GW-2

Project Report on

CCOP-GSJ/AIST-CGS Groundwater Phase II Meeting

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COORDINATING COMMITTEE FOR GEOSCIENCE PROGRAMMES IN EAST AND SOUTHEAST ASIA (CCOP)
in cooperation with
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Youhei Uchida (Chief Editor)

PREFACE

Since the establishment of the CCOP in 1966, geological and geophysical surveys have been carried out by the CCOP under the cooperative schemes in the East and Southeast Asia for offshore natural resources. These data have been distributed to member countries as printed maps and publications. As for the first groundwater project, "Groundwater database in East and Southeast Asia" had been compiled under the DCGM Phase IV project of CCOP from 2001 to 2004.

Groundwater is one of the limited natural resources of the world. Because of the lack a feeling of importance of groundwater, especially, in the late 20th century, groundwater has been significantly damaged by human activities, resulting in groundwater issues, such as land subsidence, seawater intrusion, and groundwater pollution by toxic substances, that have become remarkable problems in everywhere in the world. The countries in the East and Southeast Asia have been also faced the many groundwater problems which are needed international cooperation to be solved.

The kick-off meeting of the Phase II for the CCOP-GSJ/AIST Groundwater project was held in Bangkok in October 2009. The agreement of the meeting was to release some kinds of hydro-geological map including the latest scientific information for the end-users at the completion of the Phase II project. After the kick-off meeting, the CCOP-GSJ/AIST Hydrological Mapping under CCOP Groundwater Project Meeting was held in Bangkok in March 2010, and the Hydrological Mapping Working Group (HMWG) has been organized. The HMWG confirmed to release hydro-geological map including latest scientific information of the Chao-Phraya Plain, Thailand and the Red River Delta, Vietnam.

The second meeting of the Phase II was held in Xian, China, in September 2010. This is the publication which was compiled each country report "Groundwater Pollution and risk management in the CCOP Countries". These reports showed individual problems of pollution and method of risk management for groundwater in each country. I believe we will be able to have some solutions about groundwater management in the CCOP countries from the country reports.

I am very grateful to the authors for their invaluable contributions and to the organizations to which the authors belong for their permission to publish those important reports.

Youhei UCHIDA

Chief Editor

CONTENTS

Ground water Pollution and Risk Management in Cambodia

Sam Ol Ou*

Abstract

Most water supply programmes in Cambodia have focused on providing access to bacteriologically safe water, an approach which has led to an increasing reliance on groundwater, especially in rural areas. However, there have been very few data collected on the chemical quality of the nation's drinking water sources, and few water supply programmes have the capacity to assess chemical quality. The study was designed to address this data gap by conducting a low-cost, rapid assessment of drinking water sources nationwide to determine whether there were any chemicals of concern in Cambodian water supply sources. Results of the assessment confirm that there are several parameters of health and aesthetic concern; dissolved arsenic is the most significant. Elevated arsenic levels (some exceeding $500 \mu g l^{-1}$) were detected in aquifers of moderate depth in several highly populated areas, confirming that further investigation of the occurrence of arsenic contamination in Cambodia is warranted. Other chemicals of health concern include nitrate, nitrite, fluoride and manganese. Additionally, many groundwater sources are negatively impacted by parameters of aesthetic concern, such as iron, manganese hardness and total dissolved solids. Elevated levels of these parameters have caused consumers to reject newly installed water supplies, often in favor of surface water sources that are bacteriologically unsafe.

1. Groundwater in Cambodia

Groundwater is used in Cambodia for both community and town water supply and for irrigation. To date, there has been no comprehensive investigation of the national groundwater resources. However, there have been two studies, both under the auspices of the US Geological Survey. The first (Cushman, 1958) was a reconnaissance of the lowland area to determine the availability of groundwater for dry season irrigation. The second was a general description of groundwater availability based on test drilling data and well records obtained in the course of a USAID rural development program between 1960 and 1963. The program drilled 1,100 wells, of which some 800 were productive. Depths ranged from 2m to 209m, with an average of 23m. Information is also available from well drilling programs undertaken since the 1980s by NGOs and international organizations, particularly by OXFAM and UNICEF who have drilled more than 5,000 wells throughout the country. These wells were generally to depths of 20m to 50m. The most recent information on these wells however, mainly relates to their location and

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characteristics. The Mekong lowlands consist broadly of alluvial material overlying shale, slate and sandstone bedrock. The low hills and plateau areas are mostly underlain by igneous rocks and limestone. The depth of alluvium is 70 m. or more. The alluvium consists of sandy silt in the upper part and of clayey silt in the lower. There are occasional sand beds of up 1 m thickness. Two types of alluvium are recognized, an older one and a younger one. The younger alluvium is situated under the Mekong and Tonle Sap Lake flood Plain. Except for the occasional thin sandy beds and lenses, the alluvium has a low hydraulic conductivity and the yield is very low, typically 0.2 l/s. Yields from the sandy layer are higher, typically of the order of 1 l/s. For those UNICEF wells for which records are available, many have a yield of more than 3 l/s, while less than 3% are reported as having yields in excess of 10 m^3/hr (2.7l/s). In January 1996, the Government of Japan signed an agreement to fund a project for the supply of clean water to the Phnom Penh municipality and rural areas by using groundwater. About 30% of this groundwater was to be obtained around Phnom Penh. No artesian aquifers were found, the area being underlain at depths ranging from 18m to 80m by hard crystalline rock. The best well yielded 200 l/min, and the average of seven production wells was 80 l/min.

The study area locates at the central and southern parts of Cambodia with 157 km in width and 167 km in length and includes three major rivers: Mekong, Tonle Sap, and Bassac rivers. The Mekong River is the largest river in the Southeast Asia and full of water, forest, and aquatic resources. It starts from the southeastern Himalayan Mountains and empties out into the South China Sea with 4200 km in length. It ranks tenth in terms of discharge1). The study region of the river considered in this study is the part of the Lower Mekong Basin located in Cambodia (Fig. 1).

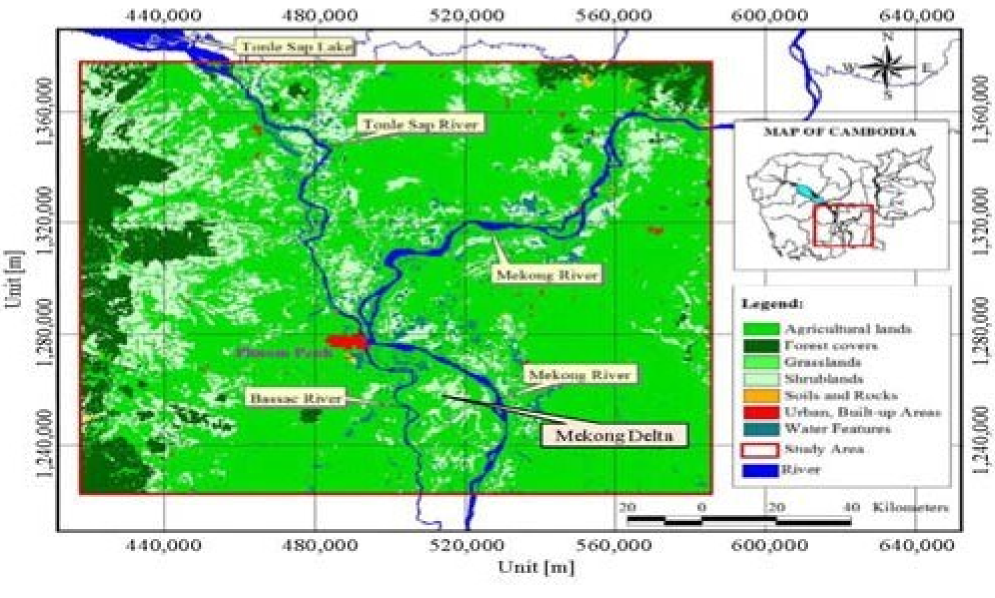

Fig.1 Location of study area with universal transverse mediator coordinate system

Figure 2 shows the geological features of study area. The following is the description of every geological unit. The sedimentary unit is dominant, especially the distribution of pediments at the western side and alluvial plain deposits along Tonle Sap, Bassac, and Mekong Rivers. The pen plain laterite deposits can be found at the northeastern part due to the erosion late rite levees of hilly area. The volcanic deposits existed in this area as well. Similarly, the organic deposits are easily recognized in the swamps area and significantly in between Bassac and Mekong Rivers. Alluvial fans deposit along the valley of the mountains and spread until the floodplains sediments in lowland. Terrace alluvial deposits distribute along small rivers in southern part as well Tonle Sap River. Quartzite can be found in the mountainous region at southwestern site, and the distribution of igneous unit such as granite is dominant in mountainous area of western region.

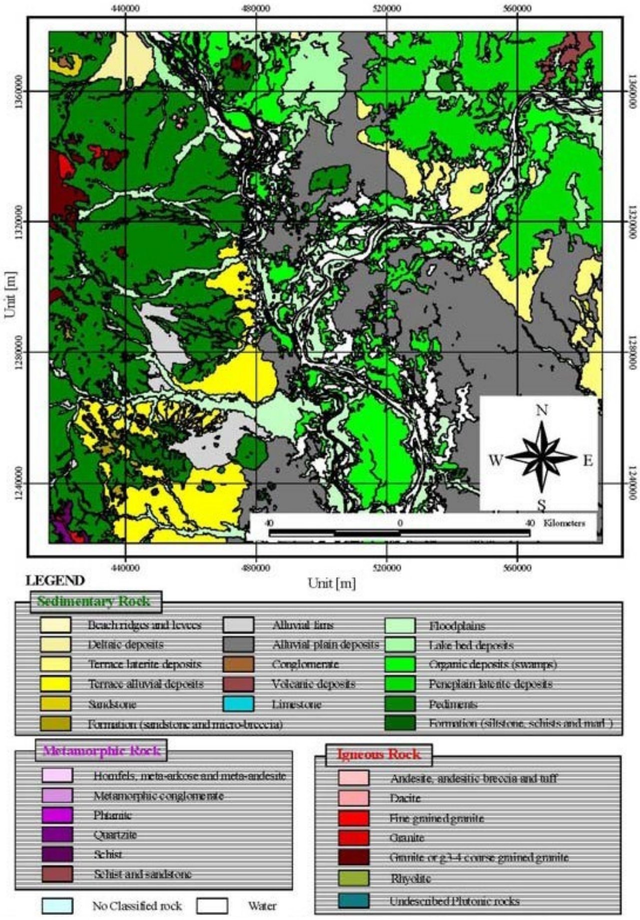

Fig.2 Geological map of study area with universal transverse mediator coordinate system

Figure 3 shows the simplified conceptual model in the unconfined aquifer of our area. A head-controlled boundary, a boundary with a known potential or hydraulic head, which is time–dependent or –independent), was assigned for the calculation. The rectangular boundary of interest area was considered as head-controlled boundary whose groundwater elevations were assumed to be time-independent. The groundwater table elevations at these boundaries were computed from the interpolation of groundwater elevations at the observation wells. In contrast, the river reaches were treated as the head-controlled boundary whose water elevations were dependent on time.

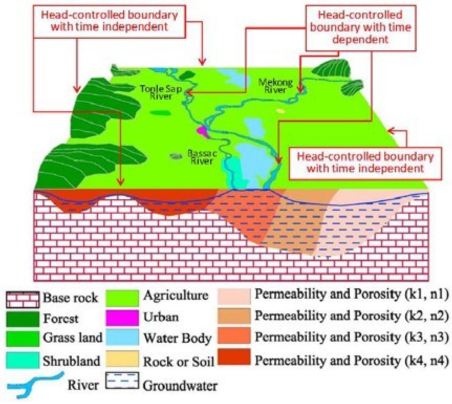

Fig.3 Conceptual model of study area

1.1 Geology and the occurrence of groundwater.

On the basis of landforms, geology and occurrence of groundwater, Cambodia can be divided into three main regions:

- The Mekong Lowlands.
- The Southwestern Highlands
- The Coastal Plain of Southwestern Cambodia.

The bedrock underlying the Mekong Lowlands consists predominately of a series of consolidated sediments of shale, slate, sandstone and limestone of Triassic and older age.

The Southwestern Highlands consist of several massive mountain ranges. These ranges commonly have relatively steep sides and flat tops. The main mass of the Highlands is formed by the Cardamoms and Elephant mountains. The Highlands are made up of a series of metamorphosed sandstone, slate, schist and quartzite units. In the vicinity of the city of Pailin these are associated with a large mass of gabbros and hyalite.

(1) Alluvium

In Cambodia, the alluvial units constitute some of the most important sources of groundwater. The alluvium, whether it is older alluvium or young alluvium, may be composed of sand, silt and clay and mixtures of these constituents. The clay portions have a low permeability and may yield water at very slow rates. The sandy beds and lenses of the alluvium are some of the best water-producing horizons. 3 Their average yield is about 16 m^3 /h in drilled wells. Groundwater from alluvium is generally believed to be of good chemical quality and suitable for most purposes in Cambodia. In many areas, dug wells are important as sources of domestic water supply.

(2) Basalt

Data available on the water-yielding capacity of basalt quote yields of 30-50 m^3/h. A large area of the country in Kompong Charm Province in the northeast is underlain by basalt. The quality of water from basalt is good and suitable for most purposes.

(3) Post-Triassic Sandstone and Conglomerate

A large part of the highland area and a large area between Kompong Cham and Pursat Province are underlain by these rock types. The original porosity and openings along joints and bedding planes make these rocks somewhat permeable. No deep wells are known to penetrate the sandstone and conglomerate beds. The groundwater from sandstone and conglomerate should contain little mineral matter as the rock consists mostly of silica.

(4) Other igneous rocks

Other igneous rocks occurring in the country are gabbros, hyalite, diorite, and granite. The water-yielding capacity of these rocks, either fresh or weathered, is believed to be similar to basalt.

(5) Limestone

Limestone has limited distribution in surface exposures. Almost no data are available on the water-bearing capacity of limestone, but it is believed that limestone could yield substantial water.

(6) Triassic Metamorphic rocks

Triassic rock units consisting of sandstone, shale, slate, quartzite, and schist appear to underlie a large portion of the Mekong Lowlands. The yields are considered to be low.

1.2 Groundwater and river water flow exchange zonation

In this section, the characteristics of groundwater exchange in the study area were categorized based on the output of numerical simulation. The zonation of flow exchange between groundwater and river water helps not only to have a better understanding about the subsurface flow in the vulnerable locations to the pollutants such as arsenic as example but also to specify the study to more detail in the future. Zone division was determined based on the above river and groundwater interaction analysis, groundwater contour map, and groundwater flow velocity. The monthly results of groundwater level from numerical simulation in 2002 were compared in order to determine the location of water exchange location. At the same time, the monthly groundwater flow velocity maps were also utilized to see the changes of velocity component, especially along the places of water exchange (determined by the comparison of groundwater level). Finally, the zone division of groundwater and surface water were drawn, and the wide of this zone was confirmed with the above groundwater interaction analysis.

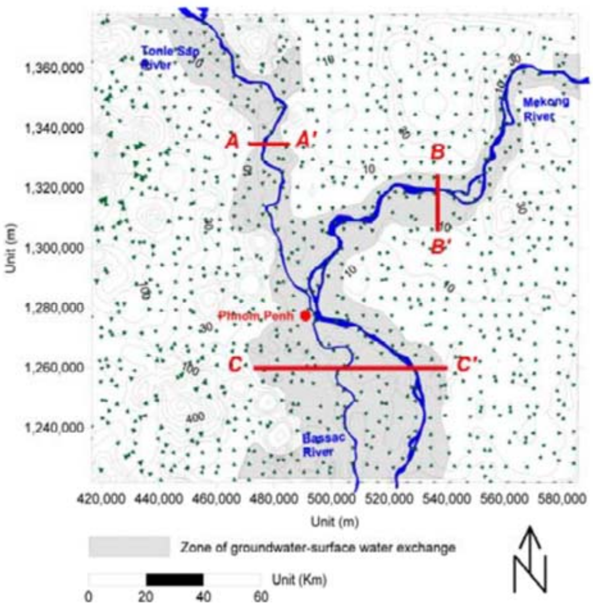

Fig.4 The zonation of groundwater

The grey dot area (Fig. 4) along the rivers shows the boundary of river effect on groundwater.

Three cross sections are presented in this paper in order to observe the consequences from the flow exchange during dry and wet season. In Fig. 5, the extensions of river water elevation during flooding period were made to make them more realistic. However, during the model calculation, the expansion area was not considered due to the small amount of covered grid number as well as the narrowness of river widths comparing to the grid size (500 m).

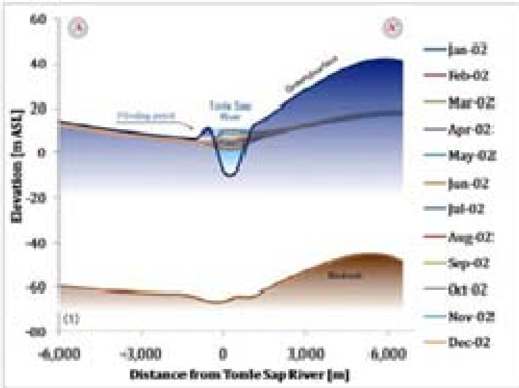

Fig. 5(1)

In Fig. 5 (1), Tonle Sap River gains discharge of groundwater coming from the mountainous and hilly areas at both sides of the river. The cross-sections A-A’ shows the monthly groundwater variation along Tonle Sap River. Groundwater levels at the east of Tonle Sap River significantly change every month, while the west side does not fluctuate so much. Figure 5(2a & b) is located along Mekong River. The river gains the recharge of groundwater in the hilly areas at the both sides of river. The cross-section B-B’ (Fig.5. 2b) shows the little change of groundwater in this location. On the other hand, the groundwater mostly supplies to the Mekong River, but only three months (August, September, and October) which the water level in the river is higher than groundwater i.e. flooding period. Figure 5 (3a & b) is located at the south of the area, along Bassac and Mekong River. Both the aquifer and river supplied the water to each other during the dry and rainy season. The cross-section C-C’ (Fig. 5.3b) shows the change of groundwater, river and lake water level. The exchange of groundwater and river during the rainy and dry seasons takes place. Moreover, the lake nearby the river receives the water from the river. It also influences the groundwater at the surrounded areas.

The numerical model of groundwater flow shows the reasonable agreement between field observation and calculation results, and it was applied for figuring out the regional groundwater flow in the study area as well by coupling the groundwater recharge model and considering the river water level. The output of numerical simulation was utilized to understand the surface water and groundwater interaction by considering the variation of groundwater and river water levels. Tonle Sap River and Mekong River from upstream to Phnom Penh is a gaining stream from the groundwater at the mountainous and hilly area during rainy and dry seasons. Bassac River and Mekong River from Phnom Penh to downstream has two functions: gaining stream during dry season and losing stream during raining season. The delay process between groundwater and river water occurred within 3 months. Groundwater and river water flow exchange zone was made in order to identify the most vulnerable place to any pollutant.

Moreover, the zonation will be helpful.

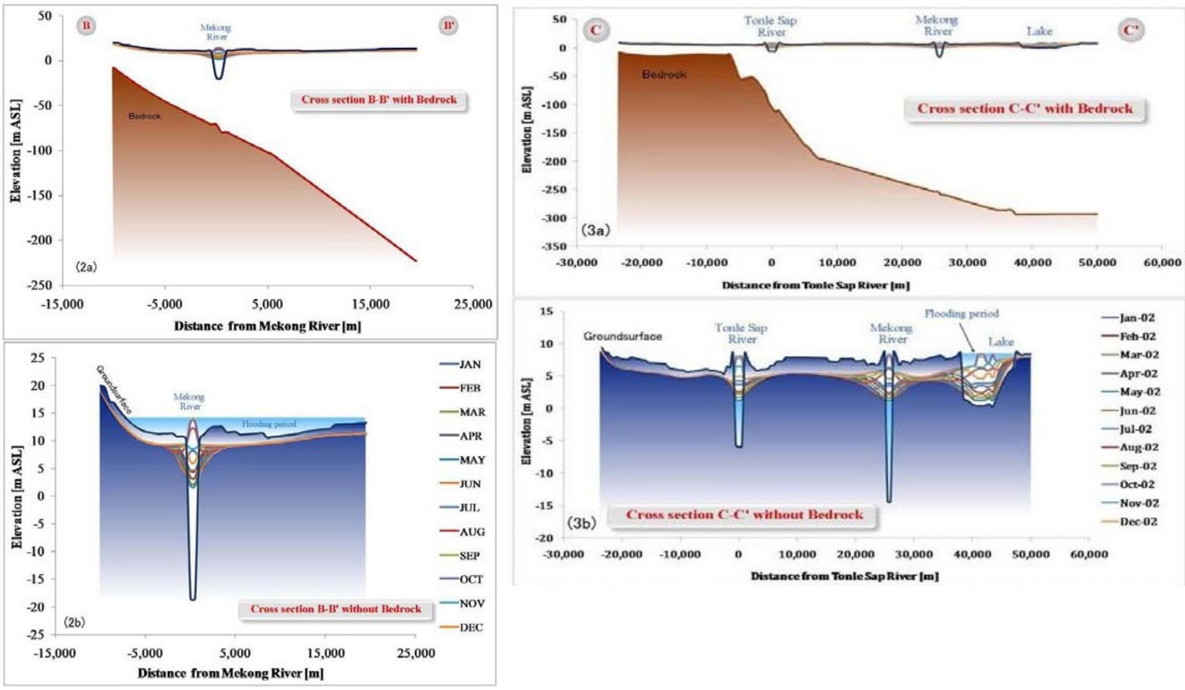

Fig.5(2), (3) Cross section of A-A' along Tonle Sap River and B-B' along Mekong river at the northern model area, C-C' along Bassac and Mekong River at the southern model area.

2. Groundwater pollution in Cambodia

2.1 Groundwater pollution

Groundwater pollution is a very serious problem. Unlike a lot of the pollution on the surface waters, like trash floating in the bay, groundwater pollution is harder to recognize until after illness has occurred.

Groundwater, which is the water that remains under the ground and is tapped into to provide drinking water for homes is generally polluted by the activities that occur just above it.

People are the number one cause of groundwater pollution. Having water samples tested regularly is the only way to be sure that the groundwater is not contaminated.

Unfortunately, there are a multitude of potential groundwater pollutants that can seriously contaminate drinking water. Most groundwater pollution happens because of improper disposal, use, or storage of chemicals, pesticides, or substances like car engine oil.

Deicing salts that are used for clearing driveways and pathways can contaminate groundwater. Landfills have been known to cause toxic runoff that infiltrates the groundwater supply and underground tanks for storing gasoline and diesel for petrol stations can develop minor leaks and seep into the ground.

A groundwater supply that is directly over a plot filled with animals, such as a farm environment, can be contaminated with the bacteria from animal waste. The chronic use of chemically based pollutants such as weed killer, insecticides, and antifreeze puts many home groundwater supplies at risk for contamination.

Because there are so many variables that can lead to groundwater pollution it is vital that the state of groundwater health be tested regularly.

Different causes of groundwater pollution have different warning signs. Sometimes these warning signs can be found in the water itself while other times it takes awareness of one's surroundings to notice a problem. Being aware of potential dangers can help determine a problem should one develop.

When buying or leasing a new property, residents should become familiar with the hazards that are nearby. Is there a landfill in the area or a gas station across the street? Does the property have a septic system? This type of information can help residents keep themselves safe from exposure to pollution that can enter groundwater.

Septic systems, residential use of pesticides or automobile chemicals, and the use of deicing salts are the three most common in home causes of groundwater pollution. If deicing salts were to seep into the groundwater supply the water's taste would become suspiciously salty. It takes a home test to determine high levels of chloride in the water itself to confirm the suspicions.

Most pesticides and other home use chemicals are either not readily detected in the water or will cause sudden illness in everything that the water is used to sustain. When plant life that is watered with pesticide polluted groundwater the plants tend to become ill and die. Animals that drink from the polluted water also become ill and may die.

If there is a stream or other small body of water on the property or nearby it is likely that the groundwater contamination has leached into the surface water and is killing the aquatic plants, fish, and other dependant animals. While it usually takes a significant amount of chemical residue create such health hazards, over time some chemicals can accumulate and the property can have much more chemical based contaminants than originally thought. Septic system pollution usually shows signs of septic system failure elsewhere. Residents are likely to find that the septic system has backed up and is creating a raw sewage flood somewhere in the yard or the surrounding property. In most cases groundwater tests are needed to determine the level of bacteria that infiltrated the groundwater. In very rare cases the water might appear to be off color or contain an unwelcome aroma.

2.2 Groundwater Contamination

Groundwater in Cambodia is generally good quality, but high iron contents and increasing salinity levels have been noted in Svay Rieng and southern Prey Veng Province. Also, water sampling in four provinces in northwestern and southern Cambodia show that high levels of iron, TDS and fluoride are found in groundwater. Many shallow wells are contaminated by fecal coliforms. All water samples in Battambang failed to meet WHO water quality guidelines. Contamination of water resources has led to frequent outbreaks of cholera.

Groundwater samples for chemical analysis were collected from 54 existing wells and 24 newly drilled wells (test wells) in May-June 1997. The following are some of the results within different provinces:

- In Svay Rieng Province the trace element chemistry, is dominated by Na, HCO_3 and Cl.
- In Phnom Penh $NaHCO_3$ is dominant along with Ca and Mg.
- In Prey Veng, Na, Ca and Mg with HCO_3 and Cl.
- In Kompong Speu, most samples contain Ca and HCO_3.

When the results are compared with the guideline values for drinking water issued by the WHO, many of wells have higher values than the WHO standards.

2.3 Drinking Water Quality Index – Health

A drinking water quality index (DWQI) has been developed in order to present groundwater risk at the commune level. The DWQI health represents the chance of deeper groundwater being safe for consumption in a commune. For example, an index of 68 for a particular commune means that there is a 68% chance that a tube well drilled in that commune will be safe. Therefore, a score of 100 is very good while that of 1 is a very poor. This index is based on the well points surveyed by RDI and the analysis of Arsenic, Manganese, Fluoride, and Nitrate – four common health-impacting groundwater contaminants, the health DWQI for each commune in Kandal, Prey Veng, and Kampong Cham. DWQI Health by Commune, Prey Veng, and Kampong Cham Provinces, Cambodia.

A DWQI score is not reported for communes where less than 5 samples were collected. In some communes, wells may not have been present or they were inaccessible at the time when field technicians visited the area.

(1) Arsenic

Arsenic is the most critical chemical groundwater contaminant in Cambodia because it affects a very large area and has the most severe health consequences for those consuming arsenic contaminated water for a long time (generally 5 to 10 years). Long-term consumption can cause various internal cancers and visible manifestations on the hands and feet, known as hyperkeratosis. Arsenic concentrations in Cambodia have been found as high as 3,000 ppb where the WHO and Cambodian drinking water quality standards are 10 ppb, and 50 ppb, respectively, areas where Arsenic has been observed to be elevated in the groundwater. Tubewell Groundwater Arsenic in Kandal, Prey Veng, and Kampong Cham Provinces, Cambodia.

Note that most of the highest Arsenic concentrations exist within a distance of 10 km from the Mekong River, its tributaries and ancient buried riverbeds. However, Arsenic is sometimes found above the drinking water standards in locations away from the rivers and this is still a cause for concern. Also, in the Arsenic impacted areas, there is a much greater risk for high concentrations in deeper tube wells as opposed to shallower dug wells. More detailed Arsenic information including province, district, commune breakdowns are provided in the Groundwater Summary Tables here.

(2) Manganese

Manganese is another health-impacting groundwater contaminant that has been found in Cambodia. Like Arsenic, Manganese is naturally present in the ground. Manganese contamination effects many wells in Cambodia but the health effects are less visible than Arsenic. Manganese is called a neurotoxin which means it can affect the function of the brain. Some studies have linked Manganese groundwater consumption to lower test scores and hyperactivity in children. The Cambodian and WHO drinking water standard for Manganese is 0.4 mg/l for health impacts. Manganese at lower concentrations can cause unpleasant water and discolouration of cooked rice but is safe to drink. Figure 4 presents areas where Manganese has been observed to be elevated in the groundwater. Tubewell Groundwater Manganese in Kandal, Prey Veng, and Kampong Cham Provinces, Cambodia. Manganese concentrations are very high throughout Kean Svay District in Kandal Province but elevated concentrations exist in small pockets throughout the surveyed area. More detailed Manganese information including province, district, commune breakdowns are provided in the Groundwater Summary Tables here.

(3) Fluoride

Fluoride is commonly added to the water supply in developing countries because at certain concentrations it can have dental hygiene benefits. However, naturally-occurring Fluoride in the groundwater is sometimes present at very high concentrations and this can cause dental and skeletal problems. The Cambodian and WHO drinking water quality standards for

Fluoride are 1.5 mg/l. It has been found that concentrations greater than 4 mg/l can cause skeletal fluorosis which can cause very serious health effects, areas where Fluoride has been observed to be elevated in the groundwater. Tube well Groundwater Fluoride in Kandal, Prey Veng, and Kampong Cham Provinces, Cambodia. More detailed Fluoride information including province, district, commune breakdowns are provided in the Groundwater Summary Tables here.

(4) Nitrate

Nitrate is present naturally in the ground but only at low concentrations. Elevated concentrations are typically associated with human disturbances such as improper human and animal waste management or heavy fertilizer usage. Small-scale animal raising is common in Cambodia and if fecal waste is not managed properly, Nitrate levels can be very high in nearby wells. High Nitrate levels can cause a blood disorder known as blue-baby syndrome or methemoglobinemia in infants under 6 months of age. The lips and finger tips of the infant may turn purple/blue and in severe cases the condition is fatal, areas where Nitrate has been observed to be elevated in the groundwater. Tube well Groundwater Nitrate in Kandal, Prey Veng, and Kampong Cham Provinces, Cambodia. Elevated concentrations of Nitrate are generally very localized and the result of poor human or animal waste management around the well. Note that the map above is for tube wells only and open wells are much more susceptible to Nitrate contamination because they are shallower. However, pockets of aquifer contamination have been found in northern Prey Veng Province, Sithor Kandal District. This condition is present because of a combination of factors; there are many tube wells in the villages, nearly all are very shallow (10 to 20 metres), the population density is high, cows and pigs are commonly raised under houses, and waste management practices are poor. More detailed Nitrate information including province, district, commune breakdowns are provided in the Groundwater Summary Tables here.

(5) Iron

Iron concentrations are generally very high in the groundwaters of Cambodia. Iron is naturally- occurring but has no health effects when consumed through drinking water. Iron can cause the water to look cloudy, taste poor, and can stain laundry or discolour rice. The drinking water quality standard for Iron is 0.3 mg/l based on aesthetic effects, but this is often exceeded in groundwaters, areas where Iron has been observed to be elevated in the groundwater. Tubewell Groundwater Iron in Kandal, Prey Veng, and Kampong Cham Provinces, Cambodia. More detailed Iron information including province, district, commune breakdowns are provided in the Groundwater Summary Tables here.

3. An Arsenic problem in Cambodia

Arsenic contamination is a significant threat to the drinking water safety in Cambodia, especially in the rural regions where hundreds of thousands of peoples rely primarily on groundwater for their drinking water needs. A recent study commissioned by the Ministry of Rural Development (MRD) and UNICEF to test the water from 16,000+ tube wells for arsenic in 7 central provinces bordering the Mekong and the Bassac rivers (including Kandal, Kampong Cham, Kratie, Kampong Chhnang, Kampong Thom, Prey Veng and peri-urban Phnom Penh provinces) found that an estimated 320,000 people in 1,600 villages are at risk. A study by the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) reported arsenic concentration as high as 1,300 mg/l, which is 26 times higher than the Cambodian standard of 50 mg/l (MIME, 2004) in the Mekong delta south of Phnom Penh (Buschmann et al., 2007). In late 2006, a knowledge, attitude, and practices (KAP) survey jointly conducted by the MRD, UNICEF and the Institute of Technology of Cambodia (ITC) found several suspected arsenics is cases in the Kandal province. These cases of skin diseases and cancers were analyzed and confirmed by the Ministry of Health (MoH) to be arsenics is (MRD and MoH, 2007). There is strong demand among various stakeholders on Cambodia to find effective solutions. A grant was awarded by the Asian Development Bank (ADB) to evaluate the applicability and limitations of the Kanchan Arsenic Filter (KAF) as a potential arsenic mitigation option for Cambodia. The KAF was developed by the Massachusetts Institute of Technology (MIT) and a Nepali NGO, Environment and Public Health Organization (ENPHO) based on 7 years of extensive inter-disciplinary laboratory and field studies in rural villages of Nepal (Ngai et al, 2006). This awards-winning filter is an open-content technology and requires no external energy/material input for operation and requires no replacement parts except nails. Refer to Figure 6 for a diagram of the filter.

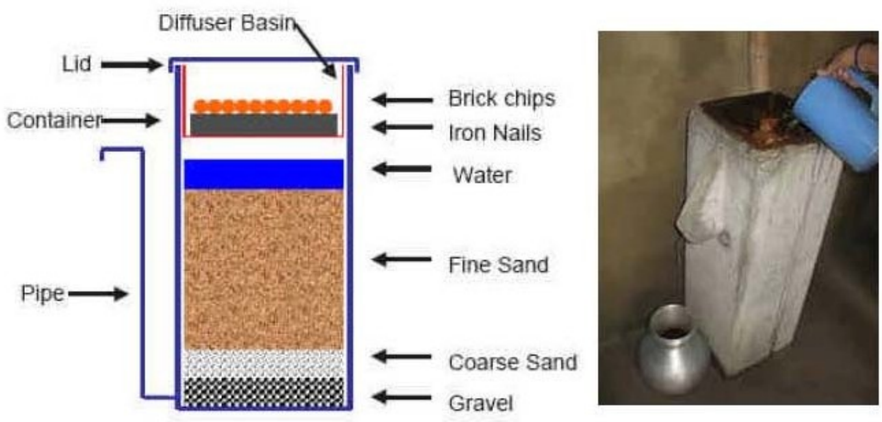

Fig.6 Components of the Kanchan Arsenic Filter (KAF)

3.1 Project Schedule, Participating Organizations & Funding Sources

<u>Overall Study Duration (Phase I & II)</u>

1st of February 2008 to 31st of December 2008

<u>Phase I Study Duration</u>

1st of February 2008 to 25th of August 2008

<u>Lead organizations:</u>

Institute of Technology of Cambodia (ITC) Ministry of Rural Development (MRD)

<u>Support organizations:</u>

Centre for Affordable Water and Sanitation Technology (CAWST) Massachusetts Institute of Technology (MIT)

<u>Funding sources:</u>

Asian Development Bank Pilot Demonstration Activity – US $50,000

Mondialogo Engineering Competition – US $6,500

3.2 Selecting a Site for Phase I Testing

We wanted to find a research site representative of the general condition of arsenic contaminated area of Cambodia so we identified published studies and summarized the water quality data in them (see Table I):

Table 1 - Arsenic-Related Data for Tubewells in Cambodia (Previous Studies)

	Buschmann et al 2007	*Berg et al 2007*	*Feldman et al 2007*	*Sthiannopkao et al 2008*
Number of samples	90	204	19	15
Arsenic (ug/L)	233	212	148	269
Iron (mg/L)	2.8	2.8	6.2	2.57
pH	7.03	6.94	6.99	6.1
PO4 (mg/L)	1.8	0.59	-	-

We randomly tested 13 tube well in Kien Svay and talked to households regarding their interest in participating in this research. One household has high arsenic and was very cooperative, so we selected that tube well as our research site. As noted below, our research site has worse conditions than average, yet not too extreme, making it a good research location.

Table 2 - Comparison of Phase I Site to Data from Previous Studies

	Buschmann et al 2007	*Berg et al 2007*	*Feldman et al 2007*	*Sthiannopkao et al 2008*	*Our site*
Arsenic (ug/L)	233	212	148	269	637
Iron (mg/L)	2.8	2.8	6.2	2.57	6.43
pH	7.03	6.94	6.99	6.1	7.02
PO4 (mg/L)	1.8	0.59	-	-	5.09

3.3 Arsenic in ground water

Arsenic was found in ground water used for both urban and rural water supplies. Arsenic concentrations during the main round of sampling ranged as high as 326mg l2l. Eight samples (8.5% of the total) exceeded the WHO arsenic guideline value of 10mg l21, and three samples (3.2%) exceeded the recently adopted CDWQS for arsenic of 50mg l21. The elevated arsenic concentrations were observed in wells located near major watercourses such as the Mekong River and its tributaries and distributaries, and in areas where the surgical geology comprised sediments of Quaternary age. Areas along the Mekong and Bassac rivers to the south and southeast of Phnom Penh (in neighboring Kandal Province) appeared to have the highest concentrations in the study area. Figure 7 shows an arsenic affected sampling locations.

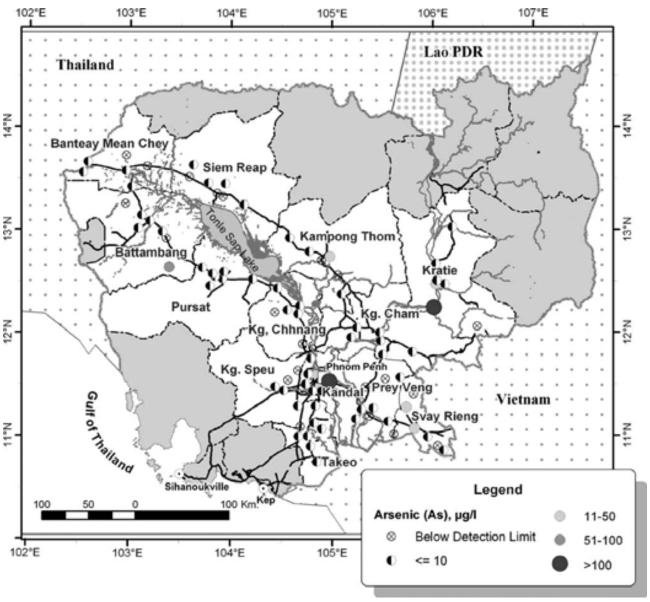

Fig.7 Sampling site of arsenic concentrations

Owing to the potential health significance of elevated levels of arsenic in drinking water, follow-up sampling was conducted in the portion of the study area that appeared to have the highest arsenic concentrations – Kien Svay and Takhmau districts of Kandal Province. Of the 16 follow-up samples taken from these two districts, 11 (nearly 70%) exceeded 10mg l21, and ten exceeded 50mg l21. Concentrations ranged up to 504 mg l21 and averaged over 130 mg l21, confirming that ground water in this densely populated area lying between the Mekong and Tonle Bassac rivers is highly affected by arsenic. Of the two districts re-sampled, Kien Svay appeared to have the higher concentrations as well as a higher percentage of affected wells (80% exceeded 50 mg l21).

Table 3 provides a summary of all arsenic-affected wells sampled during the assessment. The household and community wells with elevated arsenic had all been installed within the past 10 years, though a few of the urban supply wells were considerably older. The average depth of arsenic-affected household and community wells was approximately 40 meters, while the urban supply wells ranged from 52 to 209 meters in depth.

Table 3 Water sources with elevated arsenic levels

Sample no.	Province/district	Source type	Depth (m)	Arsenic ($\mu g l^{-1}$)	Eh (mV)	Iron ($\mu g l^{-1}$)	Mn ($\mu g l^{-1}$)	pH	Year installed
BBG-2	Batdambang/Moung Russei	Community well	29	69.0	93	12,600	532	6.55	1998
KAN-1	Kandal/Kien Svay	Urban supply well	65	32.5	–	279	947	7.26	Unknown
KAN-3	Kandal/Kien Svay	Household well	60	326	–	8,840	142	7.03	1999
KAN-9*	Kandal/Kien Svay	Household well	40	84.4	−143	239	81.3	7.00	1999
KAN-16*	Kandal/Takhmau	Urban supply well	52	85.8	−234	999	982	7.44	1996
KAN-19*	Kandal/Takhmau	Household well	33	71.9	−364	6,510	500	6.89	1997
KAN-21*	Kandal/Kien Svay	Household well	53	504	−389	6,290	1,590	7.18	1997
KAN-22*	Kandal/Kien Svay	Household well	24	89.7	−315	13,700	376	6.70	1996
KAN-23*	Kandal/Kien Svay	Household well	40	120	−335	9,250	379	6.82	1999
KAN-24*	Kandal/Kien Svay	Household well	48	338	−340	1,010	179	7.80	2000
KAN-25*	Kandal/Kien Svay	Household well	54	28.0	−282	460	410	7.25	1998
KAN-27*	Kandal/Kien Svay	Household well	57	438	−370	4,880	559	7.34	Unknown
KAN-28*	Kandal/Kien Svay	Household well	40	189	−347	14,000	185	6.87	1996
KAN-29*	Kandal/Kien Svay	Household well	53	196	−333	9,090	88.8	6.84	1997
KRT-2	Kratie/Kratie	Urban supply well	209	43.8	−270	1,120	166	7.22	1962
KRT-8	Kratie/Chhlong	Community well	37	119	−450	13,600	135	6.73	1999
KTH-3	Kampong Thom/Kampong Svay	Community well	22	27.2	–	10,800	771	6.51	1998
SVR-1	Svay Rieng/Svay Rieng	Urban supply well	120	13.8	–	3,880	231	6.50	1952
SVR-5	Svay Rieng/Romeas Haek	Community well	42	36.3	–	3,210	297	6.87	1994

*denotes follow-up samples in Kandal Province.

3.4 Arsenic Testing

Early in our assessment of the quality of ground water RDI discovered high levels of naturally occurring arsenic in water all over Cambodia. Testing wells and mapping their coordinates is a crucial part of understanding and combating this phenomenon.

Because the true extent of the situation is still not known RDI has made an agreement with the government to help address this major health concern in the country.

Photo 1

RDI now runs the leading laboratory in Cambodia for arsenic, virus, and bacteria research. Partnerships with some of the most prestigious US Universities allows the RDI labs to continue to be at the forefront of research and risk assessment.

3.5 An Arsenic Problem

Chronic exposure to arsenic at low levels has a pronounced impact on human health. It has been linked to a wide range of health effects including: cancer of the skin and internal organs, increased incidence of respiratory disease, mental slowness, hearing loss in children, lowered birth weights in babies, impaired skin sensation and more. Those who are at greatest risk to arsenic related problems are children.

We can protect children only by early detection and by taking corrective measures. The damage caused by arsenic exposure is irreversible.

Photo 2

Photo 3

4. Waste water treatment

(1) Roo Hsing Garment Wastewater Treatment Plant (Cambodia)
(2) Cambodia Beverage (Coca-Cola) Wastewater Treatment Plant (Cambodia)
(3) Eastern Steel Industry Corporation Wastewater Treatment Plan (Cambodia)
(4) M & V III Co. , LTD Wastewater Treatment Plan (Cambodia)
(5) Tack-Fat Garment Wastewater Treatment Plan (Cambodia)
(6) Wintai Wastewater Treatment Plant (Cambodia)
(7) Chu-Hsing Garment Wastewater Treatment Plant (Cambodia)
(8) Angkor Brewery Wastewater Treatment Plant (Cambodia)

(9) Gold Fame Wastewater Treatment Plant (Cambodia)

(10) Cambodia Brewery Limited Wastewater Treatment Plant (Cambodia)

4.1 New Siem Reap Wastewater, Sewerage Improvements to Curb Flooding, Aid Angkor Wat Tourism

SIEM REAP, CAMBODIA (22 APRIL 2010) - A new wastewater and sewerage treatment facility in Siem Reap should help end bouts of serious flooding in the city which serves as a base for thousands of tourists visiting the nearby, world-renowned, Angkor Wat temple complex.

At a ceremony in the city today, Prime Minister Hun Sen inaugurated the Siem Reap Wastewater Management System. In attendance were government officials from Siem Reap Province, Ministry of Public Works and Transport, Ministry of Economy and Finance, Ministry of Tourism, Ministry of Environment, and other line ministries. Also present were ADB officials along with representatives of local communities, the business and tourism sectors, and non-government organizations.

Siem Reap city, with a population of about 41,000 has been subjected to frequent floods in the central commercial and tourist accommodation areas, with an old and defective drainage and sewerage system unable to cope. Key streets have been inundated with storm and wastewater, raw sewage, septic tank effluent and even solid waste, causing public health and safety threats, as well as access problems. The aesthetic quality of urban areas frequented by tourists has also been affected.

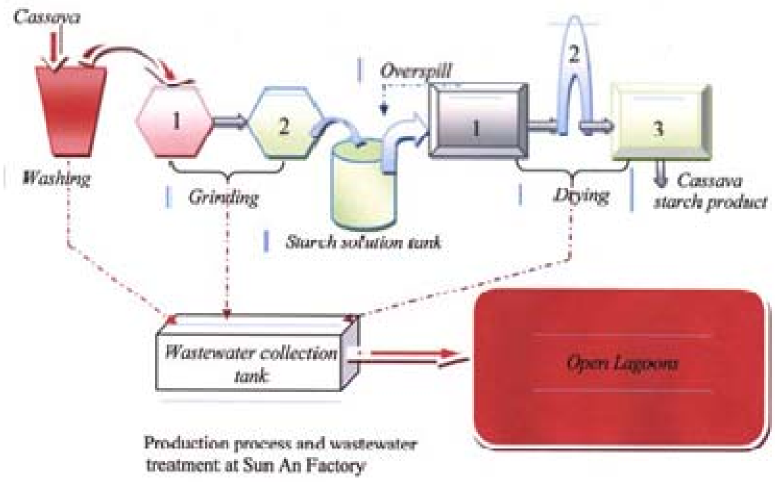

Fig.8 Waste water treatment at Cassava, Palm oil and Ethanol

5. Risk Management

5.1 Water Quality Standards

With so many agencies involved in drinking water quality there were inevitably several water quality standards in use that have different priorities and purposes and the standards used were derived from various overseas standards. Drinking water quality standards adopted in Cambodia had been mainly adopted from international standards or guideline values, partly donor driven, or from historical usage, with no reference to the actual situation in the country. Various French standards and WHO and EU guidelines had been used and values used by neighboring countries had also been used to allow for regional comparisons. In 2001 an inter-ministerial committee named the "National Committee on Drinking Water Quality" began work on the National Drinking Water Quality Standards (NDWQS). At the time, each agency applied standards that were appropriate for its operational requirements and not necessarily directly related to human health. It was intended that the standards should include all forms of drinking water including piped, bottled, and well water, and would require commitment from the relevant agencies, with input and support from technical experts and external agencies. The Cambodian NDWQS were prepared during 1999-2003 by a task force with guidance from WHO experts. The standards were based on the latest WHO drinking water quality guidelines (2003) and those of other countries with particular adaptation to the water quality problems in Cambodia. The standards are to be reviewed and revised accordingly regularly. The scope of the NDWQS are that it shall apply to all sources of drinking water that are intended for human consumption and will apply to water delivered from a water treatment plant through the distribution network and from small community sources. The microbiological quality of drinking water is seen as crucial for health and thus has the highest priority for monitoring, and in the protection of sources from contaminated with human and animal excreta. Bottled or other packaged manufactured waters are subject to separate standards. A risk-based approach has been taken with consideration of local environmental, social, economic and cultural conditions and the parameters and values were derived based on water resources and quality, epidemiological data, industrial and agricultural activity, chemical imports, cultural habits in water usage, climate. The standards aims, together with sanitary surveys and interventions, to ensure the future safety of drinking water, reduce health risks, and provide a benchmark for the assessment of water resources, treatment and supply processes. It requires that public water supplies are managed and protected from source to consumer by protecting catchments and watersheds, by operation of treatment plants by qualified operators and regular monitoring of chemicals with known health or aesthetic impacts.

5.2 Prevention of Groundwater Pollution

Groundwater pollution can not be completely prevented. However, there are a number of steps that residents can take in order to help ensure that their risks are minimized and that their home environment is not likely to cause any potential contamination.

For instance, instead of using deicing salts residents can choose to use sand or kitty litter which won't leach into the ground. Proper storage of potential contaminants like pesticides, weed killer, and automotive chemicals is imperative. Minimal use of these items is recommended and protective ground cover where appropriate can help eliminate the risk of soil absorption.

Preventing groundwater contamination from a septic system start with the proper installation. Since most residents inherit their septic systems with their property current and regular inspections are required. If the septic system accepts waste from a garbage disposal the inspection should happen every year.

Otherwise, every other year should be sufficient. Residents should be careful about what they put into their septic system. Chemical additives and household chemicals can cause damage to the septic system and result in groundwater pollution.

5.3 Risk Management base on waste management and hazardous waste management Respect to the Cambodian Sub-decree

Sub-Decree on Solid Waste Management
Household waste management

Article 4: The Ministry of Environment shall establish guidelines on disposal, collection, transport, storage, recycling, minimizing, and dumping of household waste in province and cities in order to ensure the management of household waste with safe way.
The authorities of the provinces and cities shall establish the waste management plan in their province and city for short, medium and long-term.

Article 5 : The collection, transport, storage, recycling, minimizing and dumping of waste in the provinces and cities is the responsibility of the authorities of provinces and city
The implementation as mentioned in the first paragraph of the article 5 shall comply with the guideline on the sound management of waste specified by the Prakas (declaration) of the Ministry of Environment.

Article 6 : The Ministry of Environment shall monitor the implementation in disposal, collection, transport, storage, recycling, minimizing and dumping of the household waste in the provinces and cities.

Article 7 : The disposal of waste in public sites or anywhere that is not allowed by the authorities shall be strictly prohibited.

Article 8: The domestic investment in construction of landfill, incinerator, storage sites or recycling plant for household waste shall be subject to prior approval from the Ministry of Environment.

Article 9: The exportation of the household waste from the Kingdom of Cambodia to abroad could not be conducted unless there are approval from the Ministry of Environment, and export license from the Ministry of Trade, and permit from the import country

Article 10: The importation of the household waste from abroad to the Kingdom of Cambodia shall be strictly prohibited.

Hazardous waste management

Article 11: The Ministry of Environment shall establish guidelines on the management of hazardous waste to ensure the safe management.

Article 12: The Ministry of Environment shall issue Prakas on the standard of quantity of toxin or hazardous substances contained in the hazardous waste which could be allowed to be disposed in order to ensure the human health and environmental quality protection, and bio-diversity conservation.

Article 13: The owner of the hazardous waste shall be responsible for temporary storage of his/her waste in proper technique and in safe manner.

Article 14: The owner of the hazardous waste shall make quarterly report on his/her waste and forward it to the Ministry of Environment. The report include :

- Type and amount of the waste,
- Temporary storage method, and
- Treatment or elimination method.

Article 15: The storage, transportation and disposal of the hazardous waste shall be performed separately from the household waste which will be stipulated by the Prakas of the Ministry of Environment.

The disposal of hazardous waste into public site, public drainage systems, public water area, rural area and forest area shall be strictly prohibited.

Article 16: The collection, transportation, storage and disposal of the hazardous waste from dwelling houses, markets, clinics, hospitals, hotel, restaurants and public building are competence of the local authorities.

The implementation of the first paragraph of the article 16 shall be in accordance with the Prakas of the Ministry of Environment on the guidelines on the environmentally sound management of hazardous waste.

Article 17: The transportation or construction of storage place or landfill of hazardous waste from factories and manufacturing site shall be subject to permit from the Ministry of Environment.

Article 18: The owner or responsible person of storage place or landfill of the hazardous waste shall make quarterly report on the hazardous waste which is transported for disposal of or for storage and forward this report to the Ministry of Environment. The report shall include as follows:

Type and amount of the waste, Sources of the waste,

Packing and transport facility , and

Process and management of the waste inside his/her location and forward this report to the Ministry of Environment .

Article 19: The investment of the treatment or incineration of the hazardous waste shall have prior approval from the Ministry of Environment .

Article 20: The exportation of the hazardous waste from the Kingdom of Cambodia to abroad could be conducted if there are an agreement from the Ministry of Environment, export license from the Ministry of Trade, and permit from the import country .

The exportation of the hazardous waste shall be consistent with the provisions and principles of the Basel Convention on the Control of Tran boundary Movements of Hazardous Wastes and their Disposal in1989 which come into force on May 05, 1992.

Article 21: The importation of the hazardous waste from abroad into the Kingdom of Cambodia is strictly prohibited.

Monitoring and inspection of hazardous waste management

Article 22: The monitoring on packing, storage, transport, recycling, incinerating, treatment and disposal of the hazardous waste is the responsibility of the Ministry of Environment.

Article 23: The Ministry of Environment shall take sample of the hazardous waste at every point enumerated in the article 22 of this sub-decree.

The owner or person responsible for the site mentioned in the paragraph one of article 23 of this sub-decree shall collaborate and facilitate the environmental official who come to take the waste sample so that they can carry out their technical task.

Article 24: The sample of the hazardous waste which were taken during the monitoring or inspection shall be analyzed in the Laboratory of the Ministry of Environment.

The owner or person who responsible for the site stipulated in the paragraph 1 of the article 23 of this sub-decree can request to test his/her waste sample at other public or private laboratories which are recognized formally and those laboratories must use the same testing method as used in the laboratory of the Ministry of Environment.

The owner or person responsible for the point or site stipulated in the paragraph 1 of the article 23 of this sub-decree shall pay analysis fee of his/her own waste sample following the list of testing cost determined by the Ministry of Environment and the Ministry of Economy and Finance.

These incomes shall be incorporated into the national budget for allocating the Environmental Endowment Fund.

Article 25: In the case of finding out that there are an illegal disposal or dumping of the hazardous waste without a permit from the competent institution, the Ministry of Environment in collaboration with concerned ministries, shall conduct the inspection at the places in complying with procedures as follows:

a. To present his / her identity card and mission letter while entering into the premise or any site of point source of pollution for conducting inspection and taking sample;

b. To make, at the site of inspection, the primary record and report of the inspection or sample taking with the presence of witness if necessary;

c. To inquire and require the owner or responsible person of the place to provide them with information and other relevant documents for taking statement or report and for evidence;

d. To collect and detain evidence of the offence.

Article 26: In case if there are complaint or report that there is storage or disposal of the hazardous waste which causes danger to animal or human health or public property or contaminate the environment, the Ministry of Environment shall make urgent inspection and inform concerned ministries and local authority.

Sub-Decree on Water Pollution Control

Provisions on waste and hazardous discharge

Article 4: Standards for effluent discharge from any sources of pollution shall be specified in the annex 2 of this sub-decree.

Article 5 :In the necessary cases or in response to the requirement of each area for the purpose of human health protection and the conservation of bio-diversity, the Ministry of Environment shall set up separated standard for effluent discharge for sources of pollution, that are located around the public water area.

The separated standard for effluent discharge as mentioned in the first paragraph of the article 5 of this sub-decree shall be specified by the Prakas of the Ministry of Environment.

Article 6: The discharge of waste water from any sources of pollution that is not consistent with the standards for effluent discharge as mentioned in the article 4 and article 5 of this sub-decree shall be strictly prohibited.

Article 7: In order to ensure the human health protection and bio-diversity conservation, the Ministry of Environment shall establish the standard of pollution load contained in liquid waste that could be allowed to be released from any sources of pollution into designated protected public water areas The pollution load standard as mentioned in the paragraph 1 of the article 7 of this sub-decree shall be stated by the Prakas of the Ministry of Environment.

Article 8: The disposal of solid waste or any garbage or hazardous substances into public water areas or into public drainage system shall be strictly prohibited.

The storage or disposal of solid waste or any garbage and hazardous substances that lead to the pollution of water of the public water areas shall be strictly prohibited.

Article 9: The discharge of sewage from dwelling and public buildings in to public water areas without passing through public sewerage systems or other treatment systems shall be strictly prohibited.

Effluent discharge permit

Article 10: The discharge or transport of wastewater from any sources of pollution to other places for any purpose is subject to prior permit from the Ministry of Environment. The application for this permit shall be copied to the concerned ministries or agencies.

Article 11:The types of any sources of pollution that shall be required to have a permit from the Ministry of Environment before discharging or transporting their effluent to other places as mentioned in the article 10 of this sub-decree shall be listed in the annex 3 of this sub-decree and are classified into two following categories :

a- The sources of pollution of category I that are subject to the prior permit from the Ministry of Environment when the amount of their effluent exceed ten cubic meter per day (10 M3 /day) but not including the amount of water volume used for cooling the engine.

b- The sources of pollution of category II that shall be necessarily required to apply for the permission from the Ministry of Environment.

Article 12: Permit requirement for discharge or transportation of effluent to other places as stipulated in the article 10 of this sub-decree shall apply to either the new sources of pollution project or to existing sources of pollution except any new project of pollution source that environmental impact assessment report of which has been approved may be exempt from the requirement of permit for discharge or transportation of effluent to other places.

Article 13: The owner or responsible person of the pollution source as mentioned in the article 11 of this sub- decree that intend to release or transport his/her effluent to other place shall be apply for permit to the Ministry of Environment :

- Forty days (40 days), before the beginning of the functioning, for the new source of pollution located in Phnom Penh, and sixty days (60 days) for the new source of pollution located in provinces and cities.
- Within thirty days (30 days), after being required by the Ministry of Environment, for existing source of pollution located in Phnom Penh, and forty days (40 days) for the new source of pollution located in provinces and cities.

Article 14: The effluent discharge or transportation permit from pollution source to other places could be provided if the application form meets the required technical guidelines determined by the Ministry of Environment.

Article 15: The owner or person responsible for the source of pollution that is holder of permit from the Ministry of Environment for discharge or transportation of effluent to other places and that have intention to modify the effluent discharge system shall reapply for the new permit to the Ministry of Environment within thirty days (30 days) before beginning the modification.

Article 16: Person that take on lease or ownership of source of pollution from the previous owner or the previous responsible person who already obtained the discharge or transportation permit from the Ministry of Environment shall continue to comply with criteria points described in the application form that was submitted to the Ministry of Environment.
The new owner or responsible person shall inform the Ministry of Environment about the lease or such possession within thirty days (30 days) after taking on lease or ownership.

Article 17: The permit of the discharge or transportation of effluent that is provided to the owner or responsible person of pollution source could be revoked temporarily or definitively by the Ministry of Environment after consultation with other concerned ministries or agencies, if they violate seriously the article14, 15 and 16 of this sub-decree.

Monitoring of the pollution sources

Article 18: The monitoring on the discharge or transportation of effluent from any sources of pollution is the responsibility of the Ministry of Environment.

Article 19: The Ministry of Environment shall take sample at every discharge point of pollution sources. The owner or responsible person of pollution sources shall collaborate with and facilitate the environmental official to take sample while carrying out their technical task.
Article 20: The analysis of effluent samples taken from any pollution sources during the monitoring or inspection shall be done in the Laboratory of the Ministry of Environment.

Article 21: The owner or responsible person of pollution sources shall bear the cost of the analysis of his/her own wastewater sample following the tariff determined by the Ministry of Environment and the Ministry of Economy and Finance. This income shall be included into the national budget in order to allocate to the Environmental Endowment Fund Account.

Article 22: The owner or responsible person of pollution sources may ask to have his/her effluent sample tested in other public or private laboratories which are recognized formally and such laboratories carry out the same analytical method those used in the Ministry of Environment.

Article 23: The owner or responsible person of the pollution sources as stipulated in the article 11 of this sub- decree shall:

a) be responsible for determining the method of the treatment and the discharge of their effluent so that it responds to the effluent standard as stipulated in the article 4 and article 5 of this sub-decree as well as the standard of pollution load as stipulated in the article 7 of this sub-decree;

b) have enough facilities and means to prevent the pollution of the public water area when there is eventual danger caused from his/her pollution source;

c) hold the responsibility for installing an equipment for measurement of flow, concentration and amount of pollutant contained in his/her effluent and also keep the result for record keeping.

Article 24: Even if it is found out that the discharge of effluent from any pollution source do not respond to the effluent standard as stipulated in the article 4 and article 5 or is not in consistence with the pollution load standard as stipulated in the article 7 of this sub-decree, the Ministry of Environment shall:

a) issue a written order requiring the owner or responsible person of such pollution source to correct the violation activities immediately within a specified time period, if that activity has not caused a harmful impact to human health or an adverse effect to the water quality yet;

b) issue a written order requiring the owner or responsible person of such pollution source to stop his/her activities temporarily until the violation is corrected, if that activities cause an adverse impact to human health and water quality.

Water Pollution Monitoring in Public Water Areas

Article 25: The water quality standards of public water areas for the purpose of the conservation of the bio- diversity is stipulated in the Annex 4 of this sub-decree.

The water quality standards of public water areas for the purpose of the protection of the public health is stipulated in the Annex 5 of this sub-decree.

Article 26: The Ministry of Environment shall regularly control and monitor the situation of the water pollution at public water areas throughout the Kingdom of Cambodia in order to take measure to prevent and reduce the water pollution in public water areas.

Article 27: The Ministry of Environment shall manage data relating result of the water quality testing and to assess the status of the quality of public water areas throughout the Kingdom of Cambodia.

Article 28: The Ministry of Environment shall disseminate publicly the status of the water quality and the situation of the pollution of public water areas of the Kingdom of Cambodia.

Article 29: Even if it is fount that any public water areas is suffering of pollution which could threaten human life or bio-diversity the Ministry of Environment shall immediately notify the public about this danger and shall take measure to prevent the water pollution and to restore the water quality of such public water areas.

Groundwater Pollution Investigation in China

Dongguang WEN and Liangjun LIN*

1. Background

Groundwater is an important part of water resource which is a strategic resource to support the economic and social sustainable development of China. The quantity of groundwater accounts for about 1/3 of total water resource all over the country, and nearly 20% of total water-supply. Groundwater is exploited in more than 400 cities, accounting about 72% and 66% urban water supply in North and Northwest China respectively. About 70% of drinking water comes from groundwater, especially in rural areas, and 90% of the population depends on it.

In China, with the rapid economy development in the recent 30 years, the total quantity of wastewater discharge is up to 48.24 billion m^3 every year, including: industrial wastewater, 22.11 billion m^3; domestic sewage output of urban living, 26.13 billion m^3; living garbage, more than 6 billion m^3.

The organic pollution of groundwater does not allow optimism, according to the long-term monitoring data of groundwater and the outcome of geology survey: groundwater has been polluted with punctuation or facets in certain degree in the majority of cities and regions, and some indexes even up to an unacceptable value. The results of geology survey indicate that groundwater quality in 2/3 of cities has declined universally, and deteriorated in places; and shallow groundwater in extensive rural areas has been polluted because of pesticide and fertilizer usage, which brings crisis to the residents' drinking water.

The drinking water safety is affected by groundwater pollution, which also influences the security of food and ecology. Soil and shallow groundwater in most areas is polluted because of unreasonable utilization of pesticide and fertilizer, followed by the decline in the quality of food and economic crops.

So, it is of profound practical significance to figure out the state and trend of groundwater pollution as soon as possible. And China Geological Survey has carried out the Groundwater Pollution Investigation in China since 2005.

*China Geological Survey

2. The project plan for groundwater pollution investigation in China

2.1 Objective

This project contains five main objectives as follows: to find out the national groundwater pollution conditions; to comprehensively evaluate groundwater pollution and its change trend; to compile zoning on prevention and protection of groundwater pollution; to establish early-warning system of groundwater quality and pollution; to provide evidence for national groundwater pollution's prevention, groundwater resources' protection, drinking-water quality standard's improvement, the safety and health of drinking-water's guarantee and the encouragement of harmonious coexistence between human and nature.

2. 2 Main work contents

(1) Investigation and evaluation of national groundwater pollution
The work contents mainly include investigation of pollution sources, vulnerability of unsaturated zone, investigation of pollution components, types and concentration, and migration and transformation in groundwater.
(2) Complementary investigation and evaluation of hydro-geological structure
Complementary investigation includes spatial distribution and structure of aquifer, hydrogeological condition, evolution path of hydro-geochemistry and its control action on groundwater pollution. And it will evaluate the response of aquifer on different pollutants' migration, retention, attenuation and the self-purification capacity.
(3) Zoning of groundwater pollution prevention and protection
The basic work contains logging of pollution sources, evaluation of groundwater pollution, vulnerability assessment of groundwater, risk assessment of groundwater pollution, function evaluation of groundwater. And in this project, the zoning maps of groundwater pollution prevention and protection will be compiled through combining water supply requirement with formation condition of groundwater.
(4) Set-up of early warning system on national groundwater quality and pollution
The mainly contents include database construction, simulation analysis, risk forecast system and social service system.

2.3 Work Arrangements

The first stage, during the 2005-2010 period, to carry out the work of investigation and evaluation of groundwater pollution of Pearl River Delta, Yangtze River Delta, the North China Plain, Haihe Plain and Liaohe Plain with investigation area about 440000 km2 by scale 1:250000, to make more detailed investigations by scale 1:50000 in some key areas.

The second stage, from 2011-2016, to make investigation and evaluation of groundwater pollution of Songnen Plain, Sanjiang Plain, West Liaohe Plain, Sichuan Basin, Fenwei Basin, Hubao Plain, Qaidam Basin, Junggar Basin, Hexi Corridor, Yinchuan Plain, Jianghan Plain, Poyang Lake Plain and the main cities of middle-west China, with investigation area about 1500000 km2 by scale 1:250000. To complete groundwater pollution prevention and protection regionalization in the national scope and establish a national warning system of groundwater quality and pollution.

2.4 Selection of main compounds for groundwater analysis

The selection of the main compounds for groundwater analysis is determined: though mainly based on current standards related to groundwater quality in China, such as Groundwater Quality Standards (GB/T14848), Drinking Water Hygiene Standards (GB5749), Surface Water Environment Quality Standards, etc. and some other standards related to groundwater quality, such as U.S. EPA Drinking Water Standards, WHO Drinking Water Quality Standards, etc, groundwater pollution compounds probably caused by the process of industrial and agricultural production activities and daily life and the capacity of current laboratory analysis should also be considered.

Table 1 Chemical compounds of groundwater analysis

Types of compounds		Items	Numbers
In situ items		Air temperature, water temperature, pH value, conductivity, redox potential, dissolved oxygen, turbidity	7
Inorganic	Compulsory test items	total dissolved solids, total hardness, permanganate index, metasilicate, nitrate, nitrite, ammonium, sulfate, carbonate ion, bicarbonate, chloride ion, fluoride ion, iodine, sodium, potassium, calcium, magnesium, iron, manganese, lead, zinc, cadmium, hexavalent chromium, mercury, arsenic, selenium, aluminum	27

<table>
<tr><td></td><td colspan="2">Selective test items</td><td>volatile phenol(with phenol measuring), cyanide, anion synthetic detergent(compulsory tested item in water source area), sulfide(compulsory tested item in special area), total phosphorus, bromine, total chromium, copper, barium, beryllium, molybdenum, nickel, boron, antimony, silver, thallium
Gross α and β radioactivity, total coliform group and bacterial can be increased at the ratio of 10-20 percent of total samples.</td><td>20</td></tr>
<tr><td rowspan="7">Organic</td><td rowspan="5">Compulsory test items</td><td>halogenated hydrocarbon</td><td>trichloromethane, carbon tetrachloride, 1,1,1－trichloroethane, trichloroethylene, tetrachloroethylene, dichloromethane, 1,2－dichloroethane, 1,1,2－Trichloroethane, 1,2－dichloropropane, bromodichloromethane, monochloro dibromomethane, methenyl bromide, chlorethylene, 1,1－dichloroethylene, 1,2－dichloroethylene</td><td rowspan="5">37</td></tr>
<tr><td>Chlorinated Benzenes</td><td>chlorobenzene, ortho-dichlorobenzene, m-dichlorobenzene, p-Dichlorobenzene, 1,2,4 trichlorobenzene</td></tr>
<tr><td>Simple aromatic hydrocarbon</td><td>benzene, methylbenzene, ethylbenzene, dimethylbenzene, phenylethylene</td></tr>
<tr><td>organo-chlorine pesticide</td><td>total benzex, α-BHC, β-BHC, γ-BHC, δ-BHC, dichloro-diphenyl-trichloroethane, p,p’-DDE, p,p’-DDD, o,p-DDT, p,p’-DDT, hexachlorobenzene</td></tr>
<tr><td>polycyclic aromatic hydrocarbon (PAH)</td><td>Benzo(a)pyrene</td></tr>
<tr><td rowspan="2">Selective test items</td><td>Comprehensive Index</td><td>total volatile organic compounds, total organic carbon, total petroleum hydrocarbon</td><td rowspan="2">49</td></tr>
<tr><td>Chlorinated Benzenes</td><td>1,2,3 trichlorobenzene, 1,3,5 trichlorobenzene</td></tr>
</table>

		gasoline additive	mtbe	
		organochlorine pesticides	heptachlor, heptachlor epoxide, aldrin, dieldrin, endrin, chlordane	
		organophosphorus pesticide	dichlorvos, methyl parathion, malathion, dimethoate, phorate	
		other pesticides	atrazine, carbofuran, aldicarb	
		phenols	pentachlorophenol, 2,4， 6-trichlorophenol, 2, 4 — dichlorophenol and incubated, m-cresol, phenol, p-nitrophenol	
		esters	Di(2-ethylhexyl) phthalate esters, Di(2-ethylhexyl) adipic acid lipid, Di(2-ethylhexyl) phosphate ester	
		polycyclic aromatic hydrocarbons	the total of polycyclic aromatic hydrocarbons, naphthalene, acenaphthene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, flexion, benzo（b）fluoranthene, benzo（k）fluoranthene, Indeno(1,2,3)Pyrene, dibenzo(a.h)anthracene, Benzo[g,h,i]perylene	
		olychlorinated biphenyls	polychlorinated biphenyls	
		others	dichloro acetic acid, trichloroacetic acid, chloral	

3. Progress

Investigation and assessment of groundwater pollution of Pearl River Delta started in 2005. Programs of groundwater pollution investigation and assessment of North China Plain, Huaihe River Plain, Yangtze River Delta followed in 2006. And the same programs in Northeast

China were also carried out during 2009.

During 2005 to 2009, investigation and evaluation of groundwater pollution in Pearl River Delta, Yangtze River Delta, the Huaihe River, the North China plain were basically completed. Regional groundwater pollution (437723 km2 in total) was investigated and 12206 water samples were collected, including 9563 samples of shallow groundwater and 2643 samples of deep groundwater. Several results are summarized as follows:

3.1 Shallow groundwater with variable degrees of pollution; deep groundwater in overall good condition and with local point pollution

Disorderly discharge of factory and mine leakage, regional acid rain, municipal solid waste, wastewater and extensive use of fertilizers in agricultural development during the last 30 years exerted serious impact on ground water environment, resulting in shallow groundwater pollution of some sections that shows an increasing trend.

3.2 Three-nitrogen (3N) pollution with face-shaped distribution

Three-nitrogen pollution with face-shaped distribution is common in shallow groundwater. Although the three-nitrogen pollution level of deep groundwater is much lower than that of shallow groundwater affected by the formation conditions, local pollution also produces more serious condition which is dominated by the pollution of NO3-.

3.3 Heavy metal pollution with point-shaped distribution, lead and arsenic pollution are serious

Detection of heavy metals in groundwater is common. The heavy metal pollution mainly scatters surrounding regions of cities and wastewater irrigation areas around industrial and mining enterprises. The arsenic content in some areas of deep groundwater is higher due to the influence of natural environment.

3.4 Toxic and harmful organic pollution with point-shaped distribution and characterized by combined pollution

Toxic and harmful organic pollution is mainly of point-shaped characteristics and often can be detected with variable types at a detection point. According to statistics, as many as 44 kinds of toxic and harmful organic pollutants were detected in the eastern plains.

3.5 Serious pollution of surface water is a direct threat to groundwater quality

Industrial "three wastes", disorder of urban waste discharge, unreasonable usage of pesticides and fertilizers cause linear pollution to groundwater, and most groundwater quality types are Ⅲ~Ⅳ,even partly V. The average water quality of Taihu Lake was typeⅡ in 70s, typeⅡ~Ⅲ in 80s, gradually deteriorated to type Ⅲ~Ⅳ after 1998.Wuli lake, Mei Liang lake and Suzhou, Wuxi, Changzhou section of Beijing-Hangzhou Grand Canal, the water quality type is V or even worse. In the upper reaches of Haihe River, Huaihe River regions, the water quality types are Ⅲ - Ⅳ, and gradually change to the lower class as type V or even worse In the downstream.

3.6 Because of the low treatment rate of industrial waste and domestic sewage, the soil and groundwater are polluted in dot and/or line form in the urban fringe with a large amount of emission.

The industrial wastewater emission of the Yangtze River Delta economic zone in 2007 is 4.379 billion m^3, in 2004.There are 403.000 industrial enterprises in Henna section of Huaihe River, and 749 million cubic meters of trade-waste and domestic sewage are produced in this area every year. About 7400 companies are scattered in Beijing city, whose total daily discharge of wastewater in 2005 is 2,255,900 m^3. 1,475,100 m^3 of sewage is treated everyday and 780,800 m^3 discharged into river directly. Low treatment rate of trade-waste and domestic sewage, disorderly discharge, especially rural enterprises effluent discharge through seepage pits, seepage wells, and sewage outfall to surface and underground result in spotty and linear pollution for rivers, soil and groundwater.

3.7 Serious dot pollution of garbage site to soil and groundwater

Widely distribution of garbage, solid waste in the city including waste plastic, waste paper, metals, coal ash, etc which contain more sulfate, chloride, ammonia impurities and corruption of organic matter produce Cl-, SO_4^{2-}, NH_4^+, COD, Mn, and leachate with high levels of suspended solids, and produces CO_2 and CH_4 under the effect of biodegradation and rainwater leaching. Random stacking of these wastes would finally pollute the groundwater through the recharge of sewage in the condition that no seepage control measures are taken.

Last but not the least, long time sewage irrigation, containing a variety of harmful toxic substances which are mainly ammonia, cyanide, volatile phenol, sulfide and heavy metal, has a serious effect on soil and groundwater. And the excessive usage of fertilizers and pesticides directly impacts regional soil and groundwater quality.

Natural Groundwater Quality, Groundwater Contamination, and Monitoring of Groundwater Condition in the Bandung Basin, west Java, Indonesia

Haryadi TIRTOMIHARDJO*

Abstract

At natural condition, groundwater quality in the Bandung Basin is influenced by the tropical climate, with high CO_2 production and high contents of organic material in the soil zone, and by low carbonate contents in the prevailing volcanogenic rocks. Accordingly, the hydrochemical composition of the groundwater is characterized by generally low oxygen contents and elevated Fe and Mn concentrations; low concentrations of major ions and elevated contents of CO_2 in the recharge areas; and slightly increasing salinity towards the topographically lower parts of the basin.

Since the last three decades, intensive land-use and explosive economic and population growth in the Bandung region create a high contamination potential, major hazards to the groundwater quality being the infiltration of domestic and industrial sewage water and of leachate from waste disposal. Lowering of groundwater heads as affected by large quantity of water pumped from deep aquifer system is also the main cause of the contamination problems, mainly to the groundwater at shallow aquifer system. Monitoring of groundwater quality and the introduction of measures for the protection of aquifers exploited for central urban water supply is urgently required.

Keywords: Groundwater quality, contamination potential, groundwater heads, deep aquifer system, shallow aquifer system, monitoring of groundwater quantity, protection of aquifer

1. Introduction

Bandung Basin which is covering Bandung Groundwater Basin (GB) and Lembang GB is situated in West Java and having lateral extend of about 2,200 Km^2. Geographically, the basin covers Bandung City, Bandung Regency, West Bandung Regency, Cimahi City, and Sumedang Regency, West Java Province.

Bandung, the capital of West Java Province, is one of the economic and industrial development centres in Indonesia. The present population of Greater Bandung amounts more

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than 2.5 million. Industrial activities particularly textile factories, are expanding rapidly. Bandung is situated in a groundwater basin surrounded by volcanic mountains, some of them are active volcanoes with peak elevations at around 2,000 m. The central plain of the Bandung Basin extends over 250 Km^2 at elevations between 660 and 675 m above sea-level (Fig. 1).
The tropical monsoon climate of the region is characterized by a rainy season extending from October to May, with an average monthly rainfall of more than
100 mm, and a relatively dry season between June and September, with an average monthly rainfall of around 50 mm. The mean annual rainfall is in the order of 2,000 mm.

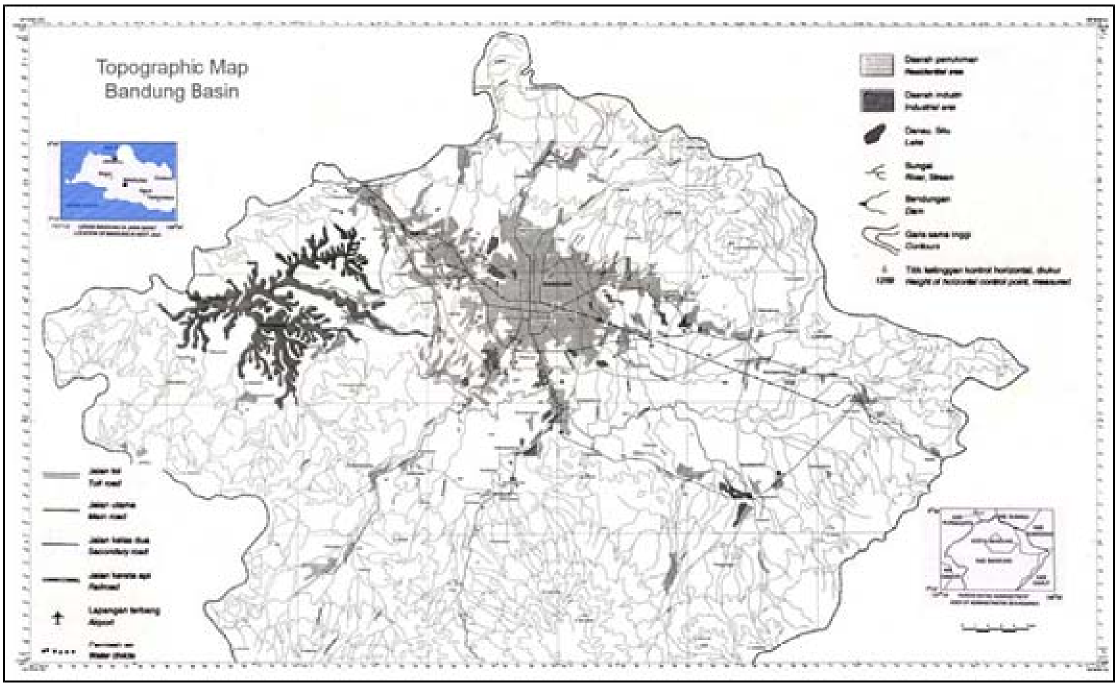


Fig. 1 Topographic map of the Bandung Basin

The most important aquifers in the basin are formed by volcanic or volcano-fluviatile deposits related to Pleistocene volcanic activity and accompanying erosion and sedimentation. From practical aspects of groundwater extraction, the water-bearing formations in the Bandung Basin can be divided into

1) Shallow aquifers at depths between 0 and 40 m below surface which can be exploited by shallow wells and, in many places, by tapping or diversion of spring- water;

2) Deeper aquifers at depths of more than 40 m below surface - down to 250 m - which are exploited by boreholes.

Shallow aquifers are composed of fluviatile-limnic sediments within the plain area, of lahar (volcanic mudflow), talus and stream deposits on the slopes of volcanoes and of Tertiary sandstones and sandstone-marl sequences in the western parts of the basin. These aquifers extend over wide parts of the Bandung Basin. They have a low to moderate productivity and are highly vulnerable to contamination from the surface. Local water supplies for a high percentage of the population of the Bandung region rely on the exploitation of shallow groundwater from dugwells, shallow boreholes or tapping of springs. Diversion of spring water discharging from shallow aquifers is a major source of irrigation water in the dry season.

The extent of deeper aquifers is limited to accumulations of Pleistocene volcanic and volcano-fluviatile deposits (lahar fans, volcanic ash deposits, detritus fans with intercalated volcanics). The deeper aquifers are confined with moderate productivities, except in limited areas where productivities are high. These aquifers are relatively well protected against contamination from the surface due to the presence of overlying shallow aquifers and low permeability layers (Fig. 2).

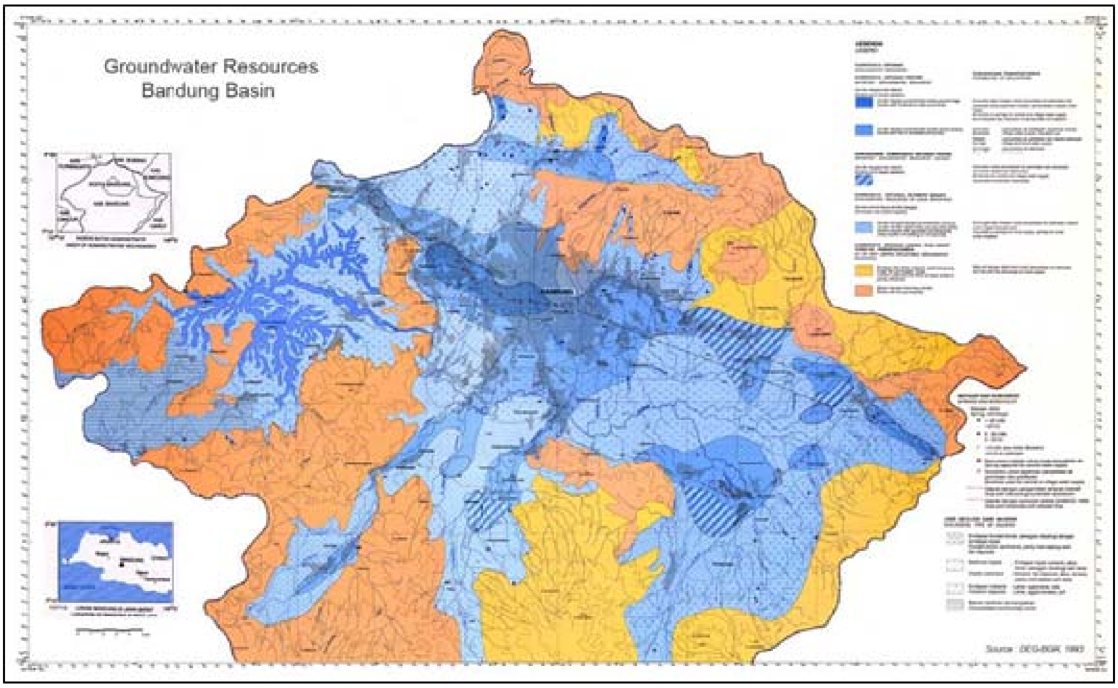


Fig. 2 Groundwater resources map of the Bandung Basin

The most productive deeper aquiferous sequences of the region are composed of volcanic agglomerates and lahars deposited at the lower slopes of the volcano Tangkubanperahu, within the urban area of Greater Bandung. Boreholes constructed in the lower parts of the Tangkubanperahu volcanic fan, comprising relatively well-sorted volcanic and volcano-fluviatile rocks, have yields of 10-30 l/s. These boreholes provide around 300 l/s for the central water supply of Bandung city.

Productive deeper aquifers extend over relatively large areas of the basin. However, because of the generally moderate yields, extended well fields are needed for larger-scale water supply schemes.

The deeper aquifers are exploited in various parts of the Bandung Basin for industrial and communal water supply. In the year 2009, groundwater abstraction (Qabs) amounts to around 55.09 million m^3 from the number of wells around 2,315.

The groundwater regime in the Bandung Basin is generally characterized by recharge from rainfall on the mountain slopes and groundwater movement towards topographically lower areas. Replenishment of the deeper aquifers takes place as leakage from overlying shallow aquifers. In undisturbed conditions, the deeper groundwater was artesian in many parts of the plain area. Shallow groundwater discharges in numerous springs and in streambeds on the mountain slopes. The central plain with the Citarum River and its tributaries constitutes the main discharge area for shallow and deeper groundwater.

The development of intensive groundwater abstraction since 1970 has changed the hydraulic situation in many parts of the basin; groundwater recharge occurs in expanding areas while the quantity of natural groundwater discharge as well as the hydraulic heads in the deeper aquifer is decreasing.

This paper intends to discuss briefly the natural groundwater quality and their monitoring, groundwater contamination problems, and proposed groundwater protection measures within the Bandung Basin in order to keep groundwater sustainable.

2. Natural Groundwater Quality

Water quality refers to such things as the temperature of the water, the amount of dissolved solids, and lack of toxic and biological pollutants. Water, including groundwater, that contains a high amount of dissolved material through the action of chemical weathering can have a bitter taste, and is commonly referred to as hard water. While the level of salinity is the most common concern, other dissolved solids present in groundwater can cause problems. Hard water causes scaly deposits to form in water heaters and pipes, and makes soap difficult to lather. High levels of iron are present in some groundwater. Iron can discolor water and stain clothing; it is undesirable for many manufacturing processes as well. Sulphates in water can leave a bitter taste, and can also have a laxative effect.

Hydrochemical processes in the unsaturated zone in the Bandung Basin (Table 1) are largely influenced by the regional climatic, geologic, and pedologic conditions including

1) high CO_2 production and relatively high content of organic substances in the soil zone, related to intensive biologic activity under all the year-round warm and humid climate;
2) low oxygen content under reducing conditions created by the oxidation of organic matter; and
3) low carbonate contents in the volcanogenic rocks and their residual soils, which extend over

wide areas of the basin.

Soils on the more elevated and steeper areas are derived from volcanic material (tuff, lava, lahars) and igneous rocks. They have interstitial waters with generally high CO_2 contents and low salinity. The soil water in alluvial soils of the plain areas is generally characterized by higher contents of dissolved solids due to enrichment of dissolved solids by evapotranspiration and to the high availability of exchangeable cations in the clayey soils.

Though no reliable information is available on the hydrochemical composition of precipitation, nor of interstitial water in the unsaturated zone of the Bandung Basin, a general picture of natural baseline concentrations of dissolved substances in recharge water can be derived from the composition of very low salinity groundwater and surface water from the higher slopes of the basin (Fig. 3). These waters are characterized by low Cl and SO_4 concentrations (mean values of Cl=3.5-10.6 mg/l, of SO_4=0.7-9.6 mg/l), originating mainly from atmospheric deposition. Mean HCO_3 concentrations of these groups of samples vary from 23 to 58 mg/l and concentrations of CO_2 are significant (up to 80 mg/l).

Shallow groundwater developed during somewhat more extended residence times in the subsurface, which is not - or only to a minor degree - affected by anthropogenic impacts or evapotranspiration, has values of electrical conductivity of 100-150 µS/cm, HCO_3 concentrations of approximately 50-60 mg/l and low Cl and SO_4 concentrations of around 5 mg/l.

Table 1 Development of the hydrochemical composition of groundwater in the Bandung Basin (schematic)

Atmospheric deposition, enrichment at the surface	
input of Cl, SO_4, HCO_4, HCO_3 (up to 10 mg/l) input of oxygen	
Soil	
Production of CO_2 and organic matter	
Unsaturated zone	Shallow groundwater mountain and hill slope
reaction between CO_2 and minerals (carbonates, silicates) increase of HCO_3 to mean values of 50 mg/l oxidation of organic matter reduction of NO_3 to NO_2 and NH_4 reduction and dissolution of Fe and Mn compounds	
	Shallow groundwater plain areas
	enrichment of Cl, SO_4, HCO_3, NO_3 by evapotranspiration and human activities
Deeper Groundwater	
consumption of CO_2 reactions with fossil organic matter reaction with volcanic CO_2 increase of HCO_3 to mean values of 220 mg/l consumption of oxygen reduction of nitrogen compounds reduction of SO_4 to H_2S	

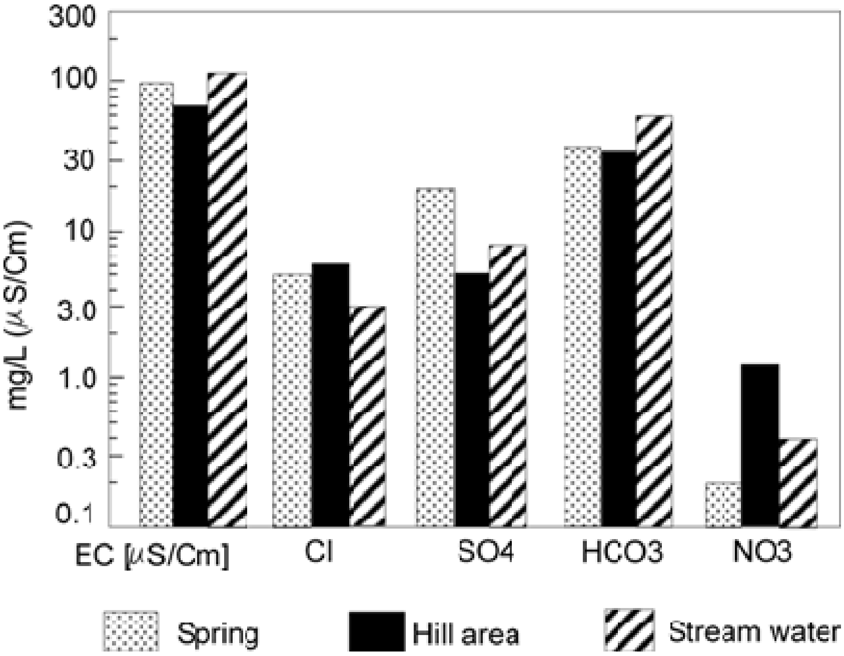


Fig. 3 Mean values of anion concentrations in low salinity water from the Bandung Basin

Groundwater in deeper confined volcanogenic aquifers, which are some hundreds to thousands of years old and is not influenced by anthropogenic inputs, has higher HCO_3 and Ca concentrations than shallow groundwater in the recharge areas. This increase of dissolved constituents, in particular of HCO_3 to mean concentrations of more than 200 mg/l, may be partly attributed to solution reactions between free CO_2 and carbonates and to reactions between water, acids (CO_2, organic acids) and silicate minerals. However, an additional carbon source has to be assumed to explain the HCO_3 concentrations in the water from some boreholes tapping deeper aquifers. The source could be fossil organic carbon or volcanic CO_2. Sulphate and nitrate concentrations are very low in the deeper groundwater, indicating reduction processes in the low oxygen environment.

Shallow groundwater in the plain area of the Bandung Basin has generally higher concentrations of Cl, SO_4 (average concentrations of 35 mg/l CI and 30 mg/l SO_4), and in some parts of HCO_3 also, and of equivalent cations in comparison to shallow groundwater from the hill and mountain areas. The sources for the higher contents of dissolved constituents can be seen in an enrichment by evapotranspiration and in anthropogenic impacts.

Most groundwaters occurring in the Bandung Basin can be classified as bicarbonate waters with a rather indifferent cation composition. The proportional HCO_3 contents in the low salinity groundwater are in the order of 60-80 meq%. Increasing salinity is generally related to hydrochemical processes leading to higher HCO_3 concentrations and proportional HCO_3

contents increase to more than 80% of the anions (as meq/l).

Generally, groundwater in the Bandung Basin is characterized by relatively low oxygen contents and low redox values. Significant CO_2 concentrations are common in the recharge areas. Elevated contents of iron and manganese above 1 mg/l Fe and 0.5 mg/l Mn occur extensively in the groundwater due to the formation of soluble Fe_2+ and Mn_2+ compounds at low redox potentials.

The impact of volcanic activity on the groundwater chemistry is obvious in several hot springs, with temperatures of 30-80°C, located on the higher slopes of volcanoes. It is also indicated by the elevated salinity and temperature in deeper groundwater on the north- eastern margin of the Bandung Plain.

The hydrochemical composition and preliminary isotope data suggest an origin from interaction between infiltrating meteoric water, acid volcanic gases and siliceous rocks. The presence of volcanic gases (CO_2, H_2S, and HCl) in varying proportions gives rise to different hydrochemical types of hot groundwater

(1) springwater with low pH, free of $HC0_3$, with elevated concentrations of Cl, SO_4, CO_2 up to 570 mg/l), H_2S, NH_4, Fe, Mn and SiO_2;

(2) springwater dominated by high HCO_3 concentrations (840 to >1000 mg/l); and

(3) deep groundwater with elevated concentrations of Na (300 mg/l), Cl (320 mg/l), and HCO_3 (400 mg/l).

According to the natural water quality, most groundwater resources in the Bandung Basin are adequate for central water supplies. In many cases, groundwater abstacted from boreholes has to be treated for CO_2 neutralization or removal of Fe and Mn contents. High Fe and Mn contents restrict the suitability of groundwater use for local water supplies for which treatment can generally not be afforded.

Fig. 4 shows the groundwater quality for shallow and deep groundwater in the Bandung Basin which were measured in 1993 (Wagner, W. Et al., 1993).

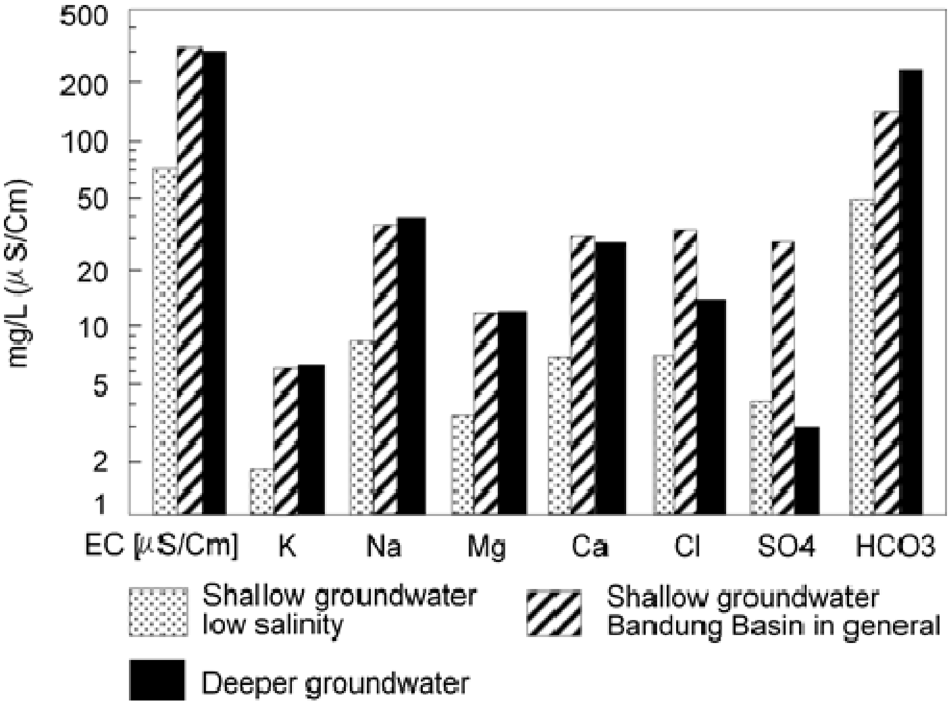


Fig. 4 Mean values of major constituents in shallow groundwater and in deeper confined groundwater in the Bandung Basin

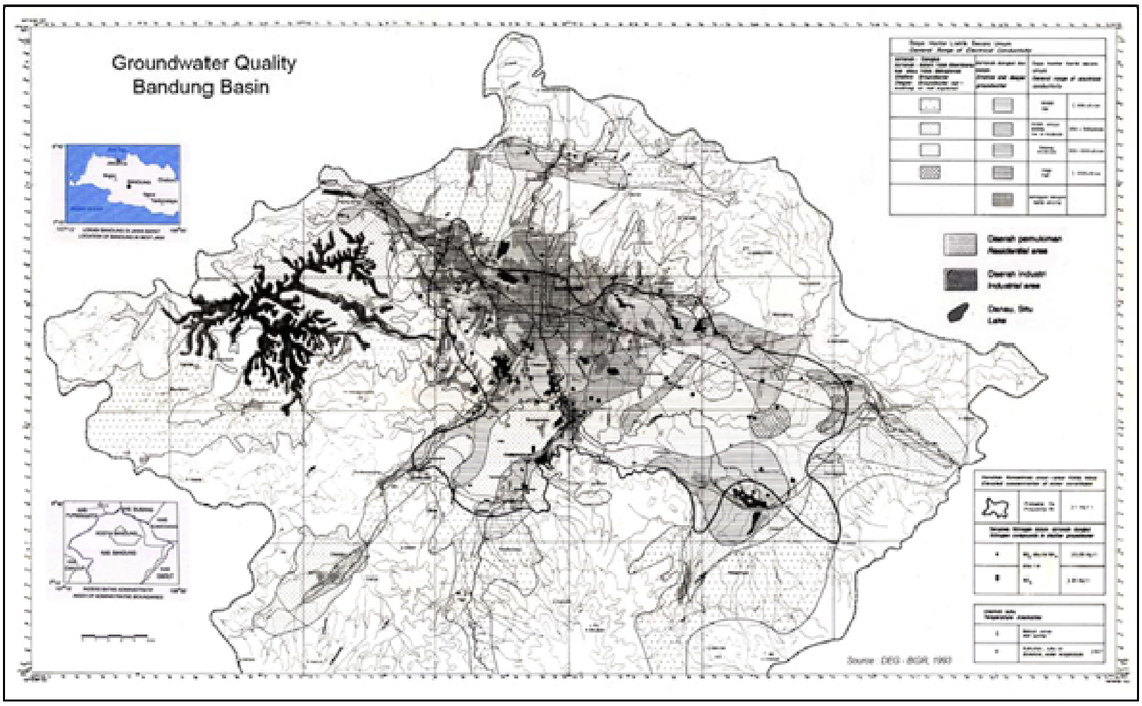


Fig. 5 Shallow and Deep Groundwater Quality in the Bandung Basin

3. Groundwater Contamination Problems

Under most conditions, groundwater is safer and more reliable for use than surface water. Part of the reason for this is that surface water is more readily exposed to pollutants from factories, for example, than groundwater is. This by no means says that groundwater is invulnerable to contamination. Although it is not as vulnerable as surface water, contaminates can still reach wells and therefore households. Any chemicals that are easily soluble and penetrate the soil are prime candidates for groundwater pollutants. A potential pollution problem can still reach a well miles away through underground water currents. For example, a chemical that spills at an industrial plant miles away, could infiltrate the ground and eventually enter the aquifer system that an entire community uses for their private wells. This situation could have devastating effects - once groundwater is contaminated, it is an extremely costly operation to remove the contaminate.

The issue of groundwater contamination of wastewater disposal is a serious problem in cities of developing countries where, generally, there are many high dense populated and unsewered areas created by high rates of migration into cities. These areas are unplanned and located in the outskirts of the cities forming shanty towns (typically between 30 and 60 percent of the overall urban population) where pit latrines or septic tanks are common. In some cities, septic tanks and pit latrines are the only way to dispose of sewage (non- integrated planned provision of sanitation), while groundwater is the main water drinking source (non-integrated planned provision of water supply). As result, the worst contaminated groundwater commonly found in the cities sited on unconfined or semi- confined aquifers. However, it should be realized that human activities in urbanized area threaten the groundwater not only due to diffuse contaminant loading from urban recharge system, but also due to point contaminant loading from landfill leakage, industrial spillages/leaks, and in many other ways. Furthermore, one should also considered, that the occurrence of contaminants in groundwater does not only depend on the characteristics of contaminant loading as a result of human activity in the unproper urban area, but also depends on the inherent attenuation capacity of the intervening strata between contaminant source and water table. This inherent attenuation capacity of the intervening strata depends on its geological, hydrological and hydrogeological condition (Daly et al., 2002 after Hendrayana et al.,2009).

The groundwater contamination hazard can be defined as the probability that groundwater in the aquifer will experience negative impacts from a given anthropogenic activity to such level that its groundwater would become unacceptable for human consumptions. Table 2 shows the impacts on groundwater quality from various sources of urban recharge, e.g. as happen in Bandung Basin.

In the Bandung region, current rapid growth of the population and economy creates increasing environmental problems (Table 3) and, in particular, a significant contamination potential for shallow groundwater. Major contamination hazards are the infiltration of domestic sewage in urban areas and releases of untreated industrial waste water. Only part of Bandung City is served by a central sewerage system. It was recorded that, in 1993, the period at which the study on Groundwater Resources and Protection in the Bandung Basin, the installation of sewers and of a sewage treatment plant for Greater Bandung are at the planning stage. Only a small number of factories in Bandung is connected to a pilot treatment plant for industrial waste water. Most of the thousands of factories operating in the region-mainly textile factories-release their waste water after stabilization in ponds or untreated, to unlined channels, streambeds or irrigated fields.

Table 2 Impact on groundwater quality from various sources of urban recharge

Recharge source /source of contaminant loading	Importance	Water Quality	Contaminants/contamination indicators
Leaking water mains	Major	Excellent	Generally no obvious indicator
On site sanitation systems	Major	Poor	N, B, Cl, FC, DOC
On site disposal / leakage of industrial waste water	Minor to Major	Poor	HC, diverse industrial chemicals, N, B, Cl, FC, DOC
Leaking sewers	Minor	Poor	N, B, Cl, FC, SO_4, diverse industrial
Pluvial drainage from surface by soakaway drainage	Minor to Major	Good to poor	N, Cl, FC, HC, DOC, diverse industrial chemicals
Seepage from canals and rivers	Minor to Major	Moderate to poor	N,B, Cl, FC, SO_4, DOC, diverse industrial chem.

B	*Boron*	*HC*	*Hydrocarbons (Fuels, Oils and Grease)*
Cl	*Chloride and sanility general*	*N*	*Nitrogen compounds (nitrate and ammonium)*
DOC	*Dissolved organic carbon (organic load)*	*SO_4*	*Sulphate*
FC	*Faecal Coliforms*		

Source: Morris et al., 2003 after Hendrayana et al., 2009

Table 3 Anthropogenic impacts on groundwater quality in the Bandung Basin (schematic)

Domestic sewage	**Industrial waste waters**
increase of Cl, HCO_3, N contents **input of organic matter** **consumption of oxygen** **reduction of NO_3 to NO_2, NH_4, N** **NO_2 and NH_4 increase to unacceptable levels**	**input of trace metals and organohalogens**
Leachate from waste dumps (domestic and industrial waste)	
increase of major constituents, input of organic acids, trace metals, organohalogens	
Intensive agriculture	
enrichment of major constituents through evapotranspiration on irrigated fields **input of residues of fertilizers and pesticides (degree of impact unknown)**	

The impact of domestic and industrial waste water results in an increase of dissolved constituents in the shallow groundwater, in particular of Cl and of nitrogen compounds. The addition of organic substances from waste water leads to a further lowering of redox potentials and to the widespread occurrence of reduced nitrogen compounds NO_2 and NH_4 at concentrations of 0.5 to higher than 1 mg/l which restrict the suitability of the affected groundwater for drinking water supply.

The impact of industrial waste water is also indicated by contents of trace metals and organohalogens significantly elevated above background levels. Zinc concentrations of up to 170 µg/l were found in the shallow groundwater of the industrial suburbs of Bandung while background levels of Zn are around 30 µg/l. The values of trace metal concentration analysed from groundwater samples of the Bandung Basin are, so far, still below admissible levels of Indonesian drinking water standards.

Contents of organic contaminants in shallow groundwater of industrial areas, as determined through AOX analysis (determination of adsorbable organic halogens), are elevated to 30-90 µg/l in a substantial number of samples. The results of random sampling from existing shallow wells indicate a significant contamination of aquiferous layers by organohalogens (e.g. solvents) used in the textile industry in large parts of the industrial areas.

Locally limited but severe contamination of shallow groundwater is found in the vicinity of urban waste disposal dumps, i.e. Dago Landfill Site which is located at the northern hillslopes of Bandung. Typically, high concentrations of HCO_3, Cl, nitrogen compounds containing halogens, trace metals, organic contaminants are found (concentrations up to 1600 mg/l HCO_3, 1900 mg/l Cl, 22 mg/l NO_2, 26 mg/l NH_4, and 1400 µg/l AOX).

The impact of intensive agriculture on the quality of shallow groundwater in the Bandung Basin is not known in detail. Potential contamination sources are, in particular, the application of pesticides and fertilizers in tea plantations, on vegetable farms and on irrigated rice fields. Relatively high HCO_3 concentrations (230-550 mg/l) and NO_3 concentrations (up to 30 mg/l) are indicated from preliminary investigations of shallow groundwater in rice fields. No reliable information is yet available on the impact of intensive pesticide application, for example of fungicides, in tea plantations on the groundwater quality, as no adequate analytical facilities exist in the region.

The deeper confined aquifers appear relatively well protected against contamination from the surface due to overlying low permeability layers and increasing hydraulic head with depth. Increasing hazards of contamination of deeper aquifers from seepage of polluted shallow groundwater must, however, be expected because of the intensive groundwater abstraction from many parts of the deeper aquifers, the high contamination load in the Bandung urban area as well as the perforation of protective layers by numerous bore holes.

Figure 6 shows the map of groundwater contamination hazards in the Bandung Basin which was established in 1993 by the Directorate of Environmental Geology (DEG) Bandung (Indonesia) in cooperation with the Federal Institute for Geosciences and Natural Resources (BGR) Hannover (Germany).

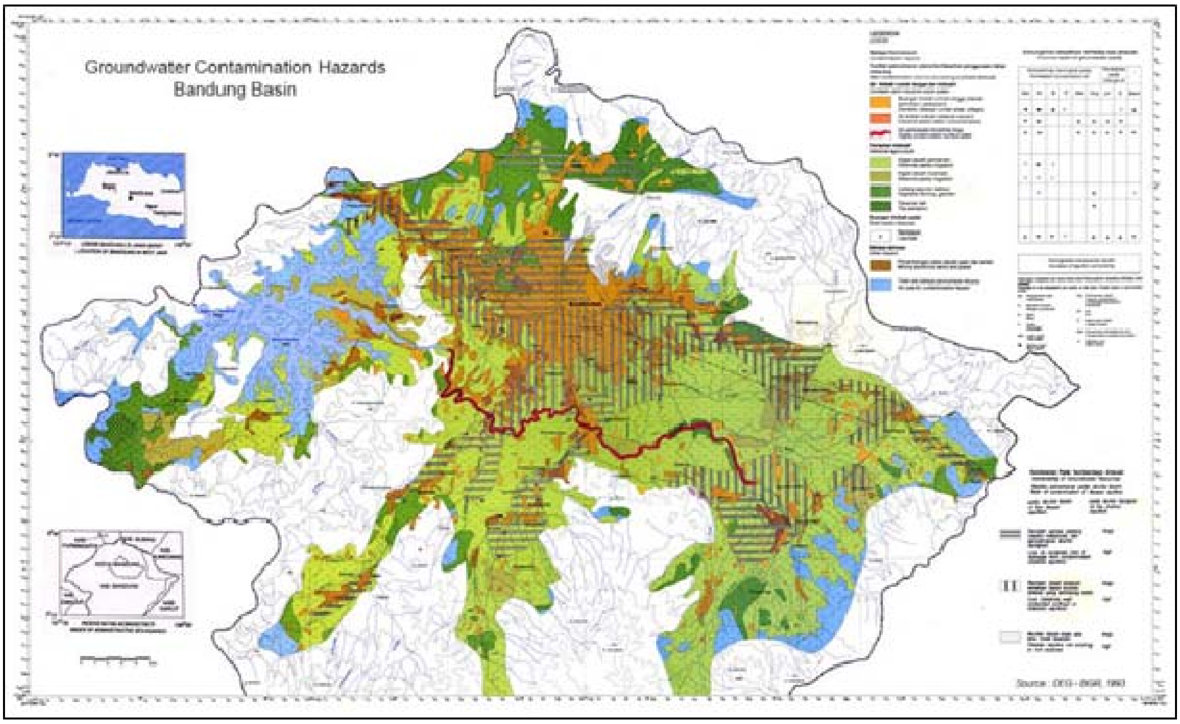


Fig. 6 Groundwater Contamination Hazards in the Bandung Basin

4. Proposed Groundwater Protection Measures

The economic development of the Bandung region depends to a large extent on the efficient use of available water resources, as well as on the conservation of water resources in adequate quantity and quality. Measures for the conservation of groundwater resources have to be directed towards two major problems, that are over-exploitation of groundwater by boreholes mainly for industrial use, and the hazards of groundwater quality deterioration related to intensive urban and agricultural land use.

To prevent further groundwater over-abstraction, which may also threaten the water quality of deeper aquifers, restrictions of the exploitation of affected aquifers are necessary. Licensing and limitation of the number of industrial boreholes have been introduced for the most heavily exploited aquifers and will have to be applied more rigorously and for wider areas in the future.

The suitability of groundwater resources for domestic supply in the Bandung Basin can only be sustained in the long term if adequate measures for protection of the groundwater quality are introduced. Three aspects of groundwater protection have to be considered in this regard

(1) protection of sources used for central water supply (springs and boreholes);

(2) protection of sources used for local water supply (village or private supply - springs, dug wells, and shallow boreholes); and

(3) general protection of important groundwater resources which are used or may be used in the future for domestic supply, or for industrial or agricultural purposes.

Depending on the local conditions, the following protection measures for deeper aquifers, which are or will be major sources of central water supply, may be practicable

(1) installation of central sewerage systems in the vicinity of water supply well fields located within urban areas;

(2) restriction of pesticide application close to water supply springs and conservation of forested areas within spring catchments;

(3) conservation of the present rural land use in the catchment area of water supply boreholes and of productive aquifers which may be exploited for water supplies in the future; and

(4) control of land use changes (urbanization, expansion of industrial areas) within the catchments of important water supply sources.

A completely efficient protection of the thousands of springs, dug wells, and shallow boreholes used for local water supply within the Bandung Basin, appears impracticable under the present conditions. For areas with low density habitation, limited protection measures may be introduced. These include establishing minimum distances between septic tanks or adsorption pits and water sources; and restricting fertilizer and pesticide application near the sources. For a safe water supply of the more densely inhabited areas - towns, suburbs, areas with mixed industrial and residential use

- general improvements of infrastructural conditions involving substantial costs are required including, in particular, central water supply and sewerage facilities.

Figure 7 shows the main groundwater resources in the Bandung Basin and proposed groundwater protection areas.

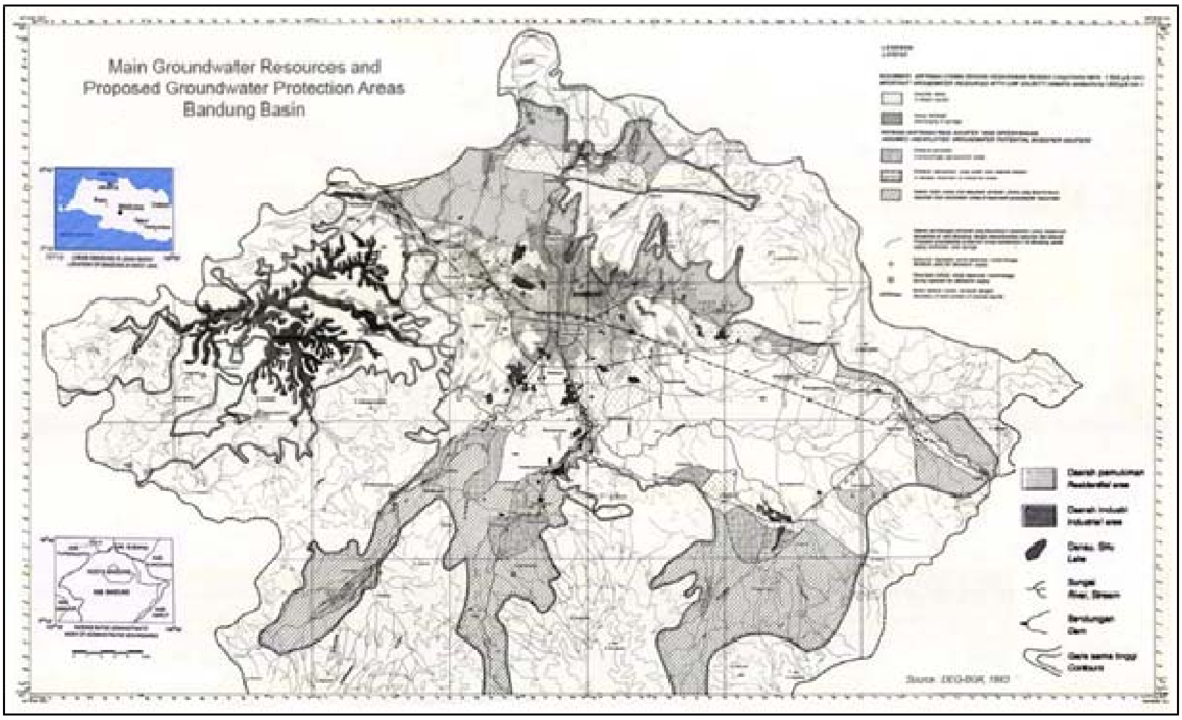


Fig. 7 Main Groundwater Resources and Proposed Groundwater Protection Areas in the Bandung Basin

5. Monitoring of Groundwater Quality

Monitoring of groundwater condition which is comprising quantity and quality of the groundwater had been being done by the Center of Environmental Geology (formerly the Directorate of Environmental Geology) since the year 2000. The monitoring activity becomes more urgent due to the fact that groundwater abstraction tends to increase yearly and had led to the lowering of groundwater heads and presumably to the deterioration of groundwter quality. Nevertheless, further impact of lowering of groundwater heads to the contamination hazards is not evaluated so far.

As it was recorded, the development of intensive groundwater abstraction had been occurred since 1970 where the volume of groundwater of about 10.5 million m^3 were abstracted from productive aquifer by 96 production wells. Significant drop of groundwater abstraction occurs in 1997/1998 from 76.8 million m^3 in 1996 to 41.7 million m^3 in 1998 due to economic crisis. The period after, groundwater abstraction tends to increase yearly up to 55.2 million m^3 in 2009 (Figure 8).

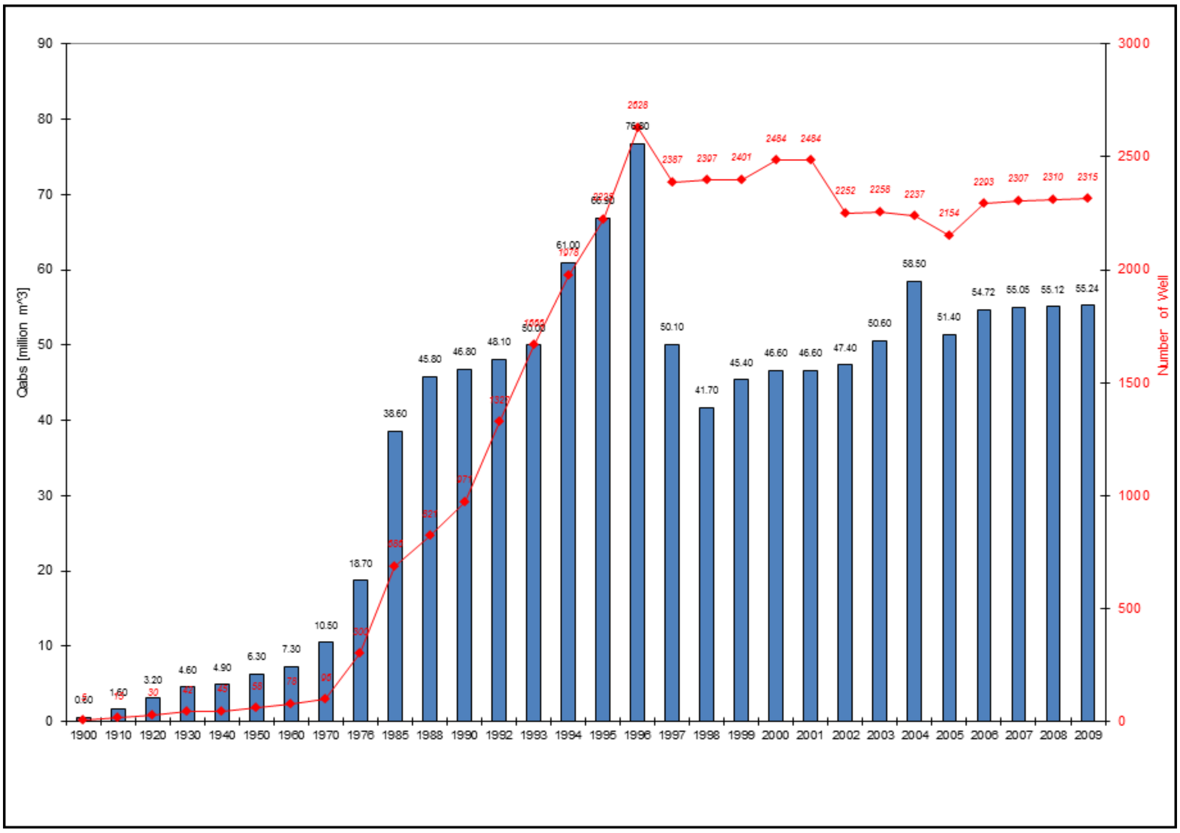


Fig. 8 History of Qabs at Deep Aquifer System in the Bandung Groundwater Basin

In general, groundwater use at unconfined aquifer system doesn't signicantly induce to the change of phreatic levels. That phreatic levels are solely influenced by local precipitation which observed from some dug wells. The phreatic levels tend to increase in rainy season and decrease in dry season. Generally, the position of phreatic levels which were observed in 2009 less than 10 m below land surface (mbls), but in some local areas were 11 to 20 mbls. Contour line of phreatic levels tend to follow the morphology of the lands surface (Figure 9).

Change of groundwater levels caused by groundwater abstraction at confined aquifer system shown by the depression cone of piezometric level observed in industrial areas, e.g. in Margaasih, Cijerah, south of Kiaracondong, and surrounding area of Ujungberung (Figure 10). The piezometric level from upper confined aquifer system were 1.3-12.7 mbls which observed in plain-hill border area from Cisarua–Cicadas–Clengkrang–Cileunyi–Cicalengka–south Majalaya-south Ciparay and Soreang, even in some areas found the self-flowing wells. The piezometric levels tend to decrease in industrial area which over exploited the groundwater. The piezometric level from upper confined aquifer system were decrease from year 2000 to year 2009.

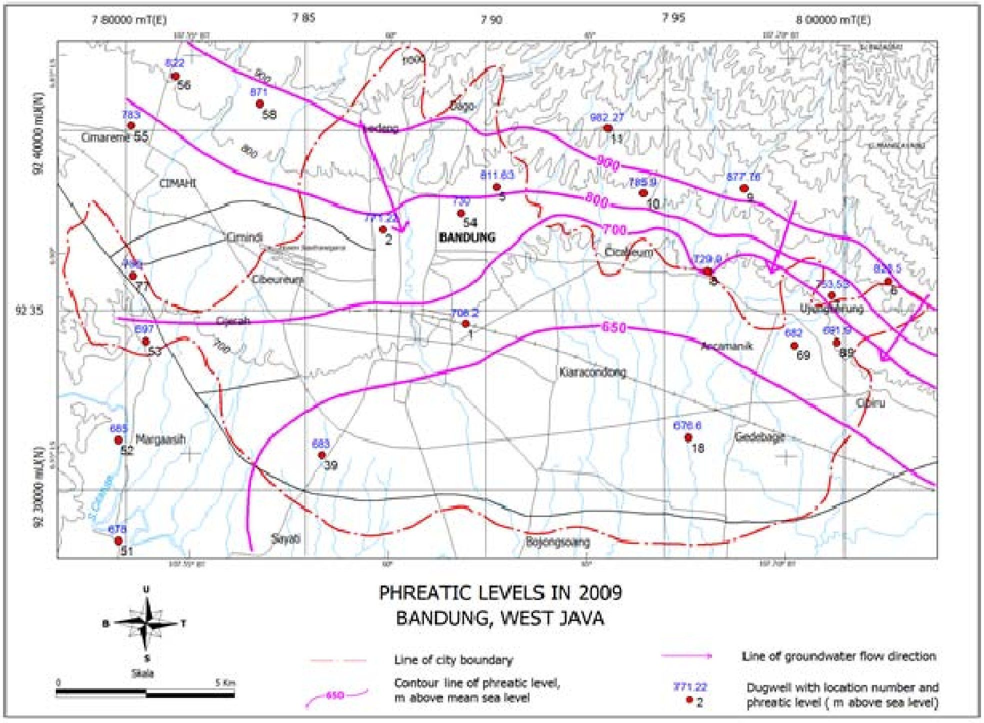


Fig. 9 Phreatic levels of unconfined aquifer system in the surrounding area of Bandung City

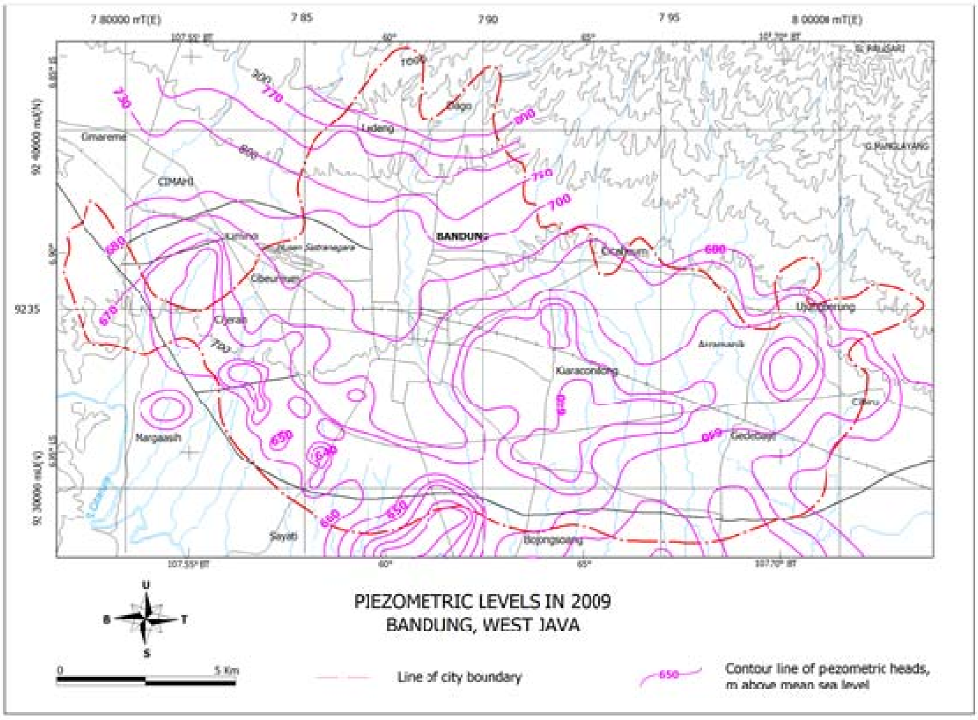
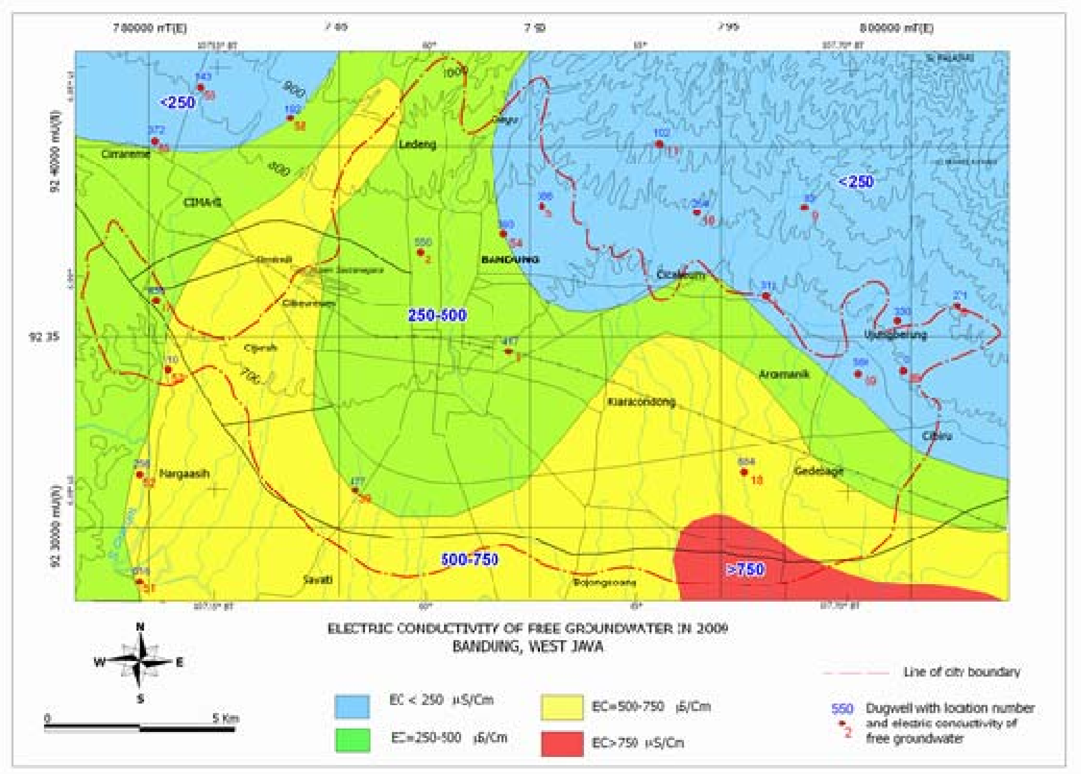


Fig. 10 Piezometric levels of confined aquifer system in the surrounding area of Bandung

Rapid increase of groundwater exploitation in the densely populated and industrialized areas in the Bandung Groundwater Basin didn't lead to change significantly the groundwater quality at unconfined aquifer system. Figure 11 shows the distribution of electric conductivity of groundwater at unconfined aquifer system observed in 2009. The values of electric conductivity at the hilly areas of north-west and north-east of Bandung City are generally less than 250 uS/cm. The values increase gradually to the south of the city and the maximum values were observed more than 750 uS/cm in south-east of Bandung City.



Fig, 11 Distribution of EC values of free groundwater in the surrounding area of Bandung

6. Closing Remarks

a At natural condition, most groundwater resources in the Bandung Basin are adequate for central water supplies. In many cases, groundwater abstacted from boreholes has to be treated for CO_2 neutralization or removal of Fe and Mn contents.

b Rapid growth of the population and economy in the Bandung region creates increasing environmental problems and, in particular, a significant contamination potential for shallow groundwater. Major contamination hazards are the infiltration of domestic sewage in urban areas, releases of untreated industrial waste water, and contamination related to sanitary landfills.

c The impact of intensive agriculture on the quality of shallow groundwater is not known in detail. Potential contamination sources are, in particular, the application of pesticides and fertilizers in tea plantations, on vegetable farms and on irrigated rice fields.

d To prevent further groundwater over-abstraction, which may also threaten the water quality of deeper aquifers, it is necessary to restrict the exploitation of affected aquifers, licensing and limitation of the number of industrial boreholes for the most heavily exploited aquifers have to be applied more rigorously and for the whole of groundwater basin.

e The suitability of groundwater resources for domestic supply in the Bandung Basin can only be sustained in the long term if adequate measures for protection of the groundwater quality are introduced.

f Monitoring of groundwater condition which is comprising quantity and quality of the groundwater is absolutely needed in order to avoid further negative impacts especially in area where groundwater is intensively exploited.

Acknowledgments

The authors wish to thank to the Head of Center of Environmental Geology, Geological Agency, MEMR in encouraging him to participate this CCOP-GSJ/AIST-CGS Groundwater Phase II Meeting. Our warm thank also goes to the Ministry of Land and Resources, People’s Republic of China who gave the opportunity to present this paper.

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Groundwater Pollution - Lenntech BV Delft : http://lenntech.com/

Problems of Groundwater Pollution in Japan

Youhei UCHIDA* and Yusaku TAGUCHI*

Abstract

Japan had experienced many sever problems of groundwater, such as land subsidence due to groundwater pumping, groundwater pollution and groundwater depletion from the 1950's to the 1970's when era of high-speed economic growth. In recent years, we got over these groundwater problems and established three techniques for protection of water resources, that is, "Reduce", "Reuse" and "Recycle".

1. Introduction

Groundwater pollution means that quality of fresh groundwater changes into undesirable one. There are two origins of groundwater pollution, that is, natural and man-made. A natural origin of groundwater pollution, such as fluorine, arsenic, iron and manganese, is affected by a geological setting, seepage from mine wastewater and so on.

Another of the most serious origins of groundwater pollution is man-made ones. There are three sources causing man-made groundwater pollution. One is the origin caused by agricultural and livestock raising activities. The second is caused by industrial activities.
The third is the origin caused by human activities in and around urbanized areas.

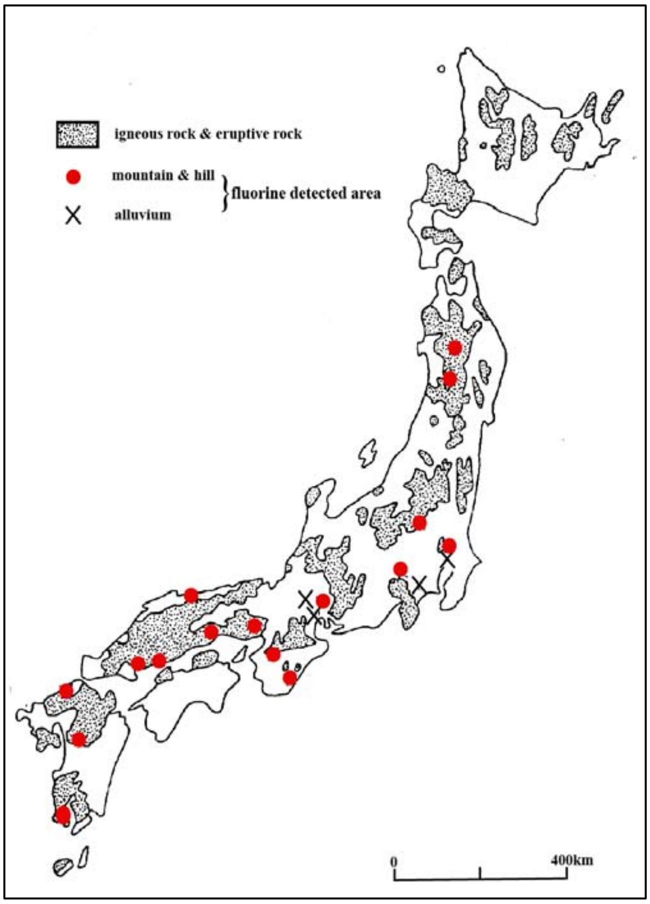

Fig.1 Areas detected fluorine in groundwater in Japan
(*after* Yamamoto, 1983)

*Geological Survey of Japan, AIST

2. Groundwater pollution in Japan

Figure 1 shows a distribution map of groundwater pollution caused by natural fluorine in Japan. Except groundwater in the alluvium, groundwater pollution by natural fluorine has occurred in or around the igneous rocks and the eruptive rocks. As all the igneous rocks and the eruptive rocks do not contain fluorine mineral, all the polluted areas by fluorine do not correspond to the areas of the igneous rocks and the eruptive rocks.

Figure 2 shows a monthly change of nitrate nitrogen in groundwater from 1970 to 1989 in Iwata, Shizuoka Prefecture of Japan. The Iwata raised alluvial fan is a very famous tea estate area. Almost all the area is covered by tea plant, where a large amount of nitrate fertilizer has been applied for tea plant. Especially after early 1980's, the total amount of nitrate fertilizer has been enormously. Accordingly, concentration of nitrate nitrogen in groundwater has been quickly increased over a drinking standard (10 mg/l). Iwata city has many wells for drinking purpose in the lower part of the fan. Due to such a high nitrate nitrogen concentration of groundwater, relocation of the wells was inevitable for the city and the city has spent a great deal of money to drill several new deep wells.

There are many papers reporting a good correlation between the area having high nitrate nitrogen concentration in groundwater and that farming livestock such as crummy and

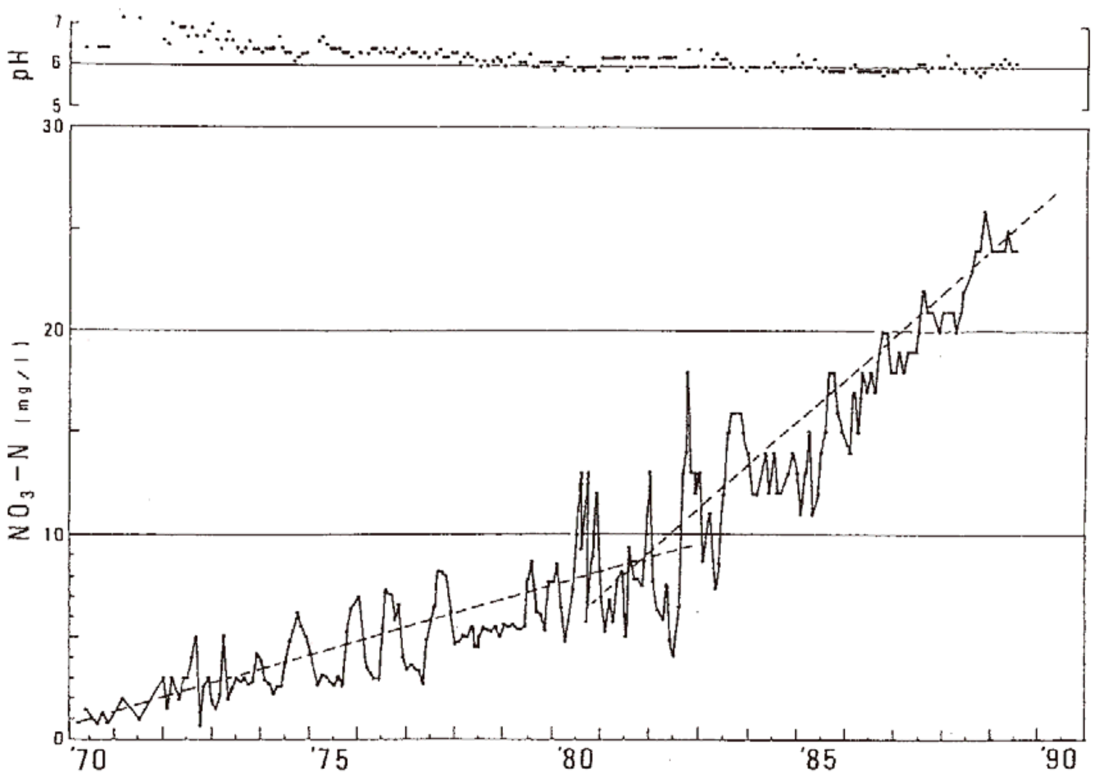

Fig.2 A monthly change of nitrate nitrogen in groundwater from 1970 to 1989 in Iwata, Shizuoka Prefecture of Japan (*after* Taguchi, 1994)

swine. The excrement of livestock infiltrates into the ground and gets mixed in with groundwater. That is the reason why the perfunctory treatment of the excrement of livestock ingenerates such a pollution. Another severe pollution of groundwater has occurred by spraying pesticides in the farmland.

There are many groundwater pollution accidents caused by inadequate treatment of wastewater from the industry. Figure 3 shows a good example of groundwater pollution caused by wastewater from the metal plating factories in Okaya, Nagano Prefecture of Japan. There is a municipal water supply well, shown in No.3 well of Figure 3, on the lower part of the basin. Cyanogen (CN) and chrome (Cr) were detected from groundwater of this well. The city stopped to supply drinking water and continued to withdraw groundwater to remove those pollutants. There are three metal plating factories, shown from A to C in Figure 3, on the upper part of the basin. Those pollutants were considered to contaminate groundwater from the three factories.

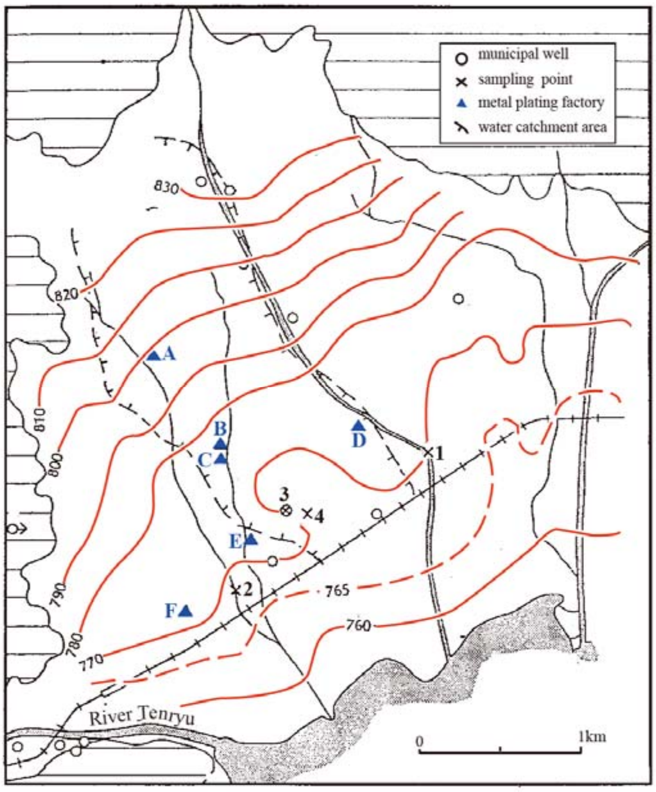

Fig.3 Groundwater pollution by metal plating factories in Okaya, Nagano Prefecture of Japan. Contours show water table (*after* Yamamoto, 1983)

Heavy groundwater pumping from the water front area conduces to decline of groundwater level and sometimes induces seawater intrusion and land subsidence. Figure 4a shows a map which seawater intrusion occurred due to heavy groundwater pumping by the industries distributed along the coast from 1960’s to 1970’s in Japan. Figure 4b shows an isopleth map of chloride concentration of groundwater in Tokyo. A diagonal area of Fig.4b shows over 1,000 mg/l of chloride concentration, where groundwater is nonconformance for industrial use.

A particular case of groundwater pollution occurs around the atomic power plants. Groundwater polluted by wastewater from atomic power plants sometimes contains high radioactivity and has high water temperature. It will undoubtedly have a negative effect not only on human health but also on ecology system.

There are two major pollution sources for groundwater in an urbanized environment.

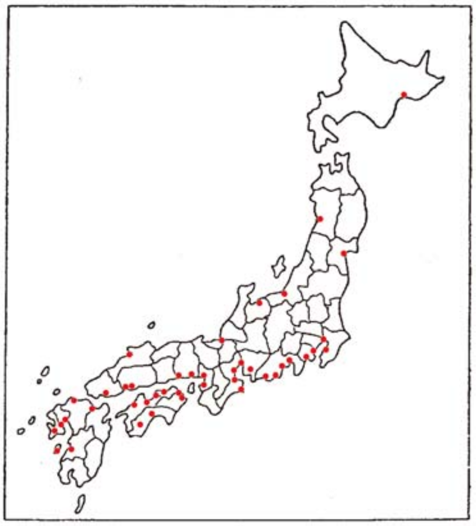

Fig.4a Seawater intrusion in Japan (*after* Yamamoto, 1983)

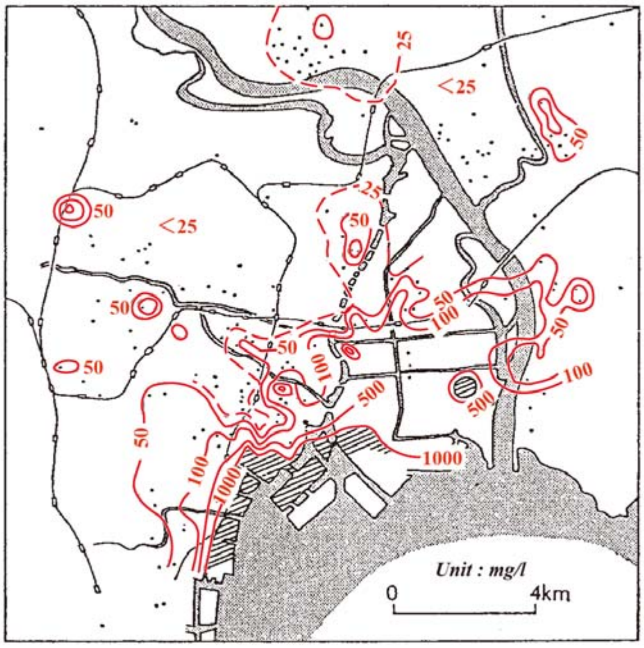

Fig.4b Isopleth map of chloride in deep wells in Tokyo (*after* Yamamoto, 1983)

One is from a domestic activity and the other is from urban activities such as commercial, industrial, and transit action.

Ordinary houses use a plenty of synthetic detergents such as dish liquid and washing liquid. They produce a large amount of garbage and drain high temperature water everyday. If those pollutants disorderly exist on the ground surface, they will become influential sources for groundwater.

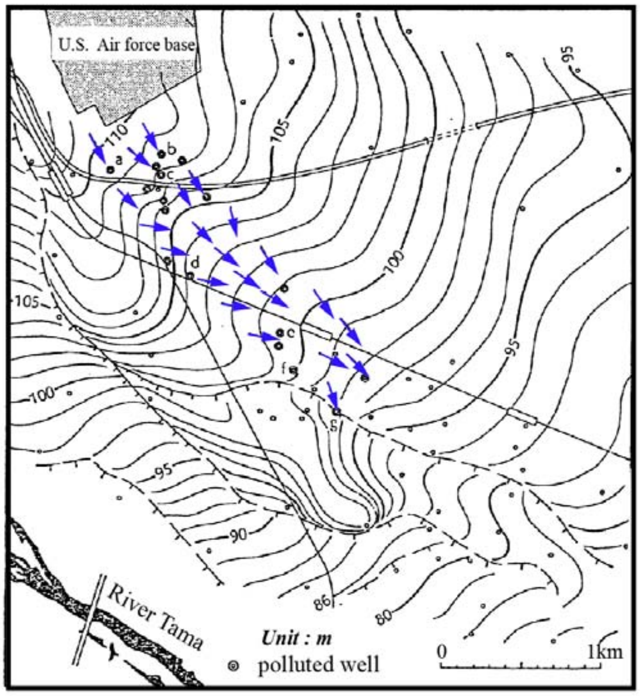

Fig.5 Groundwater table on February 24, 1967 and a groundwater pollution caused by an aviation fuel in Tokyo (*after* Hosono, 1967)

Figure 5 shows an example of groundwater pollution caused by an aviation fuel occurred in Tokyo in 1960's. There is a big U.S. air force base in the upper part of a plateau. In the lower part of the plateau, there were many wells for domestic use. As many wells among them were detected gasoline, people could not use groundwater. A researcher measured groundwater level in this area. Wells detected gasoline located along the groundwater valley that runs down from the air force base. In consequence, it was clear that an inadequate treatment of gasoline caused such severe groundwater pollution. Hydrological saying, the gasoline ironically was a good tracer and a coefficient of permeability (K) was calculated as about 2 x 10^{-1} cm/s. The value is acceptable one for a terrace gravel layer.

3. Preventive action for groundwater pollution in Japan

Japan has two main lows for preventive action for the groundwater pollution. A large amount of groundwater was used for industry and agriculture in Japan from the 1950s to the 1970s, causing declines in hydraulic head and land subsidence. Japanese government has settled on “Industrial Water Law” since 1956 to prevent land subsidence owing to groundwater pumping. The other low is “Water Pollution Control Law” to prevent intrusion of waste water on the groundwater enforced on 1971. Local governments, moreover, has settled on some regulation for preventive groundwater pollution. The final report of CCOP-GSJ/AIST Groundwater Project Phase I (2009) shows details of groundwater management in Japan and other CCOP member countries.

There are 3R techniques for protection of water resources in Japan, that is, “Reduce”, “Reuse” and “Recycle”. Sewage farm represent the techniques of water reuse and recycle. More than 1,700 of sewage farms are working in Japan and a farm is able to treat several tons of sewage per day.

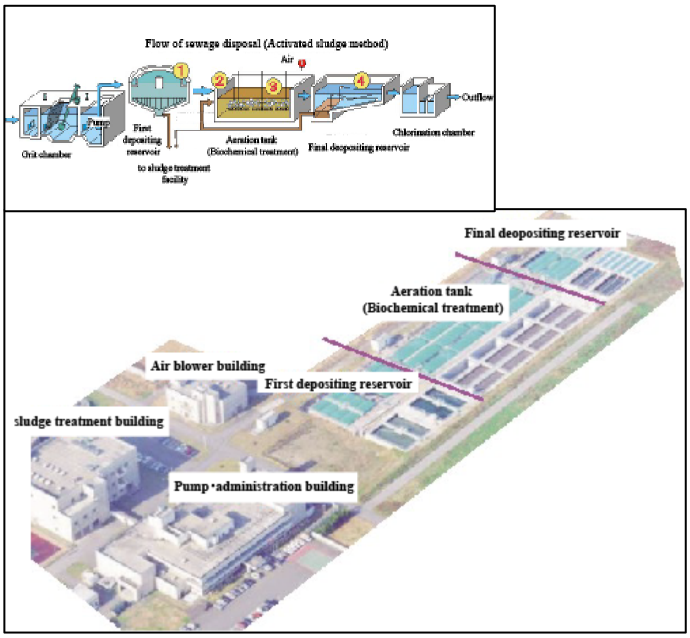

Fig.6 Sewage farm

Groundwater contamination and management (South Korea)

Kyoochul HA* and Kyung-Seok KO*

1. Introduction

Recent groundwater issues in South Korea are classified into three categories; (1) Groundwater as water resource, (2) groundwater contamination and remediation, and (3) groundwater for water industry.

In the context of groundwater as a water supply, probable groundwater problems induced by climate change have been investigated and adaptation against the climate change has been studied. The frequency and intensity of drought and flood seem to increase in the future, and the groundwater resource is vulnerable to secure as a water supply. In recent time, the flood and drought have been severe particularly in the Youngsan river and the Nakdong river basins. In those areas, lots of agricultural and industrial activities are being practiced, and the security of water is very important. There are lots of green houses in agricultural areas, and groundwater usually is the main water source for irrigation. Since groundwater pumping is concentrated during the dry season, groundwater shortage occurs frequently. Surface water is connected to groundwater, and the groundwater shortage is linked to surface water depletion. In the groundwater contamination and remediation, management for point source and non-point source is one of the most important issues and remediation techniques for the polluted groundwater have been developed and practiced. The groundwater pollution can be induced by either anthropogenic or natural causes.

ecently, groundwater is considered as high valued industrial product, 21 century blue gold. Especially, that kind of the industrial groundwater has been developed in Jeju island, because it contains high content of functional component, for example, Vanadium (V) without any harmful elements. The Vanadium is well known to be effective on diabetes cures. The functional element dissolved in groundwater can be used as an adding material to bottled water products, alcoholic and non-alcoholic beverages. Another is related to the Hydrotheraphy and Balneology. Since they can be linked to resort development and tourism, they will be a promising item of the future industry to boost local economic condition.

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2. Groundwater contamination and management

Groundwater contamination sources are classified into two categories based on contamination source origin. One is anthropogenic and the other is natural. For anthropogenic sources, point source and non-point source can be mentioned. For point sources, landfill, industrial factory, gas station, military base, and livestock are the examples. TCE, PCE, BTEX, MTBE, Phenol, NO3-N in groundwater have been reported in many times in Korea. For non-point sources, NO3-N, chloride, colon bacillus, general bacillus have mainly been mentioned.

Natural sources usually have geological origins. For example, turbidity from clay minerals, heavy metals such as aluminum, arsenic, iron, and manganese from mineralized zones, and fluoride from granite bedrock, and radioactive materials such as radon and uranium from metasedimentary rocks and granite have been reported in Korea.

Figure 1 shows the factors of groundwater contamination. Geology is the most important factor for heavy metals, Radioactive material and Fluoride contamination. Topology and soil type and land uses are factors influencing groundwater flow and contaminant transport. Particularly, land uses are closely related to the anthropogenic groundwater contaminations.

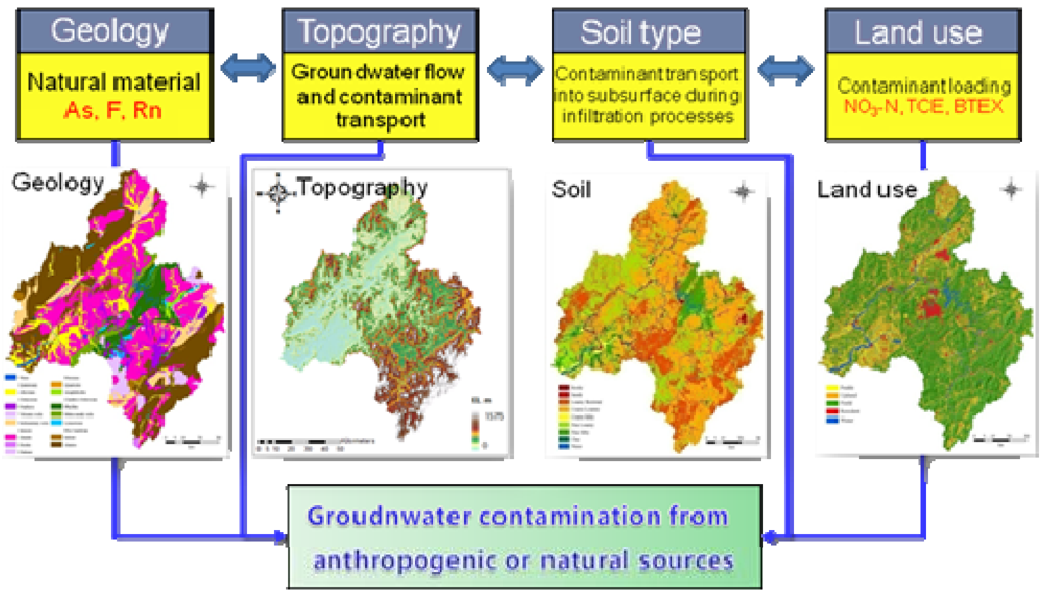

Fig. 1. Factors of groundwater contamination

KIGAM has accomplished groundwater vulnerability assessment for Keum river basin in order to manage groundwater quality. There are lots of assessment tools for the purpose of it. Index methods such as DRASTIC, modified DRASTIC, and logistic regression were applied to produce the vulnerability map (Fig. 2). Logistic method was the most effective to reveal land use effects on groundwater contamination. KIGAM has surveyed 1,180 groundwater samples in Keum river basin, and the NO3-N concentration criterion of groundwater in the assessment was selected as 3.9mg/L. Then, government controls the highly vulnerable areas to groundwater contamination in order not to make contamination occur or spread.

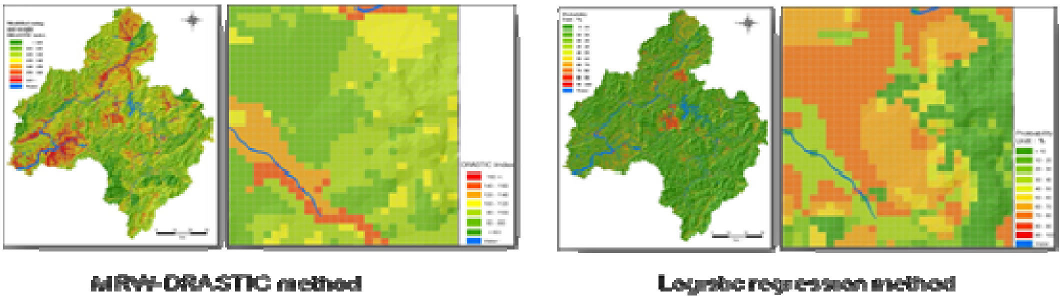

Fig. 2. Assessment of groundwater contamination vulnerability for the Keum river basin

KIGAM investigated the Nonsan area (555km2) within the Keum river basin to understand the status of groundwater quality. Table 1 shows the groundwater quality monitoring results on water supply wells in the area. 13 to 21% wells from the total surveyed wells were contaminated, exceeding to the limit of drinking water standard. Government monitoring network showed less than 10% wells were contaminated. Main contaminants in the wells are fluoride, NO3-N, arsenic, general bacteria, colon bacteria, and turbidity. Arsenic contamination was serious in Okcheon metasedimentary rocks, which indicates the close relationship with geology. One of the most common contaminant is NO3-N, which comes from the shallow groundwater and originated from the upper zone due to poor well facility.

Table 1. Monitoring result of water supply wells in Nonsan area

Time	Well NO.	Cont. Well NO.	F (1.5mg/l)	NO3-N (10mg/l)	As (ppb) 10	As (ppb) 50	G. Bac. (100↓)	Col. Bac. (-)	Turbidity -0.5
04 ¾	138	26 (18.8%)	5	5	6	1	1	1	13
5	126	27 (21.4%)	6	20	7	1			
05 ¼	130	27 (20.7%)		10			14	7	4
5 1/2	133	17 (12.8%)	2	3			6	7	7

2.1 Anthropogenic contaminants

KIGAM has conducted a comprehensive groundwater survey on the Keum river basin, and basic water analysis of groundwater in the area has been accomplished. More than 1,000 groundwater samples were collected and analyzed. Background groundwater quality map was produced for the basin. Particularly, the most common contaminant in groundwater is NO3, and it was characterized along with land uses. High nitrate concentration was shown in agricultural and residential areas. Considering the vulnerability assessment and observed data, we can draw a conclusion that land use is the important factor for nitrate contamination (Fig. 3).

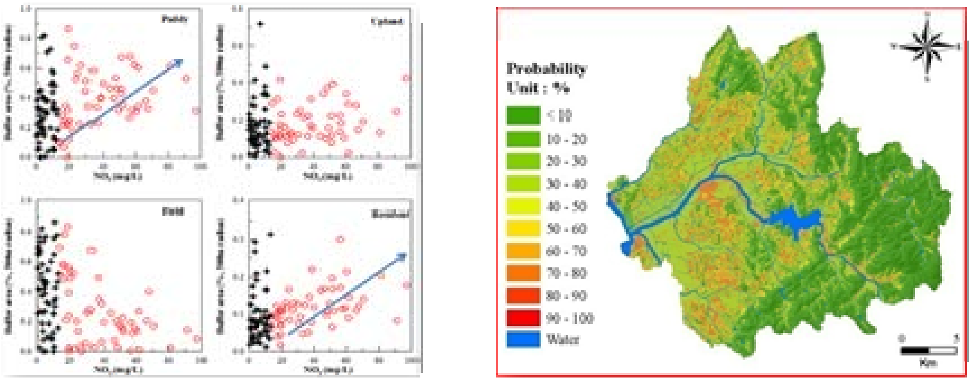

Fig. 3. Relation between land use and nitrate concentration (left) and groundwater contamination vulnerability map based on land uses (right)

Another example of nitrate contamination showed seasonal variation and spatial distribution pattern. The nitrate contaminated groundwater was accompanied by colon bacteria, which indicates rainfall and surface water inflow into the wells. The contaminations were caused by poor well condition and maintenance. Nitrate contamination source can be identified through isotope analysis, and it shows close relationship with agricultural activities and land uses. Nitrate also had animal waste or fertilizer origin. Figure 4 shows the conceptual model for nitrate contamination.

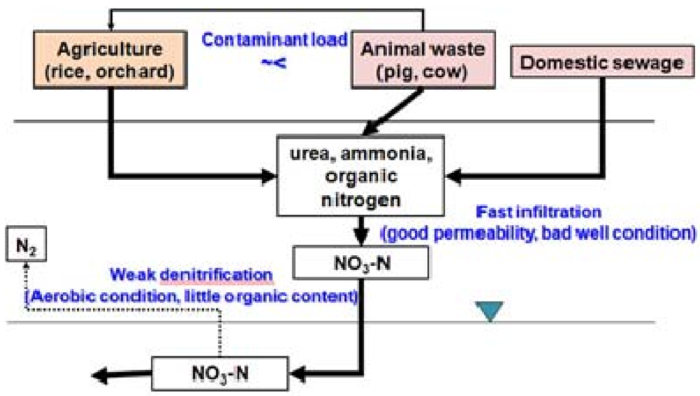

Fig. 4. Conceptual model for nitrate contamination

Management strategy for nitrate contaminated groundwater has to be in the context of both regional management and well management itself. First of all, well information with spatial data must be constructed with GIS DB. And, special management areas have to be designated for the purpose of prevention of groundwater contamination. Well conditions must be periodically checked, and some well equipments and facilities have to be built to block contaminant inflow from the surface. Special attentions should be paid to new well management in contamination vulnerable areas. Water treatment for nitrate contaminated groundwater can be done using reverse osmosis, membrane filtration, and iron absorption and reductions.

2.2 Natural contaminants

(1) Fluoride contamination

Fluoride exists naturally in water sources and is derived from fluorine, the thirteenth most common element in the Earth's crust. It is well known that fluoride helps prevent and even reverse the early stages of tooth decay. But, too much fluoride concentration make troubles such as dental fluorosis and skeletal fluorosis, and thus many countries have drinking water standard of it. Studies on 60,000 wells in the world by Amini (2008) showed the correlation between granite and fluoride concentration. There have been many articles and reports about fluoride contamination in Korea.

KIGAM surveyed the fluoride concentration in groundwater for the Keum river basin, and specifically studied fluoride contamination in the Keumsan and Boeun areas to understand the occurrences of fluoride in groundwater. The studies showed the close relationship with granite and fluoride concentration, and specifically fluoride was found to be eluted through long-term water-rock interaction. In the Boeun area, about 17% of wells were contaminated by fluoride based on drinking water standard, 2mg/l. The contamination distribution was very irregular, but the contamination cases were many in deep groundwater wells. It seems to be transported along faults or fractures. Figure 5 shows the conceptual model for fluoride contamination in the Boeun area. The studies show high concentration in granite area and in the boundary of phyllite and bedrock, especially in granite mineralizated zones.

For the management of fluoride contaminated groundwater, granite distributed area, especially fluorite mineralization zone have to be avoided to develop a new well. Membrane and absorption processes were applied to treat fluoride contaminated groundwater. Inverse osmosis, nano-membrane, electro-dialysis technique can be applicable for the membrane process. Activated alumina, clay, and AA-GAC are being used for absorbant.

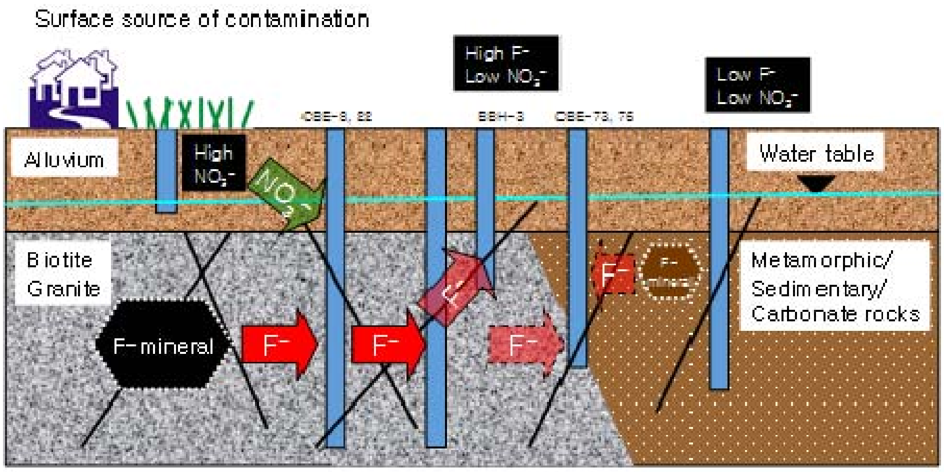

Fig. 5. Fluoride elution processes in Boeun area

(2) Arsenic contamination

Arsenic contamination of groundwater is a natural, occurring high concentration of arsenic in deeper levels of groundwater. A report found that drinking well 27% were contaminated by arsenic, and over 2.5 million people in Bangladesh and west Bengal were probably affected by arsenic poisoning of drinking water. Arsenic contamination of ground water is found in many countries throughout the world. Arsenic is a carcinogen which causes many cancers including skin, lung, and bladder as well as cardiovascular disease.

There are many studies and reports about arsenic concentration in Korea, which are mainly occurring in mining and soil contaminated areas. Arsenic has been quantitatively detected in 3.0 % of the total wells (5.0~188 μg/l), and its geographical distribution suggests 3 groups: an urbanized and industrialized area (Seoul and its neighboring province), and two naturally occurring areas (Chungbuk and Gyeongnam provinces). Natural occurrence of arsenic appears to be geologically related with Okcheon metasedimentary rocks and Cretaceous volcanic rocks.

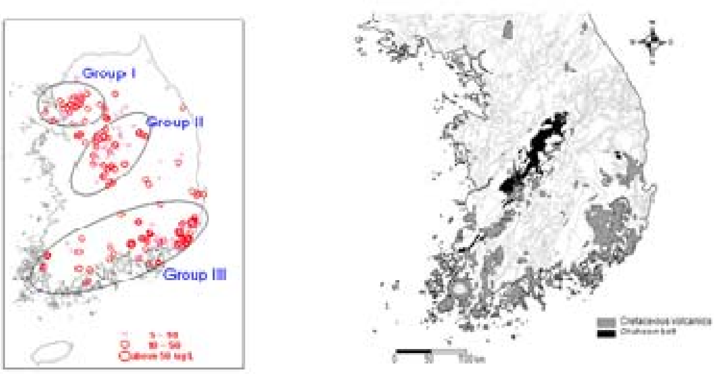

Fig. 6. Arsenic occurrences in groundwater

Based on the results of the studies in the high arsenic sites, the oxidation of sulfides can be a major control on As concentrations in groundwater in the mineralized and altered zone within the area of Cretaceous volcanic rocks. Desorption process under slightly high pH conditions may also be responsible for high As in groundwater in areas of Okcheon metasedimentary rocks (Ahn et al., 2007).

Arsenic contaminated groundwater treatment can be accomplished by reverse osmosis with membrane, but it costs high. Therefore, the treatment is now applied only to drinking water wells.

(3) Radioactive contamination

KIGAM has conducted a comprehensive survey on radioactive contamination in groundwater in Korea, and the survey results were shown on various distribution map. The radioactive contamination is closely related to geology. Radioactive contaminations occur commonly in granite areas. Figure 7 shows the distribution maps of radon and uranium with geology of Korea. Radon is a natural radionuclide originated from radioactive decay of radium in rocks and soil. It is colorless, odorless and tasteless elements that mainly distributed as gaseous phase in soil pore space.

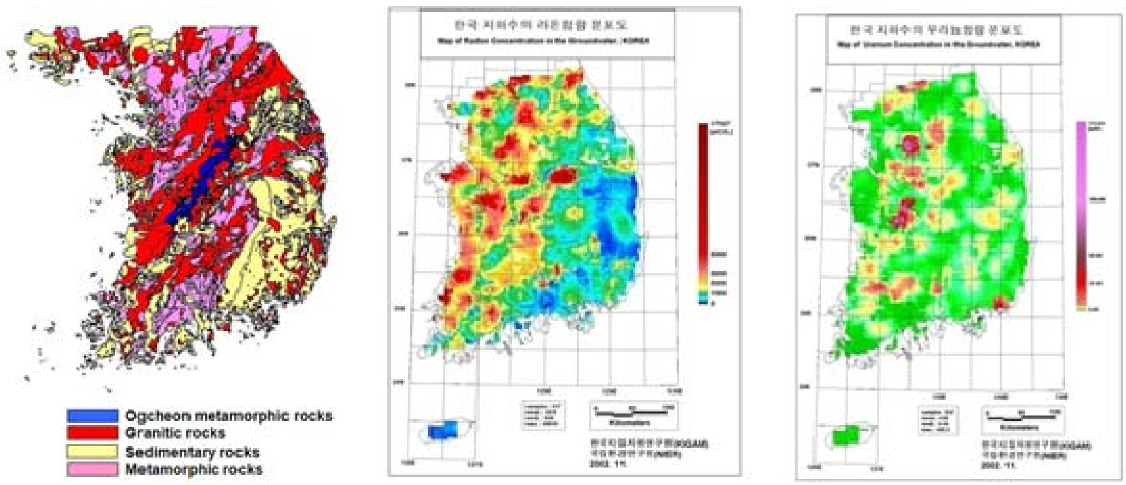

Fig. 7. Geology and natural radioactive materials (Rn, U) distribution

Table 2 shows the occurrences of natural radioactive materials (Rn, U) reported in the world. Most of radon and uranium were found in granite areas, except Korean cases. Radon was found in metasedimentary rocks formed by complex metamorphism in Korea. A survey was performed to evaluate the distribution of radon concentrations in groundwater of Korea. Groundwater of 728 wells was sampled and analyzed in recent years.

The results showed radon values ranging from 4 pCi/l to 40,010 pCi/l with a mean and a median of 1,862 pCi/l and 920 pCi/l, respectively. Mean radon concentrations were highest (2,595 pCi/l) in granites and lowest (238 pCi/l) in Jeju volcanic rocks. The groundwater generally showed the highest radon content (2,298 pCi/l) in the weathered and the fractured bedrock complex and the lowest level (672 pCi/l) in the alluvium. The results showed that the radon concentrations in Korea are low relative to those reported from other countries (Cho et al., 2007).

Radon treatment has been performed for local water supply facilities through aeration process, which has options with or without electrical power. Average removal efficiency of radon is about 70% without electrical power in the Nonsan area. Uranium treatment can be performed by Fe-GAC absorption process.

Table 2. Occurrences of natural radioactive materials reported in the world

Counntry	Sample	U (μg/L)		Rn (pCi/L)	
		Max.	Geo.	Max.	Geo.
Korea	728(708)	3,607	Gr	40,010	Meta.Sedi.
Finland[1)]	25,000<	12,400	Gr	2,094,825	Gr
Norway	4,000<	2,000[2)]	Gr	862,257[3)]	Gr
Sweden	35,000<	-	-	1,540,710[4)]	Gr
Canada[5)] (Manitoba)	287	2,020	Gr	371,270	-
USA	200000<	10,2996)	Gr	1,600,176[7)]	Gr

1) Salonen and Hukkanen, 1997, 2) Frengstad et al., 2000, 3) Dana et al., 1998, 4) Morland et al., 1988,

5) Betcher et al. 1988, 6) Cothern and Rebers, 1990, 7) Graves, 1987

3. Conclusion

As the need to use groundwater increases, the groundwater contamination and management became one of the important issues in Korea. Various contaminants have been reported and methods for management and treatment were proposed. Actually, anthropogenic contaminations were induced by poor well condition and not enough maintenance. Well surging and cleaning must be periodically performed to maintain good groundwater quality. For the new groundwater development, groundwater vulnerability assessment map can be a good tool for site selection and management of the existent wells. Land uses, geology and well depth are the important considerations. Blending, membrane filtration with reverse osmosis, and absorption with various materials can be used to treat the contaminated groundwater.

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Groundwater Contamination in Shallow Alluvial Aquifer System of Kelantan River Basin

Ismail C. Mohamad*

Abstract

The increase in population and urbanisation in the Kelantan River Basin especially in the Kota Bharu and its surrounding areas has resulted in poor environmental conditions with groundwater resources being impacted by disposal resulting from agricultural, urbanisation and industrial activities. Groundwater monitoring programme carried out since 1989 to detect changes of groundwater quality or water-level fluctuations due to groundwater abstraction in the area, indicate slightly persistent trends in deterioration of water quality in shallow alluvial aquifer system. Results from follow-up contamination studies on 1998 also showed that the shallow alluvial aquifer located in the zones of highly vulnerable groundwater.

1. Introduction

Groundwater contamination or pollution in Malaysia for the past has not been identified as key environmental issues in Malaysia. This is true since not many cases of environmental and human health incidents have been reported. However with increasing demand for drinking water use, groundwater has become an important environmental and human health issue.

The main public water supply in the districts of Kota Bharu, Tumpat and Bachok in Kelantan River Basin comes from groundwater abstracted from an alluvial aquifer system. Groundwater resources have been exploited in these three districts to meet the water demand which had been increasing steadily due to population growth, urbanisation and other forms of development. Pollution sources of urbanisation and agricultural activities threatening this groundwater system especially the shallow aquifer system. The adverse environmental impacts of urban expansion, industrial and agricultural activities could lead to deterioration in groundwater quality.

Available data based on follow-up study carried out in 1998 will be discusses and analyze with special focus on parameters such as pesticide, phenolic compound, oil and grease, anionic detergent, nitrate and chloride in the relation to human activities. The objective of this study was to determine the effects of pollution on the existing public water supply well-fields.

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2. Physical and hydrogeological setting

The river basin lies between latitudes 6° 00' and 6° 15'N and between longitudes 102° 10' and 102° 25' E. The mentioned area is the most populated area in Kelantan, and Kota Bharu, the capital of Kelantan is located in this area. The study area consists of three districts of Kota Bharu, Tumpat and Bachok, covers an area of about 1,300km2. It is bounded by the South China Sea to the north and east, and Thailand to the north-west. The location map of the study area is shown in Figure 1.

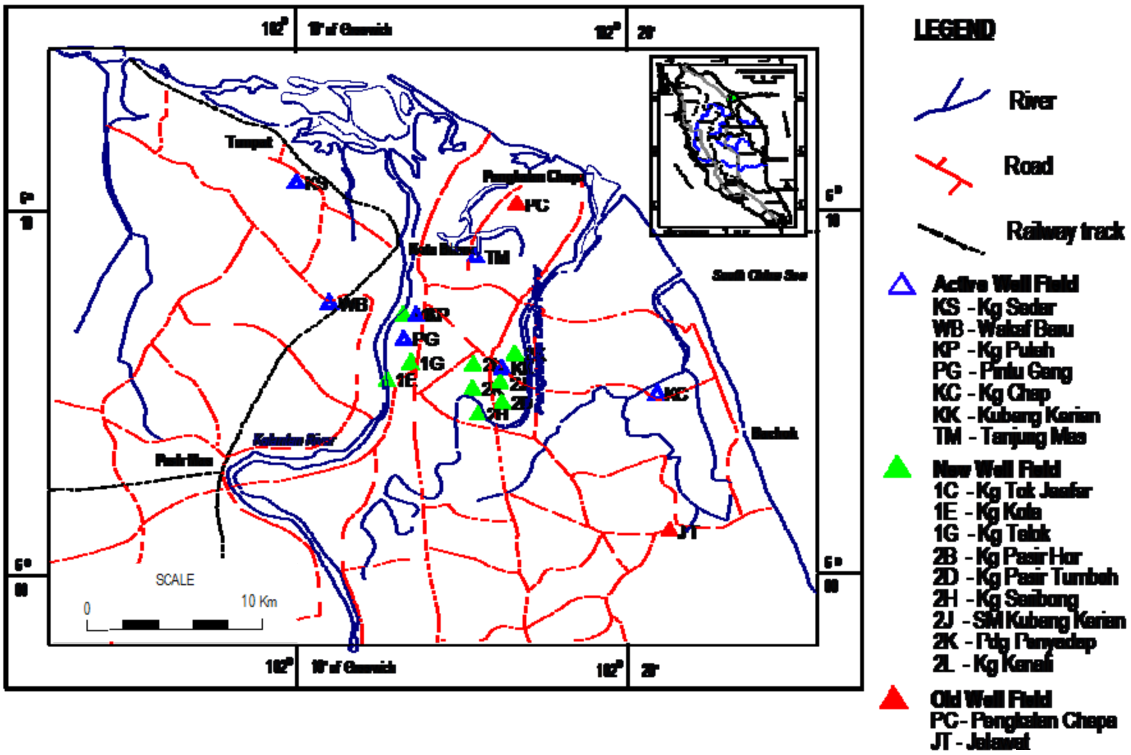

Figure 1: Location map of the study area and public water supply well-field

The area has a tropical climate with abundance of rainfall and high humidity. The mean annual rainfall is 2,700mm and average annual evaporation is 1,659mm. The coastal plain is flat and subjected to flooding during the north-east monsoon season from October to January. The area is drained by the Kelantan River in the central part and the Pengkalan Datu River to the east. Urban or built-up area use covers about 18% of the total area, agricultural activities about 39%, forest some 42% and water bodies represent a further 1%. Agriculture activities, such as rubber and oil palm can be found in the southern part of the basin or further inland. While paddy and others agricultural activities are scattered all over the region. Generally, the urban area is confined at the middle of the basin in the north of Kelantan River and near coastal line (Figure 2).

The shallow aquifer system, which lies some 5m to 20m below ground level, is generally unconfined. This aquifer is made up of mainly sand and gravel and is considered as having good aquifer properties and capable of high production rates. Recharge of the shallow groundwater system is derived mainly from the infiltration of rainfall and bank infiltration from major rivers. The shallow aquifer system is important because it serves as the main source of groundwater for most public waterworks in this area. Generally, the groundwater from this aquifer is fresh except near the coastline.

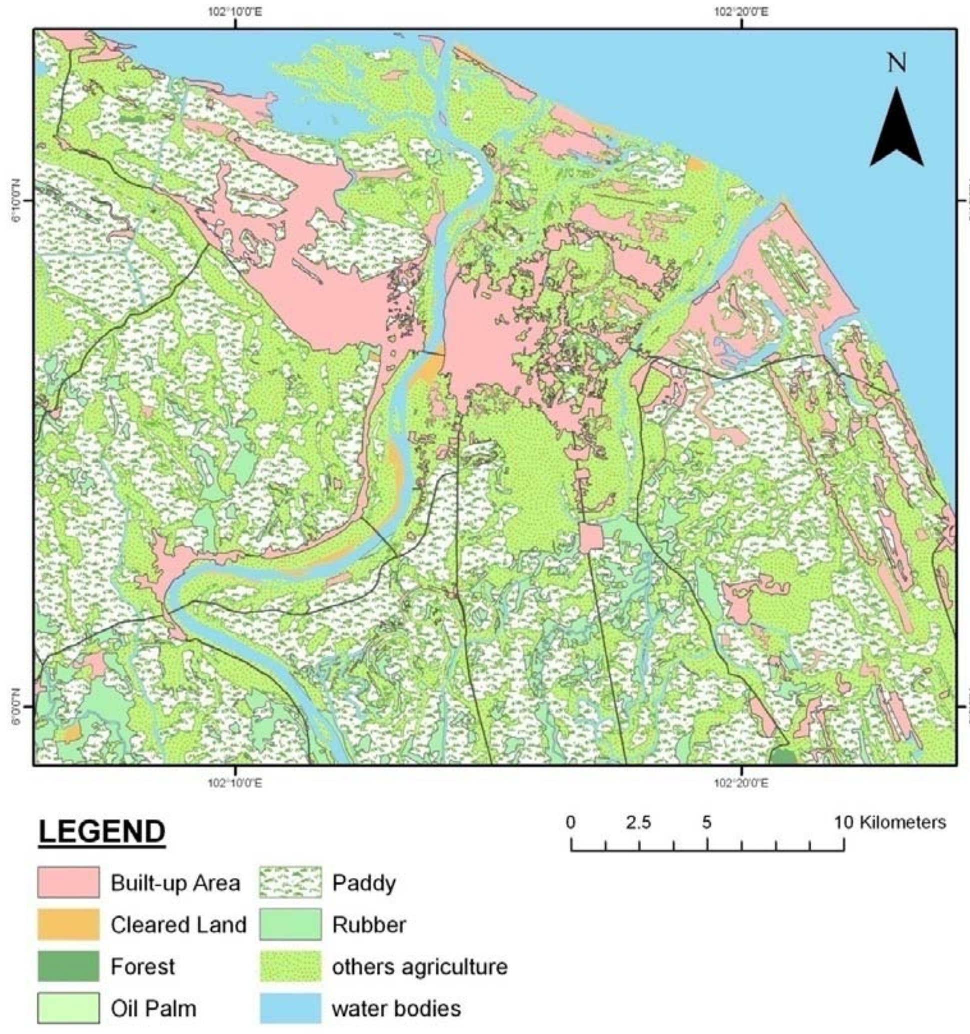

Figure 2: Land-use map of the Kelantan River Basin.

The deep aquifer system, which is separated from the shallow aquifer by clayey or silty materials, is classified as consisting of either semi-confined or confined type of aquifers (Figure 3). Hydraulic connection between both aquifer systems may occur in some places. In the deep aquifer, brackish or saline groundwater is found near the coast and at depths between 30m-50m extending to 5km inland from the coastline. Recharge to the deep aquifer system takes place mainly by percolation through the shallow aquifer. Direct infiltration from surface runoff into this aquifer system also occurs at the foothills in southern part of this area. Annual through flow in the alluvium in North Kelantan was estimated at 174 MCM (million cubic meters) or 476MLD (million litres per day) (Ismail M.N., 1985).

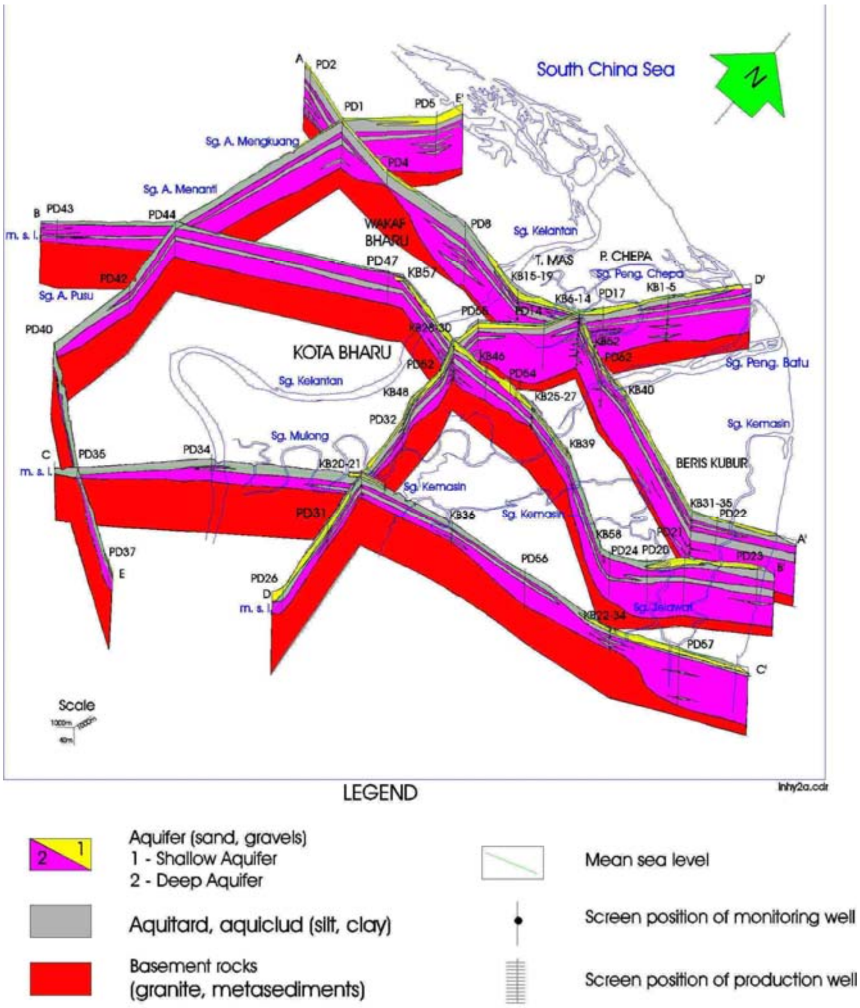

Figure 3: Hydrogeological fence diagram of Kelantan River Basin

3. Groundwater usage

Groundwater at the state of Kelantan is fully developed for potable use since 1935. The demand on groundwater for potable use has risen steadily over the last 30 years with growth of population. Currently about 75% of the population of Kelantan lives in Kelantan River Basin which includes the districts of Kota Bharu, Tumpat and Bachok.

The groundwater production was 36.37MLD in 1981, increase 45MLD in 1984 and was 66MLD in 1989. Under the North Kelantan Water Supply Project which was implemented in 1993, 72 wells were constructed which had a total abstraction of 115MLD. With these new wells constructed and taking into account of the 51 existing wells in operations, the total capacity of the these wells are 184MLD.

Presently, the groundwater is obtained through pumping carried out at 74 numbers of production wells (refer Table 1) from 14 well-fields located at the three districts. Groundwater for all these well-fields in this basin is drawn from the shallow aquifer system except in Tanjung Mas and the new wells at Pintu Geng where groundwater from the deep aquifer is exploited. At present the total groundwater consumption is 134MLD and will increase at pace of 2.5%. Figure 1 show the location map of the public water supply well-fields.

Table 1: Detail of Capacity of Treatment Plant and Number of Production Well

District	Water Treat Plant	Plant Capacity (MLD)	Nos. of Well	Remarks
Kota Bharu	1.Chicha	80	32	New well-field
	2.Kg. Puteh	35	19	
	3.Tanjung Mas	12	7	Deep aquifer
	4.Pintu Geng	8	5	Deep aquifer
Tumpat	5.Wakaf Bharu	15	7	
Bachok	6.Kg. Chap	5	4	
Total		155	74	

4. Source of contamination to the groundwater

Agricultural activities and urbanisation have been identified as the main pollution sources to groundwater in the Kelantan River Basin ecosystem. These activities contributed towards generation of point and non-point sources of pollutants. However the amount and types of pollutants produced were difficult to be exactly determined. Agriculture activities in the Kelantan River Basin utilised an area of about 39% of the total study area. The main activity for agriculture is dominated by rubber plantation, followed by paddy, oil palm and other agriculture activities such as tobacco and fruit crops. Generally, agriculture activities have been known using various types of chemicals as pesticides and fertilizers. There are also many types of pesticides being used and mainly to control weeds, insects, rats and other pests.

Rapid development in this basin is also threatening the quality of the groundwater. Uncontrolled groundwater pumping activities could cause lowering of water table and reduction in the aquifer yield through introduction of slime and clay particles into the aquifer. Intrusion of saline waters into aquifers in coastal regions may occur naturally and can be induced by exploitation of coastal aquifers as water sources. The quality of groundwater is also threatened by leachate from landfills, domestic wastewater and polluted storm water. Sources of pollution in urban areas may include parking lots, streets, and roads called urban runoff, where storm water picks up oils, grease, metals, dirt, salts, and other toxic materials.

5. Groundwater monitoring programme

One of the activities carried out by the Minerals and Geoscience Department (DMG) is to monitor the groundwater quality. Groundwater monitoring programmed was started in 1989 when a network of monitoring wells was specially designed and constructed to monitor the water quality and water level changes in the alluvial aquifer systems of Kelantan River Basin. The groundwater monitoring work is focused mainly in the districts of Kota Bharu, Tumpat and Bachok, in which groundwater are presently being abstracted for public water supply used. A number of 69 monitoring wells which was constructed by the DMG, including 24 shallow observation wells which mainly concentrated in the Kota Bharu municipal area, were used to form as part of the monitoring wells network.

Data obtained from the groundwater monitoring programme, indicate slightly persistent trends in deterioration of water quality on shallow alluvial aquifer system especially at coastal areas and intensive agricultural areas. Elevated nitrate concentration was found in the shallow aquifer system in intensive agricultural activities along the coastal zone.

6. Methodology

Totally 101 samples were collected from selected monitoring wells and dug wells within the river basin in the follow-up study carried out on 1998. Location of the sampling point is shown in the Figure 5. Samples were analysis for selected physicochemical parameters (Chloride and Nitrate) and organic chemical parameters (pesticides, phenolic compound, oil and grease, and anionic detergent) in order to understand hydrochemistry of the groundwater and level of contaminated. Available commercial computer softwares were utilised for the data analysis.

7. Results and discussion

Results of sampling programme on 1998 did not detect the presence of pesticide (organo-chlorine and organo-phosphorus) in the groundwater samples. However, phenolic compounds, oil and grease and anionic detergent had been detected in the groundwater of the shallow aquifer system. Chloride and nitrate concentration also found with a value exceeding the acceptable limit. Discussion of the parameters mentioned will describe as following:-

7.1 Anionic Detergent

The value of anionic detergent had a mean of 0.25mg/l, with a maximum concentration of 0.73mg/l. Generally, an acceptable value for anionic detergent is 1mg/l. Distribution of an anionic detergent as shown in map of Figure 6, showed that elevated high of detergent area relatively coincide with built-up or urban area. Sources of an anionic detergent generally come from material used for cleaning. Based on location of Kampung Puteh well-field which located in the middle of Kota Bharu town and distribution patterns of the contaminant, the well-field is found to be at risk of contamination by this anionic detergent.

7.2 Phenolic Compounds

Values of phenolic compounds range between 0.0mg/l to 0.98mg/L and had a mean of 0.04mg/l. An acceptable value for phenolic compounds is 0.002mg/l. Maximum concentration of phenolic compounds found in Pengkalan Chepa well-field. Phenolic compound is the most commonly occurring organic compounds found in urban groundwater as resulting from waste disposal. Phenols are toxic to human beings, but also to animal, plants, and micro-organisms. Figure 7 show the higher concentration of phenolic compound in shallow groundwater was found in Pengkalan Chepa area and distributed through large area at south-east of the basin. Waste water discharge from the activities of industries in the areas is believed to cause an increase of contaminant in groundwater surrounding these areas. The diagram also shows that the Kampung Puteh wells-field exposed to the risk of contamination by that phenolic compounds.

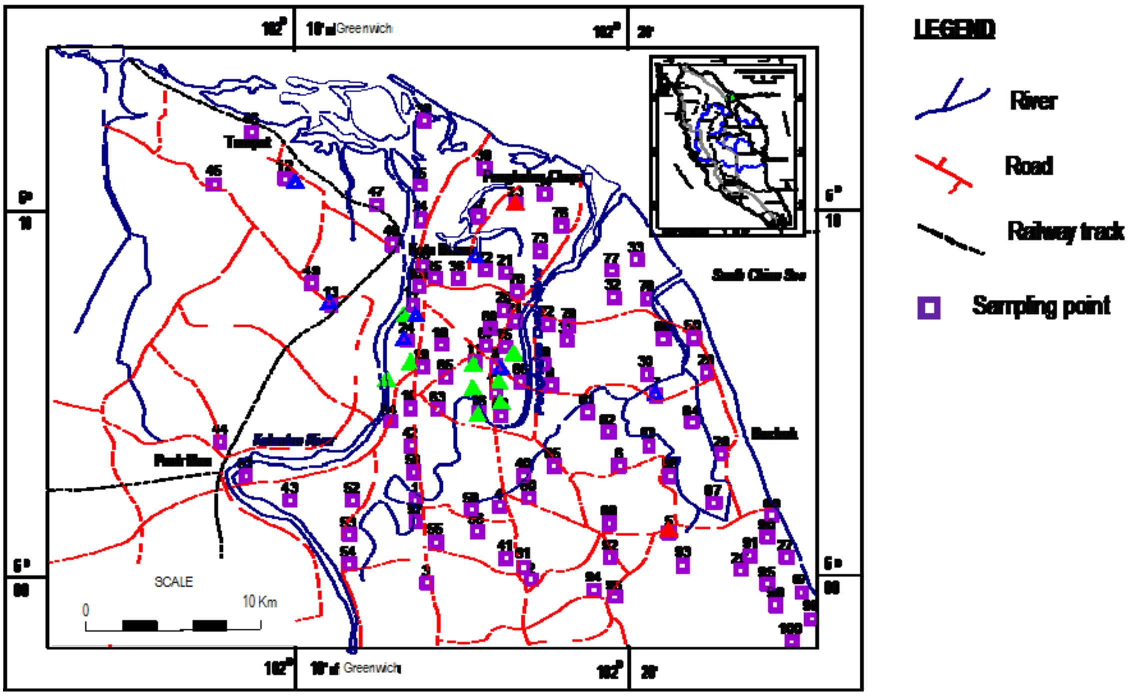

Figure 4: Location Map of Sampling Points

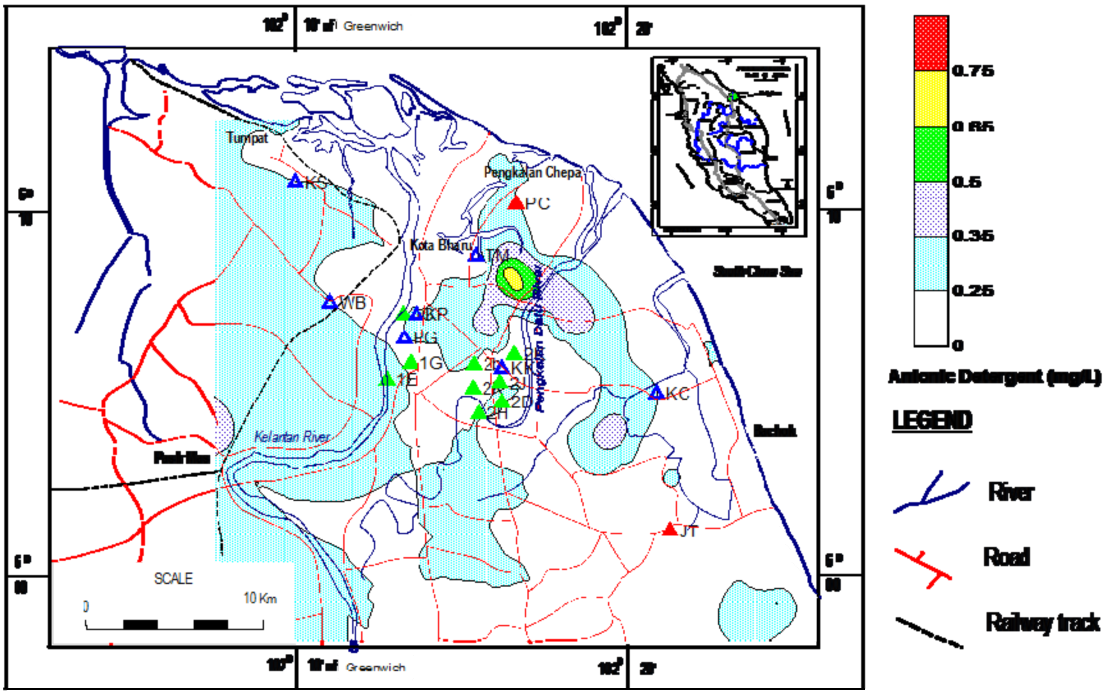

Figure 5: Distribution of Anionic Detergent in Shallow Alluvial Aquifer System

7.3 Oil and Grease

Oil and grease had a mean value of 3.8mg/l, and a maximum value of 8.1mg/l. An acceptable value for oil and grease is less than 1mg/l. These concentration levels of the oil and grease were found not to be acceptable. Generally, waste water discharges containing high concentrations of oil and grease may come from food service facilities. Figure 8 show that almost entire of the study area having levels of oil and grease concentrations in groundwater exceeded the acceptable level. Jelawat well-field, as no longer in operation, was also showed higher in concentration of oil and grease with a value of 7.9mg /l.

7.4 Nitrate

The ground-water quality (health) standard for nitrate is 10 mg/l (U.S. Environmental Protection Agency, 2008). More than 10mg/l of nitrate in drinking water can result in a condition known as methemoglobinemia, or “blue baby syndrome” in infants under six months, which can be life threatening without immediate medical attention (U.S. Environmental Protection Agency, 2008). Based on data collected from 101 wells, nitrate concentrations range from less than 3mg/l to 138mg/l, and the mean concentration is 13.5mg/l. Figure 9 shows the distribution of the nitrate concentration within the river basin. Nitrate concentration above 45mg/l was found near coastal area, especially to the north of the river basin. Based on the land-use map, the area with high concentration of nitrate (>10mg/l) are located in active agricultural areas, especially with the tobacco crop.

7.5 Chloride

The mean value for chloride is 36mg/l, and the maximum concentration is 1,406 mg/l, while the minimum concentration is 1.0mg/l. An acceptable limit for drinking water is 250mg/l. Chloride concentration was found above an acceptable limit at the old well-field (Pengkalan Chepa) probably due to seawater intrusion contributed by pumping activities (Figure 10). Areas near the coast were also affected by salt water encroachment into the river during high tide.

The major findings of the study have highlighted important findings. Based on the distribution pattern of contamination and the location of the well-fields, the Kampung Puteh well-field is of the most critical and high risk contamination by organic contaminants. The new well-fields will also facing a risk of contamination if protection measures are not taken immediately.

Contamination or pollution risks affecting the shallow groundwater are primary caused by human activities particularly from urban areas and areas of intensive agricultural. Brackish water is another source of contamination where groundwater is abstracted adjacent to the sea. Since the distance between the potential source of contamination and the existing water supply well-fields is rather small and a protective layer does not exist, careful protection of the resources is necessary. However, some of the well-fields are located inside or near the city area; later implementation of protection areas is not possible. In long term, it will be necessary to transfer the shallow groundwater production from areas which are close to city to areas with lesser contamination risk.

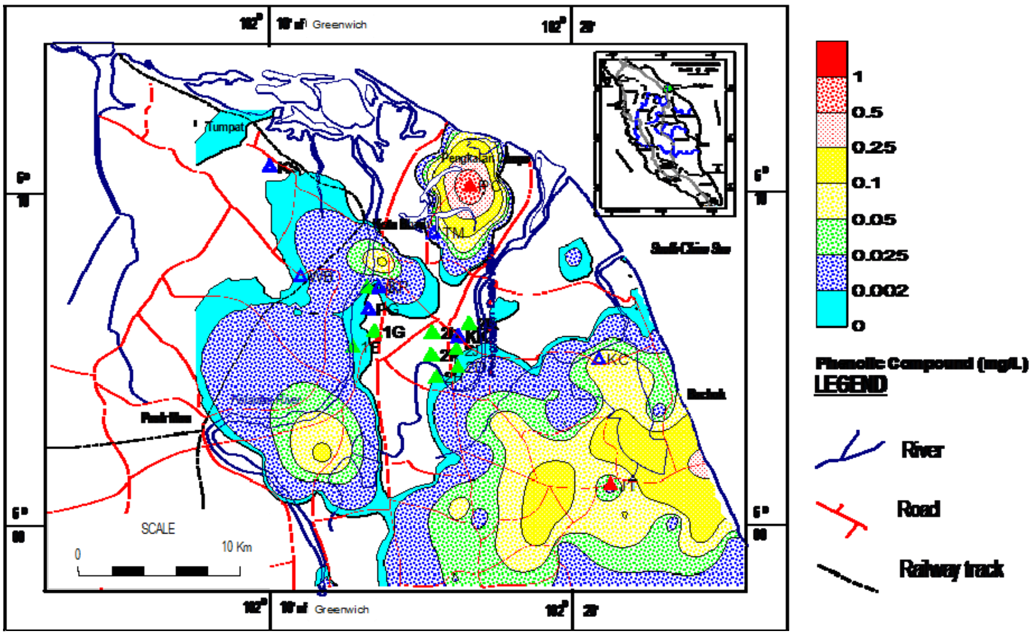

Figure 6: Distribution of Phenolic Compound in Shallow Alluvial Aquifer System

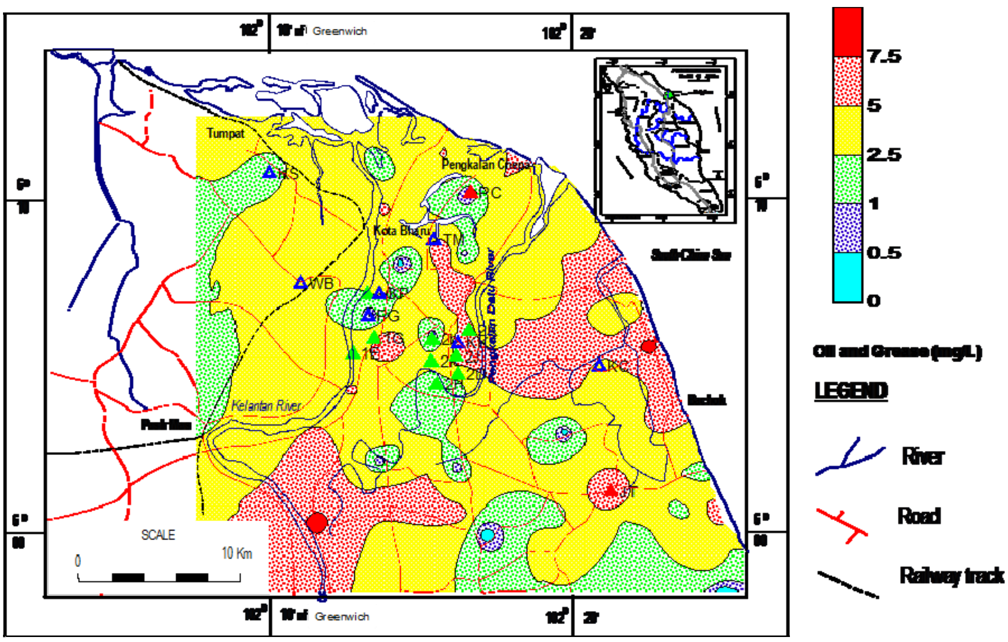

Figure 7: Distribution of Oil and Grease in Shallow Alluvial Aquifer System

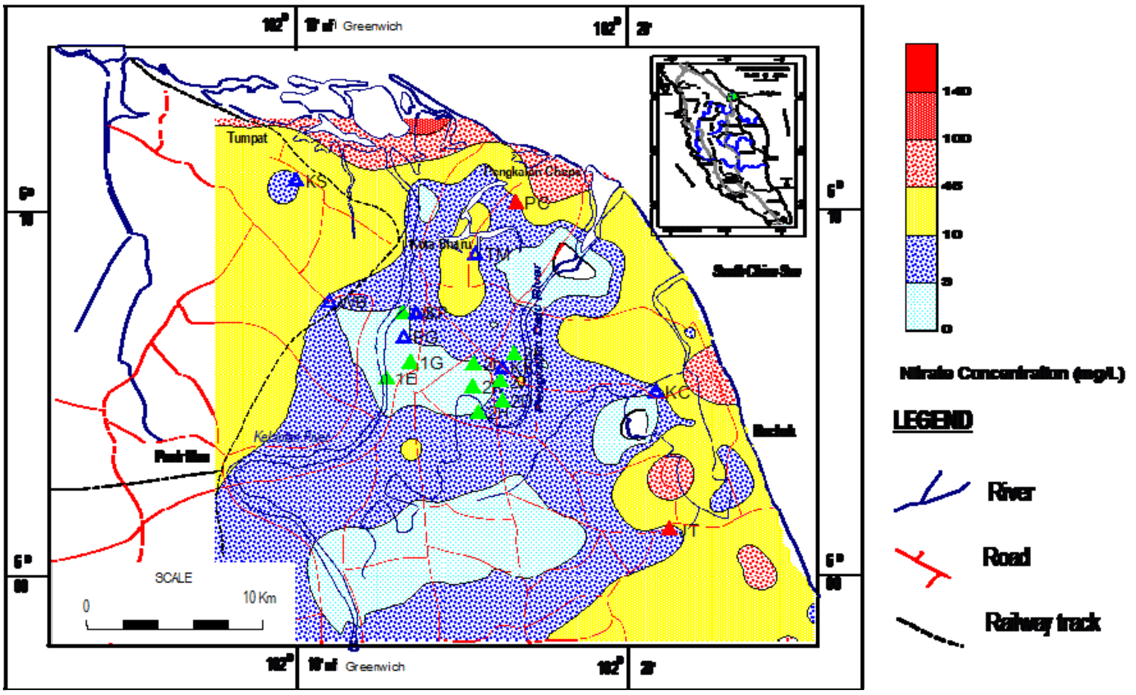

Figure 8: Distribution of Nitrate in Shallow Alluvial Aquifer System

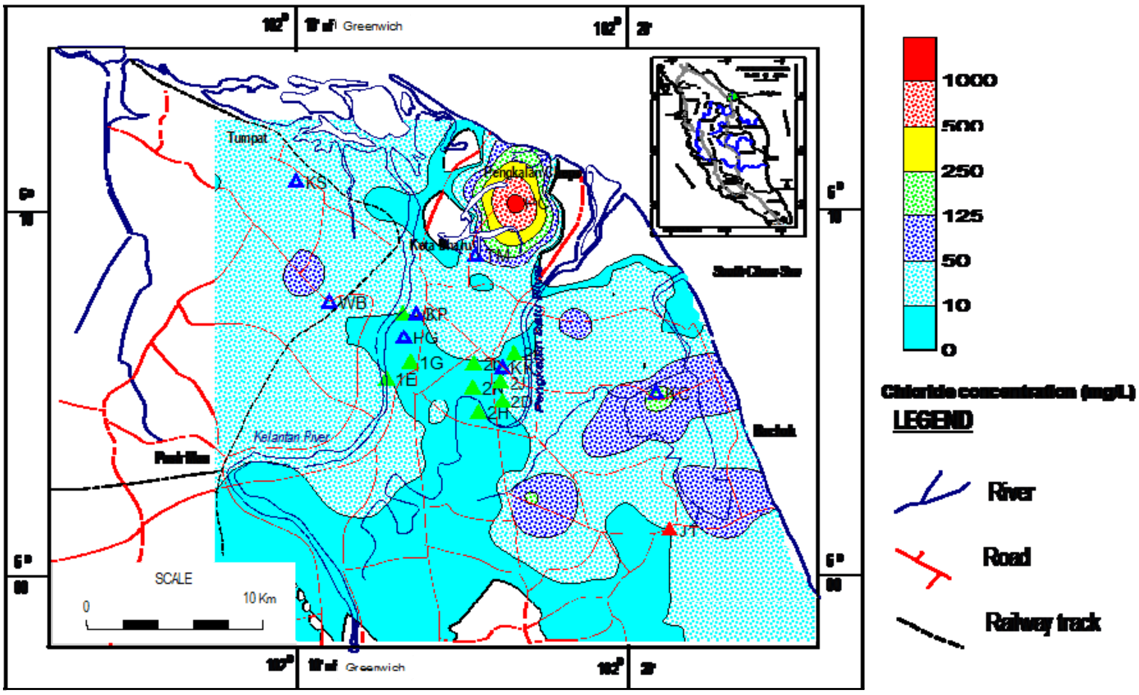

Figure 9: Distribution of Chloride in Shallow Alluvial Aquifer System

8. Groundwater management

A major concern in Malaysia in recent years is the development of water management policies. Issues about groundwater are included in the agenda due to the fact that is the main source water supply in the State of Kelantan. At present, Malaysia does not have specific regulation in the management and remediation of groundwater contaminated sites.

The groundwater resources management policies and strategies should be developed by practicing Sustainable Groundwater Management (SGRM). To achieve the SGRM policy, regulations and action must cover the aspect by collection of comprehensive groundwater data, controlling groundwater abstraction through legal and administrative procedure, licensing requirements, and controlling pollution through vulnerability mapping and the creation of source and well head protection zones.

Groundwater protection area should be planned and gazetted especially for the existing well-fields and groundwater potential areas. The groundwater protection area should be managed in an integrated manner taking into account of the relevant social, economic and environmental aspects. It should strike a cost/benefit balance of land utilisation. The establishment of Well Head Protection Area (WHPA) should be taking into consideration for the development of new well-field. Besides that, close monitoring of groundwater regime in this area is necessary in order to assess the impacts associated with increased pumping of groundwater and human activities surrounding the areas. They also need well trained monitoring and enforcement officers for effective management of groundwater contamination and effective enforcement. In addition, education of awareness in the importance of protecting the groundwater and soil quality to the communities, industry and business stakeholders should be made by relevant authorities in the country.

9. Conclusion

The shallow alluvial aquifer, which is presently being used primary for public water supply is noted to be particularly vulnerable to pollution, especially from contaminants due to human activities carried out in the built-up areas and from agricultural practices in the surrounding areas. The existing public water supply well-fields, particularly in Kampung Puteh well-fields were face to risk of contamination by organic pollutants. Contamination or pollution risks affecting the shallow groundwater are primary caused by human activities, particularly from urban areas and areas of intensive agricultural.

The maintenance and protection of groundwater ecosystem should be a major concern in water management of Kelantan. The management of groundwater resources should be carried out under proper developed policies and strategies by practicing Sustainable Groundwater Management (SGRM) to cater for current and future needs. A good policy and strategy is required in order to achieve this sustainable management practice in controlling groundwater for the future.

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State of Water Resource and Adverse Impact of Water Pollution and Risk Management in the Philippines

Lutgardo S. Laraño*

1. Introduction

Access to clean and adequate water remains an acute seasonal problem in urban and the four urban centers critical urban and coastal areas in the Philippines. The National Capital Region (Metro Manila), Central Luzon, Southern Tagalog and Central Visayas are the four urban centers critical in terms of quality and quantity.

Nearly 2.2 million metric tons of organic pollution are produced annually by domestic (48%), agriculture (37%) and industrial (15%) sectors. Untreated wastewater affects health by spreading diseases-causing bacteria and viruses, makes water unfit for drinking and recreational use, threatens biodiversity and deteriorates overall quality of life. Known diseases caused by poor water include gastro-enteritis, diarrhea, typhoid, cholera, dysentery, hepatitis and more recently sever acute respiratory syndrome (SARS), However, awareness regarding the need for improvement sanitation and water pollution control, reflected by the willingness-to-pay and connection to a sewerage system where they are easily available, is very low.

The annual economic loss caused by the water pollution is estimated at PhP 67 billion (US1.3billion). These include Php 3billion for health, PhP 17 billion for fisheries production and PhP 47 billion for tourism. To guard against environmental impact on water pollution, the Philippines has many water related laws, but their enforcement are weak and beset with problem that include: inadequate resources, poor database and weak cooperation among different agencies and local Government Units (LGU). The Clean Water Act of 2004 is now passed in congress but little improved are observed.

The Philippine Government aims to maintain the quality of its surface water according to their best beneficial used. This is embodied in the DENR Administrative Order (DAO) No. 34, which classifies bodies of water according to the degree of protection required. Hot spot areas of surface water quality were assessed by the province using Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) as parameters. Groundwater quality was assessed by using Total Dissolved Solids (TDS) and Coliform. Saltwater Intrusion was mapped based on

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National Water Resources Board (NWRB) data (see Water Quality Hot Spot Mp). Areas in water quality were assessed by river basin using the potential resource to demand for 2025 and annual water availability per capital.

Only seven percent of the country's total population is connected to sewer systems and only a few households have acceptable effluent from on-site sanitation facilities. Estimates show that over a 10-year period, the country will need to invest PhP 250billion (nearly US$5billion) in physical infrastructure, while LGUs recognized emerging water quality problem. Some of the government budgets, which are directed mostly to water supply (97% of the total), need to be diverted to sewerage and sanitation. Individual are not yet aware and willing to pay for these services and government incentives are justified in the short term for larger community-wide benefits.

The four main challenges faced by the Philippines to improved the quality of its surface, ground and coastal waters and provide healthy living conditions for all Filipinos includes:

(1) Public disclosures, raising awareness about health impacts of poor water quality and beach eco-watch program to increase stakeholders participation;
(2) Investing in wastewater management in urbanized and tourist centers, which is more cost-effective by expanding user base, promoting intermediate solution and using smaller and decentralized collection and treatment systems;
(3) Stimulating revenues and incentives to attract private sector participation in financing wastewater infrastructures project by increasing wastewater fees, industrial pollution charges and providing access to credit; and
(4) Providing effective regulation and incentives through the enactment of the Clean Water Act with clear implementing rules and regulations.

This report was prepared and referred by the undersigned were mainly extracted from excerpts published by the World Bank's Philippine Environment Monitor 2003 (PEM), DENR and other Philippine government/private agencies. PEM which issues several manuscripts since 2000 mainly focus on matters related to environmental condition of a particular country as a general environmental indicators related to environmental trends of the country i.e. solid waste management, air quality and the latest of which is the water resource and quality. Consequently, it is sole intention of the undersigned to present the country's water quality condition and possible means done by the Philippine government in combating serious treats of water supply based on such report. It is however unfortunate that the Mines and Geosciences Bureau (MGB) had very limited data regarding groundwater pollution and related topics required by CCOP as this agency is not the government's surface and groundwater monitoring arm.

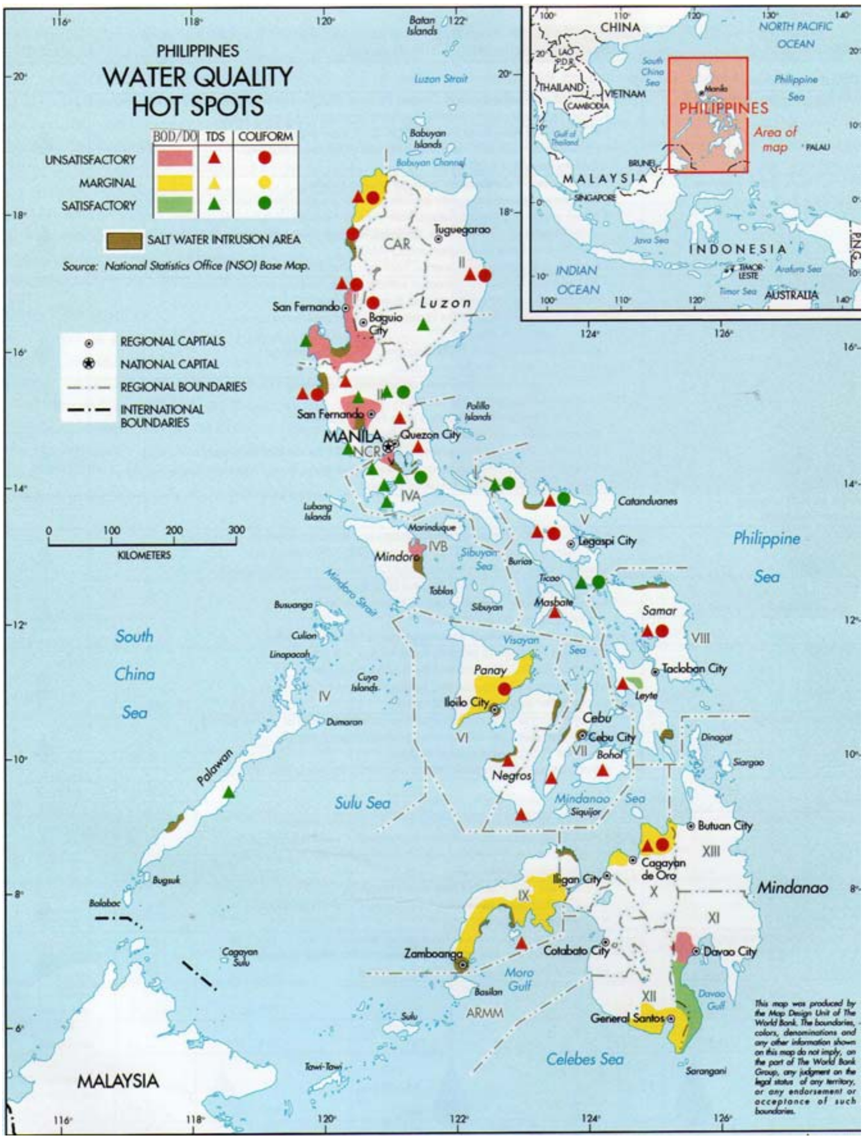


Fig.1 Water Quality Hot Spot in the Philippines

2. Water Resource, Quality and Availability

The Philippines, an archipelago of 7,107 islands is composed of three (3) major island groups: Luzon, Visayas and Mindanao. Luzon occupies nearly 50% of the land area of the country, with close to 80% of the country's manufacturing establishments and nearly 60% of all its households. Luzon had most number of regions, with seven of the 16 regions, as compare to Visayas, which has only three regions and Mindanao which has only six regions. Table 1 shows the region's comparative distribution of land area, household, gross regional domestic product etc.

Table.1 Regional Demography and Economic Activities, 1999

Region	Land Area (in km²)	No. of Households	GRDP	No. of Mfg. Establishments	GVA Mfg	Agriculture Land Area (in km²)	GVA Agriculture
NCR-Metro Manila	636	2,132,989	279,045	7,774	87,487	-	-
CAR-Cordillera Autonomous Region	13,714	263,816	22,301	88	7,410	190,235	3,348
I - Ilocos	12,840	831,549	28,639	344	1,598	415,434	11,996
II - Cagayan Valley	26,838	554,004	21,337	146	718	709,964	11,474
III - Central Luzon	18,067	1,632,047	83,940	1,840	26,652	653,607	19,174
IV - Southern Tagalog	46,844	2,410,972	142,075	3,806	44,726	1,410,315	33,696
V - Bicol	17,633	891,541	25,811	234	381	1,004,425	8,541
VI - Western Visayas	20,011	1,211,647	65,439	580	10,223	889,549	19,661
VII - Central Visayas	14,952	1,129,317	62,952	1,432	12,863	665,446	8,183
VIII -Eastern Visayas	21,432	715,025	22,171	169	4,653	957,329	6,764
IX - Western Mindanao	15,586	595,728	25,641	238	2,239	763,796	12,862
X - Northern Mindanao	14,033	542,075	39,592	311	9,205	828,515	12,632
XI - Southern Mindanao	27,141	1,066,199	51,061	727	7,561	1,103,297	16,171
XII - Central Mindanao	14,571	501,915	24,983	186	7,118	706,472	8,762
ARMM - Autonomous Region in Muslim Mindanao	18,847	393,269	9,080	13	365	–	5,203
CARAGA	11,410	393,362	13,314	144	1,468	–	4,940

Source: Philippines Statistical Yearbook, 2000.

2.1 Water Resources

The country is endowed with rich natural resources, including water, which is essential for the country's economic development. Water resources of the Philippines include inland fresh water (river, lakes and groundwater) and marine (bay, coastal and oceanic waters). Overall, there is sufficient water but not enough in highly populated areas, especially during dry season. River and Lakes occupy 1,830km² (0.61% of total area). The Philippines has 421 principal river basins in 119 proclaimed watersheds. Of these, 19 are considered major river basins. The longest river is the Cagayan River in Region II. Other important rivers in Luzon include the Agno and Pampanga, crossing the plains of Central Luzon; the Pasig, a commercially important artery flowing through the center of Metro Manila, providing the main drainage outlet for most of the waterways; and the Bicol, the principal river of Region V. The principal river of Mindanao is the Rio Grande of Mindanao, which receives the water of the Pulangi and Agusan province. The number of lakes registered in the country reaches about 72. The largest of which is the Laguna de Bay, which encompasses two regions; Metro Manila and Region IV with an area of 922km². Lake Taal, 56km south of Manila, occupies a huge volcanic crater and contains an island that is itself a volcano, with its own crater lake. The largest lake in Mindanao is Lanao Lake, which is a major source of hydropower.

Bays and Coastal Waters cover an area of 266,000km², while oceanic water covers 1,934,00km². The total length of the coastline is 36,289km. The Philippine coastline is irregular, with numerous bays, gulfs, and islets. Manila Bay, a sheltered harbor, is the country's busiest commercial hub. About 60% municipalities and cities are coastal, with 10 of the largest cities located along the coast. These coastal cities and municipalities are inhabited by about 60% of the population.

Groundwater is replenished or recharged by rain and seepages from rivers. The recharge or extraction potential is estimated at 20,200MCM per year (Table 2). Groundwater contributes 14% of the total water resource potential of the Philippines. Region X has the lowest potential source of groundwater compare to its surface water potential, while Region I and VII has the highest potential. Groundwater is use for drinking by about 50% of the people in the country. Based on the water rights granted by the National Water Resources Board (NWRB) since 2002, 49% of groundwater is consumed by the domestic sector and the remaining shared by agriculture (32%), industry (15%) and other sectors (4%). About 60% of the groundwater extraction is without water –right permits, resulting in indiscriminate withdrawal[3]. A High percentage (86%) of piped –water supply systems uses groundwater as source. In terms of sectoral demand, agriculture has a high demand of 85%, while the industry and domestic have a combined demand of only 15% (Table 3).

Table.2 Groundwater Availability (in MCM)

Water Resources Region	Groundwater Potential	Surface Water Potential	Total Water Resources Potential	Percent Ground Water to Total Potential
X Northern Mindanao	2,116	29,000	31,116	6.8
VI Western Visayas	1,144	14,200	15,344	7.45
IX Western Mindanao	1,082	12,100	13,182	8.21
XII Southern Mindanao	1,758	18,700	20,458	8.59
XI Southeastern Mindanao	2,375	11,300	13,675	17.37
III Central Luzón	1,721	7,890	9,611	17.91
IV Southern Tagalog	1,410	6,370	7,780	18.12
VIII Eastern Visayas	2,557	9,350	11,907	21.47
II Cagayan Valley	2,825	8,510	11,335	24.92
V Bicol	1,085	3,060	4,145	26.18
I Ilocos	1,248	3,250	4,498	27.75
VII Central Visayas	879	2,060	2,939	29.91
Total	**20,200**	**125,790**	**145,990**	**13.84**

Source: NWRB, 2003.

Table.3 Water Demand in the Philippines (in MCM/year)

Water Demand	1996	2025		% of Total
		Low	High	(1996)
Municipalities	2,178	7,430	8,573	7.27
Industrial	2,233	3,310	4,997	7.46
Agriculture	25,533	51,920	72,973	85.27
Irrigation	18,527	38,769	53,546	61.87
Livestock	107	224	309	0.36
Fishery	6,899	14,437	19,939	23.04
Total Demand	**29,944**	**62,660**	**86,543**	**100.00**
Groundwater (GW) Recharge	20,200	20,200	20,200	
% GW Potential/ Total Demand	67.46	32.24	32.24	

Sources: NWRB, 2003 and JICA, Master Plan Study on Water Resources Management in the Republic of the Philippines, 1998.

[3] Presentation by Engr. Jorge Estioko, Chief, Monitoring and Enforcement Division, National Water Resources Board during an NGO Consultative Workshop in 2003 at Miriam College, Philippines.

2.2 Water Quality

Water pollution affects fresh, marine and groundwater resources of the country. Surface water quality can be assessed by using Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) as parameters. The environmental and public health dimensions of the water quality situation are as follows:

(1) 36 % of the river sampling points has been classified as public water supply sources (Table 4 and Figure 1);

(2) About 60% of the country’s population live along coastal areas and contribute to discharge of untreated domestic and industrial wastewater from inland;

(3) Preliminary data indicate that up to 58% of groundwater intended for drinking water supplies are contaminated with Total Coli form and would need treatment; and

(4) 31% of illnesses for a five year period were from water related diseases (Figure2).

Rivers and Lakes. Between 1996-2001, the Environmental Management Bureau (EMB) monitored 141 rivers. About 41 rivers (29%) had minimum DO values of less than 5mg/l, which affects fish; 92 rivers (64%) had maximum values of BOD that exceeded the criterion for Class A water. These high percentages indicate organic pollution.

Classification	Beneficial Use
For Fresh Surface Waters (rivers, lakes, reservoirs, etc.)	
Class AA: Public Water Supply	Waters that require disinfections to meet the National Standards for Drinking Water (NSDW)
Class A: Public Water Supply	Waters that require complete treatment to meet the NSDW
Class B: Recreational Water	Waters for primary contact recreation (e.g. bathing, swimming, skin diving, etc.)
Class C:	• Water for the fishery production • Recreational Water Class II (boating, etc.) • Industrial Water Supply Class I
Class D:	• For agriculture, irrigation, livestock watering • Industrial Water Supply Class II • Other inland waters
For Coastal and Marine Waters (as amended by DAO 97-23)	
Class SA	• Waters suitable for the fishery production • National marine parks and marine reserves • Coral reefs parks and reserves
Class SB	• Tourist zones and marine reserves • Recreational Water Class 1 • Fishery Water Class 1 for milk fish
Class SC	• Recreational Water Class II (e.g. boating) • Fishery Water Class II (commercial) • Marshy and/or mangrove areas declared as fish and wildlife sanctuaries
Class SD	• Industrial Water Supply Class II • Other coastal and marine waters

Sources: DENR Administrative Order No. 34 and No. 97-23.

Bays and Coastal waters. EMB monitored a total of 39 bays and coast in the Philippines for a long time and regularly since 1996. Manila bay has its own monitoring program. Except for Puerto Galera, which is a protected seascape, the data indicated that 64% had DO level below 5mg/l, the minimum criterion set for water suitable as a tourist zone, fishery spawning area and contact recreation or swimming area. In the coast of Mandaue to Minglanilla in Cebu (Central Visayas), DO level varied from 0 to 14mg/l which indicate that the ecosystem is already undergoing “stress” during certain periods. Except in Cawacawa (Zamboanga City), the maximum values of BOD were all within the criterion set for Class SB water of5mg/l. Manila Bay has BOD levels that area generally within the fishing water quality criterion (Figure 3). However seasonal high organic loading from rivers draining to the bays and in particular, Manila bay, also result in harmful algal blooms (HABs) that pose a continuing threat to marine resources and public health. Groundwater. Pollution on groundwater may come from domestic wastewater, agricultural runoffs, and industrial effluents. This occurs when contaminants reach the aquifer or water table in the form of leachate. Domestic wastewater is the main contributor of bacterial contamination to the groundwater suppliers. The presence of colliform bacteria in drinking water supplies can cause water-borne diseases such as diarrhea, cholera, dysentery, hepatitis A and others. Limited data on the bacteriological content groundwater from 129 wells indicated a high level of positive bacteria in 75 wells (58%).

Another problem is saline water intrusion, which is caused by over-exploitation or excessive withdrawal of groundwater. This reduces water availability for domestic usage, including drinking and agricultural usage. At present, the large cities and coastal areas that have serious problem of saltwater intrusion are: Metro Manila (Malabon, Navotas, Manila, Paranaque), Cavite (Noveleta, Rosario, Tanza, Naic), along Laguna de Bay (Muntinlupa and Binagonan) and Cebu, Iloilo, Zamboanga, Laoag and Dagupan. One solution to arrest saltwater intrusion is groundwater recharge.

2.3 Water Availability

The amount of water availability and demand by river basin is presented in Figure 4. Water is distributed unevenly among the regions, with some areas containing more while others have limited supplies. For a the low economic growth scenario, it is projected that by the year 2025, water availability deficit would take place in Pasig-Laguna, Pampanga and Agno, Bicol, Cagayan, all regions in Luzon and Jaluar and Ilog Hilabangan and the island of Cebu in Visayas. Cebu Island was included in the analysis due to its significant economic role, which is second to Metro Manila.

All major cities, except Angeles and Iloilo, show a water supply deficit until 2025 (Table 5). This tabulation also shows the limitations of groundwater potential and extraction in highly urbanized areas, which has to be balanced with surface water. Metro Manila is currently experiencing water deficits. Although some cities like Baguio which has no shortfall considering current demand, it is known that major water shortages do occur during summer. In general, water deficit are time and site specific. Meanwhile, the basin of Agusan and Cagayan de Oro in Mindanao enjoys the highest surplus.

Table 5 Water Demand of Major Cities in the Philippines in MCM/year

	YEAR	TOTAL	Metro Manila	Metro Cebu	Davao	Baguio	Angeles	Bacolod	Iloilo	Cagayan de Oro	Zamboanga
Demand	1995	1,303	1,068	59	50	12	11	37	9	29	28
Demand	2025	3,955	2,883	342	153	87	31	111	47	98	203
Groundwater Availability Average		759	191	60	84	15	137	103	80	34	54
Surplus/Deficit	1995		-877	1	34	3	126	66	71	5	26
Surplus/Deficit	2025		2,692	-282	-69	-73	106	-8	33	-64	-149
Surplus/Deficit	1995		-82%	2%	69%	21%	1148%	179%	788%	18%	92%
Surplus/Deficit	2025		-93%	-82%	-45%	-83%	343%	-7%	70%	-65%	-73%

Source: JICA Master Plan on Water Resources Management in the Philippines, 1998.

2.4 Water Availability Per Capita

Among Southeast Asian countries, the Philippines ranks second from the lowest in term of per capita water availability per year with only 1,907m³ as reflected in Table 6. This is much lower than Asian and world averages. Areas where the per capita water supply drops below 1,700m³/year re already experiencing water scarcity. There are four river basins that belong to latter category; Pampanga, Agno, Pasig-Laguna and the island of Cebu (Table 7).

Table 6 Annual Renewwable Water Resources

Country	Total Resources (km^3)	2000 (m^3/person)
World	42,655.0	7,045
Asia	13,508.0	3,668
United States of America	2,460.0	8,838
Japan	460.0	3,393
Lao People's Dem Rep	190.4	35,049
Malaysia	580.0	26,074
Myanmar	880.6	19,306
Indonesia	2,838.0	13,380
Cambodia	120.6	10,795
Vietnam	366.5	4,591
Philippines	146.0 1/	1,907 1/
Thailand	110.0 2/	1,854 2/

Source: World Resources Institute 2000-2001.
1/ JICA Master Plan on Water Resources Management in the Philippines, 1998.
2/ World Bank Thailand Environment Monitor, 2001.

Table 7 Water Availability for All Uses Per Capita by Water Resource Region

Major River Basin WRR	Total Water Resources Potential 1/ (in MCM)	Water Availability per Capita (m^3/person)
IV Pasig-Laguna	1,816	124
VII Cebu Island	708	218
III Pampanga	4,688	888
III Agno	2,275	972
V Bicol	2,138	1,533
VI Jalaur	1,150	1,657
VI Ilog-Hilabangan	1,351	1,843
II Cagayan	5,496	2,143
XI Davao	1,449	2,368
XI Tagum-Libuganon	2,504	3,449
X Tagoloan	1,476	3,646
I Abra	2,200	4,954
XII Agus	2,479	5,070
XI Buayan Malungon	1,827	5,656
VI Panay	4,340	6,782
XII Mindanao	24,854	7,027
X Cagayan de Oro	3,672	9,321
X Agusan	15,984	13,732
II Abulog	4,326	19,228
TOTAL	**84,734**	

1/ Includes groundwater and surface water at 80 percent dependability.

3. SOURCES OF WATER POLLUTION

There are three (3) main sources of water pollution – domestic, industrial and agriculture. They can be classified further as either point source, which emit harmful substances directly into a body of water, or non-point sources, which are scattered and deliver pollutants indirectly. The technology to monitor and control point sources is well developed, while non point sources are difficult to monitor and control.

Solid waste is a major non-point source of water pollution that needs to be better controlled. Solid waste disposed either at a dumpsite or directly into water bodies, generates high loads of organic and inorganic pollution through biological disintegration. Leachate seeps through the ground and its aquifer and contaminates groundwater or seep into river, lakes and coastal water directly. Despite the passage of the Ecological Solid waste management Act (RA 9003) into law in January 2001, open dumpsite are still operated around Metro Manila and all over the Philippines.

The major pollutants monitored for water pollution are: Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO); Suspended Solids (SS); Total Dissolved Solids (TDS); coliforms; Nitrates; Phosphates; heavy metal like mercury and chromium; toxic organics like pesticides and others. Of these pollutants, extensive data has been compiled for BOD and DO between 1995 and 2001, while data for the other highly toxic pollutants are still incompletes.

3.1 Domestic Wastewater

Domestic effluents are generated by activities such as bathing, cleaning, sanitation, laundry, cooking, washing and kitchen activities. Domestic wastewater contains a large amount of organic waste with suspended solids and coliforms.

Half the organic waste is form domestic sector as shown in Table 8 and Figure 5, domestic wastewater is the main contributor to BOD pollution with 1,090,000 metric tons (48% of the total load), followed by agricultural with 822,000 metric tons (37%) and industrial with 325,00 metric tons (15%). On a regional basis, Metro Manila has the highest share of BOD loading (15%), followed by Region IV (14%). Meanwhile CAR has the lowest shares (1.8%) as shown in Table 8 and Figure 6. These estimates do not include pollution from solid waste discharge and leachate, as well as other informal non-point sources.

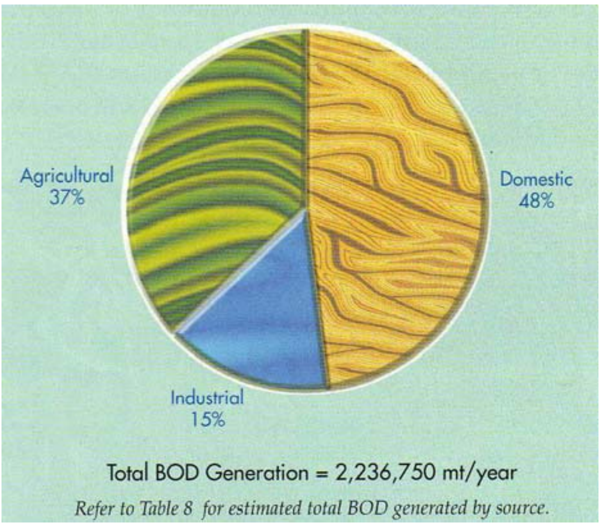


Fig.5 Share of Domestic, Industrial, and Agricultural BOD at the National Level

One-third of domestic BOD generation comes from Metro Manila and Region IV. Table 8 shows that metro Manila and Region IV account for the highest amount of domestic BOD waste at 18% and 15%, respectively, or one third of the country's generation. This is further elaborated in the Urban Sanitation and Sewerage section.

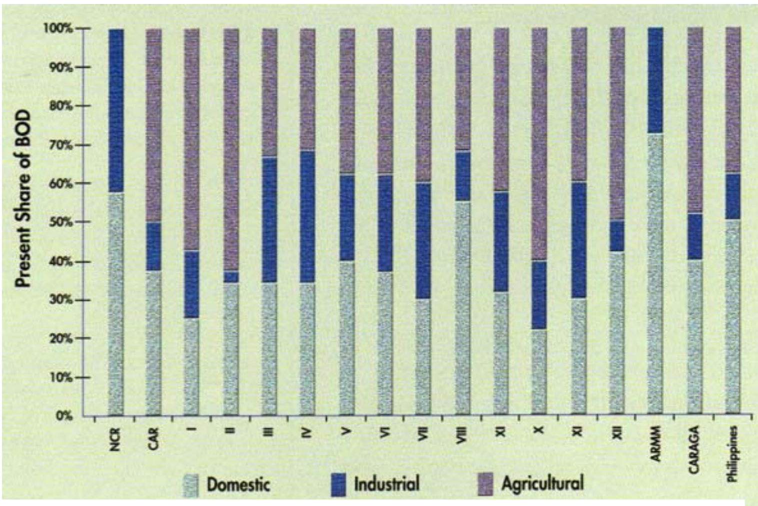


Fig.6 Regional Contribution of Domestic, Industrial, and Agricultural BOD

Industrial wastewater the volume and characteristics of industrial effluent differs by industry and depend on the production processes and scale of production used. Industrial wastewater may be organic and/or organic and/or organic. These are industries that are water intensive and correspondingly discharge large

Amount such as food and diary manufacturing; pulp, paper and paperboard products; and textile products and others. Other types of waste include thermal waste, created by cooling processes used by industry and thermal stations. The increase in temperature can change the ecology of water bodies. Additionally, hospital wastes are usually infectious and have to be controlled at the source. Thermal health care (hospital and medical) and toxic and hazardous wastes are created by industrial sources and can pose long term risk.

3.2 Agricultural Wastewater

The major source of water pollution in rural areas is agricultural farm. The absence of facilities to intercept surface runoffs from agricultural farms degrades the water quality of surface and groundwater, especially in the downstream urban areas. Major sources of agricultural effluent considered in the estimates of agricultural; BOD generations include livestock and poultry. Major sources of agricultural runoffs include; organic waste such as decayed plants, livestock manure, and dead animals, soil loss in the form of suspended solids and pesticides and fertilizer residues. Region IV and I generate the highest load of agricultural BOD, accounting for 13 and 12% of the total generation, respectively Table 8.

Table 8 Estimated Water Effluent by Source

Region	Volume of Wastewater in Region			% Share of BOD Generation in Sector			BOD Generation in Sector			Total BOD Generation	% Share of Total BOD Generation in Sector
	Domestic 2000 (1)	Industrial 1998 (3)	Agricultural 1999 (5)	Domestic 2000	Industrial 1998	Agricultural 1999	Domestic 2000 (2)	Industrial 1998 (4)	Agricultural 1999 (6)		
	In '000 m^3 per Year			%	%	%	In '000 metric tons per Year				
NCR Metro Manila	430,046	272	–	17.6%	42.5%	0.0%	192	138	–	330	14.8%
IV Southern Tagalog	406,696	80	7,499	14.6%	14.1%	13.3%	159	46	109	314	14.0%
III Central Luzon	272,471	49	4,646	9.9%	9.0%	9.1%	108	29	75	213	9.5%
VI Western Visayas	188,042	55	4,574	7.7%	5.1%	8.1%	84	17	67	167	7.5%
VII Central Visayas	180,065	57	6,394	7.1%	7.4%	10.6%	77	24	87	189	8.4%
XI Southern Mindanao	160,025	47	4,888	6.4%	6.6%	8.6%	70	22	70	162	7.2%
V Bicol	128,849	22	3,036	5.8%	3.1%	5.4%	63	10	44	117	5.2%
I Ilocos	121,268	24	7,260	5.2%	3.3%	11.5%	57	11	95	162	7.3%
X Northern Mindanao	87,085	15	5,568	3.4%	2.2%	9.1%	37	7	75	119	5.3%
IX Western Mindanao	88,734	24	3,058	3.8%	3.3%	5.2%	42	11	43	95	4.3%
II Cagayan Valley	74,556	1	3,541	3.5%	0.2%	6.1%	38	1	50	89	4.0%
VIII Eastern Visayas	101,307	8	1,236	4.5%	1.1%	2.6%	49	4	21	73	3.3%
XII Central Mindanao	74,964	4	2,346	3.2%	0.5%	3.9%	35	2	32	69	3.1%
ARMM	64,402	0.07	1,905	3.0%	0.0%	3.0%	33	0.05	25	57	2.6%
CARAGA	62,311	6	539	2.6%	0.9%	1.2%	28	3	9	41	1.8%
CAR	40,614	4	1,379	1.7%	0.6%	2.3%	18	2	19	39	1.8%
TOTAL	**2,481,435**	**668**	**57,869**	**100%**	**100%**	**100%**	**1,091**	**325**	**821**	**2,237**	**100%**

4. Critical Regions

In the hot spot map, four regions were found to have an unsatisfactory (U) rating for the water quality and quantity criteria. These are the National Capital Region (NCR) or Metro Manila, Southern Tagalog, Central Luzon, and Central Visayas.

4.1 National Capital Region

NCR, or Metro Manila, is the national capital and main hub of all socioeconomic, industrial, cultural and political activities. Metro Manila is bounded on the north by the Central Luzon region, on the southeast by the Southern Tagalog region, and on the west by Manila Bay. While NCR is the smallest in terms of land area, it has the highest number of household (28 percent of the total) and manufacturing activity (Table 1). With the highest population density of 16,497 person/km², it has no area for agriculture, and a limited land area for development expansions, except coastal reclamation. Metro Manila's industries, population and development are spilling to Central Luzon and Southern Tagalog.

There is insufficient good quality water available in the region. The largest source – Laguna de Bay – is under threat with rivers discharging large amount of pollutants. Coliform testing of deep well shows contamination and the need for treatment facilities.

(1) Water Resource

The Pasig-Laguna Basin is the major river basin of the region. It has a drainage area of 4,678km² with an annual runoff of 7,485MCM. The Pasig River is the principal river system and floodplain of the basin occupies 23% of the total area.

Since a river basin is the basis for regional water resource planning, Metro Manila is considered part of Water Resources Region IV. For the Pasig-Laguna basin, the water resource potential is taken at 1,816MCM. The projected water demand is taken at 2,977 MCM for the year 2025. The ratio between water potential and projected demand is very low at 0.61.

(2) Water Quality

In Metro Manila, 58% of its BOD loading (192,000 metric tons) was generated by domestic waste, and the remaining 42% (138,000 metric tons) was from industries (see Figure 7 and Table 8).

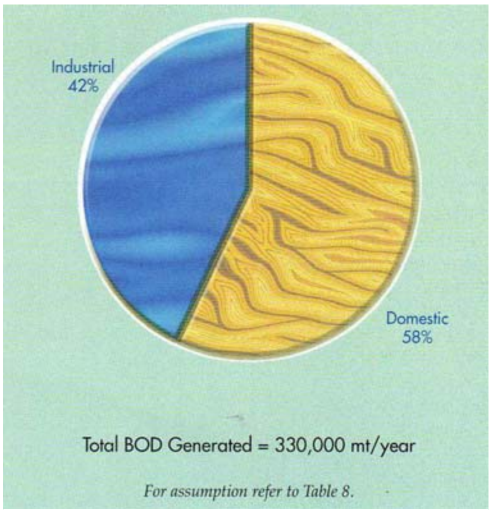


Fig.7 Sector BOD Loading Metro Manila

(3) Rivers and Lakes

The EMB sampled five rivers for the period 1996 to 2001; Paranaque, San Juan, Marikina, Pasig and Navotas-Malabon-Tenejeros-Tullahan (NMTT). The San Juan River exhibited the highest average of BOD (32.5mg/l) and the lowest average DO content (less than mg/l) which did not meet criterion for Class C waters. Marikina River had the lowest BOD average of 8.1mg/l which met the quality criterion set for its beneficial use (Figures 8 and 9). All these rivers, at one point during the sampling period, exhibited a zero reading for DO, indicating that these rivers were "biologically dead" during certain periods. Through the rehabilitation effort of the Government, the water quality of the Pasig River showed improvement over the last five years. Laguna de Bay is estimated to receive approx. 74,300 tons per year of BOD pollution. Domestic sources contribute 69% while the remaining 31% is from industrial and agricultural sources. Additionally, with the sedimentation rte of 0.5cm/yr, an estimated 66% of the land area in the watershed is vulnerable to erosion.

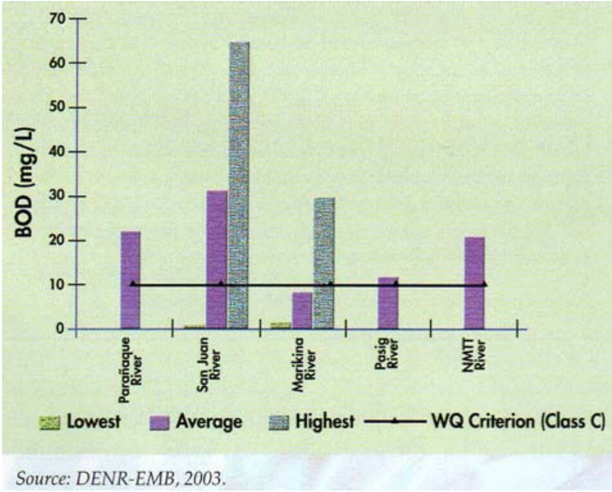
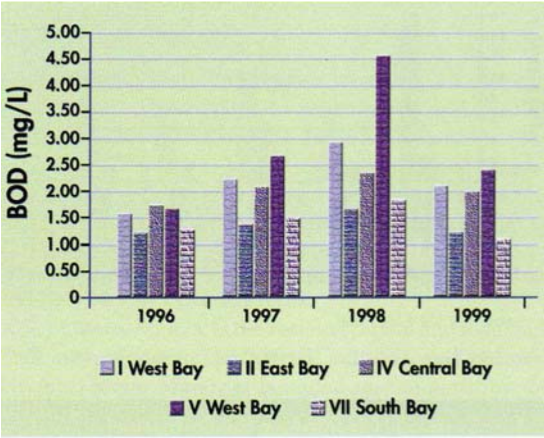
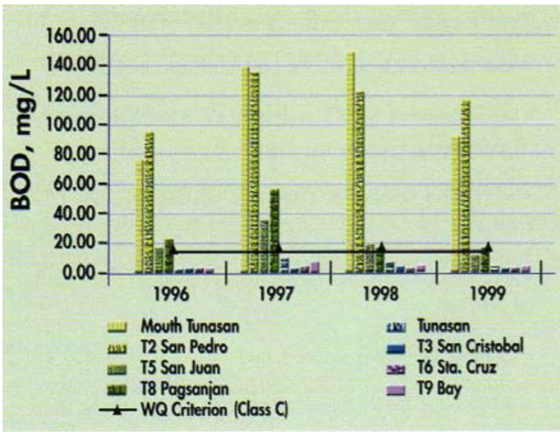


Fig.8 BOD Level in NCR, 1996-2001

Routine monitoring of BOD in Laguna Lakes shows that it meets the Class C water quality criterion (Figure 10). This indicates that BOD is not an issue, but siltation may be the main problem. While the lake water exhibited a good quality, half of the rivers that fed the lake had high BOD values (Figure 11). To improve the management of the lakes and its watershed, the government is implementing the Laguna de Bay Institutional Strengthening and Community Participation project.



Source: LLDA, 2003.



Source: LLDA, 2003.

Fig. 10 Annual Average BDO, Laguna de Bay, Monitoring Period, 1996-1999

Fig.11 Annual Average BDO, Tributary Rivers in Laguna Province, 1996-1999

(4) Groundwater

The average turbidity level of groundwater in Metro Manila is above the drinking water standard (Turbidity Unit –NTU 5). Some of the wells tested exhibited values higher than the standard for conductivity, hardness, manganese, iron and sodium.

4.2 Southern Tagalog

Bounded on the northwest by Metro Manila, Regions II and III and on the southeast by Region V and Visayas, Region IV is composed of 11 provinces, six of which are on mainland Luzon and five are island provinces. It has the largest land area for a region. Three of its provinces are located on mainland Luzon and have special economic and industrial zones. The island provinces of Region IV are coastal tourist destination.

(1) Water Resources

Three of the largest lakes in the country are located in the region: Laguna de Bay, Lake Tail in Battings (266.77km²) and Lake Anuran in Oriental Indoor (69.93km. The total water resources potential in the region is estimated at 7,780MCM at 80% dependability. The annual amount of water use is 3,636MCM with agriculture the largest consumer, followed by industrial uses and domestic demand. Sharing the same water resources with Metro Manila, it is projected that by 2025, there will be a shortfall of water supply if no water management is in place. The basin occupies the major part of Metro Manila and of Rizal, Laguna and Cavite provinces, which are the most populated areas in the Philippines.

(2) Water Quality

The estimated contribution of domestic, agricultural and industrial sources to BOD loading are 51% (159,000metric tons), 35% (109,000metric tons) and 14% (46,000metric tons), respectively (Table 8 and Figure 13).

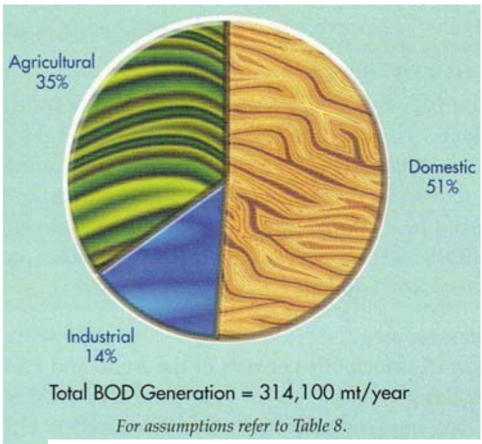


Fig.13 Sector BOD Loading Southern Tagalog

(3) Rivers and Lakes

Rivers were not mentioned for BOD and DO. However, Taal Lake and Naujan Lake were sampled. Taal Lake met the Class C Centerior for BOD, while Naujan Lake exhibit higher average value than the Class C criterion (Figure 14).

(4) Bays and Coastal Waters

Four bays were monitored from 1996 to 2001; Cajimos Bay in Romblon, Calancan Bay in Marindiuque, Puerto Glera By in Oriental Mindoro and Pagbilo Bay in Quezon. The minimum vlues of DO in the bays did not pass the Class SC criterion (Figure 15).

(5) Groundwater

Only a small number of wells in the Laguna province tested passed the drinking water criterion for total dissolved solids and coliform content

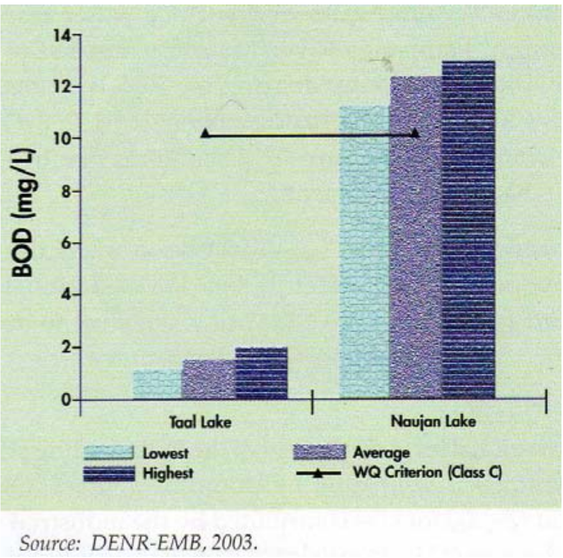


Fig.14 BOD Level, Southern Tagalog, 1996-2001

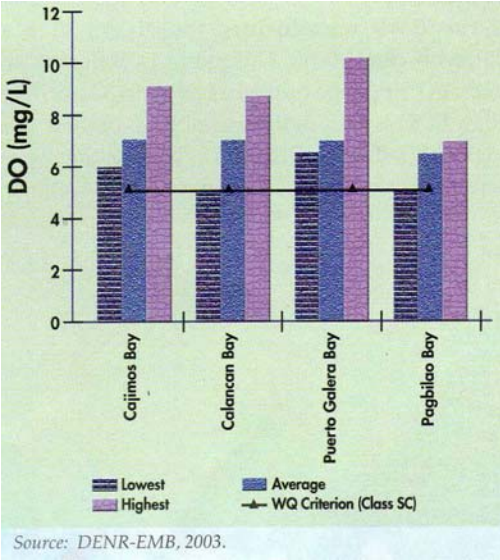


Fig.15 DO Level, Southern Tagalog Monitoring Period, 1996-2001

4.3 Central Luzon

Region III, bounded on by Metro Manila on the south, is the gateway to northern Luzon. Although one of the regions with small land area, it has the third highest numbers for manufacturing establishments and household and is the third highest contributor to the country's income from manufacturing and agriculture sectors and other economic activities.

(1) Water Resources

Region III principally consists of the Agno and Pampanga River Basins and covers an aggregate area of 23,600km². The combined drainage area of the two rivers is 15,704km² with annual runoffs of a total 17,584MCM. Floodplains area is 8,543km². The annual groundwater and surface water resources potential in Pampanga River Basin is estimated at 9,015MCM or a potential ratio of 0.52, the lowest in the country. This means the demand may be two times higher than the water potential. The same occurs in the Agno river Basin where the water resource potential is 2,275MCM. The projected annual water demand for 2025 is 4,063MCM or a potential to demand ratio of 0.56, the second lowest in the country.

(2) Water Quality

At the region level, 51% of the BOD loading (108,000metric tons) is generated by domestic sources. Only 14% (29,000 tons) is contributed by the industrial sector and 35% (75,000 metric tons) by the agricultural sector (Table 8 and Figure 16).

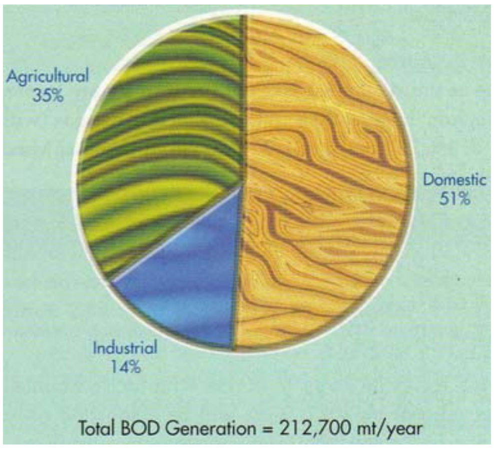


Fig. 16 Sector BOD Loading Central Luzon Region

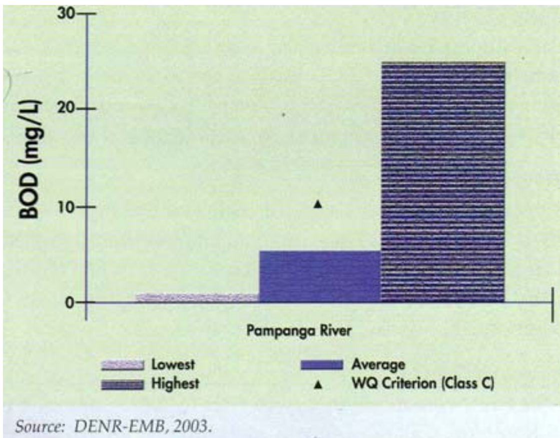


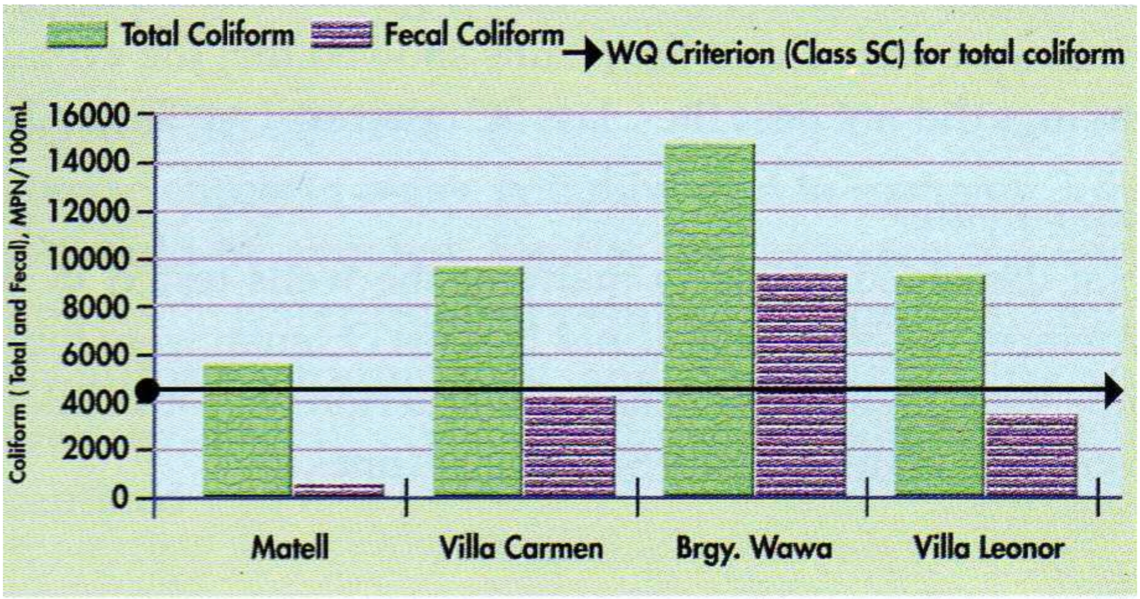
Fig.17 BOD Level in Central Luzon, 1996-2001

(3) Rivers and Lakes

From the EMB monitoring, the river of Marilao, Meycauyan, Sta Maria, Guiguinto in Blanca and San Fernando in Pampanga province had showed zero DO levels and high BOD levels, indicating of high organic pollution (Figure 17). Based on the river classification, 60% of the rivers in the region fall under Class C waters.

(4) Groundwater

A high percentage of the wells tested by MWRB and Local water Utilities Administration (LWUA) were positive for coliform bacteria. The total and fecal coliform levels for selected beaches in the Bataan coastal area for April to October 2003 are shown in Figure 18. All four beaches fail the total coliform criteria while one does not pass the criteria for fecal coliform. Additionally, total dissolved solids found in most tested wells were higher that drinking water criterion in Bulacan, Tarlac and Zambales provinces.



Source: DENR-EMB, 2003.

Fig.18 Total and Fecal Coliform for Selected Beaches in Bataan Coastal Area (April to October 2003)

4.4 Central Visayas

Central Visayas has a small land area and the fourth highest number of manufacturing establishments. Cebu, a province in this region, is known international commercial and business hub. Cebu City, which is the capital, is the second largest metropolis in the country.

(1) Water Resources

The region as a whole has no large rivers. The estimated water resource potential is 2,939MCM at 80% dependability. The water demand for 2025 is estimated at 2,226MCM with a potential to demand ratio of 1.32. The island of Cebu has a drainage area of 5,088km² with a water resource potential of 708MCM. The projected water demand for year 2025 is taken at 932MCM with a potential to demand ratio of only 0.76. Because of its significant role in the Visayas area, there is an urgent need to address the water shortage in Cebu.

(2) Water Quality

In the region, 41% of the BOD loading (77,000metric tons) is generated by domestic waste, while the remaining 46% (87,000metric tons) and 13% (24,000metric tons) are from agricultural and industrial activities, respectively (Table 8 and Figure 19).

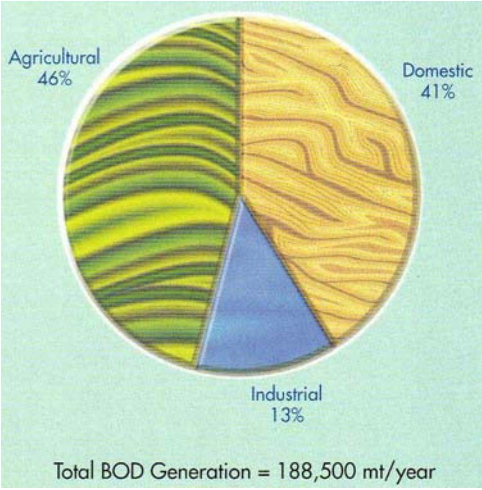


Fig.19 Sector BOD Loading, Central Visayas Region

(3) Groundwater

Total dissolved solid in many of the wells tested in the provinces of Cebu, Bohol and Negros oriental were found to be very high, higher than the criterion set for drinking water

5. Effects and Economic Losses

5.1 Effects

Untreated wastewaters threaten the health of the people and the environment. Unsightly color, reduced clarity and obnoxious odor of the receiving waters also make it unfit for recreation and other productive uses.

(1) Effects on Human Health

Untreated wastewater discharges affects humans through the spread of disease-causing bacteria and viruses. Some known examples of disease that may be spread through wastewater discharges are gastro-enteritis, diarrhea, typhoid, cholera, dysentery, hepatitis and recently, Sever Acute Respiratory Syndrome (SAR).

(2) Effects on Aquatic Ecosystem

As organic wastes are added into the receiving waters, the bacteria reproduces rapidly and may used the entire supply of oxygen, leading to the dead of fish and other living organism. When there was excessive nutrient such as nitrogen and phosphorous, aquatic plants and algae proliferates triggering euthrophication, especially in closed bodies of water. Water discharges may also contain toxic substances such as lead, mercury, cadmium chromium and cyanide, which may affect the use of the receiving water for domestic use or for aquatic life. In addition, paralytic shellfish poisoning occurs during the “red tide” phenomenon when there are toxic phytoplankton blooms.

(3) Effects on Aesthetics

Large amount of solids from inadequate treated domestic and other wastewater containing material accumulate on the banks of the receiving waters, settle at the bottom to form sludge deposits, or float on the surface to form scum. Sludge deposits and scum are not only unsightly but may also cause oxygen depletion and are sources of foul odors and gasses.

When the DO level of the receiving water drops to zero due to aerobic bacteria activity, anaerobic bacteria take over and decompose the organic load by producing odorous gases and methane.

5.2 Economic Losses

Cost to Health

Improved health of the population is a critical factor in high productivity. Keeping the workforce and society healthy would eliminate income losses due to sickness and medical expenses. One of the most prevalent causes of health decline of a population is contaminated drinking water. Estimates of water-borne diseases with reported cases of diarrhea, cholera, typhoid and paratyphoid and hepatitis A were made by DOH. More than 500,000 mobility cases and 4,200 mortality cases are very significant. Avoidable health cost due to losses in direct income and medical expenses for in-patient and out patients are estimated at PhP3.3billion in a year (Table 9 and 10)

Table 9 Direct Income Losses

Water-Related Diseases	Morbidity Cases (15-65 years old) [1/]	Mortality Cases (15-65 years old) [1/]	Losses in GDP (PhP million)
Diarrhea	512,527	2,978	1,649.23
Cholera	179	–	0.04
Typhoid and Paratyphoid	7,710	663	348.53
Hepatitis A	–	571	296.01
Total			**2,293.81**

[1/] Dept. of Health, 2000.
GDP per annum/ capita (2000 prices): PhP 43,167 NEDA, 2000.
GDP per day/ capita (2000 prices): PhP 69 NEDA, 2000.
Morbidity cases: 10 days for typhoid and 3 days for other water-borne diseases
Final Report, First Stage Priority Projects for Sanitation and Sewerage, Gen. Santos City, Philippines, DMJM International, December 1995.
Mortality cases: income loss to economy estimated at 12 years.

Table 10 Medical Expenses

Particulars	Diarrheal Diseases	Typhoid Fever	Total
Reported Cases [1/]	871,446	14,154	885,600
Medical Expenses (Out-Patient) per reported case [2/]	632	–	632
Medical Expenses (Out-Patient) (PhP million)	440	–	440
Cost of Hospitalization per reported case (In-Patient) [2/]	3,284	12,436	15,720
Cost of Hospitalization (In-Patient) (PhP million)	572	35	607
Total Costs (PhP million)[3/]	**1,012**	**35**	**1,047**

[1/] Dept. of Health, 2000. Diarrheal disease include Enteritis and others.
[2/] Final Report, First Stage Priority Projects for Sanitation and Sewerage, Gen.Santos City, Philippines, DMJM International, December 1995.
[3/] Assumptions used in the Final Report of 20% hospitalized and 80% mild cases/ non-hospitalized were adopted. Estimates in constant 2000 prices.

(2) Cost to Fishery Production

When water is polluted, fish and other aquatic resources can perish, which leads to a decline in fisheries production. Erosion from degraded upland and pollution from silt and sedimentation, as well as untreated sewerage, cause productivity losses in fishes dependent on coral reefs. The ENRAP report showed a decline in yields of municipal and commercial fisheries, due to sedimentation and silt pollution, by 30% to 50%, respectively. Other causes of fish habitat destruction include dynamite fishing, use of cyanide and muro-ami, etc. The Philippine economy loses an average of PhP17 billion due to the degradation of the fisheries environment (Table 11 and 12).

Table 11 Economic Cost to Municipal Fishery Production, 1997-2004

Year	Prod'n (in MT) 1/	Change In Prod'n (%)	change (%)	Ave. Unit Prod'n Value P/MT 1/	Prod'n Value (PhP B)	Losses (PhPB) 1/
1997	924,466	–	–	29,631	27.4	11.7
1998	891,146	-3.6	–	32,504	29.0	12.4
1999	924,693	3.8	204	33,561	31.0	13.3
2000	945,945	2.3	-39	34,459	32.6	14.0
2001	969,535	2.5	9	35,297	34.2	4.7
2002	988,938	2.0	-20	36,432	36.0	15.4
2003	998,665	1.0	-51	37,807	37.8	16.2
2004	1,015,202	1.7	68	38,895	39.5	17.0
Ave.	924,466	1.4	–	34,298	31.7	14.7

Source: BFAR, Philippine Fisheries Profile, 2002.

Table 12 Cost to Commercial Fishery Production, 1997-2004

Yr	Prod'n (in MT) 1/	Change In Prod'n (%)	Direction of change (%)	Ave. Unit Prod'n Value P/MT 1/	Prod'n Value (PhP B)	Losses (PhP B) 2/
1997	884,651	–	–	29,317	25.9	1.4
1998	940,533	6.3		31,617	29.7	1.6
1999	948,754	0.9	-86	33,984	32.2	1.7
2000	946,485	-0.2	-127	35,795	33.9	1.8
2001	976,539	3.2	1428	36,956	36.1	1.9
2002	1,041,360	6.6	109	37,366	38.9	2.0
2003	1,045,316	0.4	-94	39,563	41.4	2.2
2004	1,070,725	2.4	540	40,908	43.8	2.3
Ave.	956,387	2.8		34,295	32.8	2.0

1/ BFAR, Philippine Fisheries Profile, 2002.
2/ Losses: due to siltation and sedimentation. Municipal: 30%; Commercial: 5%.

(3) Cost in Tourism

Tourism increases the country's income receipts, generate employment and create business opportunities. A clean and healthy environment is a perquisite to tourism. The Philippine, an archipelago, has a long coastline endowed with beautiful beaches, which are the main tourist attraction. Yet, there is more to attracting tourism than just the recreational use of beaches. Other activities that draws tourists are coral reef diving and whale watching. Good coastal zone water quality is important to the health of bathers, as well as coral reefs and other living species in the coastal waters.

In 1997, the pristine water of Boracay Island, an international tourist destination in Region VI and the "world's most beautiful beach", experience a 60% decline in occupancy rate because of the news of high levels of coliform. Most islands in the Philippines are less than 50,000hectares, which is considered by the DENR as ecologically fragile. The DOT prioritizes tourist destination that are 50,000 hectares or less, including Bohol, Camiguin, Samal, Boracay (1,000 hectares), among others. The Boracay experience, where the negative effects of untreated sewage on the beaches caused the decline in tourism, could easily be replicated in these other equally fragile island of the country.

In 2002, tourism in the Philippines reached 8.5million visitors, generated Php441 million tourist receipts and employed 4.9million people. A study on the contribution of tourism to the economy revealed that a significant number of people are employed in tourism-related businesses. An estimated 20% of the labor force (4.9million) and 22% (6.2 million) were employed in 1994 and 1998, respectively. Benefits generated from employment in tourism are estimated by multiplying the average daily wage rate of selected regional tourist destination by 20% of the total force employed in the service sector. Pollution of beach waters was estimated as the cause of annual losses of Php5.3 billion from direct tourist receipts, as well as an additional Php.5 billion from tourism related activities (Table 13).

Table 13 Cost to the Tourism Industry, 2001-2004

Year	Tourist (M)[1/]	Tourist Receipts (PhP B)[1/]	Employment (M)[2/]	Losses in Receipts (PhP B)	Losses in Wages (PhPB)[2/]
2001	8.7	422	4.7	5.1	2.3
2002	8.5	411	4.9	4.9	2.4
2003	9.3	451	5.3	5.4	2.6
2004	10.2	495	5.8	5.9	2.8

[1/] *Sources: Department of Tourism for 2001 and 2002 data for Regions I, IV to XI and CARAGA; average growth rate of 5.8% from 1992-2002 for 2003-2004 estimates.*

[2/] *Phil. Statistical Yearbook, 2002 for base data (2001) and growth rate for estimates. Considered only 20% of total labor force for Regions I, IV to XI and CARAGA. Estimated at average legislated non-agricultural in daily wage rate of P183/ day Regions I, IV to XI and CARAGA.*

6. Policies and Institution

The Philippine Constitution of 1986 stipulates that the state shall protect and advance the people's right to a blanked and healthy ecology. While the current Constitution was only adopted in 1986, statutory provisions on environment issues in the Philippine legal system date back more than century. The Philippine has an extensive body of water and water-related legislation and regulation that provide the legal bases for policies and programs related to water management (Table 14).

Proposed bill on Clean Water is now approved by Congress. The bill provides for comprehensive water-quality management, specifically for the abatement and control of pollution from land-based sources.

Table 14 Legislation and Policies

Legislation	Description	Responsible Agencies E - Enforcer I - Implementer	Findings and Analysis
Commonwealth Act 383, Anti-Dumping Law (1938)	Prohibits dumping of refuse, waste matter, or other substances into rivers		Not fully enforced
Republic Act 4850 (1966), Laguna Lake Development Authority Act; as amended by Presidential Decree 813 (1975)	Regulates and controls the pollution of the Laguna de Bay Region, including sewage works and industrial waste disposal systems	LLDA (E/I)	Strictly enforcing but not to domestic wastewater
Republic Act 6234, Creation of MetroWaterworks and Sewerage System (1971)	Constructs, operates and maintains water systems, sewerage and sanitation facilities in the Metro Manila area	MWSS (E) Concessionaires (I)	Limited sewerage and sanitation service coverage
Presidential Decree 198, Creation of Provincial Water Utilities (1973)	Authorizes the creation of water districts to operate and administer water supply and wastewater disposal systems in the provincial areas	LWUA (E) Water District (I)	Operation and management of wastewater disposal system not implemented
Presidential Decree 281, Creation of Pasig River Development Council (1973)	Regulates and controls the pollution of the Pasig River	PRRC (E/I)	Not fully enforced
Presidential Decree 856, Sanitation Code (1975)	Requires cities and municipalities to provide an adequate and efficient system for sewage collection, transport and disposal in their areas of jurisdiction	DOH (E) DPW (I) now DPWH	Not enforced and monitored, e.g., connection to sewer system by houses in areas where sewerage system is available
Presidential Decree 600; as amended by PD 979, Marine Pollution Control Decree (1976)	Regulates and controls the pollution of seas	PCG (E/I)	Coverage is not efficiently monitored due to limited resources
Presidential Decree 984, Pollution Control Law (1976)	Provides guidelines for the control of water pollution from industrial sources and sets penalties for violations; requires all polluters to secure permits	EMB (E/I) now DENR	Not strictly enforced; compliance on the provision of sanitation and sewerage are not met
Presidential Decree 1067, Water Code (1976)	Consolidates legislations relating to ownership, development, exploitation and conservation of water resources	NWRB (E/I)	Not fully enforced
Presidential Decree 1096, National Building Code (1977)	Requires connection of new buildings to a waterborne sewerage system	DPWH (E) LGU (I)	Wastewater or sewage disposal are not fully enforced
Presidential Decree 1151, Environmental Policy (1978)	Recognizes the right of the people to a healthy environment	DENR (E/I)	EA system not strict on enforcement of sanitation and sewerage provisions
Presidential Decree 1152, Philippine Environmental Code (1978)	Provides guidelines to protect and improve the quality of water resources and defines responsibilities for surveillance and mitigation of pollution incidents	DENR (E/I)	Only enforced on big polluters (i.e., industries)
Presidential Decree 1586, Environmental Impact Statement System (1978)	Mandates the conduct of environmental impact assessment studies for all investments undertaken by the government and private sector	DENR (E/I)	Project review is not strict on sanitation and sewerage provisions
Republic Act 7160, Local Government Code (1991)	Devolves enforcement of laws on sanitation to LGUs and the provision of basic services such as water supply, sanitation and flood control	DILG (E) LGU (I)	Not strictly enforced due to budgetary constraints and low priority for sanitation and sewerage projects

6.1 Institution

About 30 government agencies re involved in water resources management. Their mandates include water resources planning, assessment, water quality, sanitation, and pollution control and watershed management. Some of the agencies have unclear and overlapping mandates and cooperation among them remain low. In brief, some of these agencies include;

Department of Environment and Natural Resources (DENR). Principal environment and watershed agency.

Environmental Management Bureau (EMB). Set and enforces water quality and effluent standards, criteria and guidelines for all aspects of water quality management. Also classifies and monitors quality of surface water-bodies.

Department of Health (DOH). Sets and monitors drinking water standard. Formulates and implements sanitation programs to address environmental and water related diseases.

Department of Science and Technology (DOST). Conducts research and development program with DENR for the prevention and abatement of water pollution.

National Water Resource Board (NWRB). Administers and enforces the Water Code. Assesses water resources and does overall coordination of water resources management and development in the country.

Bureau of Fisheries and Aquatic Resources (BFAR). Regulates and enforces fishery policies and laws.

Philippine Coast Guard (PCG). Responsible for preventing ocean dumping of water pollutants.

Local Water Utilities (LWUA). Promotes and oversees the development of provincial waterworks.

Metropolitan Waterworks and Sewerage System (MWSS). Construct, operates, maintains and manages water supply, sewerage and sanitation facilities in the Metro Manila area; Also regulates construction of privately owned sewerage systems.

Maynilad Water Company, Inc (MWCI). Private firm serving the waterworks and sewerage systems of the eastern part of Metro Manila.

Laguna Lake Development Authority (LLDA). Regulates and controls the pollution of the Laguna de Bay Region, including sewerage works and industrial waste disposal system.

National Irrigation Administration (NIA). Develops and manages irrigation systems.

Local Government Units (LGU's). Share responsibility in providing basic services such as water supply, sanitation and flood control, including enforcement of sanitation laws.

6.2 Enforcement

The Philippines has environmental laws and regulations but enforcement is poor and beset with several problems. Among the reasons cited for poor enforcement include:

1. Inadequate government resources (i.e. Budget, manpower and facilities). For examples, EMB has not received additional budget and continues to receive a small percentage of DENR's annual budget despite the passage of additional laws it is mandated to enforce.
2. Incomplete database. EMB only has 25,000 (3%) of the 826,783 firms, only 14,111 (46%) were inspected in 2001.
3. Inadequate guidelines. Formal guidelines and plans to enforce laws are inadequate and sometimes absent.

4. Lack of coordination among various agencies.
5. Limited access to information due to lack of comprehensive, long term environmental quality monitoring programs.

7. Urban Sanitation and Sewerge

The indiscriminate disposal of domestic water waste is the man reason for degradation of water quality in urban areas. Unlike the agricultural and industrial sources, where the cost of water pollution may be passes on the owners, the off-site domestic wastewater collection, treatment and disposal system is considered a basic service and is a major investment.

Infrastructure development for sanitation and sewerage in the Philippines began more than a century ago (Table 16). In the early 1980's, Metro Manila provided sewerage collection and treatment facilities in a few areas through MWSS. While there were programs to upgrade sewerage and sanitation facilities, its implementation was postponed due to lack of funds. Privatization in the 1990s further delayed the implementation of sewerage and sanitation projects for Metro Manila. Only the Makati Sewerage Treatment Plant (STP) has been upgraded and the proposed six to eight STP's re in the bidding process. Each STP will have a capacity of .002 to .004 MCM/day or total of .01 to .048MCM. To date, about 0.06 – 0.08MCM is covered by the existing facilities of MWCI and MWSI. To cover the MWSS area. A capacity of more than .4MCM/day is necessary.

Most water supply and sanitation system outside Metro Manila were given the option to form semi-autonomous water district in 1973. Authority was granted to the water district to operate and administered water supply and wastewater disposal system in the local communities with support and financing from LWUA. More than 200 water districts re operated, but the focus is water supply with no provision for sanitation services. This leaves Local Government Units (LGU) to provide for sanitation services.

Some attempts to provide low-cost technologies in the Lug's were initiated as early as the 70's, through clustered household and low-cost collection system. This led to a communal septic tank for partial treatment. The 1998 National Domestic and Housing Survey (NDHS) estimated that only 7% of the country's population is connected to sewers, out of which very few households actually maintain adequate on-site sanitation facilities. Due to insufficient sewer treatment garneted in the Philippines is not disposed or treated in an environmentally acceptable manner.

Table 16 Inventory of Domestic Sewerage Experiences and Practices

Location/ Age of the System	Population Served	Technology Legend: STP - sewage treatment plant CST - communal septic tank	Performance Legend: M - Manage O - Oversight
Metro Manila 100 + years (undergoing rehabilitation in the '80s up to the present)	1,010,000 (8% of the system coverage)	Collection - conventional Treatment - several levels (STP) / partial treatment (CST/ Imhoff tank) Disposal - Marine Outfall (Box 11)	Environmental Performance: On-going rehabilitation & meeting the standards for effluent quality; CSTs being upgraded to STPs. Institutional Performance: O & M by private concessionaires (MWCI & MWSI); collection rate is about 97% (50% of the water bill).
Baguio City 75 years (rehabilitated in 1994)	5,300 (2% of the system coverage)	Collection - conventional Treatment - STP (oxidation ditch & sludge drying beds) Effluent Disposal - River Outfall (Balili River); sludge disposal - agricultural use	Environmental Performance: Treatment - 94% BOD removal (but with low load), with effluent testing prior to discharge. Institutional Performance: LGU (M/O); 45 staff; collection rate = 22% of the connected households (flat rate).
Zamboanga City 70 years (not much improvements)	3,700 (1% of the system coverage1)	Collection - conventional Treatment - None Disposal - effluent by marine outfall (Basilan Strait); sludge - none	Environmental Performance: Raw sewage discharged 40 m. offshore & no effluent testing. Institutional Performance: Water District (M)/LWUA (O); 14 staff; collection rate = 99% of the connected households (50% of the water bill).
Vigan City 70 + years (not many improvements)	1,360 (3% of the system coverage)	Collection - conventional Treatment - 5 CSTs Disposal - effluent to rivers/fields; sludge is not collected	Environmental Performance: Partially treated effluent prior to river/field disposal & no sludge treatment & disposal (No effluent testing). Institutional Performance: Water District (M)/ LWUA (O); no devoted staff; collection rate = 96% of the connected households (percentage billed to water supply varies according to category).
Bacolod City 39 years in Brgys. 29 & 20 years in Montevista (built by National Health Administration)	2,020 (less than 1% of the system coverage)	Collection - conventional Treatment - individual CSTs Disposal - effluent to public drain (Brgy. 29) & creek (Montevista)	Environmental Performance: Partially treated effluent prior to creek/ public drain & no sludge treatment & disposal (No effluent testing). Institutional Performance: Brgy. LGU (M)/ City LGU(O); no devoted staff; collection rate = no user's fee.
Cauayan, Isabela 14 years (built by DPWH)	4,000 (2% of the system coverage)	Collection - small bore sewer Treatment - stabilization pond Disposal - effluent to field	Non-operational. System failed due to lack of funds for operation and maintenance.
Davao City 29 years	1,161 (less than 1% of the system coverage)	Collection - conventional Treatment - STP Disposal - unknown	Non-operational. System failed due to lack of funds for operation and maintenance.

Sources: 1. A. Robinson/EDCOP, Water and Sanitation Program's WPEP: Urban Sewerage and Sanitation in the Philippines, March 2003.
2. C. Ancheta, Water and Sanitation Program's WPEP: Urban Sewerage & Sanitation, 30 years of experience and lessons, September 2000.

7.1 Domestic, Wastewater Treatment Today

At LGU's, investment in sewerage collection and treatment facilities receive low priority compared to income-generating projects such as water supply. This is due to high cost of constructing sewer networks, poor technical capacity and low demand or willingness-to-pay (WTP) for sanitation services (Figure 21). The problem has been further exacerbated by the restricted spec available for such facilities in the low- income urban areas, where most of the generated sewerage is disposed of indiscriminately.

Wastewater generation based on the water demand shows that of the total of 7.2 MCM generated daily, 5.2MCM/dy is from the urbanized areas (2.4MCM/day) from Metro Manila alone (Table 17).

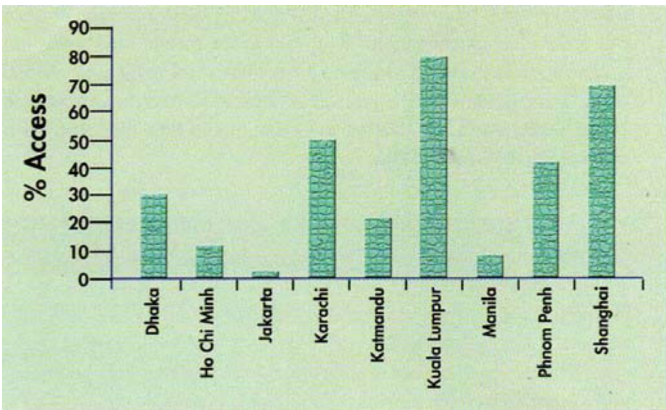
Table 17 Domestic Water Demand and Wastewater Generated

Items	Urban	Rural	Total
	(in million)		
Population[1]	43.6 (57%)	32.9 (43%)	76.5 (100%)
Per capita Water Consumption[2], l/d	150	75	-
Water Demand, m^3/d	6.54	2.47	9.0
Wastewater Generated3, m^3/d	5.2	2.0	7.2

1/ 2000 NSO ; 2/ LWUA Methodology Manual ; 3/ 80% of water demand.

8. RECOMMENDATION AND CHALLENGES

Clean water is essential in reducing poverty and achieving Millennium Development Goals (MDG) in the Philippines. The current surface and groundwater quality and availability indicate that access to clean water is becoming acute in urban and coastal areas. Poor quality water has large economic and quality of life costs, both now and in the future, in terms of health impacts, foregone tourism revenue, lost fisheries production, potable water, loss of image, etc. Economic cost of polluted water for quantifiable impacts lone, are estimated to be more that PhP67billion (US$1.3billion) annually. Household wastewater or sewage is major source of pollution because treatment facilities is lacking. There has been little investment in collection, treatment and disposal facilities. Institutional roles are unclear and revenue for investment along with operation and maintainace re low. This is because user’s fees are low and fine and enforcement are not sufficient deterrent to reduce pollution. Access to sewerage in Metro Manila is poor compared with other cities in Asia (Figure 25). Solid waste is also a major source of pollutants for water bodies which needs to be quantified and reduced.



Sources: World Bank, ADB and other reports.

Fig.25 Access to Pipe sewerage in Asia Cities

Water quality needs to address within an Integrated Water Resources Management (IWRM) framework that embeds social, economic and environmental considerations. This section discussed challenges faced by the Philippines over the next several years to improve the quality of its surface, ground and costal waters to provide healthy living conditions.

8.1 Public Disclosure and Participation

Without reliable information and active involvement, the public assumes water quality management to be purely a government function. Political action, participation in decision and demand for specific action will continue to lag without public information and knowledge. The public does not know or recognize the need and utility of its participation. Thus, there should be systematic attempt to raise public awareness of the health and economic impacts of poor water quality and encourage participation in decision making. Further, there should be a systematic collaboration and consensus building cross sectors and among affected stakeholders, to agree on priorities and adoptable measures.

Eco-watch program for beeches where they re rated according to their water quality and sustainability for recreation should be initiated in the Philippines. Through such program, coastal water quit would be recognized as economic assets that plays an important role in coastal tourism. Once beaches are rated for their water quality, the need for sanitation and sewerage facilities in coastal areas for sustainable tourism would become obvious to Lugs and other stakeholders.

8.2 Waste Management in Urbanized and Coastal Tourist centers

Focusing on critical areas is cost effective and can benefit 40million people, benefiting coastal areas and cities as Manila, Cebu and Davao. The following needs to addresses;

(1) Expanding user base. In cities, where the sewerage systems are available, service connections should be expanded to cover all connectable properties. This can lower connection and users charges while making it attractive for private sectors operators by expanding the numbers of users. At the same time, this would displace the need for individual septic tank, which pollutes the environment. The sludge from the septic tanks needs septage treatment. For the unsewerage areas, there is common sanitation and treatment technology choices that are low-cost, energy-efficient, have lower operation and maintainance requirements and produce fewer byproducts.

(2) Promoting intermediate solutions. The following options may be applied in

targeted areas; (a) dry-weather Flow (DWF) interceptors to capture solid waste and wastewater storm drainage outfalls, while serving concurrently as primary treatment system: (b) intercepting pipelines in tourist or in urbanized areas to gathered individual septic tank effluents, preventing direct discharge to ground and surface water and enabling proper treatment prior to disposal; (c) reuse and recycling of treated wastewater for irrigation and industrial use to minimize groundwater abstraction; (d) where saline water intrusion and seepage pollution from surface runoff has occurred, recharge of groundwater to stop further damage.

(3) Smaller collection and treatment systems. Prohibitive coats of conventional technologies for large sewage collection and treatment systems is major deterrent to investment and operation. Unbundling or creating smaller, manageable system for community and neighborhood based sub-systems may allow cost and acceptable technologies to flourish. Examples include: community-based small-bore sewerage system in Port Bardon, Palawan and Orangi in Pakistan; and the condominial sewerage systems of Malang in Indonesia, Karachi in Pakistan, La Paz Suburb in Bolivia, and Natal, Brasilia, Recife and Salvador in Brazil. Similarly, decentralized wastewater treatment system, based on semi-standardized designs and a modular approach in operation and maintenance, do not have to depend on expensive technical inputs and energy. This has been successfully implemented by small and medium-sized coastal resorts in Bali, Indonesia. With active community participation, user needs and benefits would be better understood, and the resulting system will enjoy their active support and participation. The role of wetlands also needs to be explored.

8.3 Stimulating Revenue and Investments

Both tested and innovative approaches are needed to expand financing options for wastewater infrastructures. Inadequate funding ability of LGUs is furthered constrained by the limited willingness of household to pay for sewerage services. These constrains are obstacles to investment by the private sector.

Increasing wastewater fees. The current levels of sewerage fees are considered lower than other middle-income countries. There is need for LGUs to demand and collect reasonable fees to recover the operation and maintainace cost of sewerage facilities, at a minimum.

Broad-base industrial pollution charges. Successive governments have committed to Agenda 21, which articulates the need for implementing the "polluter pay principle” (PPP).

Modest gains have been made in Laguna de Bay through the introduction of pollution charges and more recently DENR mainstream a nationwide pollution charges program. Beside providing incentives to enterprises to reduce pollution, the revenues could also be used to support wastewater facilities. LLDA experience indicates that a pollution charge program is most effective at the watershed level.

Incentives for private sector participation. The task of sewage collection, treatment and disposal facilities by the private sector would need guaranteed user fees and increase accountability of service delivery to reduce risks. Incentives could be in form of: tax incentives for the service provider, a guaranteed rate of return and tax discount for users. Other incentives are needed to increase the market viability. Since financing for such facilities is new to commercial banks, there is a need to access to credit or guaranteed facilities. Private sector or quasi-government organization such as water districts may be encourage, thus helping the Government to reduce the pollution loads that are disposed into water-bodies by allowing interested companies to collect, treat and dispose the wastewater for a fee. This reduces the financial burden of the LGUs by capitalizing investment for treatment facilities.

8.4 Effective Regulation

Enacting the Clean Water Act. The proposed Clean Water Act is a national strategic goal. While the passing this bill is important, implementation will require financing enforcement. The government would need PhP25billion/year for the next 10 years for physical infrastructures alone. Unless the law is assured of adequate funding, it will remain unimplemented or under implemented as in the case of Clean Air and the Ecological Solid Waste Management Laws. Considering the Government's growing fiscal deficit, it will be necessary to secure private sector participation and investment. Clean Implementing Rules and Regulation (IRR), where roles, standards, procedures, etc. are clearly detailed, should be promulgated as soon as the Clean Water Act is passed. The need for separate environmental agency should be evaluated.

Status of Groundwater Pollution and Risk Management in Papua New Guinea - An Overview

Gabriel KUMA*

1. Introduction

The demand for groundwater has increased significantly recently to supplement existing urban and rural water supply systems. Many rural communities rely on groundwater sources for their daily subsistence and domestic use after surface natural water sources are becoming scarce.

Changes in regional climatic conditions and local weather patterns appear to be the major factor for the recent increase in exploration and exploitation of groundwater resources in PNG. Other important factors are increasing social and environmental issues impacting on existing water supply schemes as well as increasing population and demand for clean water. As a result, several towns in PNG are using groundwater to supplement their existing water supply. Apart from those towns, Lae city and Alotau town rely entirely on extracting groundwater for their town water supply.

Fig. 1 shows the location of major towns (Lae and Alotau) in PNG that are actively extracting groundwater for their town water supply.

*Mineral Resources Authority of Papua New Guinea

Pollution of groundwater sources is likely to impact on the lives of communities that rely on groundwater for their water supply. Groundwater pollution is regarded as critical at the moment in PNG and there are many evidences at present that indicates that existing water sources (surface water and groundwater) will be impacted very significantly by pollution in the near future.

This report aims to give an overview of the groundwater conditions in relation to pollution and risk management practiced at present in Papua New Guinea.

2. Potential sources of pollution

There are many factors that contribute to pollution but the main ones that have the potential to impact significantly on groundwater in Papua New Guinea are;

1. Mining and petroleum Projects
2. Commercial agriculture projects
3. Expansion of and Urban towns and Rural settlements

2.1 Mining and Petroleum Projects

PNG is at present experiencing mining and petroleum boom as a result of very high global mineral, oil and gas commodity prices. Mineral and petroleum exploration activity has increased significantly over the last 3 years and is continuing at present.

Several existing large mining projects (Figure 2) such as the Ok Tedi Copper Mine, Porgera Gold Mine, Lihir Gold Mine, Tolukuma Gold Mine, Hidden Valley Gold Mine and few other small mines produce millions of tonnes of waste annually. There are other new mining projects including Ramu Nickel Mine which will be coming on stream soon and that will be contributing additional waste to the environment.

Fig 2 shows the location of the major mining operations in PNG.

Production of large volumes of mine waste and their disposal by means of riverine tailings or tailings storage dams has a very significant impact on the groundwater. The chemical components (arsenic, mercury, cyanide etc) and other heavy minerals of the mine waste are easily transported through permeable sediments in the waste storage dams and river beds and affect the groundwater. Chemical pollution is the primary impact on the groundwater, especially from chemical waste produced from tailings and Acid Rock Drainage.

Fig 3 shows mine tailings storage facility of Ok Tedi Mine under construction at Bige in Western Province, PNG

Artesian Alluvial Mining also contributes to river and groundwater pollution. Mercury is used extensively in most parts of the country by local miners for extracting gold from alluvial sediments.

PNG is developing its natural gas resources by producing Liquefied Natural Gas (LNG) within the country for exporting overseas. The PNG LNG Project is estimated to cost about USD12 billion. Construction of the project commenced early this year and is expected to be completed in 2015. Figure 4 shows the alignment of the pipeline route and the gas processing facilities.

A gas pipeline will be constructed to transport the natural gas from the central highlands to the coast near Port Moresby which is about 200km long. The pipeline will pass through low-lying flat river deltas, alluvial plains and the seabed before reaching the LNG processing facility in Port Moresby.

Environmental studies, including assessment of groundwater have been carried out and indications are that the impact will not be significant during construction and in the entire life of the project.

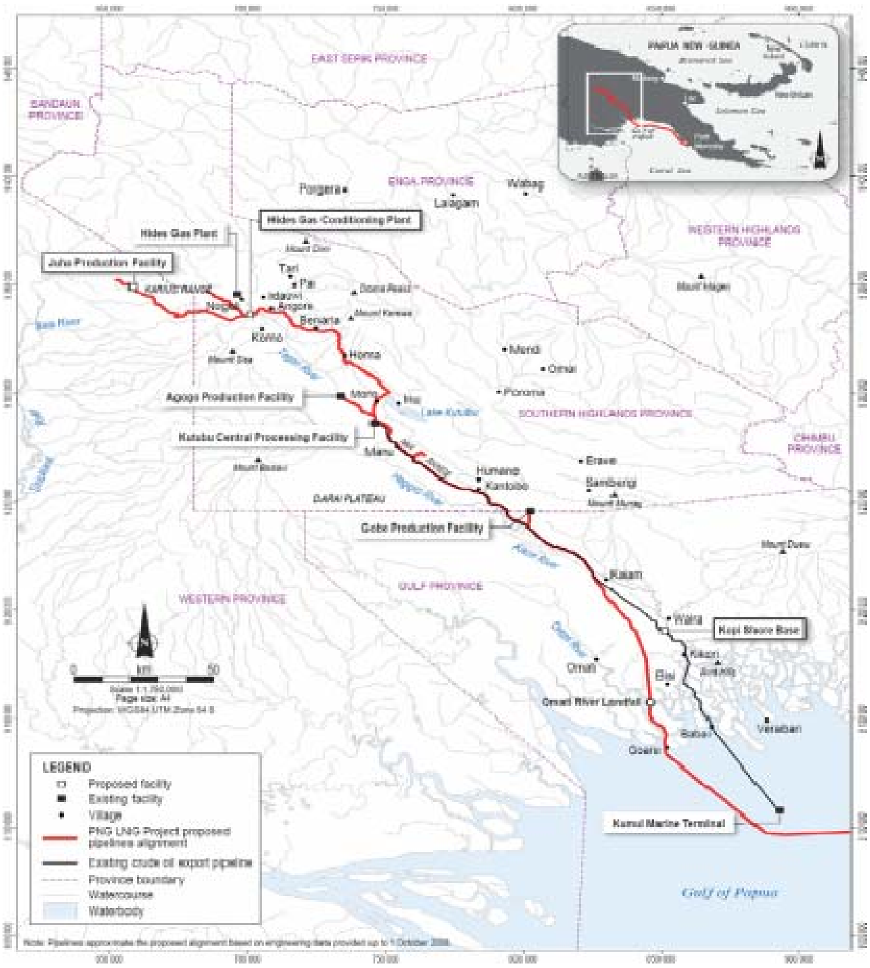


Fig 4 showing the location of Gas Processing facility and pipeline route of the PNG LNG Project

2.2. Commercial Agriculture Projects

PNG has several large agriculture projects such as coffee, sugar, cocoa, oil palm and tea. Most of these projects are located in wide broad valleys and alluvial plains these sites are also the best sources of groundwater.

Apparently, weedicides and pesticides are often used to control weeds and pests in large volumes. Although, no significant pollution to groundwater on large scale has been observed, there is potential to cause some impact in the future. The commercial cultivation of oil palm and sugar has recently increased very significantly.

Fig 5 shows the location of the commercial cash crop plantations in PNG

2.3. Expansion of Urban Towns and Rural Settlements

PNG is experiencing a surge in urban development and several towns have expanded in size to accommodate new infrastructure. Two of these towns are Lae, Morobe Province and Alotau, Milne Bay Province and both towns use groundwater as their only source of clean water for their town water supply.

The well fields at Alotau town will be abandoned soon to accommodate a new real estate development. An alternate site has been identified and only one production borehole has been drilled successfully and is in operation.

Lae city is the hub for industrial manufacturing and processing of goods. Several large manufacturing companies such as soap, tinned fish, cement, alcohol and plastics are located in

Lae city. Expansion of the city and discharge of chemical waste into the environment will impact on the groundwater quality. Most of the well fields are located within the city.

The coastal villages in PNG rely on groundwater during long periods of dry season. Most of the groundwater along the coast are only shallow freshwater lenses and can be accessed by excavating down to 1.0m to 2.0m on the beach.

Poor sanitation conditions, especially disposing human waste and household waste into the sea and on the beach poses a threat to groundwater. Open shallow groundwater wells located near residential houses on/near the beach have been contaminated.

More than 350 people died recently from Cholera in PNG and it affected mainly communities situated along the coast in Lae, Madang and Port Moresby. An approximate location of affected areas is shown in Figure 5.

Fig 5 shows settlements areas that were affected by cholera recently between 2009 and 2010.

3. Risk Management

The main stakeholders that develop and manage groundwater resources in PNG are;

1. PNG Department of Environment and Conservation (DEC)

   The DEC is responsible for developing policies and manages the water resources through the Water resources Act and the Environment Act 2000.

2. Eda Ranu

Eda Ranu is a private company that provides reticulated water supply for Port Moresby city.

3. Mineral Resources Authority (MRA)

   MRA through the Geological Survey Division provides technical expertise in groundwater throughout PNG. It is the only scientific institution of the PNG Government with the expertise and technical knowledge to undertake all aspects of groundwater investigations.

4. Urban town Development Authorities

   All the towns have government administrators that are involved in permitting, funding and execution of groundwater investigations as well as other projects.

5. Non-Government Organizations (NGOs)/Aid Donors

   NGOs provide funds for groundwater investigations for rural water supply schemes. Most NGOs are affiliated with international aid donors and foreign governments; e.g.; AUSAID, World Vision, Red Cross and Salvation Army etc.

6. Local rural communities

   Local communities are regular users of groundwater and they provide valuable information on occurrences of groundwater in their areas.

7. PNG Waterboard Ltd (PNGWB)

   PNG Waterboard Ltd is a government agency that develops and manages urban water supply systems for most of the towns in PNG. PNGWB utilizes surface water from rivers and also groundwater for their water supply systems.

Project managers and developers of all major projects are required by law to submit detailed environmental feasibility studies and provide information on all aspects of potential pollution problems associated with the projects to the Department of Environment and Conservation. Monitoring of the groundwater resources is part of the environment monitoring program and it starts from commencement of the projects and continues about 10 to 15 years after the end of the project. For instance, monitoring of the environment is a requirement as part of the Mine Closure Plan for each mine.

The data collected in the field on regular intervals are interpreted and submitted to DEC and their respective government authorities by the companies as part of the compliance. For instance, Mining and mineral exploration companies submit some copies of their reports to MRA while Petroleum companies send their copies to Department of Petroleum and Energy.

Monitoring of groundwater in urban areas is a requirement from DEC and the Department of Health and other relevant authorities. Reporting procedure is the same as from the Mining and Petroleum companies.

From the monitoring of the environment, the government and the key stakeholders are aware of the risks of pollution associated with each project. Often project proposals and plans are either modified or altered to accommodate the risks of pollution, e.g., modification of tailings storage facility in alluvial plain.

4. Risk Management Issues

Groundwater is an important part of the water resources, there is lack of coordinated effort and responsibility from the stakeholders to recognizing risks of pollution and managing their impacts. Groundwater is not well understood and a lot of effort is needed to carry out proper research to understand the full potential of groundwater in the country.

Geological Survey Division of MRA is a repository of all geological data and related information for Papua New Guinea. It provides technical expertise to the government and other stakeholders in groundwater in general. However, monitoring of groundwater is a responsibility of other stakeholders and often the data is not available. The data is held by different organizations and is not readily available to others apart from the designated authorities due to legal confidentiality requirements.

Apparently, minimizing and possibly preventing pollution in the groundwater and managing its risks will require identifying the sources of pollution and the risks. Withholding data prolongs delays in information dissemination and increases risks to groundwater pollution to high levels

5. Way Forward

MRA is the repository of all geological data of PNG and is the leading government agency that provides technical expertise in all aspects of groundwater investigations, drilling and monitoring. Hydrogeological data from most parts of the country is held at the MRA library. Apparently, MRA is already playing an important role in geological data acquisition and archiving and will continue by:

1. Preparing a regional hydrogeology map that will show existing and potential groundwater sources of PNG, possibly at 1:1 million scale.
2. Collecting data (chemical analysis) on groundwater from all stakeholders and archiving them in a database. Data acquisition will require direct interaction with other stakeholders

3. Analyzing, modeling and interpreting data to identify potential pollutants such as mercury and other heavy metals.

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Groundwater Pollution and Risk Management
Case Study: Chiang Mai Basin, Thailand

Adisai CHARURATNA *

Abstract

Chiang Mai basin is a total area of 38,992 km2 in the northern part of Thailand. It is one of 27 classified groundwater basins which is very important and high groundwater potential. Due to economic growth has been rapidly continuing during the last 10 years. Groundwater consumption is commonly applied for various activities such as agriculture, industrial and domestic purposes whereas public water supply by pipe system can not provide throughout the communities. The tendency of groundwater use is expected to be increasing in the future.

Since 2005, Department of Groundwater Resources has intensively studied in various aspects of groundwater such as detailed hydrogeological units, constructing monitoring wells, mathematical modeling, vulnerability map and VOCs contamination. Aquifer identification by using electric loggings and drilling sample descriptions shows that unconsolidated sediments forming as alluvial aquifer, low terrace aquifer and high terrace aquifer-totally 2,800 km2 are high groundwater potential and the most of wells exploited water from these aquifers within the total sediment thickness of approximately 200 meters. From dating analysis of peat found at the depth of 70 meters to point that low terrace sediments is about 30,000 years and to be underlain unconformity by high terrace sediments. Particularly high terrace aquifers can be separated in to several layers but most of them gains generally low groundwater potential. The most area of consolidated rocks consisting of sedimentary, igneous and metamorphic rocks is normally less potential and only used for domestic purpose.

According to observed groundwater usage, groundwater pumping is ranging from 85-138 million m3/year whereas numerical modeling recharge circulating into the system is about 145 million m3/year Finally current water balance in the plain is still good situation by normal groundwater level in monitoring wells. For sustainable groundwater management in the future, vulnerability index map by using DRASTIC method is implemented including VOCs contamination in an industrial estate and surrounding area was initially studied to protect their distribution.

Keyword: Aquifer identification, Risk groundwater management.

*Department of Groundwater Resources, Thailand

1. Hydrogeological Setting

Chiang Mai basin composes of wide range in lithological rocks of consolidated rocks and unconsolidated rocks of Precambrian - Quaternary age coverage totally area of 38,992 km^2. In topographic areas formed as high ground level relief, various typical rocks are older ages as metamorphic, igneous and sedimentary rocks of Precambrian to Tertiary periods whereas the youngest sediments of Quaternary rocks as semi-consolidated or unconsolidated formed as intermontane plain. The high groundwater potential and significant role in term of pollution and risk management are in the plain of 2,800 km^2 where Chiang Mai and Lumphun cities located and there are many activities to consume huge groundwater resources. The typical of aquifers is unconsolidated rocks consisting of mostly sand and gravel with silt and clay. The identification of hydrogeological units was mainly classified as alluvial aquifer (Qcp) – low flat terrain along the banks of Mae Ping and Mae Kuang rivers, low terrace aquifer (Qcr) – low terrain between high terrace and flooding plain including alluvial fans and high terrace aquifer (Qcm) – elongated high terrain along periphery of the basin (Fig.1).

The results of drilling exploration for deep wells and groundwater monitoring wells by using electric logging data show that low terrace aquifer in vertical profiles can be separated into two subaquifers – Qcr1 and Qcr2 as well as high terrace aquifer having 3 subaquifers at the depth to 500 meters - Qcm1, Qcm2 and Qcm3. The dating analysis of peat to be found at 70 meters in depth by using C-14 implies that low terrace sediments is approximately 30,000 years and underlain unconformity by semi-consolidated sediments of high terrace aquifer.

As for groundwater potentials, both of the alluvial and low terrace aquifers are generally good in quantity and quality at the depth of less than 200 meters – over 20 m^3/ hr. Whereas the high terrace aquifers normally obtain less yield – 10 - 20 m^3/ hr and deeper in depth.

However, these subaquifers can not definitely separated by using only description of drilling samples because of similar sediments as mostly sand grovel and silt with sparsely in clay layers. On the other hand, it means that groundwater can flow linkable among them.

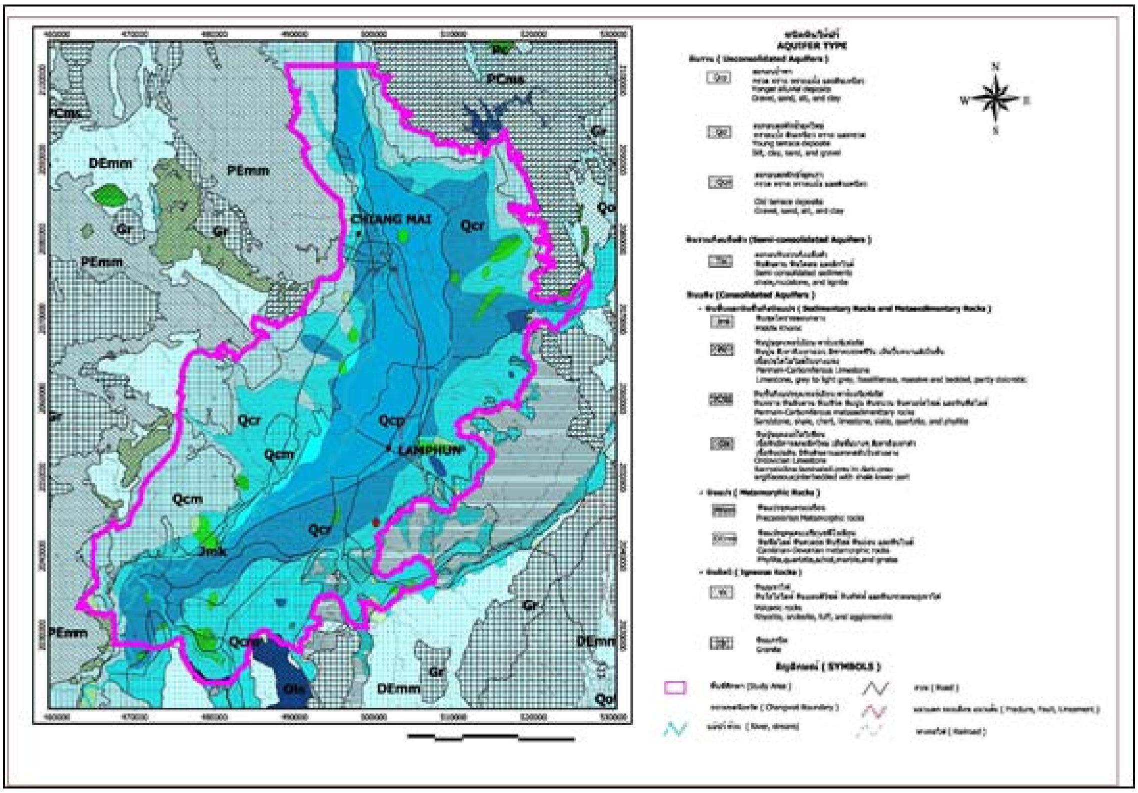

Fig.1a Hydrogeological Map of Chiang Mai Basin

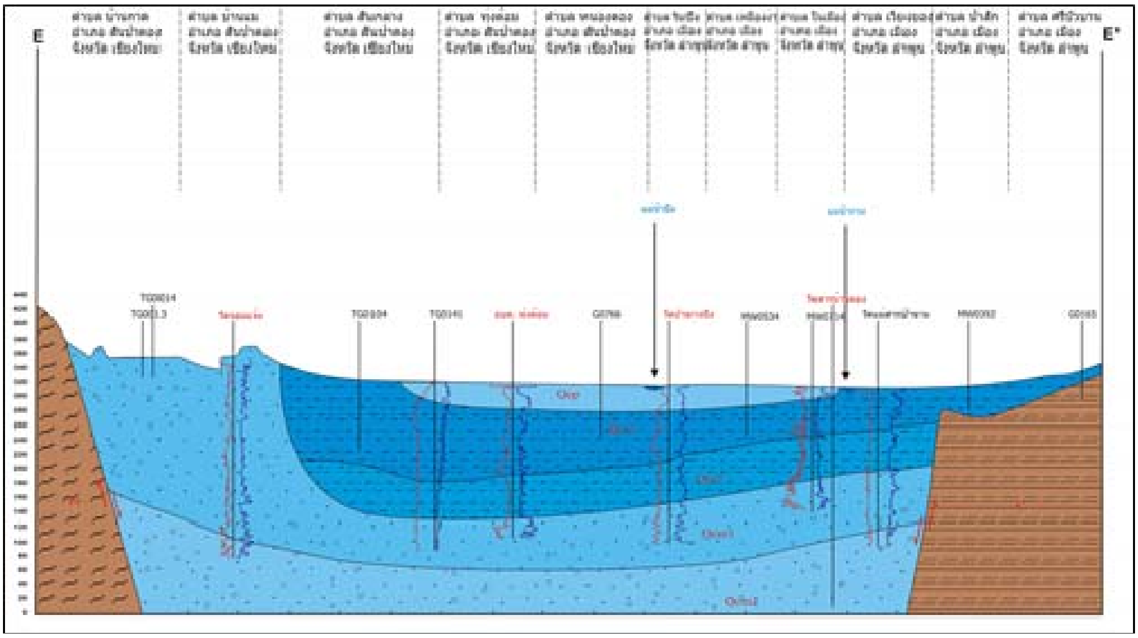

Fig.1b Cross Section E-E'(Fig.1a) of Chiang Mai Basin

2. Groundwater Balance

As for groundwater balance in the basin by applying numerical modeling has been studied by Panya consultant co. ltd. since 2004 (Fig.2). The results show that the amount of water totally 257 million

m^3 /year are circulating into the system and 145 million m^3/year of this figure should be an initial safe yield as follows:

Inflows = Outflows

Rainfall recharge + Inflow from the north + Inflow form the rivers

= (Groundwater pumping + Outflow to the south + Outflow to the rivers) + Evapotranspiration

207 + 3 + 47 = (77 + 3 + 65) + 112 (million m^3 /year)

257 =145 +112 (million m^3 /year)

In 2005, DGR (Department of Groundwater Resources) crucially observed in the field of various activities such as agriculture, industrial and domestic purposes using groundwater resource throughout subdistricts in the basin. The result shows that the total of groundwater usages would be 85 – 138 million m^3 / year depending on climate environments in each year (Fig.3). However, the situation of groundwater extraction is currently good condition by observing at the normal groundwater levels in existing monitoring wells. (Fig.4)

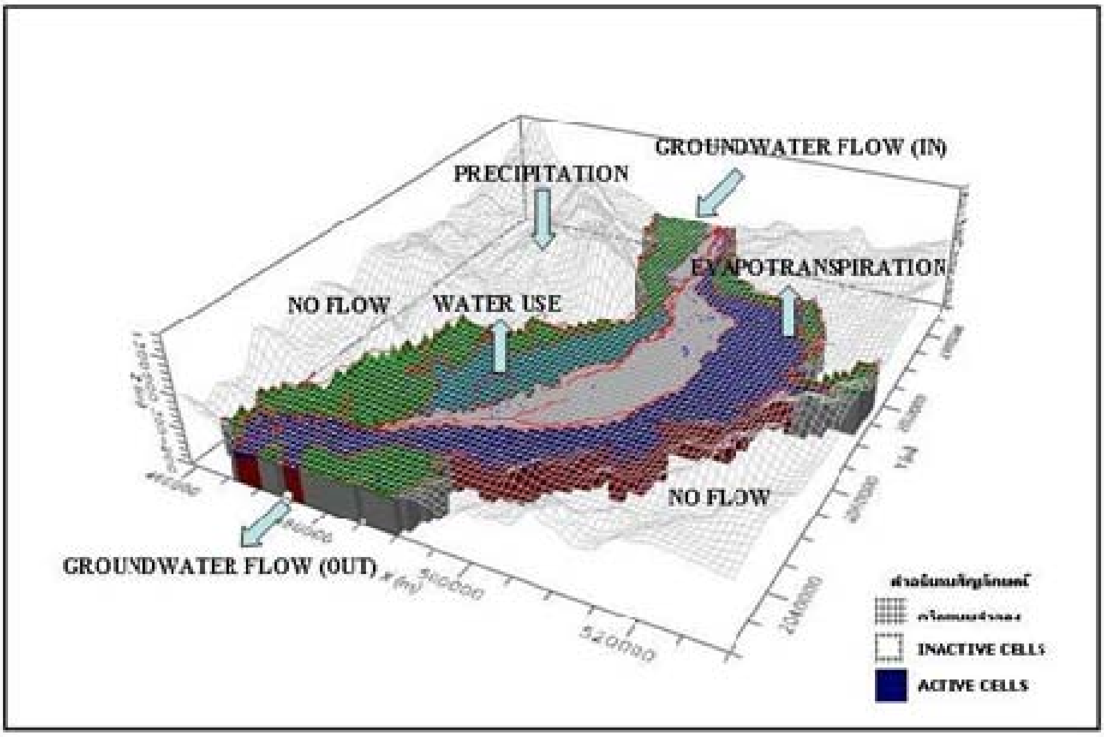

Fig. 2 Conceptual Model of Groundwater Evaluation.

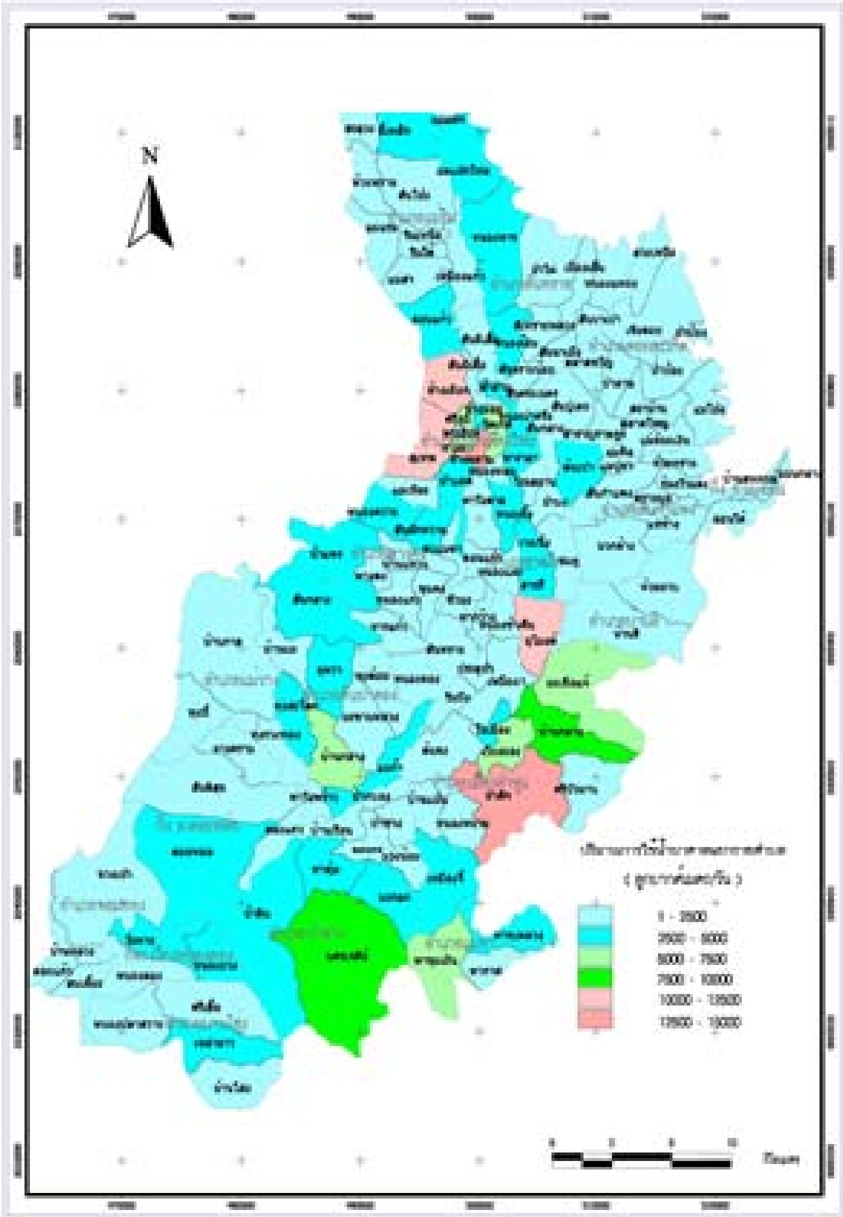

Fig.3 Zone of Groundwater Usage (m^3/day) in Subdistricts.

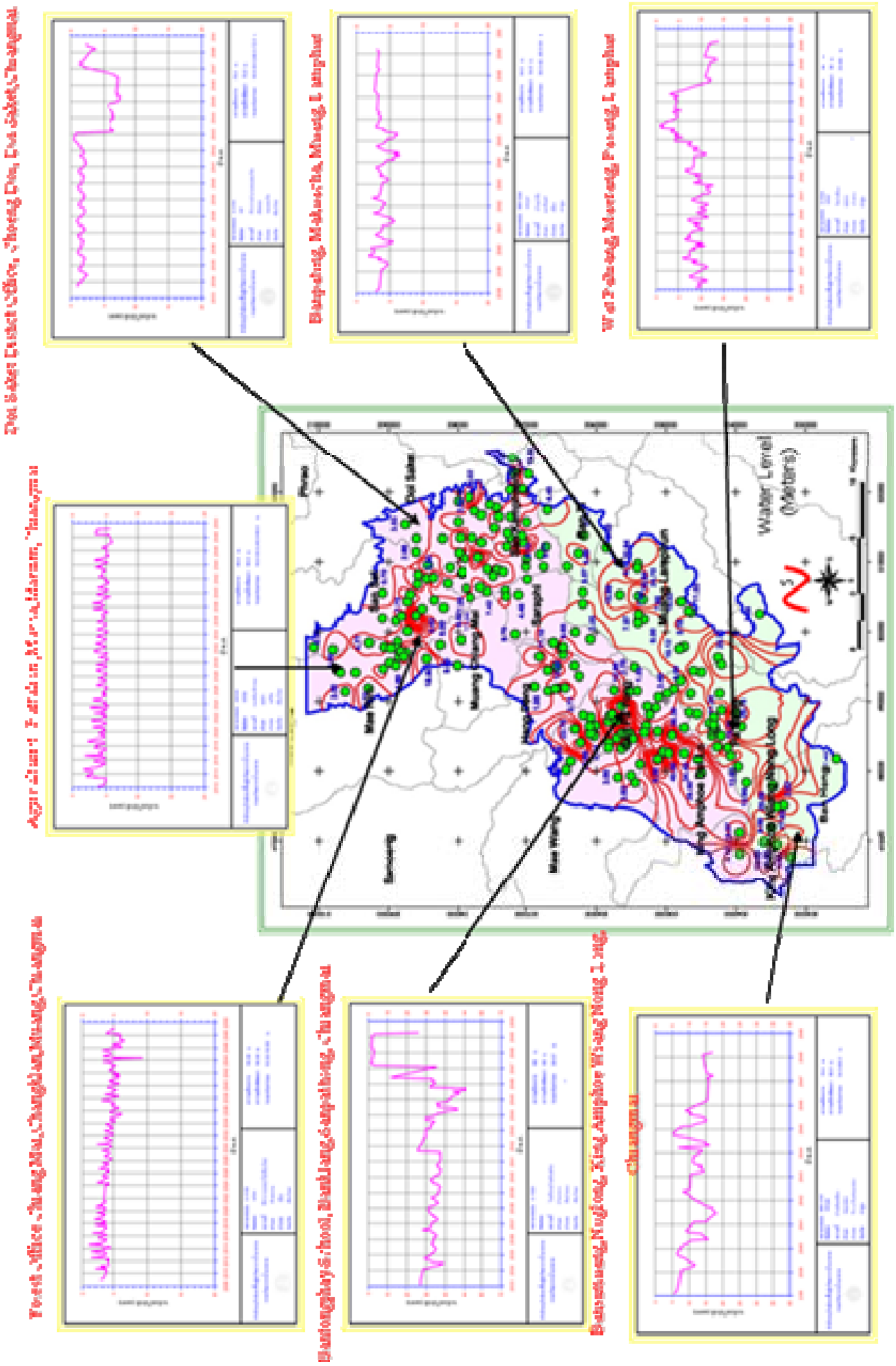

Fig.4 Observed groundwater levels in monitoring wells.

3. Vulnerability Map

Groundwater vulnerability by using DRASTIC method (Aller and others, 1987) is defined as the intrinsic sensitivity of land to contamination or natural vulnerability. Vulnerability is a relative indicator of where contamination will occur if the contaminant sources are introduced at the land surface and groundwater vulnerability is a relative property not an absolute property. The degree of groundwater vulnerability is depends on hydrogeological characteristics, the topography of the area, and meteorological conditions. The hydrogeological factors such as flow paths, thickness of the vadose or unsaturated zones, and composition of soil media, are greatly influence the degree of groundwater vulnerability. Materials composition above the groundwater level will act as a barrier either to attenuate or accelerate the contaminants movement. This chemical reaction e.g. ion exchange, and physical reaction e.g. adsorption and absorption will reduce contaminant concentration.

The rated and weighted thematic maps will show different levels of vulnerability to contamination - very low, low, medium, high and extremely high vulnerability. Hydrogeological data of the DRASTIC method in the Chiang Mai basin (Subtavewang, 2007) were grouped and rated. The vulnerability maps were used as tools for prioritized areas, where high degree of vulnerability area was preserved as groundwater protection areas. The parameters used in calculation are summarized as follows:

Depth to groundwater table; used drilled depth less than 100 meters.

Net recharge; used wet period of rainfall as net recharge.

Aquifers types; used re-grouped aquifers.

Soil types; used soil modification of soil classification.

Topography; used derived slope (in percent) from contour lines and spot height elevation.

Impact of vadose zone was determined from drilled logs.

Hydraulic conductivity valued was obtained from pumping test method.

The vulnerability index value was produced by this equation.

$$\mathbf{V = Dr*5 + Rr*4 + Ar*3 + Sr*2 + Tr + Ir*5 + Cr*3}$$

Where: V = DRASTIC Vulnerability Index

Dr = Rating of Depth to groundwater level

Rr = Rating of Net recharge

Ar = Rating of Aquifer media

Sr = Rating of Soil media

Tr = Rating of Topography

Ir = Rated of Impact of vadose zone

Cr = Rating of Hydraulic conductivity

Vulnerability index using grid map of 100*100 meters cell size was assigned to 9 equal classes ranging from 68 to 194, and re-classified to 5 equal classes which corresponding to DRASTIC classification, very low, low, medium, high, and extremely high vulnerability index, respectively(Fig. 5) and for only Chiang Mai plain(Fig. 6)

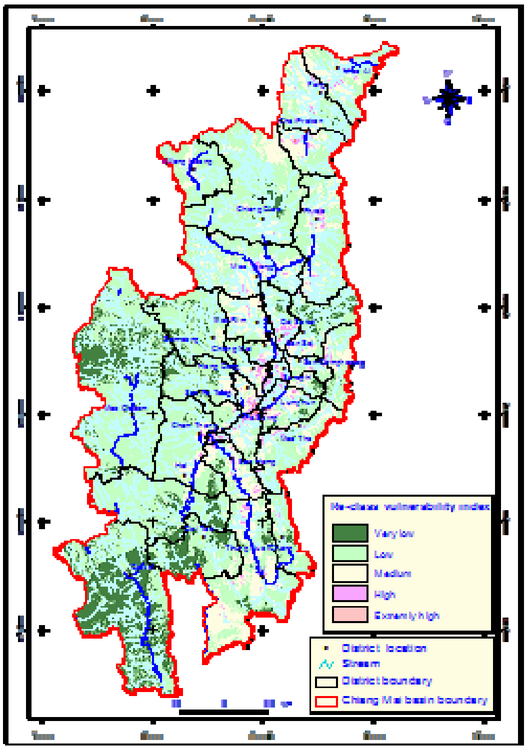

Fig.5 Vulnerability index map.

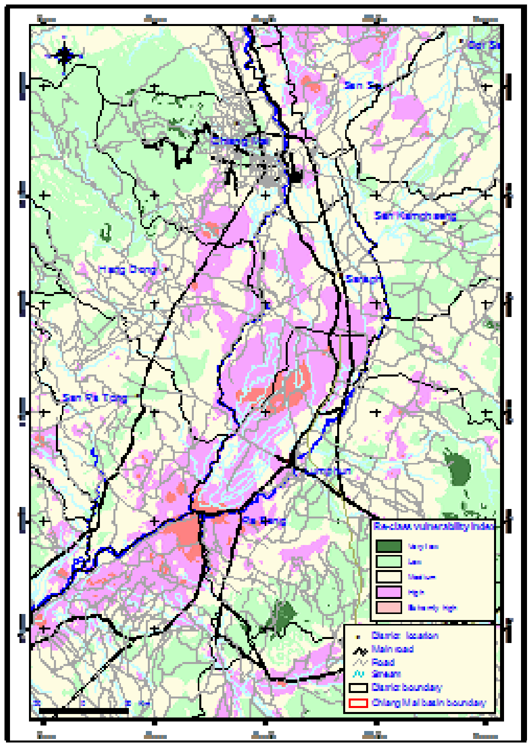

Fig.6 Vulnerability index map in Chiang Mai plain.

4. Volatile organic compounds (VOCs) contamination

According to Department of Environment Quality Promotion found chlorinated ethenes contamination in soils and groundwater of at least 3 factories in the Northern Region Industrial Estate (NRIE) located in Lumphun city of Chiang Mai plain. These compounds included trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene and vinyl chloride whose concentrations were 7.22, 0.57, 0.35 and 0.32 µg/l, respectively. All of these compounds were far significantly beyond maximum contaminant level. DGR has established a project for more detailed study of their sources and distribution in 2008 (Chiang Mai University). Various groundwater aspects were conducted for their studies such as detailed hydrogeological conditions of NRIE area, geophysical survey, groundwater uses and flow direction, groundwater sampling and analyze for VOCs, drilling observation wells including groundwater modeling for simulating solute transport and predicting the contamination trend and dispersion VOCs.

Sixty groundwater samples were collected from dug wells and groundwater wells twice during wet and dry seasons. The samples were analyzed for thirteen commonly found volatile organic compounds including 1,1-dichloroethylene, trans-1,2-dichloroethylene, cis-1,2-dichloroethylene, chloroform, 1,2-dichloroethane, benzene, trichloroethylene, 1,1,2-trichloroethane, toluene, tetrachloroethylene, ethylbenzene, *p*-xylene and *o*-xylene, in order to assess the groundwater contamination. The results of analyses indicated that at least one or more volatile organic compounds in the aforementioned list were detected in 12 out of 30 dug wells and 18 out of 30 groundwater wells. Although VOC concentrations in groundwater were not exceed maximum contaminant levels of the groundwater standard, but some VOC concentration is obviously high. This result implied that groundwater contamination in the study area was of anthropogenic origin. It was speculated that there would be significant impacts on public health and groundwater resource in the area.

The solute transport simulation was carried out in the local model only. First, a back-tracking simulation was conducted to trace the travel paths of contaminants and determined where they originated. Then, a forward simulation was performed to determine plume concentration and to assess the extent and damage of groundwater contamination. Figure 7 showed possible sources of VOCs both inside and outside the NRIE. These locations were used as a source zone in the simulation of solute transport model. The resulting contaminant plume was shown in Figure 8. The volume of contaminated groundwater was then calculated from the model and it was found that 44.0 million cubic meters of groundwater was contaminated at concentration higher than 1.0 µg/l.

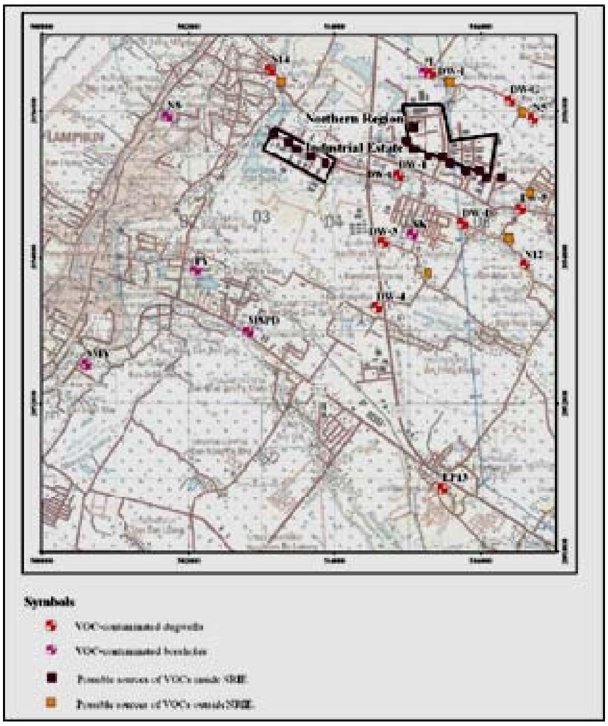

Fig.7 Possible sources of VOCs both inside and outside the NRIE.

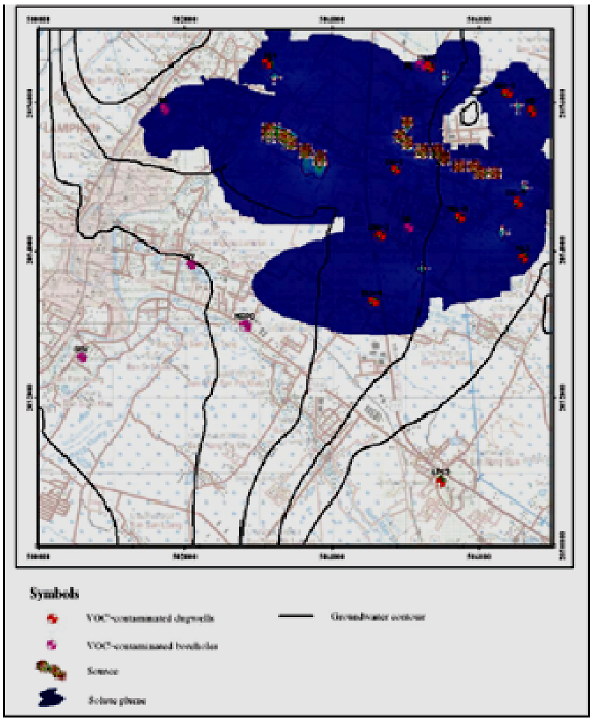

Fig.8 Contaminated plume at concentration higher than 1.0 µg/l

5.Conclusion

Chiang Mai basin is a small groundwater basin coverage the total area of 38,992 km^2 and 2,800 km^2 for unconsolidated sediments of a significant groundwater plain. The tendency of population and economic growth is expected to be increasing in the future due to tourist cities located. Hence, Chiang Mai basin is suitable for a model in groundwater studies of various aspects such as aquifer identification and hydrogeological mapping, groundwater balance, pollution and risk management etc. for sustainable groundwater management and further implemented direction in other basins of Thailand.

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Groundwater Polution and Risk Management in Timor Leste

Francisco Xavier PEREIRA*

1. Introduction

Groundwater pollution means that quality of fresh groundwater changes into undesirable one. There are two origins of groundwater pollution are: natural and men activities

1. A natural origin of groundwater pollution, such as fluorine, arsenic, iron and manganese, is affected by a geological setting, seawater influence due climate change, flooding (partly natural but also human)
2. Another of the most serious origins of groundwater pollution is human activities.

- Indiscrete waste disposal
- Pit latrines and septic tanks (no study conducted – but problems are there)
- agricultural and livestock raising activities
- caused by industrial

2. Groundwater Resources

- Generally in consolidated aquifers in alluvial formations and karst limestone about 40% country area
- Mostly salty water sources underground – especially coastal areas
- Water also available in crystalline aquifers in rocky formations
- No detailed historical data on groundwater resources
- Currently Directorate of WRM undertaking groundwater studies
- Total storage 99,000 m cm equivalent to 100 years storage, drought proof.

3. Effects of groundwater pollution

- Compromised water quality for drinking
- A lot of domestic shallow wells in Timor-Leste including Dili
- No voluntary water quality testing initiative among the urban population
- No institutional arrangements for ensuring water quality

*Ministry of Infrastructure, Timor Leste

4. Quantifying groundwater resource

- Very minimal quantities – studies underway
- Recharge- of aquifers very minimal
- Very high runoff compared to infiltration
- Very little vegetative cover
- Poor farming methods
- Pressure on natural resources for livelihood

The Democratic Republic of Timor-Leste has recently implemented programs in the management of groundwater and investigation of contamination. This has been facilitated under the program of the Australian Government, Department of Climate Change and Energy Efficiency and Geoscience Australia. The program is an assessment of the impacts of climate change on groundwater in Timor-Leste. Initially, data was gathered on climate and geology to developed a National Hydrogeology map for development of groundwater management policy and assessment of vulnerability of village water supplies to climate changes. These include changes in annual rainfall, salt water intrusion from rising sea level and changes in the variability of wet seasons.

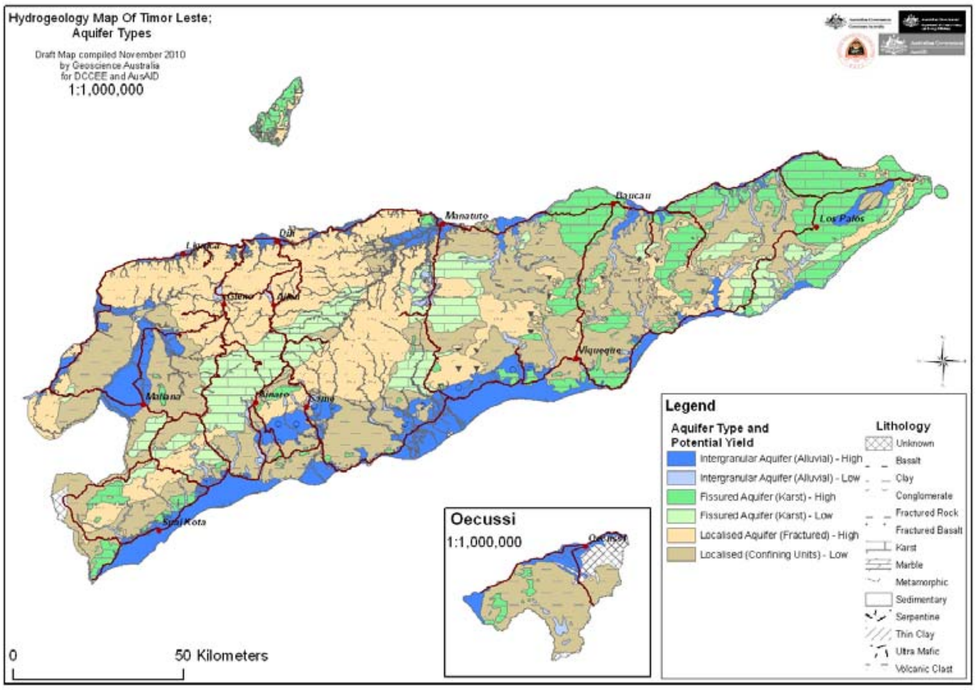


Fig 1. Hidrological map of Timor Leste. (Still Draft by geosciences Australian)

The groundwater resources of Timor-Leste are primarily used for water supply and sanitation in urban and rural settings. There has been no major development of groundwater for agriculture and industries. Typically rural water supplies are obtained from groundwater springs.

In some geological environments the spring water supplies are very small and highly dependent on seasonal conditions. As such they are also susceptible to contamination from land use practises and direct contact with humans and animals. Similarly shallow groundwater resources in urban settings are frequently contaminated by coli form and e-coli bacteria.

Now that the country has a hydrogeological map to characterise the potential aquifers it is planned to develop a vulnerability classification based on aquifer type, climate zone and climate variation. Then a policy can be developed to prioritise upgrading of village water supplies to limit the impact of climate changes and reduce the risk of pollution of the groundwater resources. Similarly in the urban setting the pollution of shallow groundwater with waste water needs to be removed from the water supply and sanitation systems by conversion to deep groundwater resources and supply systems.

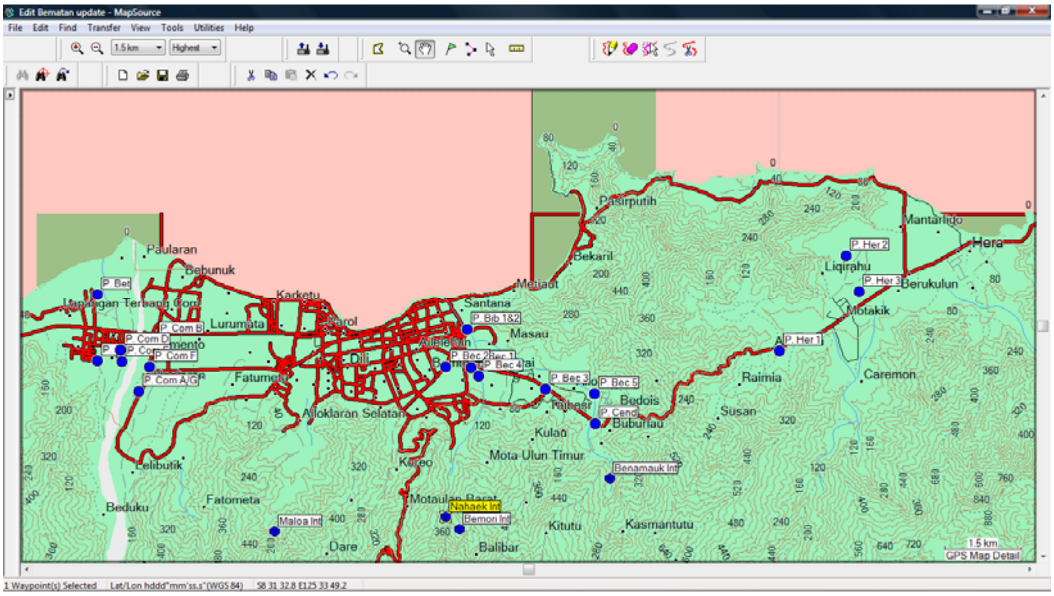


Fig 2. Capital Ground water supplay in Dili, Timor Leste.

Timor-Leste is seeking assistance to develop mapping of the springs used for rural water supplies, input of the data to a database and inclusion of the spring locations on the hydrogeological map. It is proposed that enumerators from the Statistics Department who carried out population census activities in the 2010 national census and are familiar with GPS equipment, be trained to survey springs and wells and to measure flow rates. Assistance will be required for logistical planning and operations, transportation, database development and GIS presentation. We will then use the data to design management schemes to minimise pollution risk at the springs and to locate replacement wells in high risk circumstances.

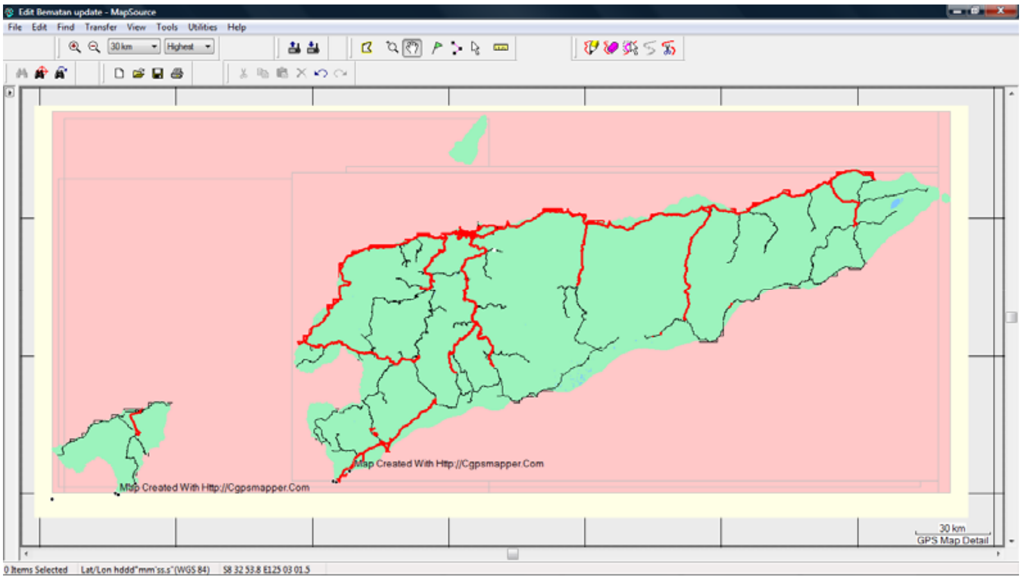
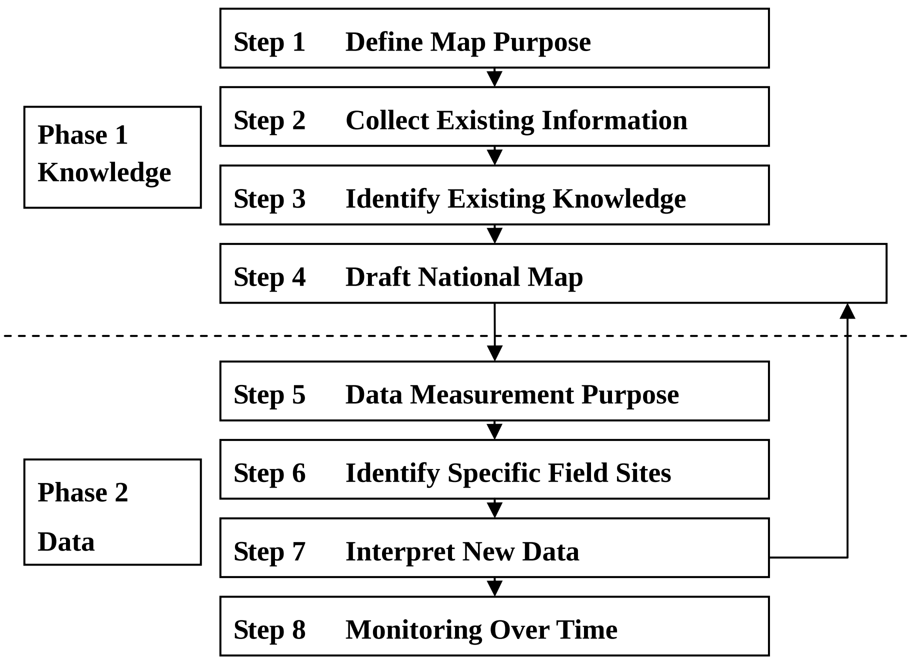


Fig 3. Map of Timor Leste wich to identified ground water level next 6 year 2012 by Geosciences Australian

5. Geosciences Australian Support

5.1 Framework Method

(This framework method from geosciences Australian, now are on going study on phase 1 from Step 1-step 4) The phase 2 from step 5-8 will start around July 2011)



5.2 Framework Method - Phases

Knowledge vs Data Approaches

Knowledge-Driven Approach – Use typical groundwater-geology relationships combined with Timor-Leste geology map and local knowledge of groundwater to produce surrogates for groundwater aquifers.

Data-Driven Approach – Use groundwater data of quality and quantity from specific locations to use as case-studies for groundwater behaviour.

Aims and Objectives

· To provide support for T-L NAPA through a review of existing information on groundwater

· To build T-L water agencies' capacity for assessing, monitoring and managing groundwater in a changing climate

· Produce a report on results from the project and develop a national guide for groundwater monitoring

· GA project working closely with DNWRM, RWSSP and other T-L agencies – funding support from Department of Climate Change, Australia

Groundwater Quality in Vietnam and Management Methods

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Abstract

During social-economic development, the groundwater plays very important role. The Groundwater quality is one of interested questions in research and management. The monitored data showing that there are some criteria which are higher than standard limitation. The status of Groundwater quality in some areas and management methods in Vietnam are summarized bellows.

1. STATUS OF GROUNDWATER QUALITY

1.1 Red river delta plan

The monitored data in 2009 showed that the TDS of Pleistocene aquifer (qp) is 726.5mg/l in average (dry season) and 761.1mg/l (rainy season) and more or less the same with values in 2008 (Table 1). The values of the trace elements showed that there are some elements having values higher than limitation (standard No QCVN 09/2008/BTNMT): Mn: 53,57%; As: 17,86 – 21,43 % ; NH4 :66,67-77,78% of samples having values higher than limitation. The max value of Mn is 4.1mg/l (dry season) and 2.35mg/l (rainy season) - Q.129b- Lam Son - Hung Yen, of as is 0.28mg/l (dry season) and 0.31mg/l (rainy season) - Q.58a Hoai Duc-Hanoi; of NH4+ (as N) is 35.78mg/l (rainy season)- Q.77- Chuong My- Hanoi. The samples having high values are in the south of Hanoi, Hai Hau-Namdinh, Thai Binh, Hai Phong, Phuly-Hanam (Fig. 1).

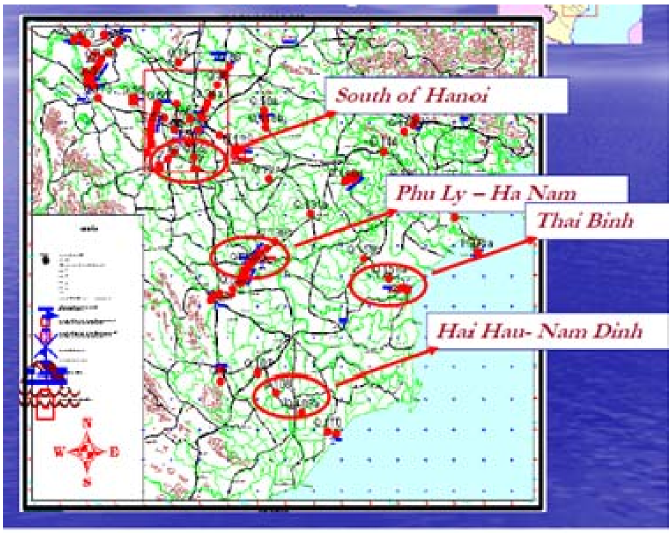

Fig.1 Map showing high value of As, Mn and NH_4^+ in Red river delta

*Centre for Water resources monitoring and forecast, Viet Nam

Table 1 Water quality in the Red river delta in qp aquifer(mg/l)

Criteria	TDS	Mn	As	Cr	Se	Hg	NH4+ (As N)
Permitted value (mg/l)	1500	0,5	0,05	0,05	0,01	0,001	0,1
Dry season							
Number of higher samples/Total samples	8/60	15/28	5/28	0/28	0/28	0/28	10/15
Average value	726,5	0,90	0,024	0,001	0,001	0,0001	8,70
Max. value	5231	4,10	0,279	0,002	0,001	0,0002	31,11
Min. value	75	0,05	0,001	0,001	0,001	0,0001	0,00
Rainy season							
Number of higher samples/Total samples	8/58	15/28	6/28	0/28	0/28	0/28	14/18
Average value	761,1	0,62	0,033	0,005	0,0021	0,0002	11,60
Max. value	5008	2,35	0,311	0,008	0,0050	0,0008	35,78
Min. value	76	0,06	0,002	0,001	0,0005	0,0001	0,00

1.2 Mekong river delta plain

Results of comparing analysed values with limitation showed that there are some elements having higher values like TDS, NH4+, Mn, As, Hg (Fig. 2). Table 2 shows water quality in the Mekong river delta in qp aquifer (mg/l) in dry season. The values in the aquifers are as follows :

+ qp3 aquifer: TDS and NH4+ values is higher than limitation with max value in well Q17701Z: 26410mg/l and 24,34mg/l respectively (precinct No 9, Ca Mau city, Ca Mau province); Mn max.value is in well Q409020M1 (4,58mg/l - precinct 6, Soc Trang, Soc Trang);

+ qp2-3 aquifer: TDS max. value is in well Q822030M1 (40,280mg/l -Long Hoa, Can Gio, HCM city); max. values of Mn and Hg are in wells Q177020 (7,44mg/l and 0,004mg/l (precinct No 9, Ca Mau city, Ca Mau); max. value NH4+ is in well Q224020 (6.88mg/l -Thoi Hoa, Ben Cat, Binh Duong);

+ qp1 aquifer: Max. value of TDS is in well Q21402ZM1 (15,980mg/l - Tan Long Hoi, Mang Thit, Vinh Long); Max. value of Mn is in well Q039030 (1,53mg/l -Hiep Phuoc, Nhon Trach, Dong Nai); Max. value of NH4+ is in well Q004030 (1,40mg/l -Thanh Loc, urban No 12, Ho Chi Minh city);

+ n22 aquifer: Max. value of TDS is in well Q406040 (25,300mg/l -Long Son, Cau Ngang, Tra Vinh); Max. values of Mn and Hg are in wells Q17704T (9,04mg/l and 0,003mg/l

-precinct No9, Ca Mau city, Ca Mau); Max. value of Ni is in well Q80404T (0,03mg/l -Dong Du, Cu Chi, Ho Chi Minh city); Max. value of NH4+ is in well Q714040 (4,57mg/l - Binh Son, Long Thanh, Dong Nai);

+ n21 aquifer: Max. value of TDS is in well Q219040 (24,760mg/l - Ba Tri, Ba Tri, Ben Tre);

* Stalinization due to overexploitation

- In Soc Trang, due to overexploitation, in the production aquifer there is saline intrusion and some wells have been closed.

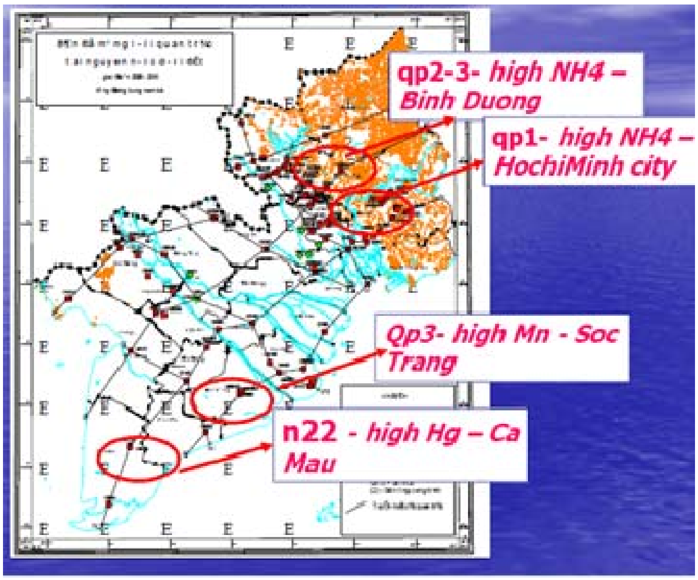

Fig.2 High value of As, Mn and NH4+ in Mekong river delta

Table 2 Water quality in the Mekong river delta in qp aquifer (mg/l)in dry season

Criteria	TDS	Mn	As	Cr	Cu	Pb	Hg	Ni	NH_4^+ (As N)
Permitted value (mg/l)	1500	0,5	0,05	0,05	1	0,01	0,001	0,02	0,1
1. qp_3 aquifer									
Number of higher samples/Total samples	8/25	4/7	0/7	0/7	0/7	0/7	0/7	0/7	2/11
Average value	3093	1,22	0,002	0,004	0,008	0,000	0,000	0,005	2,90
Max. value	26140	4,58	0,009	0,007	0,023	0,001	0,000	0,014	24,34
Min. value	30	0,05	0,000	0,000	0,000	0,000	0,000	0,000	0,00
2. $qp_{2\text{-}3}$ aquifer									
Number of higher samples/Total samples	10/29	2/8	0/8	0/8	0/8	0/8	1/8	0/8	2/5
Average value	4535	1,11	0,002	0,003	0,003	0,000	0,000	0,003	2,51

Criteria	TDS	Mn	As	Cr	Cu	Pb	Hg	Ni	NH_4^+ (As N)
Permitted value (mg/l)	1500	0,5	0,05	0,05	1	0,01	0,001	0,02	0,1
Max. value	40280	7,44	0,004	0,007	0,021	0,000	0,004	0,008	6,88
Min. value	30	0,03	0,000	0,000	0,000	0,000	0,000	0,000	0,00
3. qp_1 aquifer									
Number of higher samples/Total samples	7/21	2/8	0/8	0/8	0/8	0/8	0/8	1/8	1/4
Average value	2483	0,55	0,006	0,003	0,005	0,000	0,000	0,007	0,35
Max. value	15980	1,53	0,021	0,008	0,033	0,000	0,001	0,038	1,40
Min. value	35	0,01	0,000	0,000	0,000	0,000	0,000	0,000	0,00
4. n_2^2 aquifer									
Number of higher samples/Total samples	12/27	3/12	0/12	0/12	0/12	0/12	1/12	1/12	2/4
Average value	5271	0,96	0,004	0,002	0,005	0,001	0,000	0,006	1,76
Max. value	25300	9,04	0,017	0,008	0,020	0,008	0,003	0,030	4,57
Min. value	50	0,02	0,000	0,000	0,000	0,000	0,000	0,000	0,00
5. n_2^1 aquifer									
Number of higher samples/Total samples	10/22	0/4	0/4	0/4	0/4	0/4	0/4	0/4	
Average value	5250	0,10	0,004	0,002	0,002	0,000	0,000	0,003	
Max. value	24760	0,19	0,005	0,002	0,004	0,000	0,000	0,007	
Min. value	79	0,03	0,002	0,001	0,000	0,000	0,000	0,000	

1.3 Central region

Table 3 shows water quality in Central region (mg/l). Average value of TDS in 2009 is 165mg/l (dry season) and 139mg/l(rainy season). The analysed data showed that almost values of trace elements are meet limitation except for Mn and Hg. The max.value of Mn is 0.94mg/l (dry season) in well LK136T - Dien Binh - Dac To - Kon Tum) and 0.92mg/l (rainy season) in well LK18T -An Khe- Gia Lai). Max.Value of HG is 0.002 mg/l in well C11a (precinct Le Loi-Kon Tum town, see in Fig. 3).

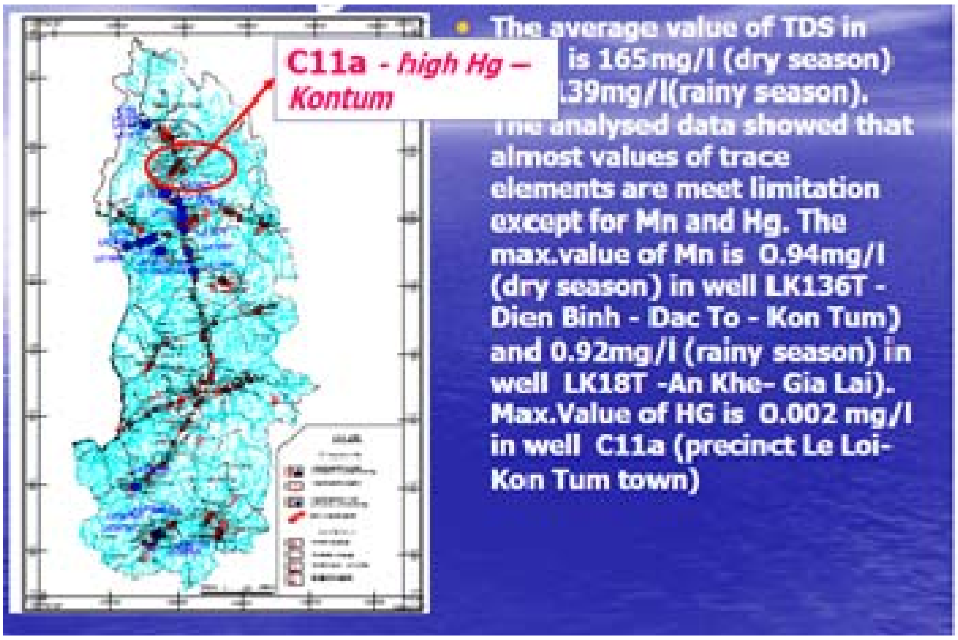

Fig.3 High value of Hg in Central region

Table 3 Water quality in Central region(mg/l)

Criteria	TDS	Mn	Hg	As	Pb	NH4+ (As N)	Phenol	CN
Permitted value (mg/l)	1500	0,5	0,001	0,05	0,01	0,1	0,001	0,01
Dry season								
Number of higher samples/Total samples	0/105	2/23	1/23	0/23	0/23	2/19	0/23	0/23
Average value	165	0,12	0,0007	0,001	0,002	0,09	0,0003	0,002
Max. value	806	0,94	0,0020	0,002	0,007	0,14	0,0008	0,006
Min. value	34	0,01	0,0005	0,001	0,001	0,03	0,0001	0,001
Rainy season								
Number of higher samples/Total samples	0/106	3/24	0/24	0/24	0/24	0/22	0/24	0/24
Average value	139	0,17	0,0005	0,001	0,001	0,06	0,0003	0,002
Max. value	732	0,92	0,0005	0,002	0,003	0,09	0,0009	0,005
Min. value	32	0,02	0,0005	0,001	0,001	0,03	0,0001	0,001

2. Causes of Groundwater pollution

The causes of Groundwater pollution can be many sources. The below description is main sources can cause Groundwater pollution.

- Domestic waste water: large portion with high values of nutrion, BOD5 and nitrogen components.

- Industrial waste water: from industrial areas, private produccers. There are not treatment system or under standard treatment system in theses areas. The waste water flows into environment with toxic elements. Recently the Vedan phenomenon is hot even in Viet Nam. The untreated wast water flow unlegal into Thi Vai channel and caused serious impact to the life of people. Now, the vedan factory leaders have agreed to compensate to the famers along this channel.

- Waste water from Hospital without treatment can be a pollutant sources.

- Mineral mining can be polutant source

- Waste water from trade villages can be pollutant sources

- Abandon wells without sealing can be pollutant way into Groundwater.

- Over exploitation in the coastal area and climate changes can be reason for saline intrusion.

3. Water resources management

3.1 Government

The Government has been issueing law, under law documents to manage water resources.

1. Law No 08/1998/QH10 issued by national assembly on water resources

Law No 52/2005/QH11 issued by national assembly on environmental protection;

Decree No 179/1999/ND-CP dated 30th December 1999 issued by Government stipulating implementing of water law;

Decree No 149/2004/ND-CP dated 27th July 2004 issued by Government stipulating on regulation on licensing for exploration, exploitation of water resources and flow waste water into water resources;

Decree No 34/2005/ND-CP dated 17th March 2005 issued by Government stipulating on regulation on administrational punish in water resources regards;

Resolution No 27/NQ-CP dated 12th June 2009 issued by Government stipulating on water resource management. In this resolution, the responsibilities of Ministry of Environment and Natural Resources and relating ministries;

Decree No 117/2009/ND-CP dated 31st December 2009 issued by Government stipulating on treatment on violate in environmental protection.

3.2 Ministry of Environment and Natural Resources (MONRE):

(1) Legal framework

The MONRE has been issuing legal documents to manage water resources.

Circular No 02/2005/TT-BTNMT dated 24th June 2005 issued by MONRE to guide to implement decree No 149/2004/ND-CP dated 27th July 2004 issued by Government stipulating on regulation on licensing for exploration, exploitation of water resources and flow waste water into water resources

Circular No 8/2009/TT-BTNMT dated 15th July 2009 issued by MONRE stipulating on management and protection of environment in the economic zones, high-technic zones

Decision No 05/2003/QD-BTNMT dated 04th September 2003 issued by MONRE promulgating regulation on licensing on exploration, exploitation and drilling on groundwater resources;

Directive No 02/2004/CT-BTNMT dated 02nd June 2004 issued by MONRE regarding to enhancement of groundwater resources management;

Decision No 14/2007/QD-BTNMT dated 04th September 2007 issued by MONRE promulgating regulation on sealing of abandon wells;

Decision No 17/2006/QĐ-BTNMT dated 12th October 2006 issued by MONRE promulgating regulation on licensing on groundwater drilling;

Decree No 13/2010/TT-BTNMT stipulating on Price of Vietnamese environment.

(2) Implemeting research projects

1. Diminish arsenic value in domestic water in Viet Nam

2. Groundwater protection in big urban areas in Viet Nam

3. Constructing water resources monitoring network

4. Inventory of water resources

5. Mapping on water resources, hydrogeology.