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SOME NOTES ON GROUNDWATER AS A DOMESTIC WATER SUPPLY OF THE YOGYAKARTA MUNICIPALITY

by
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ABSTRACT

Water supply in Yogyakarta municipality is mainly originated from two main sources, the pipe water and groundwater. The pipe water which is operated by the local drinking water authority does not suffice for the water demand of the people in the city. The second source is groundwater, which is used by most people in the city by traditional system. The aquifer of the Yogyakarta which consists of volcanic materials erupted by Merapi volcano is fairly good, however the expansion of the city area toward the northern and north eastern area may reduce groundwater recharge. The rapid growth of population and other city facilities such as hotels may cause groundwater supply to decline. Groundwater quality in certain area may subject to pollution by domestic wastes, assigned by the high content of chemical substances such as iron and sulphate, besides high content of coliform bacteria, and nitrite. Heavy metals were undetected in the groundwater of the area.

INTRODUCTION

Yogyakarta municipality covers an area of 32.57 square kilometres and consists of 14 subdistricts. Total population of the city in 1992 was 429,000 people. Yogyakarta is located in the lower slope of Merapi volcano, which is the most active volcano in Java, in Indonesia and even in the world. The area of the city is growing large and the number of population is increasing. One among problems which are faced by the Yogyakarta, besides the rapid increase of the number of population is limited water supply. Water supply for the city is obtained from two major sources, they are pipe water and groundwater. The pipe water is managed by the local water supply authority which is called Perusahaan Daerah Air Minum, which at the present does not suffice for the total population water demand. The pipe water supplies only about 11-20% of the total population. The rest of the population consume groundwater for their water supply.

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The increase of population and the physical development of Yogyakarta to the north may exert impact on the environment, including on groundwater in the city. Some impacts on groundwater quality caused by the human activities have been detected in a number of dug-wells. The extension of Yogyakarta has been studied by Hadi Sabari Yunus (1970). Groundwater in the area has a limited quantity, in the other hand the future demand for groundwater of the city increasing. This fact is very interesting to be studied, especially the impact on groundwater of the area, which is the main source of the water supply of the population in the city. The use of groundwater for domestic use has been discussed by Sudaryanto (1972) and Dewi Bujonowati (1981). The groundwater in the area of Yogyakarta is briefly presented in the paper.

THE STUDY AREA AND DATA USED

The study area covers the whole Yogyakarta municipality, which consists of 14 sub districts (Table 1 and Fig.1).

Table 1. Sub District in The Yogyakarta Municipality and Their Areas

No.	Sub District	Area (km2)
1.	Tegalrejo	2.93
2.	Jetis	1.72
3.	Gondokusuman	4.04
4.	Danurejan	1.10
5.	Gedongtengen	0.99
6.	Wirobrajan	1.80
7.	Ngampilan	0.86
8.	Gondomanan	1.13
9.	Pakualaman	0.64
10.	Mergangsan	2.33
11.	Kraton	1.37
12.	Mantrijeron	2.58
13.	Umbulharjo	7.58
14.	Kotagede	3.43
	Total	32.57

Data of population were collected from the Statistical Bureau of the Yogyakarta Municipality in 1990. Data on geology, geomorphology and climate were collected from publications issued by the Department of Geology, Bandung (1983) and Bureau of Meteorology and Geophysics, Jakarta (1961-1990). Data on geohydrology and groundwater consumption were collected in the field by observation 1990, while groundwater quality were obtained from laboratory analyses of samples collected during the study.

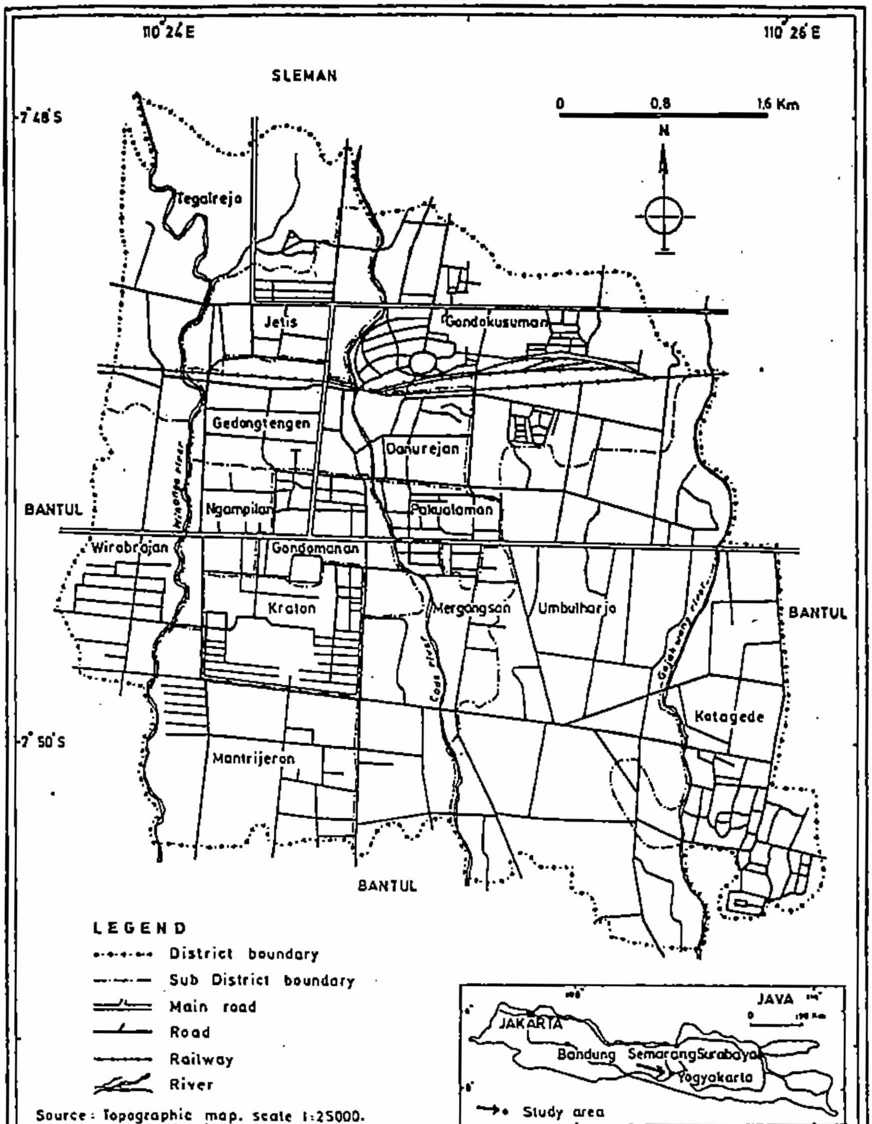

Fig. 1. Yogyakarta Municipality

GEOLOGY AND GEOMORPHOLOGY

The city of Yogyakarta is located in the volcanic foot plain of Merapi volcano. The city has an average elevation of 113 metres above mean sea level. Lithologically it consists of volcanic material erupted by Merapi volcano, mainly sand, tuff breccia and lahar. The material erupted by the volcano consists of augite, microlite, hiperstein and hornblende (Van Bemellen, 1949, Purbohadiwijoyo, 1965). Yogyakarta is located in the lower slope of Merapi volcano with an average slope of 1 degree to the south. There are three rivers flowing across the city, the Winongo in the west, Code river in the middle and the Gadjahwong in the east. Those three rivers are effluent stream, which mean that their discharge are supplied by the groundwater in the surrounding area. Some small springs and seepages occur in the bank of the rivers.

In term of hydrogeology, the volcanic material in the area is good as an aquifer. The high amount of annual rainfall (about 2500 mm per year) is favourable for the groundwater in the area.

WATER SUPPLY

As described above, water supply for the population of Yogyakarta population is mainly obtained from two sources, groundwater and pipe water. The Yogyakarta urban area known as Kotamadya Yogyakarta (municipality) covers an area of 32.57 square kilometres and has an estimated population in 1985 of 429.000 people. From the aerial photograph taken in 1981 it is clear that the Yogyakarta urban area has greatly expanded especially to the north and east of the official Kotamadya Yogyakarta. The present urban area is estimated to cover 80 square kilometers with the estimated population of 557,000 people (MacDonald and Partner, 1984).

Yogyakarta drinking water system has been recently constructed by the Projek Air Minum (PAM) Water Supply Project aided by Switzerland. The project was an extension of the old system constructed in 1925 (which serves only 11% of the total population of Kotamadya Yogyakarta) to a system which by the end of 1985 would provide 60 liters per capita per day to 60% of the Kotamadya population. The available capacity of the drinking water system declines to about 350 1/sec. in the dry season, while the required capacity is 550 1/sec. In order to meet the required capacity eight deep wells have been constructed in Ngaglik and surrounding area just north of Yogyakarta to supply more 200 1/sec. The operation of the scheme is managed by the PDAM of Yogyakarta. Some complains come from the consumers due to high iron content in the pipe water which causes brown color of the water.

The second major sources of water supply is groundwater which is abstracted from wells (dug wells, electrical pumped wells, etc). The dug wells are mostly traditional system which use tipping buckets to lift water from wells. Some hotels and industries in the city also use groundwater for their needs. Some families living in the area close to the rivers also use small springs and seepages which occur in the bank of the rivers flowing across the city.

GROUNDWATER

Aquifer and groundwater.

In the southern slope of Merapi volcano there are two main formation which act as aquifer systems, known as Sleman formation and Yogyakarta formation. The aquifer consist of unconsolidated gravels, sands, silts and clay of the Quarternary age. The sediment is partly alluvium. The older Sleman formation emerges in the north of Yogyakarta, but it is overlain by the Yogyakarta formation to the south. The Sleman formation generally has coarser materials than that of the Yogyakarta.

Although the lithological division between the two formations is reasonably distinct at outcrop, the decrease at depth (particularly south of Yogyakarta), and their hydrogeological relationship are not so clear. In general it is assumed that the two formations act as one aquifer system with groundwater flows in the Sleman formation upwards through the Yogyakarta formation. The two formations are therefore described as one aquifer system.

In the wet season groundwater may be only of 5 metres deep below ground surface. The groundwater level fluctuation is quite high. In the wet season groundwater level may rise to about 2-5 metres below ground surface, while in the dry season (April-October) may drop markedly to about 7-15 metres below ground surface. Groundwater flows southward, similar to the general slope of the area. Expansion of settlement area to the north of Yogyakarta creates a significant pavement area, which reduces the infiltration capacity of the area, hence the groundwater recharge decreases. Beside the low recharge in the upper area (northern part of Yogyakarta), the use of electric water pump since about 1970 has caused the abstraction of groundwater in the city increased markedly. It was caused by the high rate of pumping compared to the abstraction using tipping bucket. Nevertheless, study conducted by Dian Desa (1992) found:

a. 87.4% of wells owner said that, even in the dry season, the water quantity from their wells is sufficient to support their need;
b. 4.4& have experienced water shortages during dry season and;
c. the remaining 8.1% have water shortages only during very long dry season (not every year).

From this point of view it could be said that generally most of the people do not suffer from the decrease of groundwater level in the area, however most of the people realize that comparing to the previous years the groundwater level is declining. Groundwater recharge may decrease due to the physical expansion of Yogyakarta Municipality, especially to the north and to the northeast. Some of the settlements to the north cover such a large area, that may cause a high rate of use of groundwater in the settlement area, therefore it affects the groundwater supply in the southern area. The north area of Yogyakarta acts as recharge area of groundwater. If the recharge area is mostly occupied by settlement, the infiltration of rainwater decreases and it is followed by the increase of rainwater converting into surface runoff. On the other hand, the abstraction of groundwater by the local people in the northern part of Yogyakarta may occur. This situation may also cause the supply of groundwater in the aquifer itself to decrease.

Groundwater quality.

The groundwater quality in the Merapi volcanic slope is generally good. Physically, water from this area is safe quantitatively to be used for domestic purpose. The chemical quality shows that water from the area, especially from deep aquifer have a relatively high iron content. This high iron content was detected in the deep wells as reported also by MacDonald and Partners (1977). The other problems related to the chemical quality of groundwater are pollutions from domestic waste, home industrial waste and other pollution introduced by human activities. Some wells show the groundwater quality which are indicated by the high sulfate, nitrite, and some other pollutant which may be originated from domestic waste, such as detergent. The study area has no sufficient data to analyse the change of groundwater quality. If the data was sufficient it would be able to show the trend of groundwater quality, as what have been done by Yamamoto and Hida (1974) in Mushasino Upland. Some data related to water quality from a number of dug-wells in the city (Fig.2) representing the groundwater in the study area are presented in Table 2. Some test on bacteriological quality of groundwater in some dug wells by Sudaryanto (1974) and Dewi Bujonowati (1980) show a relatively high number of coliform bacteria. Similarly, Sudarmadji (1991) found high number of coliform bacteria in some dug-wells in the study area (see Table3).

Table 2. Groundwater Quality from dug Wells in the Yogyakarta Municipality

Sample Numb	1	2	3	4	5	6	7	8	9
A. Physical :									
1. Total susp. soilds	251.0	210.7	276.0	195.1	325.0	162.0	113.8	307.0	123.0
2. Turbidity	2.0	5.0	2.0	4.0	2.0	0.50	21.0	1.0	34.0
3. Temperature	27.0	28.0	27.2	28.0	28.1	28.1	27.5	27.5	27.4
B. Chemical									
1. Mercury	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Arsen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Iron	0.10	0.17	0.06	0.00	0.00	0.00	1.70	0.06	0.32
4. Fluoride	0.33	0.18	0.24	0.32	0.42	0.30	0.32	0.24	0.47
5. Cadmium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6. Hardness	132.60	121.85	163.04	130.43	184.77	78.26	71.74	206.51	93.47
7. Chloride	8.03	11.05	15.06	9.04	20.08	5.02	2.01	29.12	2.01
8. Chromium hexavalent	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9. Mangan	0.04	0.40	0.12	0.175	0.05	0.075	0.175	0.00	0.02
10. Nitrate, as N	2.65	0.33	1.76	1.54	3.89	2.35	0.05	3.91	1.21
11. Nitrite, as N	0.005	0.001	0.012	0.000	0.002	0.001	0.00	0.014	0.033
12. pH	6.7	6.7	6.9	7.1	6.9	7.4	7.3	7.3	8.4
13. Zink	0.056	0.108	0.053	0.125	0.19	0.113	0.175	0.04	0.14
14. Cyaide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15. Sulphate	40.76	17.72	34.18	311.12	24.51	12.35	6.84	38.49	8.52
16. Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17. Detergent	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18. Org. matter ($KNnO_4$)	5.88	1.87	4.33	4.04	2.53	1.54	3.38	4.33	4.54

Note : all units used are in mg/1. exept temperature in degree celcius.
Source : Laboratory Analyses

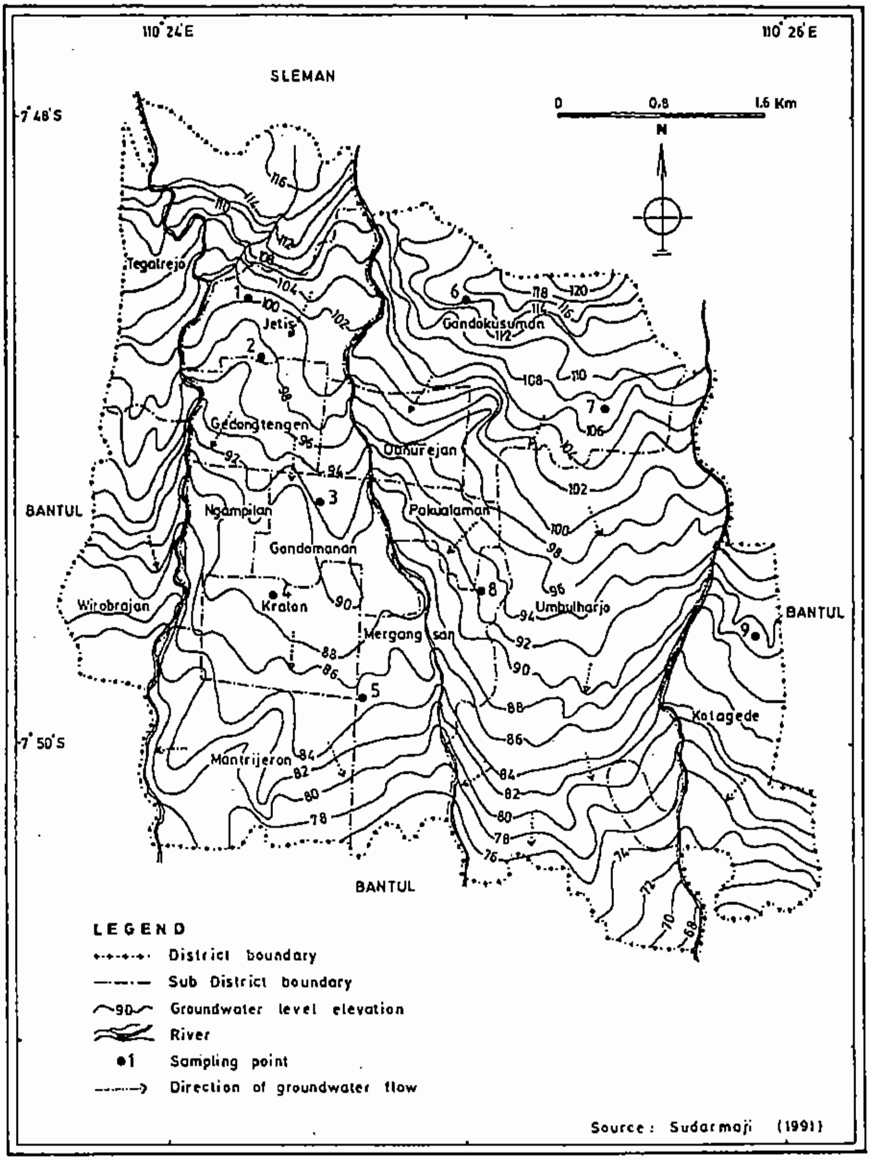

Fig. 2. Groundwater flow in the Yogyakarta Municipality

Table 3. Coliform Bacteria in Groundwater Detected from Some Dug-wells in the Study Area

Location of Dug Wells	Coliform Bacteria (MPN/100 ml)
Kricak Kidul, Tegalrejo	42
Kricak Jatimulyo, Tegalrejo	19
Kuncen, Wirobrajan	11
Patangpuluhan, Wirobrajan	4
Bugisan, Wirobrajan	11
Bluyahrejo, Jetis	3
Gowongan Kidul, Jetis	3
Gedongtengen, Gedongtengen	11
Kauman, Kraton	11
Dipowinatan, Mergangsan	7
Tamansiswa, Mergangsan	11
Pengok Kidul, Gondokusuman	11
Kompleks PJKA, Gondokusuman	44
Demangan Kidul, Gondukusuman	11
Gambiran, Umbulharjo	11
Glagah, Umbulharjo	7
Warungboto, Umbulharjo	11
Rejowinangun, Kotagede	11
Ndalem, Kotagede	4

Source: Sudarmadji, 1991.

Attention should be paid to the high bacteriological quality in some dug wells. The high bacteriological content indicates that faecal pollution has occured. Due to leakage of septic tanks, or the failure of the use of chespool in the area. The high transmisibility and high permeability of aquifer, which consists mainly of sand, the relatively high groundwater level gradient allow bacteria and other pollutants to travel in a relatively long distance from the source. Some parameters obtained from the analyses are higher than the drinking water standard adopted for the area, such as iron and bacteria.

CONCLUSION AND REMARK

1. Local Drinking Water Authority of Yogyakarta has expanded the operation by drilling new supply wells with 200 1/sec capacity, however water supply from the authority can only be consummed by 60% of Yogyakarta population. This means that groundwater is still an important domestic water supply for Yogyakarta Municipality. At the present groundwater is sufficient for domestic water supply, though some dug wells showed a declining groundwater level. In the text ten years the groundwater depth would be critical, which may affect pumping groundwater out from the wells.
2. Expansion of the area of Yogyakarta to the north of may reduce groundwater supply for Yogyakarta, due to the decrease of groundwater recharge to the aquifer, increase of abstraction of groundwater in the upper area and decrease infiltration of the area caused by the compaction (pavement) of the soils.

3. Chemical and biological pollution has to be recognised, as these may get worse in the future due to the rapid growth of settlement to the north and the rapid increase of number of the population which may exert the pollution. Some parameters shows a higher concentration than the drinking water standard.
4. To overcome the decrease of groundwater quantity and quality in the study area, artificial recharge of groundwater is recommended to maintain groundwater supply and to flush the pollution in the Yogyakarta Municipality. The artificial recharge structures could be dug-wells or pound to collect and allow rainwater enter into groundwater system.
5. The awarenes of the people to the environment have to be created and increased. Consequently, if people used groundwater for any purpose, they must use groundwater in a proper way and proper quantity. The use of groundwater for domestic has to be in the first priority.

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