Policies, governance and management for groundwater resources – Cases in urban areas of Asian cities

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(Abstract)
This paper pays special attention to groundwater and discusses sustainable management of groundwater and governance. In particular, it explores problems as well as management practices related to groundwater in urban and peri-urban areas of economically developing Asian countries, such as Bangkok in Thailand, Bandung in Indonesia, Ho Chi Minh in Vietnam and Tianjin in China. Due to excessive groundwater exploitation, declining water table and consequential land subsidence have been commonly observed in these Asian cities. Land subsidence has caused many societal problems, including damages to urban infrastructures. Groundwater quality has also been degraded in these cities, posing threats to human health of local people. These examples illustrate the failure of sound groundwater management, which shall negatively affect the regional sustainability. It examines groundwater management practices in these case study cities from the viewpoint of policy measures and management that are essential for coping with the associated problems. I argue that timely measures, integrated approach and stakeholders' participations, while fully taking into account the local socioeconomic conditions, are of vital importance to tackle the complex groundwater related problems and to ensure the soundness of the essential local commons in rapidly urbanizing areas of Asian cities.

Keywords: Asian cities, Groundwater, policy measures, sustainable management

1. Introduction

Along with the rapid economic growth, industrialization and urbanization, various resources have been intensively exploited and consumed in Asian countries. Water is a precious natural resource. But it is also under the threat of overexploitation in many cases. Past studies show the evidence that demand for water has been steadily increasing in Asia over the last decades and that this trend is predicted to continue in the decades to come in accordance with the continuing population growth and economic development. This paper focuses on groundwater and addresses the socio-economic impacts associated with its overexploitation by looking into actual cases in Asian cities.

Groundwater has long been utilized as a readily accessible and stable source of water supply for domestic, industrial and agricultural uses throughout the world. Asian countries also depend considerably on groundwater for various beneficial uses. Empirical studies have proven that the volume of groundwater use in the cities tends to increase in tandem with economic growth because it is a readily accessible and relatively cheap water source. On the other hand, groundwater is a vulnerable water source, which tends to be overexploited if an adequate care is not provided, particularly where a rapid economic growth is taking place.

Along with the increasing urban population and growing economic activities, demand for groundwater has been growing very rapidly in Asia. Importantly, excessive groundwater pumping has been causing a serious problem of groundwater depletion. Groundwater depletion could potentially cause the irreversible problem of land subsidence. Land subsidence could then lead to various negative social impacts, such as damages to infrastructures. It is also important that cities with land subsidence can be prone to floods particularly in the coastal areas. In addition to such quantity aspect, groundwater quality has been degraded in many parts of Asian cities, becoming another serious groundwater related problem. In fact, water contamination means the reduction of available water, which otherwise could have been used for other various purposes such as drinking.

In this paper I first present the current status of groundwater use in Asian cities and address the impacts associated with the increasing groundwater use, such as land subsidence, in the selected Asian cities including Bangkok in Thailand, Bandung in Indonesia, Ho Chi Minh in Vietnam and Tianjin in China. I also address groundwater quality problems observed in these cities. I then discuss policy measures to deal with such problems and groundwater management practices in these areas. While there are commonalities and differences among cities in terms of how groundwater is managed by using what kind of measures, it is important to derive lessons from the past experiences. I finally highlight that sharing knowledge and lessons for sustainable management should be effectively shared by emerging Asian cities.

2. Groundwater use in Asian cities

Groundwater is used as a primary and essential water source in Asian countries. Groundwater actually accounts for around 30 percent of the water supply in the

Asia-Pacific region, making the total number of people relying on it for drinking purposes the largest in the world (Sampat, 2000). Groundwater has long been used for various purposes. Especially at a time when the economic growth takes places, groundwater tends to be used intensively as a readily accessible and cheap water source for various purposes, such as drinking, agricultural and industrial uses. In Bandung, for example, groundwater used in the industrial sector in 1993 was about 59 % of total water requirements and the figure grew to 66.34 % in 1995. The figure is then estimated to be more than 70 % in 2004 (IGES, 2006). Figure 1 illustrates the percentage of groundwater use by sector in Bangkok, Bandung and Ho Chi Minh and Tianjin around the year 2004. This figure demonstrates that industrial use is particularly significant in Bangkok, Bandung and Ho Chi Minh, whereas agricultural use accounts for the large part of groundwater use in Tianjin.

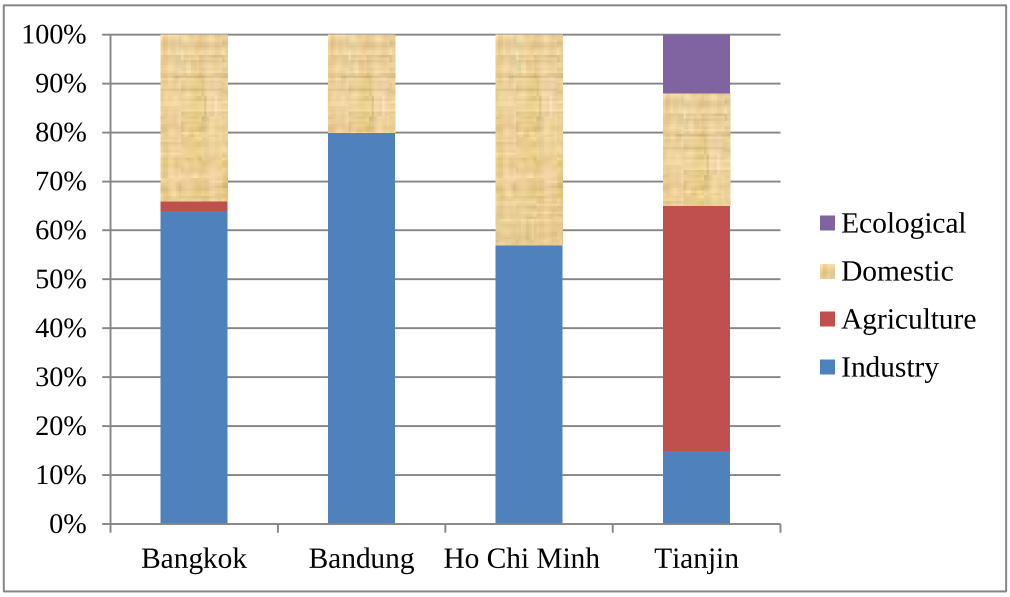

Fig.1 Ratio of groundwater use by sector (IGES, 2006)

Table1. Population, area and precipitation in each city

	Population (million)	**Area** (km^2)	**Precipitation** (mm/year)
Bangkok Metro	8.6	5,589	1,800
Bandung Basin	5.9	2,341	2,190
HCMC	5.3	2,091	1,900
Tianjin	9.1	11,919	500

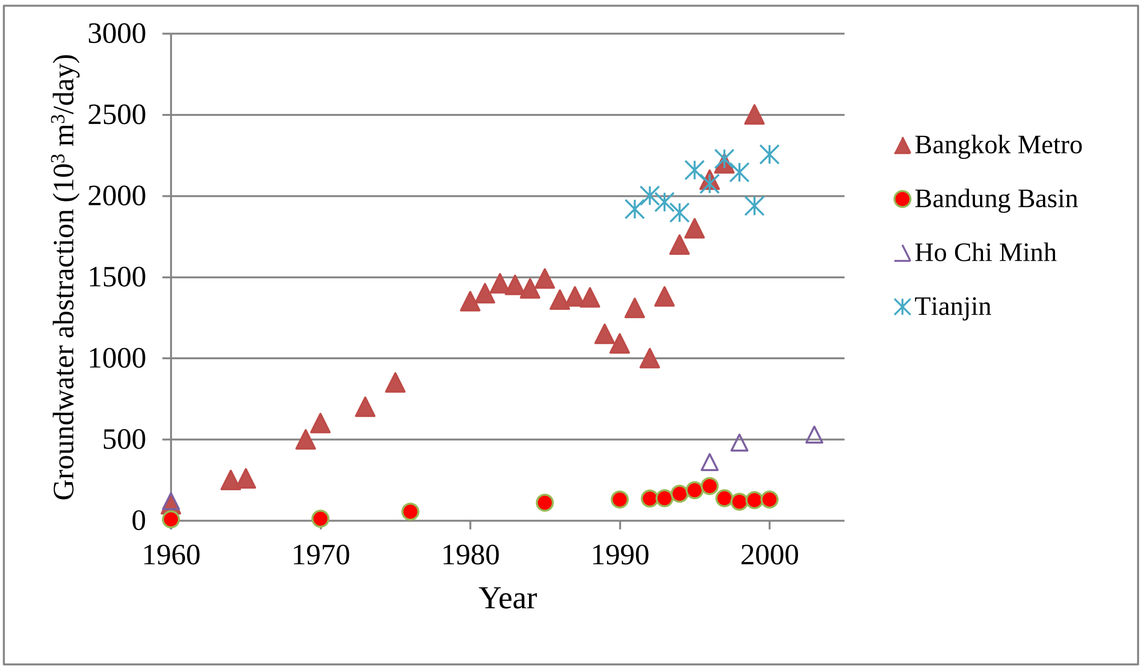

Fig. 2 Chronological trend of groundwater pumping (Created by the author based on IGES, 2006)

Table 1 shows the information of population, area and precipitation for each case study areas, including Bangkok, Bandung, Ho Chi Minh and Tianjin. Bangkok metropolitan region, one of the case study areas, covers a total area of 10,318.5 km^2 with the total population of about 10.6 million as of 2003. Bandung basin is located in the western part of the Java Island in Indonesia, covering a land area of 2,341 km^2 with a total population of 5.85 million as of 2003. Ho Chi Minh City has an area of 2,095 km^2 with a total registered population of 5.63 million in 2003. Tianjin has an area of 11,919 km^2 with the total registered population of 9.19 million in 2002, of which about 40% of population lives in the urban area (Herath et al, 2005). Notably, each city has experienced a steady population growth and rapid economic development in the last decades.

Along with such socio-economic development, a continuing growth of groundwater use has been observed in these cities. The total amount of registered groundwater use per day in Bangkok metropolitan area in 1980, 1990 and 2000 is estimated to be around 0.54 million m^3, 0.50 million m^3 and 1.40 million m^3, respectively. If unregistered groundwater abstraction is included, then the total amount of groundwater use becomes 1.36 million m^3, 1.50 million m^3 and more than 2.00 million m^3 in the same years. In

Bandung, total groundwater use per day had steadily increased from 0.17 million m^3 in 1980 to 0.28 million m^3 in 1990 and 0.30 million m^3 in 2003. In Ho Chi Minh, total amount of registered groundwater use increased from 0.15 million m^3, 0.25 million m^3 and 0.53 million m^3 in the same period (Herath et al, 2005). Figure 2 indicates the chronological trend of groundwater usage in the case study cities, showing that each city experiences a steady growth of groundwater use over the last several decades.

The problem, however, is that increasing amounts of groundwater exploitation exceeded the sustainable yield levels, leading to a sharp decline of water level in these cities. Indeed, land subsidence caused by the overexploitation and subsequent water level decline has been detected in some cities.

3. Overexploitation and its consequence

Groundwater drawdown and land subsidence due to excessive groundwater exploitation have been observed in such cities as Bangkok, Bandung and Tianjin. In some parts of such cities, land subsidence is found to be very severe, resulting in the negative impacts, including the damages to buildings and urban infrastructures. In Ho Chi Minh, water table down has been already noticed or monitored in some specific points in the city. Although there was no system specifically designed to monitor land subsidence in Ho Chi Minh City as of 2006, there was already an indication that land subsidence could occur within the city.

In Bangkok, water level in aquifers has been reported to be declining since the late 1960's. Since then, the indications of possible land subsidence have been confirmed in Bangkok. The maximum subsidence rates of more than 10 cm were detected in the eastern part of Bangkok. The average degree of land subsidence in some monitoring points in Bangkok between 1980, 1990 and 2003 were 23 mm/year, 25 mm/year and 15 mm/year, respectively (IGES, 2006). Due to a tight regulation to groundwater pumping introduced as a countermeasure in Bangkok, water table has gradually shown its recovery in some aquifers. Nonetheless, land subsidence is still observed in some parts of the city. Given the irreversible nature of land subsidence, continuous monitoring and timely measures are needed to ensure the recovery of water table level and prevent the land subsidence from taking place.

A monitoring from July 1995 to July 2004 in Bandung indicates that the speed of groundwater depletion in mid-level aquifers was about 0.12 to 8.76 m/year and was 1.44 to 12.48 m/year in deep aquifers. Land subsidence has also been detected in Bandung since around 80's. In several locations, the pace of land subsidence reached even 24 cm/year (IGES, 2006). It is not difficult to imagine that overexploitation and possible land subsidence will lead to the degradation of living conditions and will be ultimately affecting regional sustainability in a negative manner. These examples in the case study cities clearly demonstrate the failure of proper groundwater management from the viewpoint of water quantity (i.e. excessive groundwater pumping).

4. Groundwater contamination

Groundwater in many parts of the world is found to be contaminated by such pollutants as arsenic, fluorine, heavy metals, coliform, chloride (salinity), pesticides, petrochemicals, nitrates, and volatile organic compounds (VOCs) (IGES, 2006). Once an aquifer is contaminated with the pollutants, removing them is not an easy task. Therefore, preventing such contamination is most essential. This section briefly summarizes the groundwater contamination and quality aspect by looking into the case study cities and discusses policy measures applied in each city.

Basically, pollutants can be categorized as (1) naturally occurring and (2) anthropogenic types. Naturally occurring pollutants include Arsenic, Fluorine, Hardness (such as Magnesium, Calcium). Although there are both naturally occurring and anthropogenic causes of arsenic contamination, many cases were found as naturally occurring pollution in many parts of Asia. In fact, 65 million of the over 100 million people worldwide which are estimated to use water supplies contaminated with arsenic are located in Asia (Kadushkin et al. 2004). Long-term exposure to water contaminated with arsenic can lead to serious health-related problems, such as skin lesions. It is reported that arsenic pollution crises are very severe in West Bengal in India, Bangladesh, China, Nepal, Pakistan, Thailand, and Vietnam. In Bangladesh alone, for example, where groundwater is heavily used domestically, it is estimated that more than 35 million people drink water contaminated with arsenic (Islam et al. 2004).

Anthropogenic types of pollutants include VOCs (Volatile Organic Compounds), Heavy Metals such as cadmium, Nitrate, pesticide, Coliform, LNAPLs (Light Non-Aqueous Phase Liquids). The anthropogenic pollutants can be further categorized depending on the types of pollution sources. The main pollution sources could be basically grouped into industrial activities, effluents from domestic wastewater, agricultural activities, undesirable waste management (leakages from landfill sites, etc) and excessive groundwater abstraction which could cause groundwater table drawdown and eventually result in aquifer salinization. The following summarizes the typical and possible pollution sources as well as the representative pollutant items caused by the respective pollution sources (Hara, 2010).

a) Industrial activities (e.g. industrial wastewater discharge, leakages from chemical storages): VOCs, Heavy metals, such as zinc, copper, chromium, etc and LNAPLs
b) Domestic wastewater (e.g. effluent from sanitary systems, livestock manures): Coliform and Nitrate
c) Agricultural activities (e.g. Fertilizer, pesticide): Nitrate and pesticide
d) Failure of sound waste management (e.g. leakages from landfill sites, illegal industrial wastes dumping): Heavy metals and VOCs
e) Excessive groundwater abstraction: Salinity caused by water table drawdown.

Table 2. Groundwater contamination in Asian cities and typical causes

Name of Pollutant	**Typical causes**	**Case study cities facing problems**
Fluorine	- Naturally occurring	Bangkok Tianjin
Metals (e.g., manganese, iron)	- Naturally occurring	Bangkok Ho Chi Minh Bandung
Heavy metals (e.g., chromium, cadmium)	- Discharge from industry - Leakage from landfill	Ho Chi Minh
Nitrate	- Fertilizer in agriculture - Sewer effluent, livestock waste effluent	Bangkok Ho Chi Minh Bandung
Coliform	- Sewer effluent, livestock waste effluent	Ho Chi Minh Bandung Tianjin
Salinity (chloride)	- Saltwater intrusion - Wastewater use for irrigation - Sewer effluent	Bangkok Ho Chi Minh Tianjin

Source: Hara (2006)

These groundwater contaminations are found to be pervasive in the case study cities, as well. Table 2 shows a summary of types of groundwater contamination, typical causes for contamination and cities where quality problems were observed in early 2000. Such contamination can be a cause of human health problems especially where groundwater is the main source of drinking water. However, measures directly targeting the aquifer contamination are found to be not well developed or immature in these cities.

5. Groundwater management – Lessons from case study cities

5.1 Measures to prevent overexploitation

To cope with the excessive groundwater exploitation, taking appropriate measures is of critical importance. In case of Bangkok, for example, the Groundwater Act was originally enacted in 1977 and amended in 1992 to enhance the control of groundwater abstraction. The main amendments included: 1) identification of the restricted groundwater pumping zone (i.e. zoning), 2) enhancement of charging for pumping and 3) introduction of penalties for illegal groundwater activities (Herath et al, 2005). The groundwater charge was increased to from zero to 3.5 Baht/m3 and then progressively to 8.5 Baht/m3 in 2003. So-called "groundwater preservation charge" was additionally introduced in 2004 and applied to the regions where groundwater was critically depleted. The combination of groundwater charge and preservation charge could have served as the driving force to reducing the groundwater abstraction in Bangkok (IGES, 2006). Additionally, following measures have been adopted in Bangkok to deal with the overexploitation (Hara, 2010):

- Regulation for groundwater abstraction
- Economic instruments : Groundwater charge
  (From 3.5 Baht/m3 in 1994 to 8.5 Baht/m3 in 2003)
- Groundwater Preservation fee (introduced first in 2004)
- Expansion of public water supply facilities
- Advancing regular monitoring system
- Requirement of drilling and groundwater use license
- Imposition of penalties and fines for lawbreakers
- Designation of critical subsidence area (i.e. Zoning)

In the meantime, it is also important to carefully examine the true effects of such economic instruments for capping the demands for groundwater. As noted below, a variety of measures have been taken and the very impacts of individual measures (instruments) should be carefully analyzed. It is equally important that while the government-owned wells are easy to control, private wells are usually difficult to handle. Hence, the actual impacts of such measures on publicly owned wells and private wells would have been different. Such effects of policy measures should also be examined in local contexts, because socioeconomic and physical conditions vary from place to place.

Other cities facing the water table drawdown, such as Tianjin and Bandung, are also seriously taking groundwater preservation and its proper management. In Bandung, the government of Bandung municipality introduced a zoning and permitting system for the purpose of groundwater controlling in 1995 and even started charging systems for groundwater abstraction 1998. According to the Bandung Mining Agency records, the inefficiencies in implementation have resulted in increase of illegal groundwater abstractions within Bandung basin. Thus, the West Java Province in 2003, with a help of the Mining Agency, initiated extensive monitoring exercises on existing wells to control illegal and damaging extractions, which led to the closure of over 250 boreholes in Bandung Basin in the same year (Herath, 2005). Tianjin also adopted measures, such as licence systems for groundwater pumping, zoning for critical areas in terms of overexploitation and possible land subsidence and charges to groundwater uses (IGES, 2007).

In Ho Chi Minh City, on the other hand, up until 2006, official record of land subsidence is not available. Monitoring systems for land subsidence was not set up until recently, despite the rapid increase in groundwater use within the city and detected decline of water tables. With the recognition of possible occurrence of land subsidence, Ho Chi Minh City has just recently decided to set up the monitoring systems for land subsidence.

5.2 Quality control and preventive measures

Comprehensive understanding of pollution mechanism is therefore necessary for a proper groundwater management of groundwater quality. However, identifying clearly the pollution sources is not an easy task. Pollutions can occur both from point sources and non-point sources. In addition, there are many factors involved in the pollution mechanism, such as soil conditions, water velocities, etc, making the clarification of appropriate policy measures rather difficult. It is very important that once soil and groundwater have been contaminated, it is not easy and costly to recover. Hence, preventive action is most essential. If contamination is detected, immediate and appropriate measures have to be taken without delay to remedy the contaminations or to prevent further spread of the contamination (Hara, 2006).

From the surveys in these case study cities, it is found that measures to manage quality aspect are rather immature and rather underdeveloped. Setting an appropriate monitoring system is a prerequisite for total quality management. However, such monitoring system in the case study cities is not systematically carried out. The frequency and the coverage of the monitored pollutants items are not sufficient at all. Nonetheless, the awareness of local governments in Asian cities has been improving, in recognition of the importance of quality management and possible threats and risk for human health without adequate cares. In Bandung, for instance, measures for quality management, which are either implemented or now under consideration, include the following:

- Improving community's awareness for contamination and health risks, through campaign clean hand action
- Requesting industries to monitor and measure their wells
- Requesting industries to share their wells with its surrounding residents as a part of corporate responsibility for community development
- Monitoring ground water quality occasionally in certain locations

Some of these measures can be applicable to other cities. In the meantime, the following list could be an example of possible measures that can be applied to various types of groundwater contamination in general (Hara 2006):

- Setting-up an appropriate and systematic groundwater quality monitoring systems
- Setting groundwater quality standards
- Regulating wastewater and solid waste discharge from the household, livestock, and industrial sectors
- Creating a zoning system for polluted areas
- Penalizing polluters
- Using economic instruments (i.e., charging system, tax)
- Creating registration systems for hazardous substances in the industrial sector

Since groundwater and surface water are interlinked, pollutants in surface water possibly could affect aquifers through such interconnection. This means that groundwater quality management should always take integrated approaches taking care of both surface and groundwater.

6. Conclusions - towards water security and regional sustainability

Asian cities share the same experiences of increasing groundwater usages, overexploitations driven by the growing groundwater use and groundwater contamination. Taking prompt measures is needed as some of the groundwater related problems, such as land subsidence, are irreversible. In this paper I briefly summarized policy measures for groundwater management in some Asian cities. Timely measures, integrated approach and stakeholders' participations, while fully taking into account the local socioeconomic conditions, are of vital importance to tackle the complex groundwater related problems and to ensure the soundness of the essential local commons in rapidly urbanizing areas of Asian cities.

In the meantime, there are barriers and constraints which have been commonly observed. For instance, the lack of human resources capable of dealing with groundwater quality management is one of the biggest barriers. Lack of capable human resources is actually hindering the implementation of effective and proper water quality monitoring. Capacity building to nature the personals who can deal with monitoring and water quality management is therefore of critical importance. Other constraints include, but are not limited to, budget limitations, deficient access to relevant technologies, limited and fragmented information and knowledge about groundwater quality management, inadequate research activities, inefficient institutional arrangements (e.g. overlapping governmental agencies responsible for quality monitoring surveys) and low public awareness about contamination and problems associated with contamination, such as health risks (Hara, 2006).

Finally I highlight the importance of sharing knowledge and lessons among Asian countries. As Asian countries face the same kind of problems and patterns of groundwater usage and associated problems, it is highly essential for the countries to share these problems, relevant knowledge and effective practices for effectively overcoming such problems and to enhance the cooperation to tackle the same problems. While there are already many cooperative research and international projects which are undertaken in the relevant fields of water resource management, it is indispensable to continue these cooperation and common initiatives.

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