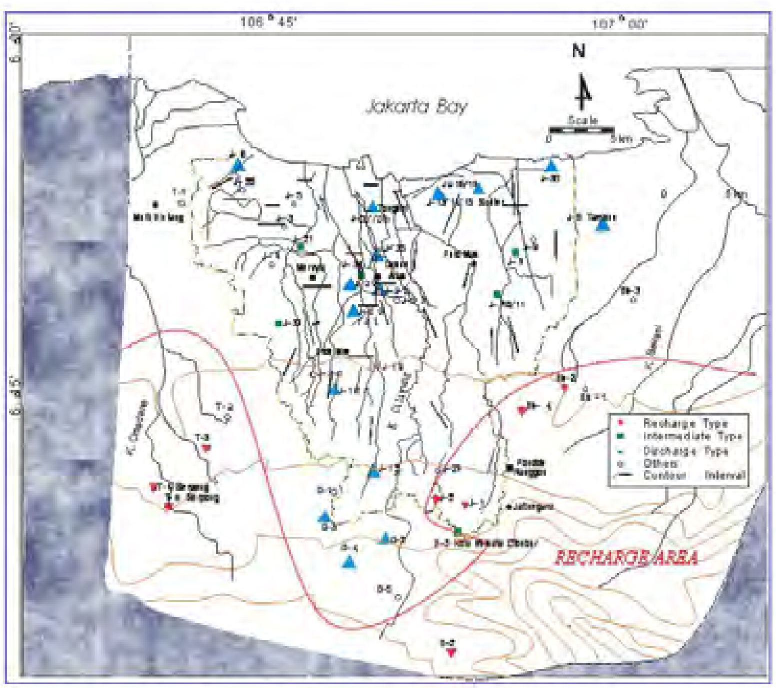

Fig.4 Distribution of the recharge type, intermediate type, discharge type and others using subsurface temperature profiles in Jakarta Groundwater Basin

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Study of subsurface temperature environment in metropolitan Seoul area

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1. Introduction

Subsurface temperature distribution preserves history of ground surface temperature (GST), hence it is an excellent index of the urbanization and climatic change. As shown by strong city heat-island effect, GST has increased by human activities in the urban areas. Although the mean rate of warming by meteorological surface air temperatures (SAT) of 0.3 to 0.5 K due to global warming estimated in the last centennial interval, it is recognized that SAT shows the warming of more than 2.5 K / 100 years in the Japanese large cities such as Tokyo and the Kanto area (Miyakoshi et al, 2003). Subsurface temperature environment seems to be affected by the drastic warming trend as shown in the SAT change in urban area.

Increase of GST causes increase of subsurface temperature at shallow depth. This effect is shown at depths shallower than those of minimum temperature in the temperature-depth profile. The effect the urbanization has on the subsurface environment can be evaluated using the temperature increase data and the depth of the minimum temperature in temperature-depth profile.

The purpose of this study is to evaluate the effect of urbanization on the subsurface temperature environment in the Seoul area, Republic of Korea. In 2005, we collected data on temperature-depth profiles of 15 wells as preliminary field survey.

2. Study area

Seoul area is situated between the mountains in the north and south, and the Han River flows from east to west through the central part of this area. Eight observation points were located in the north of Han River while 7 points in the south (Figure 1). Figure 2 shows the geological map of Seoul area. Jurassic granite and Pre-Cambrian gneiss are exposed in uplands and mountains, while alluvium fills lowlands along the rivers. Seven observation points are located in alluvium, 5 in granite, and 3 in gneiss.

3. Observation methods

Temperature-depth profiles at 15 wells from 3/Aug/2005 to 5/Aug/2005 were obtained. Those wells have been used for the source of emergency water supply. Temperature was measured at 1 m interval from the top of water level to the bottom of the well using thermister thermometer (resolution 1/100 ℃).

4. Results

Temperature-depth profiles show contrasting difference in temperatures between the north and the south clearly demarcated by Han River (Figure 3). Temperature is more than 16.9 ℃ in the north, with particularly high temperatures of 17.4 to 18.2 ℃ shown at #CH, #1, #45 and #66 wells. In the south, temperature is lower than 16.9 ℃. Especially low temperatures less than 16.2 ℃ are shown at #5 and #98.

5. Discussion

Observed temperature-depth profiles show that the temperatures higher than 17.4℃are located in granite or gneiss areas in the north. On the other hand, temperatures between 16.9 and 17.4 ℃ are found in alluvium areas. In the south, subsurface temperatures are found to be lower than the north. Especially low temperatures less than 16.2 ℃ occur at #5 and #98. #5 is located in alluvium area. However, #98 is located in gneiss area at comparatively high elevation of 52 m above sea level. The subsurface temperature distribution thus seems to be related with topography and geology in the Seoul area.

Thermal gradients at depths are considered to be 2.4 to 2.6 ℃/100m in the Seoul area (GSJ and KIGAM, 2002). Thermal gradients in the shallower depths than 100 m are estimated to be about 0.7 K/100 m using the temperature-depth profile of #99. This gradient is lower than that of the deeper part. The difference in thermal gradients between the shallow and deep parts suggests that observed temperature-depth profiles are affected by groundwater flow.

Groundwater temperature data from 8 wells (#1, #5, #12, #37, #45, #55, #66 and #105) were reported in 2001 (Kim et al., 2001, Figure 3). Observed subsurface temperatures in this study were 1.6 to 2.0 ℃ higher than the previous data. However, this increase cannot be explained by surface warming within the last 5 years. Since the previous data show daily fluctuations, our data seem to be interfered with intrusion of low temperature groundwater flow from pumping.

6. Conclusions

(1) Subsurface temperatures in the northern area of Seoul are 0.6 to 0.8 ℃ higher than those in the southern area.

(2) The temperature distribution is related to the topographical and geological characteristics of Seoul area. In the north, areas of gneiss or granite show relatively high temperatures while alluvium area show relatively low temperatures. In the south, uplands and alluvium areas along the branch of Han River show low temperatures.

(3) Subsurface thermal gradient in the shallow depths is lower than that in the depths. The difference suggests observed temperature-depth profiles have been affected by groundwater flow.

(4) Observed subsurface temperatures are 1.6 to 2.0 ℃ higher than those reported in 2001. This higher temperatures cannot be explained with surface warming or other effects in human activity such as pumping

(5) Temperature data with higher quality than those of this study are required for the evaluation of the effects of urbanization using subsurface temperatures. The temperature-depth profiles acquired by measurements in observation wells are indispensable for this purpose.

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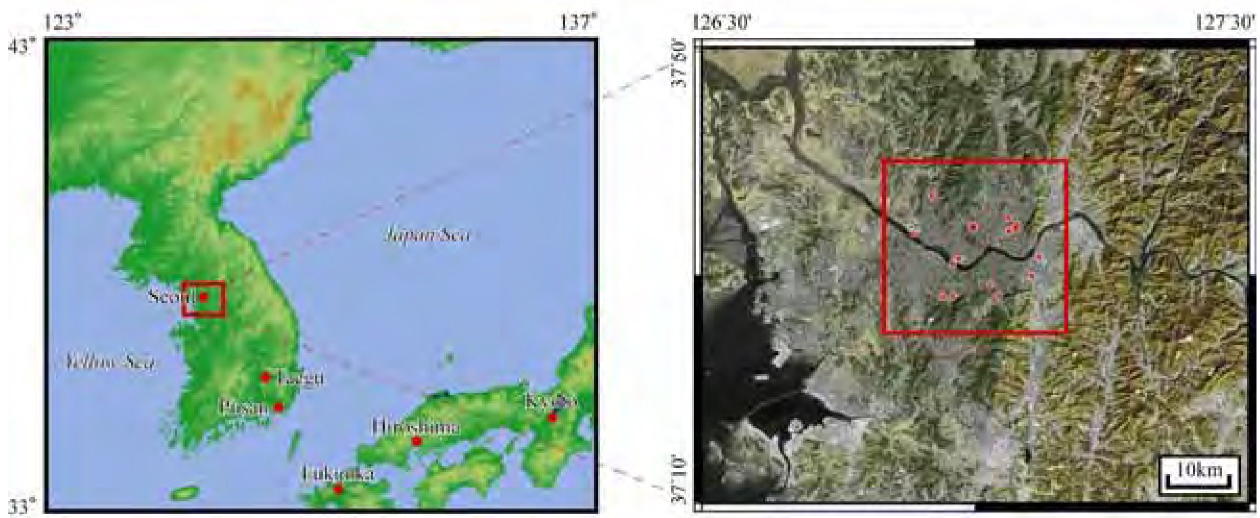

Figure 1. Study area

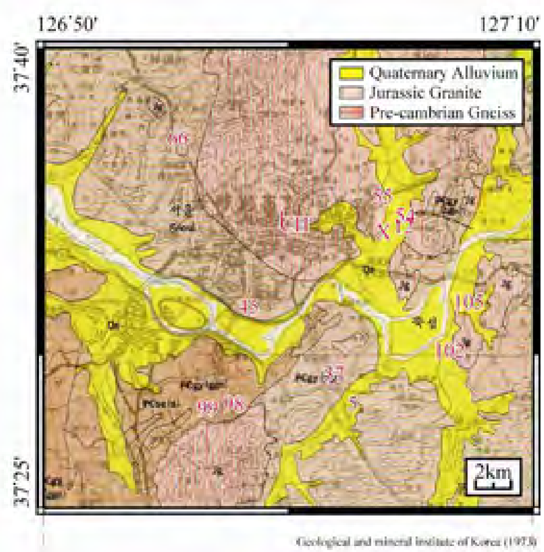

Figure 2. Geological map

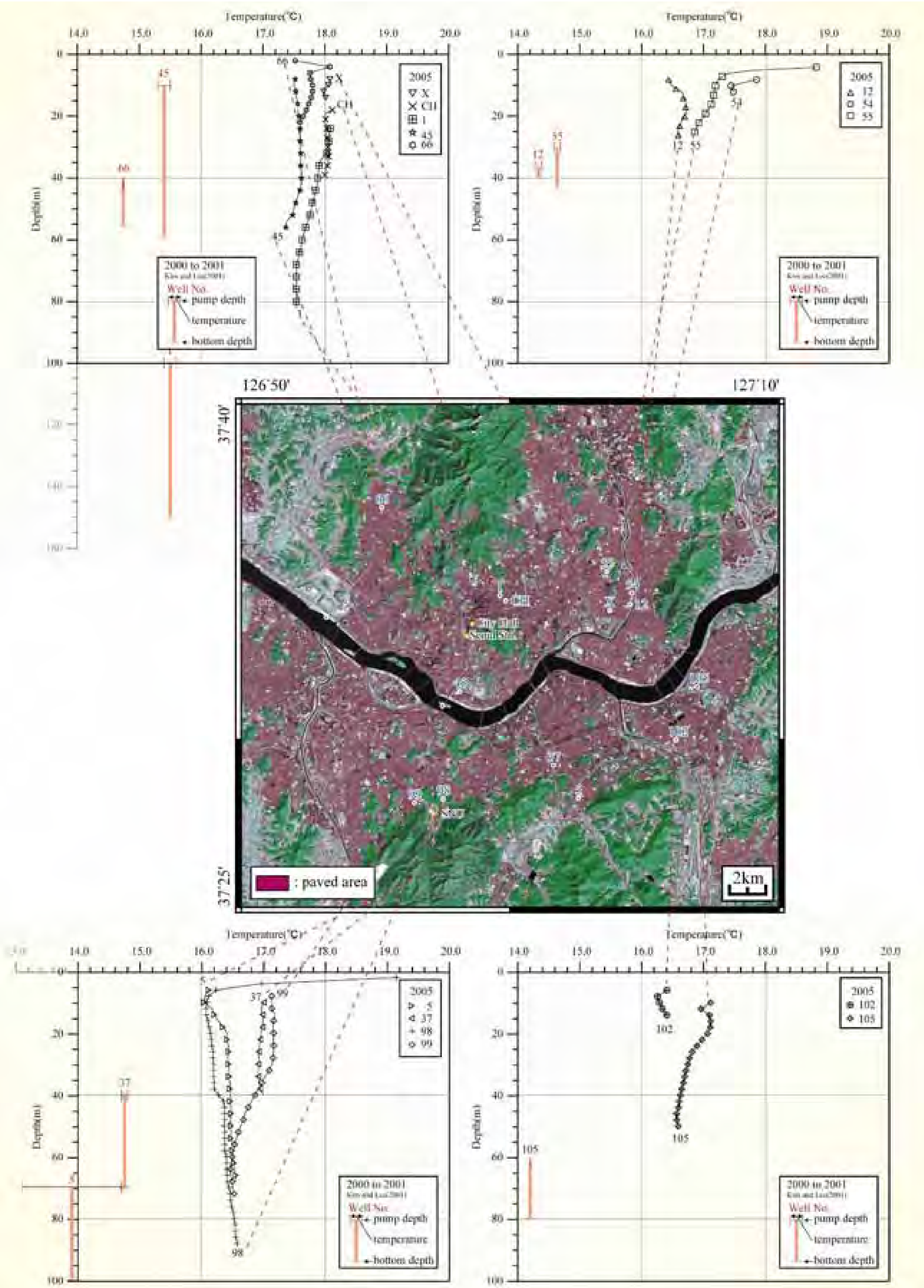

Figure 3. Temperature – Depth profile

Thermal Environmental Data in Thailand

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[2] Former・National Institute for Environmental Studies, Japan

Abstract

Meteorological data distributed by Thai meteorological department is from January 1951. Most of stations started with only daily observation and added three-hourly observation after 1981. Only eight stations provide hourly observation data that started after 1987 instead of three-hourly observation data. The number of meteorological observatories in Thailand is smaller than that in Japan. Observation period is also shorter. Therefore, field surveys for searching new data source are important.

Yearly mean temperature at Bangkok Metropolis station, representative observatory in Bangkok city, increased about 1.5˚C from 1951 to 2004. Period of higher temperature season became longer, and especially temperature between July and August increased. These months are rainy season in Thailand.

Bangkok Metropolis station moved twice in Bangkok city. However, it is difficult to consider the effects of those relocations to temperature, because the information about relocations of observatories is not enough in public. Studies for making confidential data from field surveys are essential.

1. Introduction

Studies about thermal environment in Thailand are quite few (For example, Niitsu 2000; Naas *et al.* 1995) and thermal environmental data existing in Thailand is not well known. Then, in this paper, we introduce the meteorological data related with the thermal environment of Thai meteorological department (hereafter, TMD) and examine variations of mean temperature at Bangkok Metropolis station from 1951 to 2004.

Fig.1 Thai meteorological department (March, 2005)

2. Meteorological data of TMD

Meteorological data distributed by TMD (Fig.1) is from January 1951. Fig.2 shows the location of observatories and year when observation was started. Total number of observatories is eighty-seven including Surat Thani station that was abolished in 1998. Although observatory is increasing, the number of stations in Thailand is smaller than that in Japan. Observation period is also shorter. Most of stations started with only daily observation and added three-hourly observation after 1981. Only eight stations [Chiang Mai, Phitsanulok, Ubon Ratchathani, Bangkok Metropolis, Don Muang (airport), Surat Thani (airport), Hat Yai (airport), and Phuket Airport] provide hourly observation data that started after 1987 instead of three-hourly observation data.

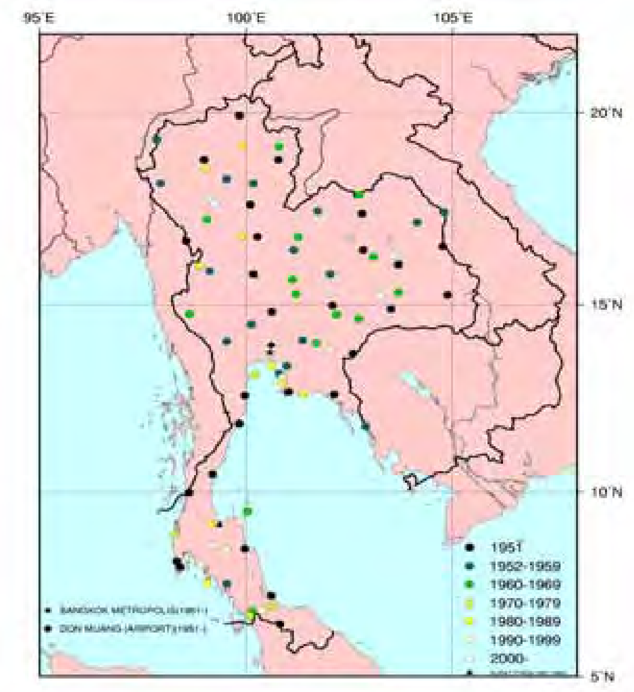

Fig.2 Location of observatories and year when observation was started

Tab.1. List of observation elements (from the TMD)

METEOROLOGICAL DATA	HOURLY	THREE HOURLY	DAILY	MONTHLY
PRESSURE	1	1	4	4
TEMPERATURE	1	1	4	4
MAXIMUM TEMPERATURE			2	5
MINIMUM TEMPERATURE			2	5
RELATIVE HUMIDITY	1	1	4	4
VISIBILITY	1	1	4	4
CLOUD AMOUNT	1	1	4	4
WIND SPEED / DIRECTION	1	1		4
MAXIMUM WIND			2	5
EVAPORATION			2	5
RAINFALL	1	1	2	5
SUNSHINE DURATION	1		3	3
SOLAR RADIATION	1		3	
PHENOMINA			2	5

LEGEND

1	OBSERVATION
2	OBSERVATION
3	PROCESS FROM HOURLY DATA
4	PROCESS FROM THREE HOURLY DATA
5	PROCESS FROM DAILY DATA

Tab.1 shows current observation elements. This table was obtained from TMD. Some elements of daily and monthly data are processed from hourly or three-hourly observation data.

3. Variations of mean temperature at Bangkok city

Representative observatory in Bangkok city (Fig.3) is Bangkok Metropolis station. Bangkok Metropolis station moved twice in Bangkok city, shown in Fig.4 (1951-1991: Sukhumvit, 1992-1993 Bang Na, 1994- Chaloemprakiet). Since latitudes and longitudes of old stations are not opened officially, we obtained those data by hearing.

Fig.5a shows variation of yearly mean temperature at Bangkok Metropolis station from 1951 to 2004. Under assumption of those relocations affected small impact to yearly mean temperature, temperature increased about 1.5˚C for past 54 years.

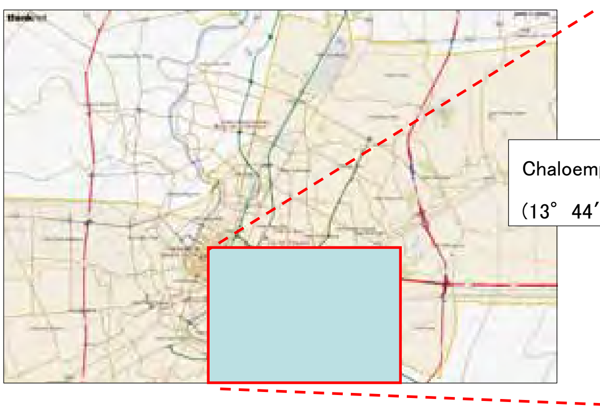

Fig.3 Bangkok City

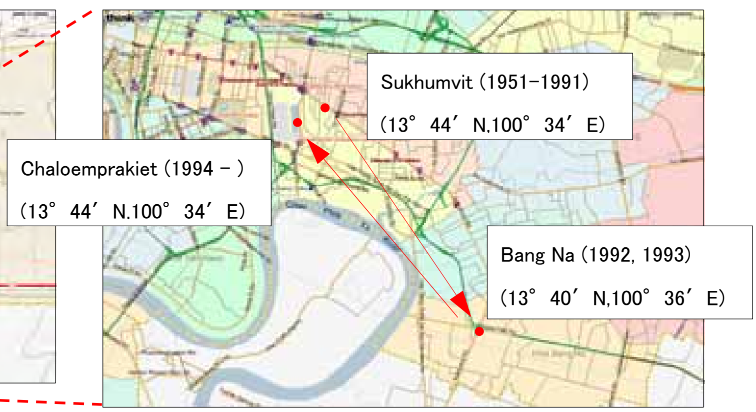

Fig.4 Relocations of Bangkok Metropolis station (Latitudes and longitudes of old stations are obtained by hearing)

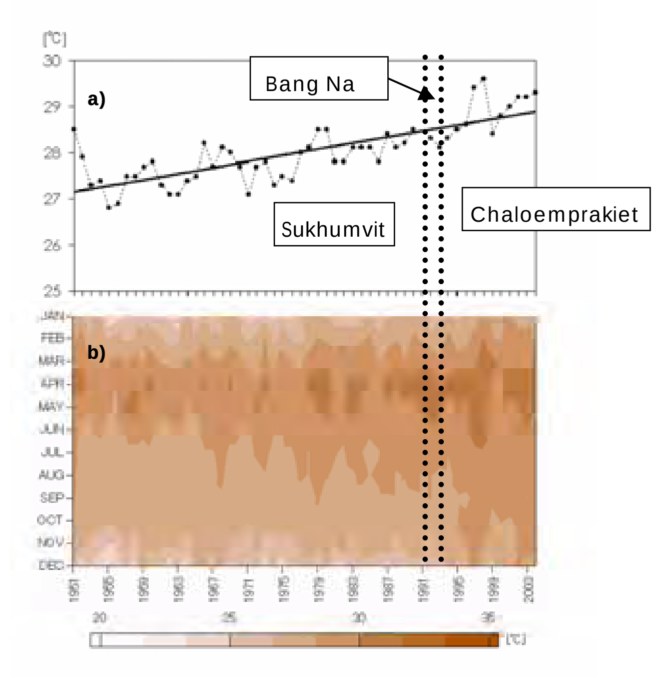

Fig.5 Variation of a) Yearly and b) Monthly mean temperature at Bangkok Metropolis station (1951-2004)

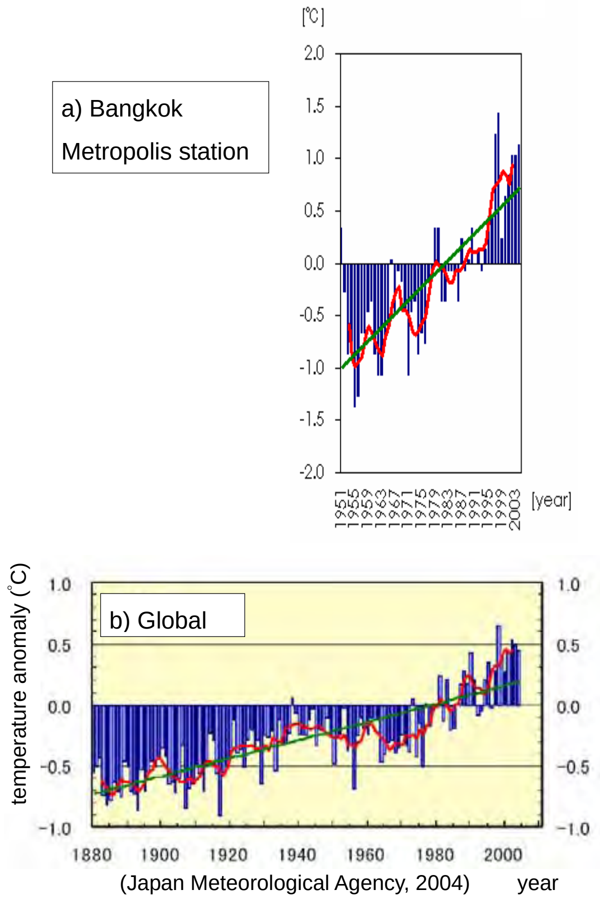

Fig.6 Anomaly of a) Bangkok Metropolis station (1951-2004) and b) global (1880-2004) mean temperature

Fig.5b shows variation of monthly mean temperature at Bangkok Metropolis station. It is obvious that period of higher temperature season became longer even when the period after station moved (after 1992) is ignored. This figure also shows temperature between July and August increased especially. These months are rainy season in Thailand.

Fig.6 shows anomaly of a) Bangkok Metropolis station (1951-2004) and b) global (1880-2004) mean temperature. Anomaly of global is quoted from Japan meteorological Agency (2004). Both anomalies changed from negative to positive in the 1980's and could be considered indicating global warming. Increasing amount of Bangkok Metropolis station is larger than that of global.

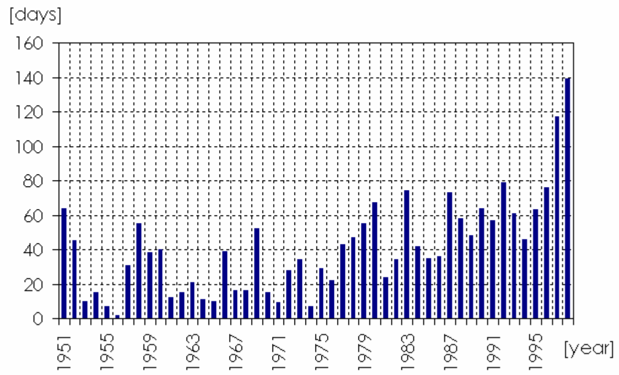

Fig.7 Number of days that mean daily temperature is ≧ 30˚C (1951-1998)

Fig.7 shows number of days that mean daily temperature is ≧ 30˚C from 1951 to 1998 (recent data is not yet obtained). The number of such days has increased since latter half of 1980's and became over 100 in 1997 and 1998.

These tendencies are need to be compared with other stations in Thailand and countries in different latitudes.

4. Future assignment

The number of meteorological observatories in Thailand is smaller than that in Japan. Observation period is also shorter. Therefore, field surveys for searching new data source are important. Moreover, information about relocations of observatories is not enough in public. Studies for making confidential data from field surveys are essential.

5. Remarks

Thai meteorological department(TMD） http://www.tmd.go.th/index_eng.php

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Groundwater Discharge Mechanism around Tokyo Bay Estimated by Subsurface Temperature

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ABSTRACT

Previous studies and borehole temperature measurements have suggested that subsurface temperature distribution on the west side (from Tokyo to Yokohama) of Tokyo Bay is higher than that of the east side (Chiba side). In order to understand the characteristics of the groundwater flow systems and other factors which may contribute to the subsurface temperature, a couple of cross-sections have been made. Data of groundwater temperature profiles measured, both from previous studies and this study, have been used. Moreover, preliminary numerical simulation of groundwater flow and subsurface temperature distribution along Tokyo Bay is carried out.

These results show that the subsurface temperature in the Tokyo area is higher than in Chiba. This fact suggests that groundwater discharges into Tokyo Bay. The different distance of recharge area results in the variability of the topographical driving force. Human activities such as urbanization and groundwater pumping also affect the subsurface temperature and groundwater flow systems in the study area. The result of the numerical simulation confirms the subsurface temperature variation along Tokyo Bay.

Keywords: *SUBSURFACE TEMPERATURE, TOKYO BAY, GROUNDWATER FLOW SYSTEM, OBSERVATION WELL*

1. INTRODUCTION

Tokyo is one of the most populated and urbanized cities in Japan. There are some studies about hydrology, in which groundwater flow system can be estimated from the distribution of subsurface temperature in basins and plains (Uchida et al., 1999; Sakura, 1993). Groundwater flow systems and temperature along Tokyo Bay have been drawing the attention of many hydrogeologists. The area was once suffering severely from groundwater related problems such as land subsidence which was the result of over-pumping of groundwater. Since then the geology and hydrogeology of the area have been actively studied. As a result, a lot of information and database on the hydrogeology of the area can now be found, especially the data and information about water quality in the Tokyo area. However, data concerning physical groundwater is still very limited, for example, subsurface temperature in and around Tokyo Bay. It is of great interest to choose the location for the studies on groundwater temperature distribution.

The purpose of this research is to understand the present characteristics of the subsurface temperature distribution around the bay and at the same time, compare the influences upon groundwater flow systems that topographical and geological differences have. Moreover, we would like to evaluate the effects of human activities on the subsurface environment.

2. STUDY AREA AND METHODOLOGY

Figure 1 shows the location of the study area and observation wells. The location, around Tokyo Bay, is situated between Ichihara city of Chiba Prefecture and Yokohama city following the coastal line was selected as the study area. The shallow part of Tokyo Bay basin is composed basically of sedimentary layers. Suzuki et al. (1995) suggested that the formations of Tokyo Bay and its adjacent areas are composed of the Paleogene Mineoka Group, the Early to Middle Miocene Hota and Hayama Groups, the Middle Miocene to Middle Pliocene Miura Group, the Middle Pliocene to Middle Pleistocene Kazusa Group and the Middle to Late Pleistocene Shimosa and Sagami Groups in ascending order. Each group is unconformably overlain by the younger group. The western part of the bay is quite flat and rises gradually until it reaches the upland of the mountains of Kanto area. On the other hand, the geographical terrain of the eastern side of the bay, Chiba area, emerges suddenly from the coastal lowland. The geological structure of Chiba area is tilting which allows water to flow fast and deep into the ground. Topography of this area consists of diluvial uplands, river terraces, alluvial lowlands and reclaimed lands (Kondoh., 1985).

Many observation wells around Tokyo Bay were located and borehole temperature profiles and hydraulic heads were measured. Taniguchi (1987) analyzed free thermal convection in wells and concluded that the temperature profiles measured in the wells are stable and could, therefore, represent the subsurface thermal regime. These stations are owned and looked after by local government agencies. These observation wells were drilled and some recording materials were installed for the purpose of monitoring groundwater levels and/or land subsidence. Some stations have more than just one well and they are called piezometer nest. Each well has a different depth. The thermometer system used to measure the subsurface temperature is the applied thermometer system which is made by the probe unit (Type: PXW-46, Thcnol Seven Co.Ltd., Japan), Teflon cable (400-600m long) and the data logger unit (Type: K-210, Thcnol Seven Co.Ltd, Japan). The groundwater temperature was measured at 2 meter intervals from the water level to a depth of 300m, and then 5 meter intervals thereon. The depth of the observation wells varies between 30m and 600m (A. Miyakoshi et al., 2003). The precision of the thermometer is 0.01 degree Celsius. The collected data have been used for the data analyses. A couple of cross-sections across and around the bay have been made to understand the groundwater flow systems and subsurface temperature distribution. Finally, to confirm the groundwater flow systems and subsurface temperature distribution, a preliminary groundwater simulation (SHEMAT, Clauser) was used.

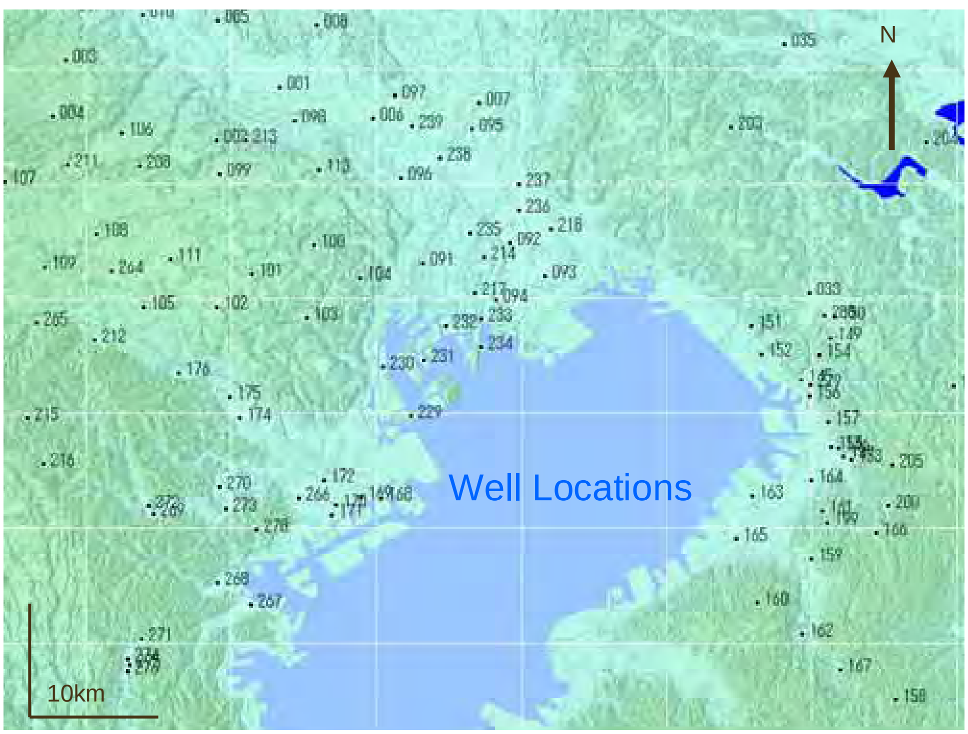

Figure 1. *Locations of the study area and observation wells*

3. RESULTS

All the cross-sections, A-A', B-B', C-C', and D-D' have shown the same tendency. On the Tokyo side, the temperature is comparatively higher than that of Chiba. The locations with high temperature are located along the coastal area of the Tokyo side. In contrast, in the Chiba area the temperature is low even in the lowland close to the sea. Groundwater temperatures at depths less than 50m below sea level are affected by seasonal change, groundwater flow systems, and surface temperature. According to the Domenico and Palciauskas (1973), temperature-depth profiles with downward water fluxes in recharge areas are concave, and those with upward fluxes in discharge areas are convex, though the gradient is a constant without vertical fluxes. Subsurface temperature itself is higher in the discharge area than in the recharge area of the groundwater flow system (Taniguchi et al., 1999a, b). The subsurface temperature profiles, in the lowland areas along the bay, clearly indicate that the areas are in the discharge type of the groundwater flow systems and have higher temperature than the recharge area. The temperature-depth profiles selected from some boreholes in the areas close to the bay show high temperature and they are in the category of discharge type of groundwater flow systems.

Hydraulic heads along the A-A' vertical cross-section which cuts across Tokyo Bay from Kiyose of Tokyo area to Mizusawa of Ichihara, Chiba Prefecture show that hydraulic heads are high in the Chiba side and low in Tokyo side. This also suggests that water recharges and flows in larger quantities in the recharge area of Chiba upland.

Preliminary numerical simulation of groundwater temperature distribution

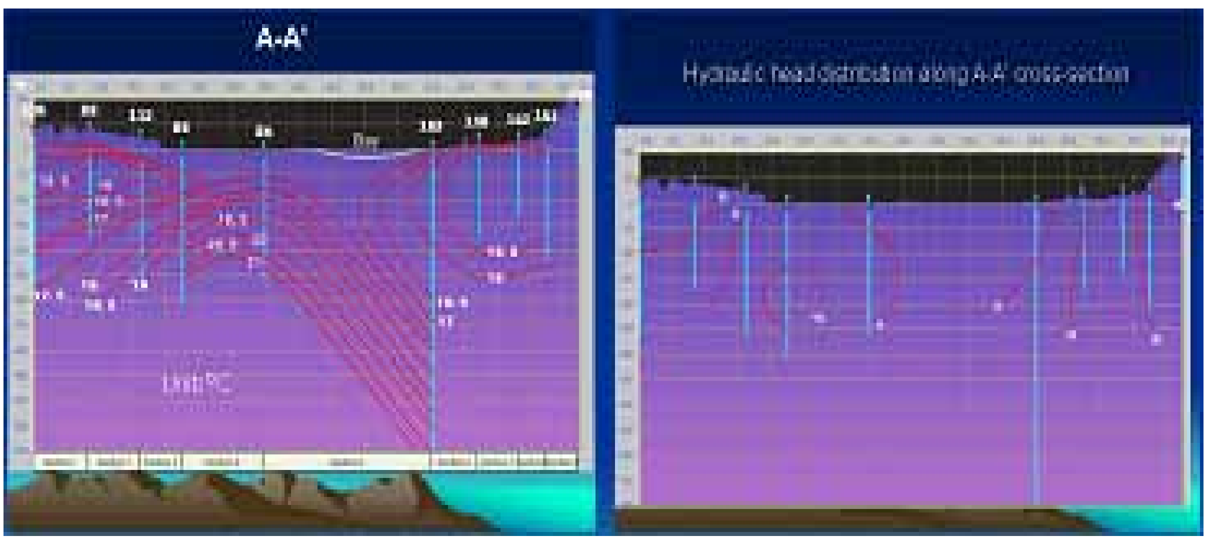

Figure 2. *Distributions of subsurface temperature and hydraulic head along A-A'.*

along A-A' also agrees with the 2-D A-A' vertical cross-section of subsurface temperature distribution. The subsurface temperature along the coastal line of Tokyo area is higher than that of Chiba.

What is more, the horizontal distributions of subsurface temperature at depths of 50m and 100m below sea level also prove that the temperature gets higher when it gets closer to the sea.

4. CONCLUSIONS

According to the results, we could finally conclude that:

- The groundwater temperature along the coastal areas of Tokyo side is comparatively higher than that of Chiba. The temperature gets higher closer to the bay.
- Groundwater recharges, in the upland and hills on both Tokyo side and Chiba, into Tokyo

Bay. These are called recharge areas. Discharge areas are in the lowland areas along the bay.

- In Chiba area, the hydraulic heads have higher value than that in the Tokyo area.
- The shallow part of the groundwater flow systems is affected by natural phenomena and human activities such as; groundwater flow systems, and urban warming, respectively.

5. ACKOWLEDGEMENTS

The author is very grateful to Mr. Jules Rostand Dim (Chiba University), for his help with the simulation work. He also dedicates his thanks to Mr. Rachmat Fajar Lubis, (Graduate School of Science and Technology, ChibaUniversity), for his endless help and assistance. Last but not least, he would love to express his gratitude to Mr. Takeshi HAYASHI for his valuable comments and advice.

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Ground surface temperature history in the southeastern part of the Republic of Korea over the last 300 years, inferred from borehole temperature data

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Abstract

In order to infer past climate change in the southeastern part of the Korea peninsula, we reconstruct ground surface temperature (GST) history of the last 300 years by analyzing borehole temperature profiles in Ulsan, southeast of the Republic of Korea. The reconstructed GST history shows a cold period in the late 19th century. After the cold period, the GST shows an increase of 1.5 K by 1980. The increasing of the GST in Ulsan in the 20th century is greater than that of northern hemisphere temperature. Ulsan has developed as one of the major industrial cities in the Republic of Korea since 1962. Thus, our result suggests that industrial activities in Ulsan caused locally strong warming in the area.

1. Introduction

Past changes in temperature at the earth surface have penetrated into the subsurface and have been recorded as transient temperature perturbations to the background thermal field. In the absence of fluid moving, changes in ground surface temperature (GST) slowly propagate downward by heat conduction. Depth of the perturbation and time at which GST changes have occurred is linked nonlinearly by thermal diffusivity of rock. Subsurface temperature perturbations attenuate with increasing depth due to the diffusive process. The attenuation depends on frequency of GST variations: higher frequency components are diffused out at shallower depth. Thus, subsurface temperature perturbations indicate signals of long-term trend of GST variations.

GST is closely related to surface air temperature (SAT) that is in direct response to climate at that site at that time. To infer past climate changes, numerous borehole temperature profiles have been investigated and GST histories have been reconstructed (e.g., Huang *et al*., 2000; Beltrami and Bourlon, 2004).

Northeast Asia is geographically important to study global and hemispheric climate trend. However, there are a few studies using geothermal approach to infer past climate change (Huang *et al*., 1995; Pollack *et al*., 2003). The purpose of this study is to infer a change in GST over the last 300 years in Ulsan, one of the major industrial cities in the Republic of Korea, by inversion of borehole temperature logs. The reconstructed GST history shows a colder period prior to the present warming. Finally, we compare the GST history with northern hemisphere temperature time series. The result suggests that industrial activities in Ulsan caused locally strong warming in this area.

2. Borehole temperature data in Ulsan, southeast of the Republic of Korea

Southeastern part of the Korea peninsula (Fig.1) is occupied by thick Mesozoic sedimentary rocks with intrusions of Cretaceous volcanic rocks. In Ulsan, the most southeastern part of the peninsula, nineteen borehole temperature logs have been carried out for geothermal and hydrological surveys since 1986. To avoid non-climatic distortions (heterogeneity of the earth material and advection due to groundwater) to the GST history reconstruction, we selected three boreholes (Fig.1). Temperatures in boreholes 5220013 and 5220014 were logged in September 1990. Temperatures in borehole 5220005 were measured in February 1988.

Fig.2 shows temperature profiles of the selected boreholes. All of these temperatures are measured at an interval of 2 m. An accuracy and resolution of the temperature sensor are 0.5 K and 0.05 K, respectively. Temperatures shallower than 30 m are not plotted in the figure because effects of annual temperature change at the ground surface are seen. Because of lack of core samples from the boreholes, the vertical distributions of thermal conductivity and diffusivity are unknown. Instead, thermal conductivities and diffusivities on rock samples collected near the boreholes were measured as 2.6–3.1 W/m/K and 1.3–1.5 $\times 10^{-6}$ m^2/s, respectively. Background thermal regime for each borehole, calculated by a linear fitting from the temperatures deeper than 180 m, is shown as a solid line in Fig.2. The temperature gradients are 24–30 mK/m (K/km). Fig.3(a) shows the reduced temperature profiles that represent departures from their background thermal regimes (Fig.2). All of these reduced temperature profiles show positive temperature anomalies with amplitude of ~0.8 K at a depth of 30 m, indicating the recent warming.

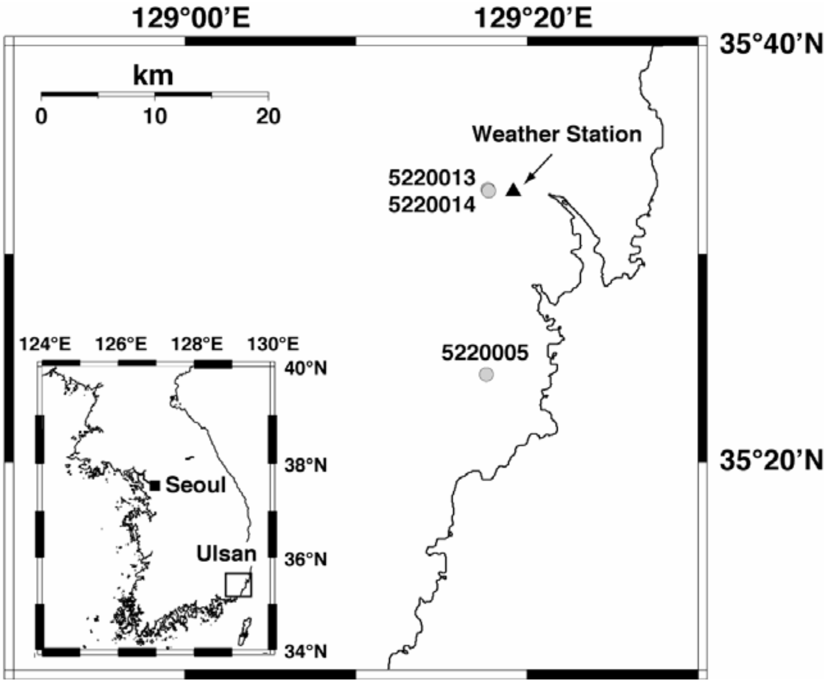

Fig.1 Locations of boreholes and weather station (Ulsan Gauging station of Korea Meteorological administration) in Ulsan, southeast of the Republic of Korea. Index map of the location of Ulsan is inserted.

3. Method

We assume a semi-infinite homogeneous earth material. We also assume that heat transfer in the material is one-dimensional heat conduction alone. At the surface (depth z = 0), temperature fluctuates as a series of step function. Subsurface thermal response to the surface boundary condition at the time of borehole temperature measurement (t = 0) is given as (Carslaw and Jaeger, 1959):

$$T(z,t=0)=\sum_{i}^{M}\Delta T_i\left[erfc\left(\frac{z}{2\sqrt{\kappa t_i}}\right)-erfc\left(\frac{z}{2\sqrt{\kappa t_{i-1}}}\right)\right] \quad (1)$$

where t_i is the time before temperature measurement and ΔT_i is the temperature change at time between t_{i-1} and t_i, *erfc* is the complementary error function and κ is the thermal diffusivity of the earth material. In this study, we invert most probable values of κ and ΔT_i in the equation from the reduced temperature profiles in Fig.3(a) by the Bayesian inversion. To stabilize and uniquely determine the solution by this inversion, appropriate a priori parameters and their a priori standard deviations for model and data must be provided. We use a priori thermal diffusivity of 1.4×10^{-6} m^2/s (a priori standard deviation: 0.2×10^{-6} m^2/s). Because there is no a priori information about GST history, we take a priori GST model to be uniformly zero (a priori standard deviation: 1 K). A priori standard deviation of borehole temperature data is set to 0.2 K. The inversion procedure and the constraints are discussed by Goto *et al*. (2005) in detail.

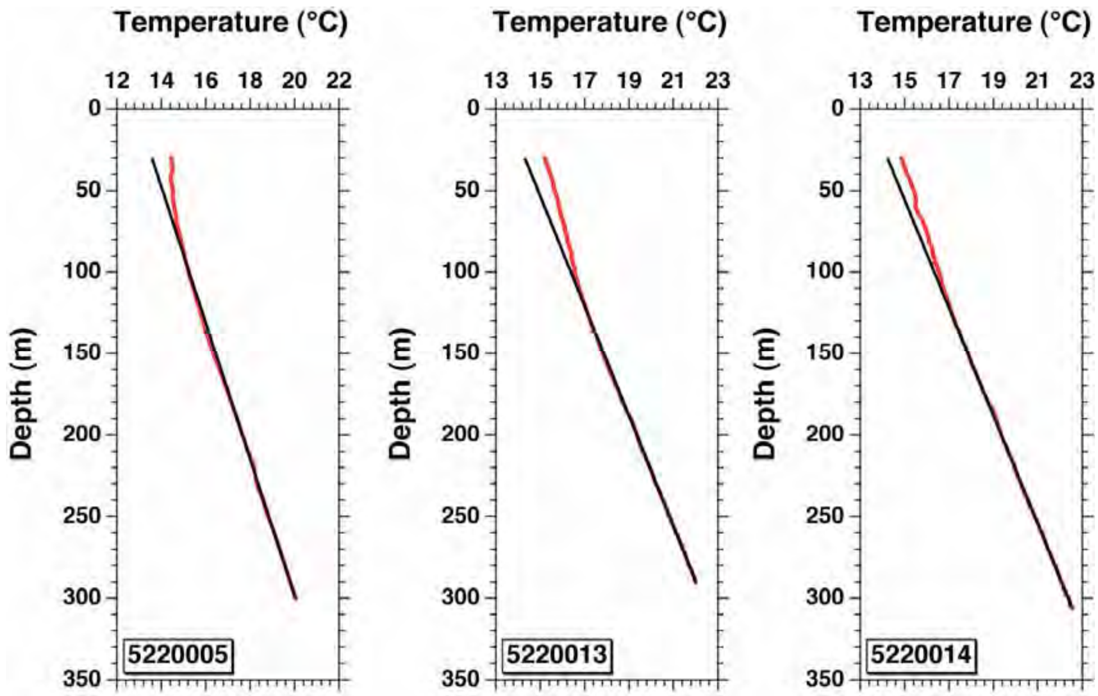

Fig.2 Temperature profiles in boreholes in Ulsan. Red open circles indicate measured temperatures. Black solid lines are the background thermal regimes. (a) Borehole 5220005. (b) Borehole 5220013. (c) Borehole 5220014.

4. Results and discussion

Fig.3(b) shows the result of GST history reconstruction from the three reduced temperature profiles in Fig.3(a). The simultaneously inverted a posteriori thermal diffusivity is $1.42 \pm 0.15 \times 10^{-6}$ m^2/s. In the reconstructed GST history, a cold period is seen in the late 19th century. After the cold period, the GST shows an increase of 1.5 K by 1980. The synthetic temperature profile calculated from the GST history explains the long wavelength trends of the reduced temperature profiles (Fig.3(a)).

We compare the GST history with northern hemisphere (NH) temperature time series over the last 300 years (Jones *et al*., 1998) (Fig.3(b)). Characteristics of the NH temperature time series are (1) cold period in the 19th century, (2) warming in the early 20th century, and (3) stable condition after 1930. Before the 20th century, the GST change in Ulsan agrees with the long wavelength trend of the NH temperature time series. The beginning of warming on the GST history is almost the same as that of the NH temperature change. Although the NH temperature time series after 1930 is a stable condition, the GST in the same period shows continuous rising.

In Ulsan, SAT measurement has begun since 1946. The weather station (Ulsan Gauging station of Korea Meteorological administration) is located near the boreholes (Fig.1). In Fig.3(b), the mean annual SAT records from 1946 to 1988 are plotted. Before 1970, the pattern of the SAT change is similar to that of the HN temperature time series. After 1970, the SAT increases although the NH temperature time series is stable condition. The GST history in Ulsan agrees with the long wavelength trend of the SAT records. Since 1962, Ulsan has developed as one of the major industrial cities in the Republic of Korea and major industrial plants and factories have been built. Thus, the increase in SAT in Ulsan suggests local warming due to the industrial activities in the area. If so, the GST history in Ulsan reflects a climatic history from pre-industrial period to industrial period in this area.

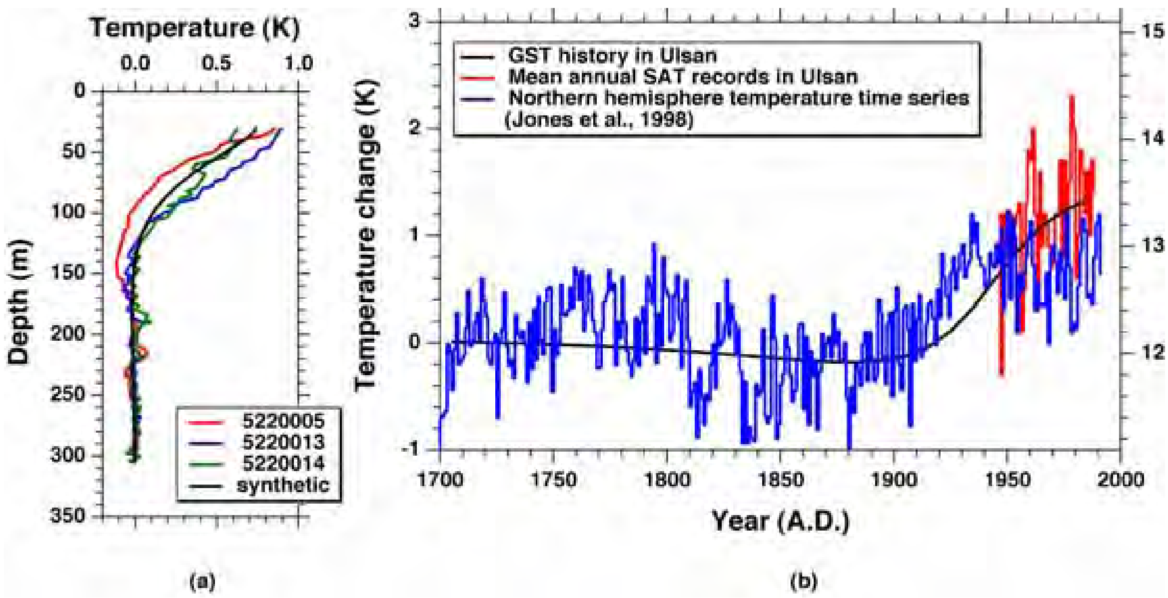

Fig.3 Results of GST history reconstruction. (a) Comparison of reduced temperature profiles and synthetic temperature profile calculated from the reconstructed GST history in the right figure. (b) Plots of GST history and SAT records in Ulsan and northern hemisphere temperature series time (Jones *et al*., 1998).

5. Conclusion

To infer climate change over the last 300 years in southeastern Korea peninsula, ground surface temperature (GST) history is reconstructed from geothermal temperature-depth profiles in Ulsan, southeast of the Republic of Korea. The reconstructed GST history shows a cold period in the late 19th century and subsequent warming to the present time. After 1970, the increase in GST in Ulsan is greater than that of NH temperature change. Since 1962, Ulsan has developed as one of the major industrial cities in the Republic of Korea.

Thus, the increasing of GST in Ulsan after the middle of 20th century probably reflects local warming due to the industrial activities in the area.

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Meteorological Observation on Mitigation of the Summer Thermal Stress: A Case Study of Cheonggye Stream Restoration Project (First Report)

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Abstract

The purpose of this study was to clarify the effects after the restoration of Cheonggye stream in Seoul, in order to pursue effective methods to mitigate the summer thermal stress in mega-city.

Through collaboration with KMA, the joint research group distributed 14 data-logger installations along the Cheonggye stream. The Thermal recorders measure temperature and humidity every 15 minutes. The joint research group also has been having monitoring on thermal environment change in summer around the Cheonggye stream area using thermal-graphy.

The results of field observation in 2004's summer showed that the stream-effect as a cooling source was confirmed. In particular, after 19:30, the maximum air temperature difference between air temperature on the bridge and surrounding streets was 2.1℃. The appearance of the obvious low temperature was proportional to the extent of stream-effect, and it was also affected by wind speed and direction. In cloudless night, the discernible reduction in air temperature was spread to the extent about 20-30m. In the other hand, the extent of both sides of the stream-effect was different. However the most variation in low temperature was restricted in course of construction (in 2004), the stream-effect would become wider spread after the restoration of Cheonggye stream.

1. Introduction

Seoul, as the capital city of Korea and the largest city in Korea, rebuilt its capital in the shortest time recorded in world history after the Korean War (1950-1953). Now, the area of Seoul Metropolitan city is 605.52 km^2 (1997). Seoul Metropolitan city as a mega-city with 10.26 million populations (2000), 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 shows the rise in annual mean temperature in Seoul is as much as Tokyo, a mega-city with 12.26 million populations (2005). Furthermore, The monthly mean temperature in both the maximum temperature and the minimum temperature in January (the coldest month) has risen over 2.0℃ since 1954 (Fig.2).

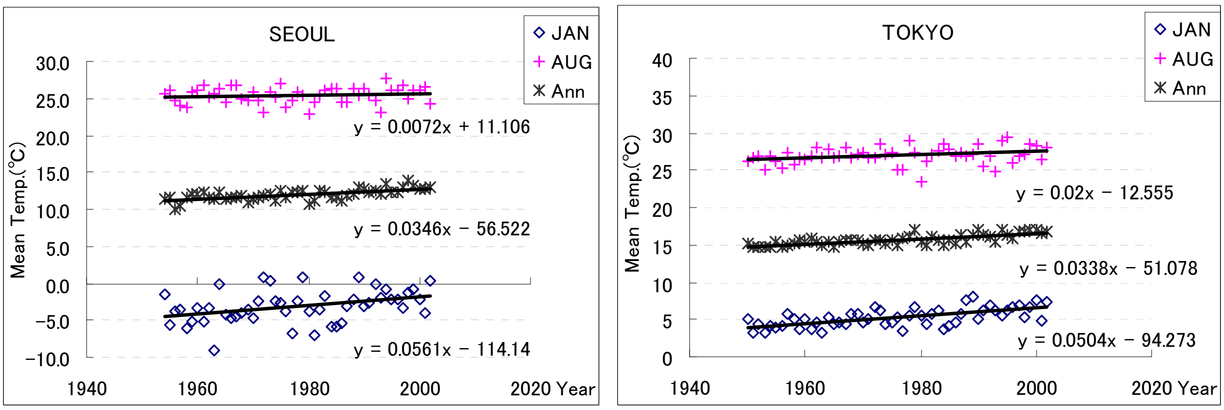
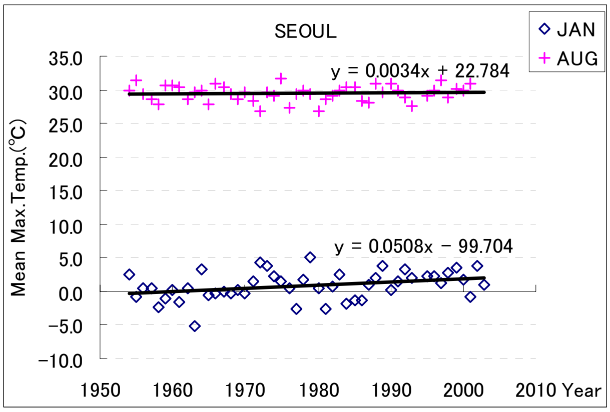


Fig. 1 The increase of the annual mean temperature and monthly mean temperature in Seoul and Tokyo (1954-2004)
(The warmest month is August, whereas January is the coldest one.)



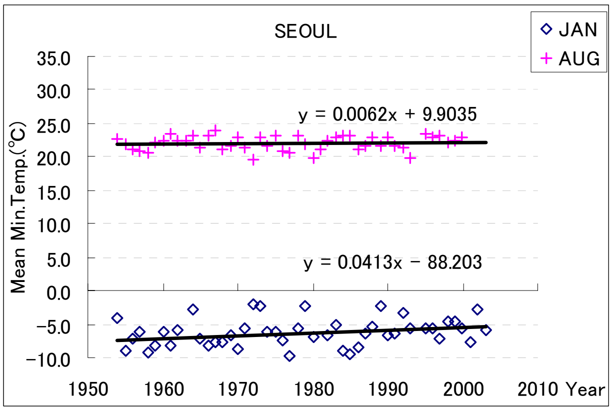


Fig. 2 The increase of monthly mean max.temperature and mean min.temperature in January and August (1954-2004)
(The warmest month is August, whereas January is the coldest one.)

Some experts reported much of those rises may be related to the increase in the global mean temperature. However, the global mean surface temperature has increased by between 0.3 and 0.6℃ since the late 19th century, a change that is unlikely entirely natural in origin. Actually, Many Japanese researchers warn that urban warming in large cities continues, due to the "heat island effects"[1].

Currently, studies indicate that the three big causes of urban warming are an increase in heat emissions from human activity, a reduction of green spaces and water surface area, and heat retention in surfaces such as concrete and asphalt. Now, the diverse researches on monitoring techniques for document and characterize the effects of large green space and water spaces in an urban area, including “Klimaatlas” in urban planning such as creating "wind paths" to let the ocean wind cool the metropolis, have been developed to mitigate the urban heat islands (UHI) in Asian mega-city[2]. Moreover, both governments and NPO become actively working toward improving the living environment. In 2003, the Tokyo Metropolitan Government has passed legislation mandating that buildings of more than 1000 sq. meters contain greenery comprising at least 20 percent of their area.

Furthermore, Seoul Metropolitan Government decided to demolish the overpass above the Cheonggye road which ran through the heart of the city, in order to restore the stream. The project was focused on promoting ecological transformations and evolutions in urban planning, the restored Cheonggye-cheon will make the environmental improvements as well as will influence the redevelopment of the surrounding areas.

However, direct observations on environmental improvements after reviving the city’s landscape are rare. The needs to analyze and predict the effects of ecological structure of the city in order to find the most effective methods to recover and improve the changed urban thermal environment are acute. The purpose of this study was to clarify the effects after the restoration of Cheonggye stream in Seoul, in order to pursue effective methods to mitigate the summer thermal stress in mega-city, based on field meteorological observations. This study will give appropriate guidelines for developing the urban planning of mitigating UHI in Asian Mega-cities.

2. Meteorological Observations

2.1 Study Region

For the past 600 years, “Cheonggye-Cheon” (“Cheon” means river) had been the center of Seoul’s structural foundation, running east and west of Hanyang (the capital of Joseon Dynasty and the name of former Seoul) and connecting the south and north. Cheoggye-Cheon was once a living river used for everyday by the public and was covered in 1958-1961 to solve pollution and floods caused by increased population(Fig. 3). The historical Cheonggye stream Restoration Project began in July 1, 2003 with the demolition of the 5.8km Cheonggye overpass (Fig. 4).

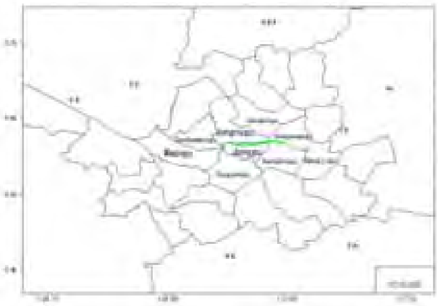


Fig. 3 Cheoggye-Cheon

Fig.4 Cheonggye overpass (Date: Jun. 2003) and the restored Cheonggye stream (Date: Aug. 2005)

2.2 Observations

Through collaboration with KMA, the joint research group distributed 14 data-logger installations along the Cheonggye-Cheon (Fig. 5). Thermal recorders (data-logger) measure temperature and humidity every 15 minutes from 2003. The joint research group also has been having monitoring on thermal environment change in summer around the Cheonggye stream area using thermal-graphy (Fig. 6).

Fig.5 Data-logger installation

In addition, in order to study on the stream-effect, 13 data-logger installations were conducted along the stream in 2004's summer. Meteorological element — air temperature, humidity were measured along street from the stream side.

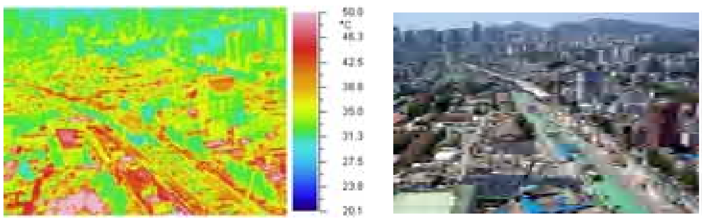


Fig.6 Surface thermal image by thermal-graphy

3. Results

The results of field observation in 2004's summer showed that the stream-effect as a cooling source was confirmed. Fig.7 proved that the surface temperature around the Cheonggy stream had changed because of the restored stream. The drop in air temperature above the stream in summer created the surface temperature difference between the water surface and asphalt pavement, and the surface temperature difference was affected by the meteorological elements.

In particular, after 19:30, the maximum air temperature difference between air temperature on the bridge and surrounding streets was 2.1℃. The appearance of the obvious low temperature was proportional to the extent of stream-effect, and it was also affected by wind speed and direction. In cloudless night, the discernible reduction in air temperature was spread to the extent about 20-30m. In the other hand, the extent of both sides of the stream-effect was different (Fig.8). However the most variation in low temperature was restricted in course of construction (in 2004), the stream-effect may become wider spread after a few years of the restoration.

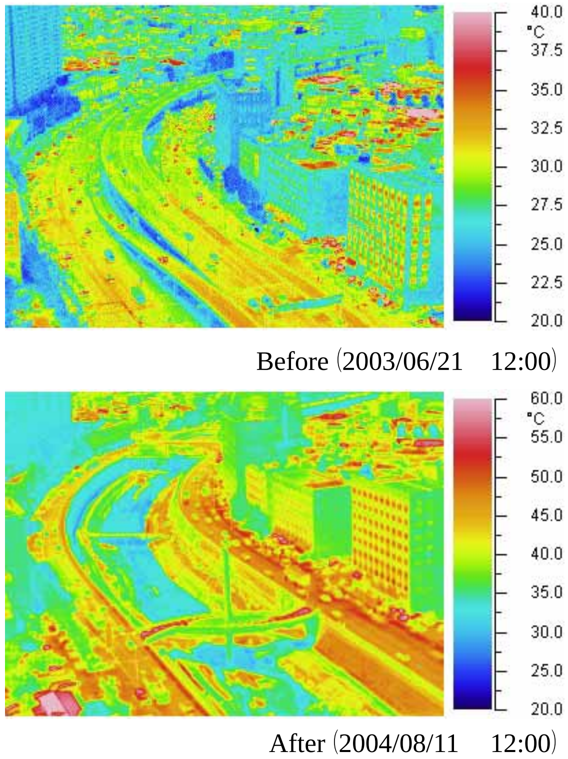


Fig.7 Surface temperature

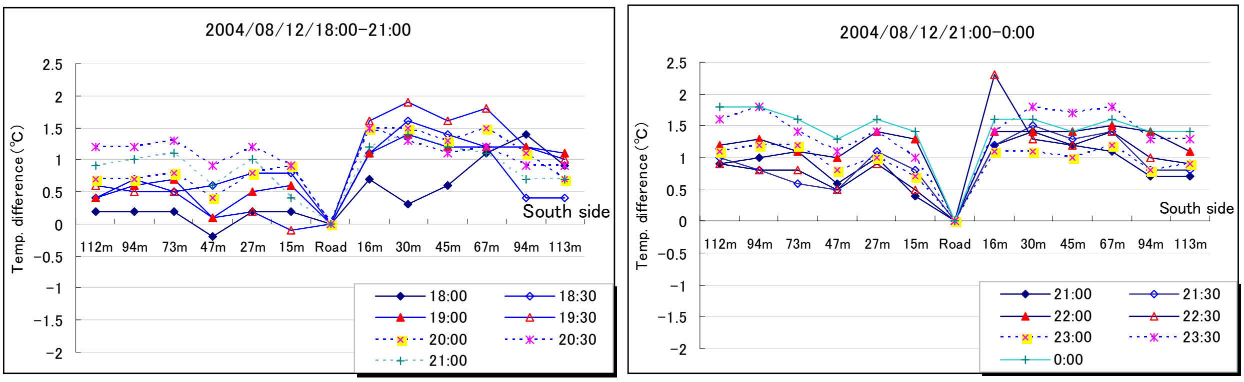


Fig.8 The changes of temperature difference (2004/08/12)

Murakawa et al. (1988) pointed out that the discernible reduction in air temperature could be spread to the extent about 150-500m from the river [3]. As Cheonggye-Cheon is an urban stream running through the center of the capital's east to west, it can not be practically restored as a natural stream so that the water surface is not wide, its average depth is only 40cm (amount of water supply: 120,000m^3/1 day; average speed of water: 0.25m/s). From those results, the author suggests that a well-ventilated building distribution should be considered in order to improve the stream-effect. In addition, the author indicates the bank along the stream side may obstruct the diffusion of cooler air-mass above the stream.

Even though the project was completed in Sept. 2005, the public has tried their utmost to make an appropriate new waterside space and maximize the usage of the changed environment. All field observations will continue. Further study is certainly needed to explore the complicated relationship between the change of local UHI with the stream-effect.

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[3] Murakawa. S. et al. (1988): Study on the effect of river on thermal environment in urban area. *Journal of Architectural Institute of Japan.* 393, 25-34.

Changes in Hydrological Landscapes and Human Activities Related to Urbanization in Asia Cities

Taiko TODOKORO
Graduate student, Ritsumeikan University, Japan

This is the outline of an independent research subject in the urban geographical study group.

1. Introduction

Urbanization, the concentration of the population and industry into the center and the periphery of cities, is worldwide tendency and it has been fully in progress in Asian cities since 1970. Hydro-environment has been fully influenced and changed by the socio-economic human activities under the each developmental stage of the cities. This is especially true in Asian coastal cities where visual hydro-landscapes have been changed rapidly by the development of water supply and sewage system. On the one hand urban landscapes tend to be homogenized by globalization, but at the same time the regional identity of urban landscapes have gotten a lot of attention recently in every city. Therefore, it is one of important perspectives to analyze the changes in hydro-environment and human activities related to urbanization when we consider the ideal Asian urban environment and social policies.

2. Research purpose

One of research subjects of urban geographical study group is to develop change models for urban hydro-environment in Asian cities through urbanization. With this subject in mind, this study is intended to clarify changes of urban forms in Asia cities through modernization process, focusing on changes of their hydro-landscapes. Especially, it will be analyzed the relationship between socio-economical human activities in city areas and the spatiotemporal dynamics of utilization and functions of waterways focusing on the development of water supply and sewage system.

3. Methodology

Research procedure of this study is based on the approach of British urban morphology which discusses changes in urban landscapes. Urban morphology has dealt with such topics as the diffusion of innovations, cycles in house building, the redevelopment of city centers and, especially, the physical form of cities.

This research based on urban morphology may be summarized under four heads: first, the collecting of urban morphogenetic data, such as historical data, aerial photographs, land uses and so on; secondly, the converting those data into a digital form suitable for GIS; and thirdly, the integration of those morphogenetic and land-economic conceptions of cities; and fourth, uncovering of the agents responsible for urban hydrological landscape development. In the final analysis, the desirable relationship between hydro-landscape management and human activities will be discussed.

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Whitehand, J. W. R.. : *The making of the urban landscape*. Blackwell, 1992, 239p.

Whitehand J. W. R and Larkham, P. J. eds. : *Urban Landscapes: International perspectives*, Routledge, 1992, 333p.

PROGRAM

Oct 18 (Tue)

13:15-13:45 **TANIGUCHI, Makoto** Project Introduction

Session A "Urban and Materials Environments"

(Convener: WATTAYAKORN, Gullaya)

Room C

13:45-14:15 **KANEKO, Shinji** "Socio-economics in Asian cities"
14:15-14:45 **YOSHIKOSHI, Akihisa** "Urban Geography of Asia"
14:45- 15:00 Comments by **DELINOM, Robert M.**
15:00-15:15 Coffee break
15:15-15:45 **ONODERA, Shin-ichi** "Material transports from the Asian coastal cities"
15:45-16:15 **NAKANO, Takanori** "Sediment environments in Asia"
16:15-16:30 Comments by **BURNETT, William**
16:30-18:00 Poster session with ice break

Oct 19 (Wed)

Session B "Subsurface Environments in Asian Cities"

(Convener: TANIGUCHI, Makoto)

Room C

9:00-9:30 "Bangkok, Thailand" **BUAPENG Somkid** and **: WATTAYAKORN, Gullaya**
9:30-10:00 "Seoul, Korea" **KIM, Guebuem** and **LEE, Kang-Kun**
10:00-10:30 "Jakarta, Indonesia" **DELINOM, Robert M.**
10:30-10:45 Coffee break
10:45-11:15 "Manila, Philippines" **SIRIGAN, Fernando**
11:15-11:45 "Taipei, Taiwan" **WANG, Chang-Hu**
11:45-12:30 Discussion
12:30-14:00 Lunch

Inter-Project Plenary Session Session 1

"Human History in the Changing Climate"

Room C

Opening Address:
Prof. **SATO, Yo-Ichiro** and/or Prof. **NAKAWO, Masayoshi**
14:00-15:30
Speakers
P1-1: **KITOH, Akio**, Meteorological Research Institute, Japan
"Approach to Human Impact on Climate through Modeling the Past and Future Climate"
P4-1: **ZHANG, Qibin**, Institute of Botany, China
"Tree-ring Data for Climate Reconstructions – Relation with Human History - "
P2-4: **HUANG , Shaopeng**, The University of Michigan, USA
"Penetration of human induced warming in the continental landmasses"

Commentators on climate change
P1-1: **YATAGAGAI , Akiyo**, RIHN, Japan
P4-1: **FUJITA , Koji**, Nagoya University, Japan
P2-4: **WANG, Chung-Hu**, Academia Sinica, Taiwan

15:30-15:45 Break

Session2 "Challenging for Better Human/Water Relationships"

15:45-17:15

Speakers

P1-1: UMETSU , Chieko, RIHN, Japan

P4-1: CHENG, Goudong, Cold & Arid Regions Environmental & Engineering Research Institute, China

"Chinese Challenge against the Water Shortage in the Heihe Basin, Western China"

P2-4: BURNETT, William C., Florida State University, USA

"Human Impacts on Land-Ocean Interaction"

Commentators

P1-1: EKMEKCI, Mehmet, Hacettepe University, Turkey

P4-1: TSUJIMURA , Maki, Tsukuba University

P2-4: SIRIGAN, Fernando, (University of the Philippines)

17:30-17:45: Speech by Director General of RIHN: HIDAKA, Toshitaka

18:00- Reception

Oct 20 (Thu)

Session C "Water and Heat Environment"

(Convener: NESS, Gayl)

Room B

9:00-9:30 SHIMADA, Jun "Subsurface water environment in Asia"

9:30-10:00 FUKUDA, Yoichi"Gravity and groundwater in Asia"

10:00-10:15 Comments by LEE, Kang-Kun

10:15-10:45 YAMANO, Makoto "Subsurface thermal conditions in Asia"

10:45-11:15 ICHINOSE, Toshiaki "Heat Island in Asian cities"

11:15-11:30 Comments by HUANG, Shaopeng

11:30-12:30 Discussion

Business meeting (Session D)(at RIHN)

14:00-17:00

(1) MOU

(2) Future cooperation in each countries (Korea, Taiwan, Phillipine, Thailand, Indonesia)

(3) Further Funding (Urban, Material, Water, and Heat)

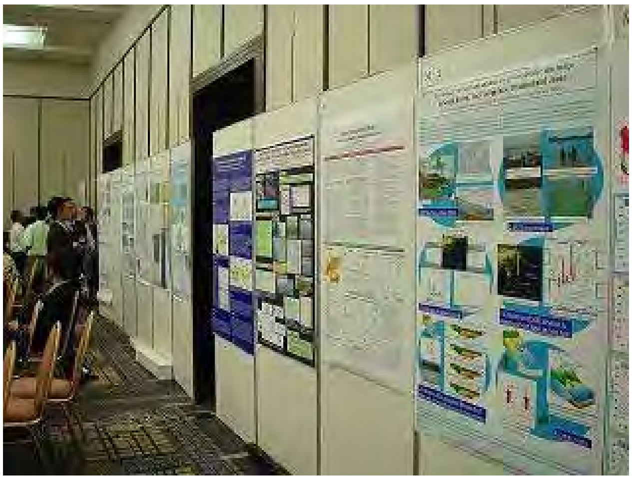
(4) Others

17:00 Closing


RIHN Pre-Symposium

RIHN Pre-Symposium
Human Impacts on Urban Subsurface Environments

RIHN Pre-Symposium





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