14th WEDC Conference

Water and urban services in Asia and the Pacific

Kuala Lumpur 1988

Bangkok's deteriorating groundwater - environmental issues

Chandran Nair

INTRODUCTION

Groundwater resources in the Bangkok Metropolitan area and surrounding provinces are being depleted and contaminated at alarming rates. They are highly vulnerable to excessive exploitation and quality deterioration associated with rapid industrial development and the resultant population growth. These factors coupled with the lack of effective accompanying controls have led to serious depletion of aquifers with subsequent environmental impacts. In addition to depletion this paper will also address the issue of quality deterioration which has roots both in over abstraction as well as in the lack of adequate pollution abatement measures. Both are interelated issues and can be linked to the lack of the practical application of water conservation and re-use strategies among the major industrial water users.

In observation wells water levels have dropped 10-12 m since 1985. Although the Groundwater Act was passed in 1978 restricting digging of wells it does not cover areas without municipal water and enforcement has been difficult. In some parts of the municipal area, there has been no development of surface resources and all the water is obtained from the ground.

GROUNDWATER IN BANGKOK

The Bangkok area is a metropolis consisting of the city of Bangkok and the surrounding districts of Thon Buri, Nonthaburi and Samut Prakarn with an area of about 750 km^2. The population of the metropolis is estimated to vary between 7-8 million. To serve this large population and the expanding industrial sector, water is drawn from both surface sources (Chao Phraya River) and groundwater reserves (increasingly in the last 15-20 yrs).

The groundwater underlying the area can be distinguished by 8 different aquifers.

1) Bangkok Aquifer which is the uppermost and extends to about 50 m. This aquifer can be tapped at 15 to 30 meters from the ground surface. It is however not used widely due to high salt levels.
2) Phra Pradeng Aquifer the top of which lies at about 60-80 m below groundlevel and is heavily used.
3) Nakhon Luang Aquifer which is at 100 to 140 m. below the ground and has a depth of 50 to 70 m. It is probably the most exploited aquifer for water supply in Bangkok.
4) Nonthaburi Aquifer which is very extensive and lies at a depth of 170 to 200 m below ground level. It has been used extensively by large consumers since deterioration in the above aquifers.

The deeper aquifers have not been used extensively. However there are some deep wells extracting water from the Sam Khoh aquifer at a depth of 250 m and located in the north of Nonthaburi and Pathum Thani. The other aquifers are: Phya Thai Aquifer (350 m zone), Thon Buri Aquifer (450 m zone), Pak Nam Aquifer (550 m zone)

The recharge to these aquifers by percolation is hindered by an impervious clay layer underlying the area. Therefore most recharge to the aquifer is essentially from lateral groundwater flow from the periphery of the Lower Central Plains. Groundwater recharge has also been reduced by the combined effects of an increased amount of paved area and pond eutrophication. Groundwater recharge is estimated annually at 3 percent of the mean annual rainfall of 1,191 mm. Due to this low level of recharge over abstraction above the safe yield has quickly led to overdraft.

The number of wells in each district in the metropolis and adjoining provinces was determined in a well inventory carried out 10 years ago. The survey established that for most of the wells surveyed the output could not be assessed since no information on rates and quantity of pumping is kept by the owners. This clearly demonstrates that actual abstraction rates are very approximate and that control on drilling and the monitoring of usage has not been a priority, a reflection of the administrative and planning problems. The Groundwater Act of 1987 has however required all well owners to register with the Groundwater Division of the Department of the Department of Mineral Resources. Areal distribution of private wells is shown in Table I "(ref. 1)".

The total groundwater extraction during 1979-1980 was estimated from the well inventory

Table 1 Areal Distribution of Private Wells as of January 1982 (Source: Department of Mineral Resources)

Usage / Area	Domestic	Industry/Factory	Agriculture	Total Number of Wells	Total Pumpage in m³/day
	Number of Wells (Pumpage in m³/day)	Number of Wells (Pumpage in m³/day)	Number of Wells (Pumpage in m³/day)		
Bangkok	3,353 (245,492)	1,838 (212,744)	100 (9,194)	5,291	467,430
Samut Prakan	1,478 (49,582)	1,392 (266,472)	103 (2,905)	2,973	318,959
Samut Sakhon	325 (4,779)	207 (30,594)	98 (2,741)	630	38,114
Nonthaburi	139 (27,738)	59 (14,000)	1 (10)	199	41,748
Pathum Thani	64 (5,372)	119 (72,986)	12 (307)	195	78,665
Ayutthaya	20 (597)	27 (2,601)	8 (344)	55	3,542
Total	5,379 (333,560)	3,642 (599,397)	322 (15,501)	9,343	948,458

to be over 1 million m^3/day. It is now estimated to be in excess of 1.5 million m^3/day although the Metropolitan Water Works Authority (MWWA) has considerably reduced its abstraction. The MWWA currently draws about 200,000 cu.m/day (7% of its total needs) from 50 deep wells. The MWWA plans to extend its service to the industrial districts of Paknam and Prapradaeng where groundwater depletion is a serious problem. The MWWA has an active program to stop abstraction by the year 1990.

The critical areas of groundwater exploitation include the administrative districts of Bangkapi, Phra Kanong and parts of Phra Pradaeng and Samut Prakarn. This area consumes about a half of all groundwater withdrawn. The central parts of Bangkok with the highest population consumes only a fourth of the total groundwater extracted. This is directly due to the fact that in the critical areas there is no public water supply while central Bangkok is fully covered.

CAUSES AND EFFECTS OF DETERIORATION

Having classified deterioration as a problem encompassing depletion and pollution we can now idetify the attributing causes. Excessive utilization coupled with poor controls has resulted in depletion. Depletion of reserves in turn has had different environmental impacts.

Subsidence

The most prominent environmental impact of groundwater depletion has been land subsidence on a large scale. Latest reports according to the Artesian Well Administration show that it has spread from Bangkok to the new industrial zones in Samut Sakhon, Ayutthaya and Chonburi. The cost in damage to buildings, roads, and drainage systems is considerable. The threat of floods increases everyear as large sections of the city sink and as existing storm drains become redundant especially when the level in the Chao Phya river is high. The maximum rate of subsidence in the metropolitan area has exceeded 10 cm/year in the period 1978-1979 and was as much as 1.14 metres between 1940-1980.

One of the major causes of ground surface subsidence is the result of cumulative compression of each soil layer due to pore water pressure drop in the layer. The uppermost clay layer in the Bangkok area is highly compressible and a large pore pressure drop in this layer will cause substancial compression. The rate of pore pressure drop in central Bangkok is larger than those observed in areas further away.

The ground surface elevation in the central part of Bangkok is about 1.0-1.5 m. above mean sea level (MSL), while it is only 0.4-1.0 m. above MSL in the critical areas. The result was severe flooding for a 2 month period in 1980 and floods of varying intensities every year.

Subsidence has created serious problems in the design, construction and maintenance of buildings, roads and bridges, drainage and sewage structures, water distribution systems, canals, conduits, pipelines and dock facilities. Negative skin friction on piles and settlement of pile foundations results from subsidence due to groundwater withdrawal.

Large number of engineering structures which rest on deep foundations are found to stand up against the subsiding ground. The lowering of the ground surface with respect to sea level has caused a reduction in the hydraulic gradient for drainage and sewage systems resulting in serious threat of floods during high tide and also posing a health hazard as drains overflow into low lying areas.

Subsidence has also caused damage to well casings and water transmission pipes that are connected to the pumping wells. Protrusion of well casings is common in subsidence areas, an indication of land subsidence. The negative skin friction from the soil tends to compress the casing. The damaged casings and pipes have caused pollution to spread to lower aquifers further complicating efforts to control quality deterioration.

Water Quality

Groundwater pollution (quality deterioration) has usually four main origins: industrial, domestic, agricultural and environmental pollution. Each of these can be divided into continious and accidental types.

1) Industrial pollution is carried to the aquifer by:
   - Used water which contains chemical compounds and trace elements
   - Rain infiltration through waste disposal sites
   - Accidents, like the breaking of a pipe line
2) Domestic pollution is carried to the aquifer by:
   - Rain, infiltrating through sanitary landfills
   - Accidents, like the breaking of septic tanks
3) Agricultural pollution which is due to irrigation water or rain carrying away fertilisers, minerals, salts, herbicides and pesticides
4) Environmental pollution in mainly due to seawater intrusion in coastal aquifers.

Of the above the most serious threat to groundwater resources in Bangkok is that posed by seawater intrusion and is due to depletion. This quality deterioration is most obviously shown in the rise of salts such as Cl, Mg et. Salt water intrusion was not detected until 20 years ago. Since then many wells have been abandoned both by the MWWA and private well users. Numerous instances of industries being forced to abandon wells are on record and new wells are dug to tap water at greater depths. There is a great reluctance on the part of industries to switch to the MWWA supply where it has been made available for the simple reason that the pricing policy makes it economically sound to continue to use groundwater. It costs 1 Baht/m^3 (One pound sterling = 40 Baht) for groundwater as compared to 8 Baht/m^3 for the municipal equivalent. The rate of saltwater intrusion differs in various parts of the metropolis from 500 m per year in areas of heavy abstraction to 100 m per year in other areas. As water levels decline the rate of encroachment is expected to accelerate. The worst affected areas are the Phra Pradeng and Thon Buri areas.

There are also numerous cases of vertical leakages of salt water from upper aquifers to lower aquifers. This a problem in heavily industrialised areas where many wells operate in a small area and where the quality of well casings and maintenance is poor. Reliable information on the extent of intrusion is not known and this is especially true of the deeper aquifers due to the lack of data. Municipal wells used by the MWWA have shown five fold increases from levels of 200-250 mg/l to over 1,000 mg/l in a period of 15 years. In the Bangkok aquifer chloride contents range from 500 to several thousand mg/l.

Contamination of groundwater is also attributed to the corrosion of well casings or from imperfectly sealed wells. In areas of improper drainage and poor waste disposal the threat imposed by this form of groundwater contamination has not been adequately monitored or evaluated. Every time an area floods the potential for contamination via inadequately disposed industrial and domestic waste entering poorly sealed/cased wells is very high.

FACTORS CONTRIBUTING TO DETERIORATION

Solutions to the problem of groundwater deterioration and the resultant environmental impacts have been hampered by a number of factors including the lack of comprehensive and relevant legislation coupled with the inadequacies of coordinated efforts at various levels.

Inadequate legislation and tarrifs

Inadequate legislation has certainly been a stumbling block in efforts to curb over abstraction. Although laws prevent the drilling of wells in certain areas when old wells are abandoned implementation of this has been difficult.Conscientization of the general public and industrial management to the needs of water demand regulation is needed. This process should ideally go hand in hand with an integral set of laws, incentives, fiscal and other penalties (or tax reliefs), standards, and last but not least, there is the need to look at a tariff system for the consumption of water, commensurate with the amount of water withdrawn (used), the purpose for which it is used, and the degree of contamination it causes. If a progressive pricing system is socially and politically acceptable, and which means it can be enforced among the large amount of water consuming industries, it may become a major cause of water conservation, reuse and purification. It will certainly contribute to the cause of restoring peziometric levels.

In order to address the problem in this content we need to weigh social, economic and environmental factors and be prepared to make difficult trade offs in allocating limited resources to the solution of the problem. Attention has to be focussed upon the economic, management and public policy aspects of natural resource development and use. Overall institutional arrangements should serve to permit the implementation of economically efficient water quality management in the metropolitan area. Changes called for are therefore not just structural but also others such as public education and pricing which seek to change peoples habits and consumption patterns.

Lack of Water reuse and conservation strategies

Lack of water reuse and conservation strategies in the industrial sector is a serious factor. Industrial wastewater reuse and water conservation should be employed as tools for pollution control and abatement and in this way help reduce groundwater abstraction. This type of conservation produces the benefits of less wastewater to be treated and a reduction in overall consumption, a dual strategy of water conservation and water resource recovery.

Many industrial water users (using groundwater) have very poor housekeeping practices due to the traditional belief that the water is free. Very often the first line of defence against waste, the metering of all water use is not employed. The need to re-use and conserve will be motivated by the pressures of limited water supply, poor water quality and other environmental considerations.

In view of current and prospective environmental standards, each industrial plant should ask itself which way is best to proceed to comply with regulatory demands. In considering the alternatives, there are really only two: no discharge, or discharge comploying with current and future requirements of the regulatory agency. Where conditions may initially dictate treatment for discharges, the resulting effluent might be suitable for reuse within an industrial plant-either as cooling water and/or boiler feed make up. So why throw it away?

The burden of initiating these changes lies with the engineers and scientists, with assistance of the planners and decision makers. Rational water management in the metropolis needs a co-operative, multi disciplinary effort. Engineers, hydrologists, agronomists, ecologists, economists and sociologists have to act in conjunction with civil servants and corporate executives and politicians. Their objective must be to increase efficiency by re-use, re-cycling and conservation (reducing waste).

Other major factors contributing to deterioration are:-

- Lack of adequate alternative surface water sources, partly due to increased pollution of existing streams through industrial and municipal wastes as well as due to reasons of poor natural resource management (e.g. increasing silt levels and reduced stream flows)
- Absence of efforts towards large scale artifical recharge schemes
- Slow pace of industrial decentralization programme into regional centres
- Inadequate creation of industrial zones and estates where integration of reuse reclamation schemes into comprehensive water resources planning can be done with economic benefits.

CONCLUSION

The paper has attempted to link the current deterioration in groundwater quality to a variety of issues which highlight the need for greater attention to the environment in general. The future supply and demand as well as quality of water for the metropolis will be influenced by the trends and initiatives taken now to combat overuse and pollution. To succeed the goals should reflect the desires of an informed industrial sector and public.

REFERENCES

1. Asian Institute of Technology Groundwater Resources in Bangkok Area: Development and Management Study, Phase 1: Final Report, 1978
2. Asian Institute of Technology Groundwater Resources in Bangkok Area: Development and Management Study, Comprehensive Report 1978-1982.

SESSION III
POLLUTION AND ITS CONTROL

Chairman: Dr Abu Bakar bin Jaafar
Department of Environment
Ministry of Science, Technology and Environment

PAPERS PRESENTED

L G HUTTON
Establishing environmental monitoring in Sri Lanka

Dr SUPORN KOOTTATEP and Dr KIYOSHI KAWAMURA
Information consolidation of pollution problems

MANSOR IBRAHIM, AHMAD TAJUDDIN KECHIK and AMRAN HAMZAH
Town planning and pollution control

CHANDRAN NAIR
Bangkok's deteriorating groundwater - environmental issues

DISCUSSION

L G HUTTON

1. Mr NEPAL wished to know if the laboratory was set up for regular monitoring of air, water and noise pollution.

2. Mr HUTTON replied that the laboratory was set up to support the NBRO Environmental Division with research and testing programmes. This included providing baseline data on the state of pollution of surface and groundwaters, air and noise. The water quality surveillance programme was an additional responsibility recently given by the Ministry of Local Government, Housing and Construction. This programme would involve some re-design of the operations and staffing of the laboratory.

3. Mr NEPAL asked if the results would be acted upon or would the laboratory treat them in a similar way to the ones from the Water Supply Board.

4. Mr HUTTON said that the surveillance programme results would be reported to the National Water Supply and Drainage Board, Ministry of Local Government Housing and Construction, Ministry of Health, National Health Coordinating Committee and the Interministerial Committee on the Environment. He assured Mr NEPAL that it would not be like the NWSDB laboratory. The wider reporting of the results would ensure that action would be taken. He suggested that Mr NEPAL should refer to the WHO Guidelines on Drinking Water Quality (1983) for details of the surveillance programmes.

5. Mr RICHARDSON wished to know if in addition to the annual review of environmental impact of a factory's operation when its factory licence was being renewed, there were standards set for discharge of effluent which gave the framework for monitoring and control between the annual licence reviews.

6. Mr HUTTON explained that standards were set for effluent quality as follows:
i. tolerance limits for industrial effluents discharged into inland surface waters (SLS 652:1984); and
ii. tolerance limits for industrial wastewater discharged into marine coastal waters (SLS 721:1985).
He said these standards had been reproduced together with the interim standards of CEA in Chapter 9 of Environmental Assessment Procedure for Development Activities in Urban Areas. A manual for planners and decision makers. NBRO Environmental Division, 99/1 Jawatte Road, Colombo 5. (Price US$25).

CHANDRAN NAIR

1. Mr ABHYANKAR asked if people and industries stopped using groundwater would MWWA have enough surface water to meet demands.

2. Mr NAIR explained that it was not clear but it appeared not. The plan, however, was not to completely stop using groundwater but to reduce it to levels compatible with recharge (about 0.8 million m^3/day).
With increasing surface water deterioration it was unlikely that MWWA itself could tackle the issue which was one of regional water resource development (ie conservation, wastewater treatment etc).

3. Mr ABHYANKAR asked when MWWA was planning to discontinue the abstraction of groundwater (at present reported to be 7%).

4. Mr NAIR said the plan was to discontinue by 1990 but he thought this was unlikely.

5. Mr ABHYANKAR also asked what was the pricing policy for domestic and industrial users.

6. Mr NAIR explained that there was a differential pricing policy based on water consumption. For residential areas it varied from 4 to 7.65 Baht/m^3 and for industrial users, using more than 200 m^3/day it varied from 5 to 8.7 Baht/m^3.

7. Mr KOLSKY wished to know the safe yield of Bangkok's aquifer.

8. Mr NAIR said that based on several models studied over the years it was estimated to be in the region of 0.8 million m^3/day.

9. Mr KOLSKY noted that the paper called for economic pricing policies, but the costs of MWWA water appeared to be prohibitive relative to illegal tapping of the aquifer. If MWWA lowered its tariff, consumption would increase. If the price was increased, there would be even more illegal tapping. Pricing policy would be of little benefit as long as illegal tapping was permitted.

10. Mr NAIR replied that MWWA was attempting to lower prices in the critical industrial zones yet treatment and capital costs of the waterworks were increasing. The enforcement of existing regulations and the imposition of stricter controls in areas served by the MWWA was crucial (ie if it is supplied it must be used despite the presence of wells).

11. Mr NEPAL asked if the lowering of groundlevel in Bangkok was still continuing.

12. Mr NAIR said it was but in some areas it had been arrested as piezometric heads had been restored. In the worst areas it was still in the region of 10cm/year.

13. Mr NEPAL commented that with deteriorating groundwater quality treatment would be required. He asked if groundwater would still be available at Bh 3/m^3 if treated.

14. Mr NAIR explained that legislation did not permit the treatment of abstracted groundwater. Therefore if a user found the quality of groundwater to be unacceptable, by law he was not permitted to treat it in order to avoid drilling a new deeper well (if that was permissable) or paying a higher rate for the metropolitan water supply.

15. Mr NEPAL also commented that abstraction (about 2 million m^3/day) was more than the safe yield (0.5 million m^3/day). He said groundwater was being mined and asked how long this mining would continue.

16. Mr NAIR replied that mining was a continuing problem. In central Bangkok it had been arrested but in other areas it continued unabated. Until alternative supplies were provided in those areas not served by municipal supply mining would continue. The problem was central to the topic of depletion.

17. Mr RICHARDSON commented that charges levied by the Department of Mineral Resources were 1 Baht/m^3. O & M costs of an average well have been calculated at 1.5 to 2.0 Baht/m^3 giving a total cost of 2.5 to 3.0 Baht/m^3. He said alternative supply to groundwater was not available to many areas - eg Samutprakarn, where there were 2000 factories, nearly all were forced to use groundwater. MWWA was extending its service to these areas and had covenanted with its financiers (ADB) to enforce a switch to piped water when available. There were difficulties such as well licencing being for 10 years (in which time Bangkok could go down another meter), but the main requirement was political will.