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Erratum to "Integrated research on subsurface environments in Asian urban areas"

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ABSTRACT

The RIHN project "Human impacts on urban subsurface environments" aims to suggest improved development plans of urban centers for human well-being. This will be done by examining reconstructed past changes in urban environments, and by developing integrated nature-social models. Subsurface environmental indicators are developed from the points of view of: (1) human activities; (2) climate change; and (3) character of urban development and social policies. Water, heat, and material environments and transport vectors are being evaluated by a number of different approaches. Some of these include investigating changes in groundwater resources using satellite observations, reconstructing effects of climate change and urbanization using subsurface thermal regimes, and evaluating past contamination patterns from preserved subsurface records. In this overview paper, we describe the current status of urbanization in Asia, subsurface water conditions, material and contaminant transport to surface waters by groundwater, and subsurface thermal anomalies due to the heat island effect. The rapid pace of urbanization in Asia requires that we develop a better understanding of how to deal with environmental impacts, both above and below ground.

1. Introduction

The world is a very different place today than it was only a short period ago. Urbanization and industrialization are changing the character of the planet. From a historical viewpoint, the development of our major cities progressed in two major transitions. From roughly 1750 to 1950 Europe and North America (and Japan and Oceania) became urbanized in the process of the industrial revolution. By about 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 (Ness and Talwar, 2004). At that time, New York City was the world's only "megacity," a city with more than 10 million people. Now there are 17 such cities around the globe, 14 located in coastal areas, and 11 in Asia. And today, Asia, Africa and Latin America are following the West in the urban-industrial transition.

A key point of concern is that the current urban transition is occurring much faster than ever before. What took two centuries in the past will now occur in decades. In addition, the absolute numbers today are much larger than ever. The North Atlantic urban transition involved a few hundred million people; the transition today, especially in Asia, involves billions of people. The greater speed and numbers of this transition impose on Asian urbanization a much greater sense of urgency to identify and address the problems the transition is bringing.

The Research Institute for Humanity and Nature (RIHN) in Kyoto, Japan has been established to address global environmental issues such as climate change, shortage of water resources, and decrease of biodiversity by an integrated approach involving both the natural and social sciences. One of RIHN's on-going projects "Human Impacts on Urban Subsurface Environments," is investigating the subsurface as a unique environment. Specifically, we are assessing the effects of human activities and climate changes on groundwater — the primary component of the subterranean environment.

While groundwater has become an increasingly important aspect of human life, its role as part of the urban environment has not as yet been evaluated. This is especially true in Asian coastal cities where urban population numbers and densities have increased very rapidly and uses of the subsurface environment have grown correspondingly. The primary goal of our research is to evaluate the relationships between the development of Asian cities and various subsurface environmental problems. For example, we see reoccurring patterns in groundwater withdrawals, extreme subsidence, groundwater contamination, and subsurface thermal anomalies. We are also addressing

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the sustainable use of groundwater and subsurface environments to provide for improved future development and human well-being.

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

Perhaps the most dramatic and obvious subsurface environmental problem occurring in Asian coastal cities is the subsidence due to excessive pumping of groundwater. This has occurred repeatedly in major cities throughout Asia with a time lag depending upon the speed and character of urbanization. When the extent of subsidence becomes unacceptable and serious structural and flooding problems occur, governments typically impose changes in reliable water resources from groundwater to surface water supplies. Unfortunately, this has not stopped subsidence in all cases. On the other hand, even when land subsidence has ceased due to regulation of groundwater pumping (e.g., Tokyo, Osaka), the associated increase in groundwater level has caused other types of damage by flooding and buoyant forces to underground infrastructures (e.g., subways) that were constructed during the drawdown period.

Another important aspect of the subsurface environment concerns material (contaminant) transport to the coast. Research over the last few years has shown that direct groundwater discharge to the coastal zone is a significant water and material pathway from land to ocean (Moore, 1996; Taniguchi et al., 2002; Burnett et al., 2003). We hypothesize that many water quality and associated problems influencing coastal environments around the world today are related to past and on-going contamination of terrestrial groundwaters because those groundwaters are now seeping out along many shorelines. For example, chronic inputs of fertilizers and sewage on land over several decades have resulted in higher concentrations of various nitrogen species in groundwater. Because these groundwaters will eventually display slow yet persistent discharge along the coast, coastal eutrophication may result. Such inputs may thus contribute to the increased occurrences of coastal hypoxia, nuisance algal blooms, and associated ecosystem consequences. Since most Asian megacities are located on the coast, material and contaminant transport by groundwater is a key to understanding present and future coastal water pollution and effects on associated ecosystems (Capone and Bautista, 1985).

While investigations of groundwater discharge into the coastal zone have increased dramatically over the last several years, few studies have been performed in and around urban centers and there have been very few studies anywhere in Asia outside of Japan (Taniguchi et al., 2002). This may be a significant oversight as the region is characterized by many features that are typically present in areas of high submarine groundwater discharge (SGD). For example, many parts of Southeast Asia contain regions of high rainfall, karst terrains, and high relief.

While global warming is considered a serious contemporary global environmental issue, most discussions of the phenomena have been limited to above-ground issues. However, subsurface temperatures are also affected by surface warming (Huang et al., 2000). In addition, the "heat island effect" due to urbanization creates subsurface thermal contamination in many cities (Taniguchi et al., 2003). The combined effects of these two processes may be recognized up to more than 100 m below the surface. The increased rate of surface and subsurface temperature change in cities is thus caused by these combined effects.

Our research aims to suggest improved development plans of urban centers for human well-being by reconstructing past changes in urban environments (from present to past), and by developing integrated nature-social models (from past, present to future). Subsurface environmental indicators will be developed from the points of view of: (1) human activities; (2) climate change; and (3) character of urban development and social policies. Water, heat, and material environments and transport vectors are being evaluated by

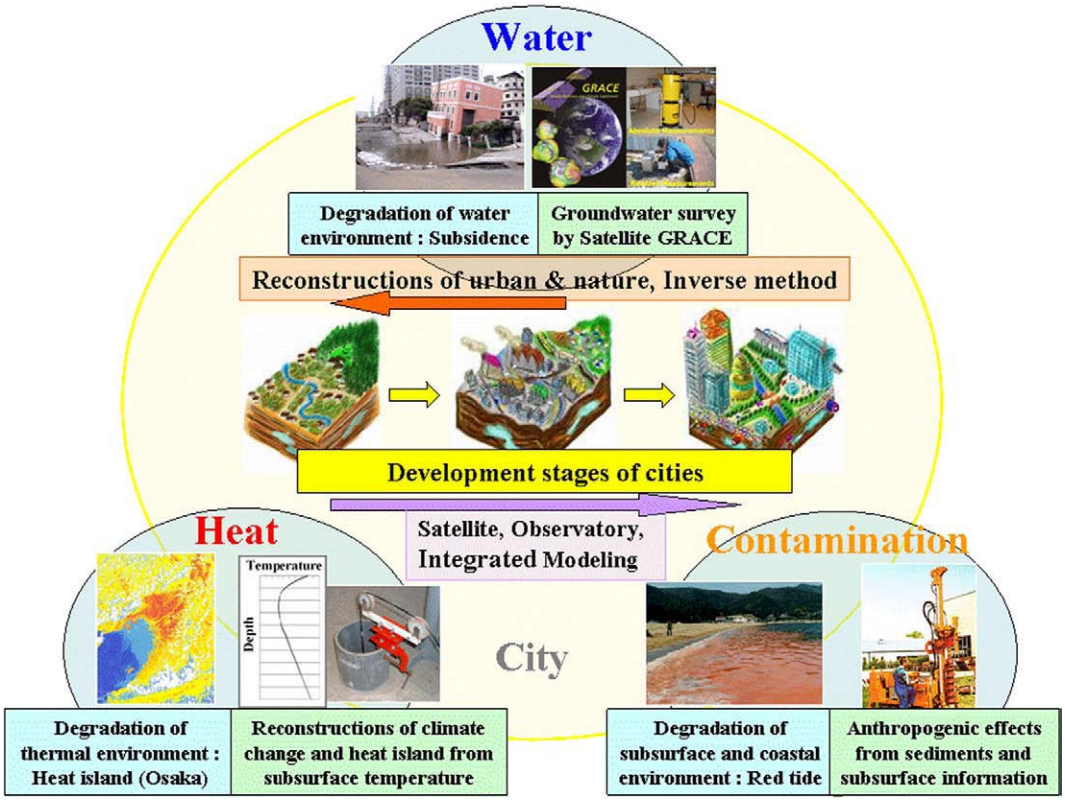

Fig. 1. Integration of subsurface environmental problems. Four sub-themes, urban water, heat, and contamination in subsurface environments are integrated from the two different points of views, reconstructions of the environment (from current to the past) and development stage of the cities (from the past to current and future).