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Hydrochemistry of Groundwater in Yogyakarta Graben, Area of Code Sub Drainage, Yogyakarta, Indonesia

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***Abstract*— Eruption of Mount Merapi in 2010 ago had an impact on the quality of surface water, but no clear effect on the groundwater. Code Sub-drainage Area is an affected area of the volcanic eruption, because the river is located on the slopes of Merapi and its upstream comes from the upper slope of the mountain. Groundwater flows in the area surrounding the River Code in south direction, with gradient flow smaller in the downstream direction. This flow pattern resembles the surface topography. Types of shallow groundwater chemistry is dominated by sodium calcium - bicarbonate water, consist of Ca-HCO_3; Ca-Cl,SO_4,HCO_3; Na,Ca-HCO_3 whereas the hydrochemistry types of deep groundwater is more varied (Na,Mg-Cl,HCO_3; Na,Ca,Mg-SO_4, HCO_3 and Na, Ca,Mg-HCO_3. Groundwater from the springs which were found has the type of Na,Mg - Cl,HCO_3. The hydrochemistry of groundwater is highly dependent on the Merapi volcanic rock aquifers, especially from Yogyakarta Formation and controlled by mixing and leaching hydrochemical processes.**

Keywords- hydrochemistry, groundwater, Code Sub-drainage Area.

I. INTRODUCTION

A. Background

The research areas included in Yogyakarta Groundwater Basin . This basin is limited by Quaternary volcanoes in the northern part, which is still very active. Code River has upstream area in the upper slopes of Merapi and it flows through the Yogyakarta city and surrounding areas. Groundwater in the area is of course also supported by the flow of water from the river.

Eruption of Mount Merapi in 2010 had an impact in many aspects of life, not least in terms of potential groundwater in the area of Yogyakarta. Code River is a river that divides the Yogyakarta city, where in its sub–drainage area, many people live and take much quantity of groundwater.

Some previous researchers have examined the quality of groundwater in the Yogyakarta Groundwater Basin, and found indications of pollution caused by household and industrial. Contamination of groundwater due to eruption of Merapi is less obvious. However, studies of groundwater quality remains an important part in understanding the potential of groundwater in the area which has quite densely population .

By knowing the type of groundwater chemistry, interpretation of hydrochemical process and indications of groundwater pollution in an area can be known. Type of groundwater chemistry are an indication of the various hydrochemical processes and travel duration of groundwater in rock formations in a groundwater basin. The dominance of the major cations and anions can be studied to see the evolution of chemistry and groundwater salinity.

B. Location

The research area is located in the Code Sub-drainage Area, covers an area of Sleman, Yogyakarta and Bantul Districts, Yogyakarta Province. This area is in the southern part of Java Island, Indonesia (Figure 1). Code Sub-drainage is part of the Opak Drainage Area , where the river flow into the South Sea (the Indian Ocean). Code Sub-drainage selected in this study because the river flows through a region with a large population , and the area affected by the eruption of Merapi (2010). This hydrogeology studies is related to groundwater quality after the eruption of Merapi (2010).

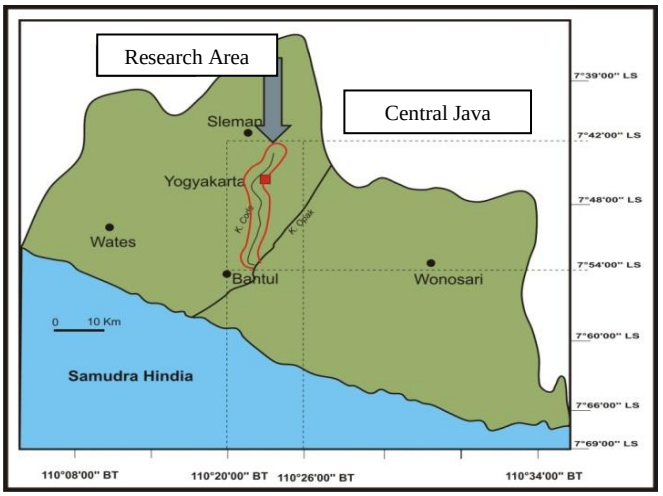

Figure 1. Research area is located at Code Sub-drainage Area, Yogyakarta Province, Java, Indonesia.

II. PURPOSE AND GOAL

Purpose of this study is to conduct hydrogeological survey in the field, equipped with a sampling of groundwater, both on shallow wells, springs encountered in the well. The goal is to conduct a chemical analysis of the water to see hydrochemical character of groundwater in the study area.

III. METHOD

Hydrogeological survey was preceded by previous literature review. After that, the geological observation has been carried out in the field. The equipment used is standard equipment field geologist (hammer, loupe, compass), hydrogeological field equipment (pH meter, TDS meter, measuring rope), equipped with a rock sample bag and sample bottles of water. The primary data of groundwater samples have been taken in 2012.

Description geomorphology, petrology and geology of the environment carried out especially in locations of outcrops. Description groundwater at several wells, randomized, accompanied by measurement of groundwater level, pH and TDS groundwater. Samples of groundwater taken from several shallow / deep wells and springs. Furthermore, groundwater samples tested in the laboratory of chemical / physical groundwater in Yogyakarta (BTKL/*Balai Teknologi Kesehatan Lingkungan*/Environmental Health Technology Office). Tests conducted on the physical properties of water (color, turbidity, taste, odor, turbidity) and the chemical composition of water. The test results of the chemical / physical groundwater is then analyzed to determine the hydrochemistry of groundwater in research areas.

IV. DISCUSSION

A. Aquifer Characteristic

The research area is included in Yogyakarta Groundwater Basin (Sir Mac Donald & Partners, 1984)[1]. Quaternary stratigraphy of this area is composed by young Merapi volcanic rocks that include two rock formations, namely the formation of Sleman and Yogyakarta Formation (Fig. 2). Rocks from both formations have become a free aquifer and semi confined aquifer in the study area.

Figure 2. Right: Old Merapi sediments (Sleman Formation) outcropped at research area (Ndalutung Village).
Left: Young Merapi sediments (Yogyakarta Formation) outcropped at riverbank of the middle part of Code (Sorosutan Village).

Warsono (1990) [2] said that aquifer group of Sleman and Yogyakarta formations is primarily semi unconfined. It appears that between Sleman Formation and Yogyakarta Formation are continuous rock, no clear impermeable barrier layer rock.

However, look at the position of Yogyakarta Formation located at the top, or near the soil surface, then aquifer formations formed is still possible in the form of free aquifer. This aquifer is characterized by the upper limit in the form of alluvial deposits which have almost the same aquifer permeability of Yogyakarta Formation. Due to impermeable boundary between Yogyakarta and Sleman Formations often does not exist, then both these formations are often merge into one group aquifer .

Groundwater generally flows to the south, through the Sleman and Yogyakarta Formation aquifers. Shallow groundwater aquifer is generally tapped from Yogyakarta Formation, while deep groundwater is taken from Sleman Formation. Catchment areas are in the northern part of the study area that is around the peak to the slopes of Merapi while discharge area is on own research area on the lower slopes to the foot of Mount Merapi .

B. Quality and Chemical Type of Groundwater

Secondary data were obtained from several previous researchers. MacDonald and Partners (1984, in Putra, 2011)[3] said that the inorganic chemistry quality of groundwater in Yogyakarta is very good for irrigation, drinking and industrial water. Springs have EC < 100 µS/cm, TDS < 70 mg/l. Geological boundary in the south, east and west have EC < 600 µS/cm, TDS < 500 mg/l . Nitrate content known as 0.00 to 2.8 mg/l .

Meanwhile, Sudharmaji (1991, in Putra, 2011) and Hendrayana (1993, in Putra, 2011) [3] said that the degradation of the quality of inorganic chemicals in the shallow groundwater associated with human activity in the late 80s and early 90s in the middle of Yogyakarta City. However , groundwater quality is generally good at the time, and only in a few places that have a nitrate concentration exceeded 10 mg/l. Nitrate content is generally 0.03 to 12.92 mg/l .

Based on the results of the groundwater quality testing, Sutriati *et al* (2011)[4] concluded that the quality of well water around river which has examined was not affected by the eruption of Mount Merapi. This groundwater usually has relatively good water quality and meet the Source Water Quality Standards. Results of water quality checks performed well in the field shows lava flows with Merapi volcanic ash does not significantly affect pH, DHL and dissolved oxygen .

Meanwhile, the primary data of shallow groundwater taken in this study are summarized in Table 1. The samples were taken from some population wells. Analysis of the data showed that the groundwater in the study area is generally show Na,Ca - HCO_3 type. High enough of nitrate concentration sample found on the CD-S4 .

Deep groundwater samples taken from three wells in the PDAM (Regional Company of Drinking Water) in Mlati and Tempel Sleman and Bantul PDAM wells (Table 2). Primary data of shallow and deep groundwater in Tables 1 and 2 then combined with secondary data obtained from the Geological Agency and PAB (Clean Water Agency) Yogyakarta. Analysis of the compilation of these data resulted in shallow

groundwater hydrochemical map as shown in Figure 3 as well as in the deep groundwater hydrochemical map (Fig. 4). From the map it appears that the type of shallow groundwater chemistry dominant form of calcium - sodium bicarbonate water, whereas deep groundwater chemical types are more varied.

Testing the physical / chemical properties of groundwater is also performed on samples derived from springs (see Table 2) . The analysis showed that the water has a type of Na, Mg - Cl , HCO_3. It is interesting to note in this regard is the significant presence of Cl. Indications of pollution may be seen from the content of Cl in this water .

TABLE I. TESTING RESULT OF PHYSICAL/CHEMICAL CHARACTERISTICS OF GROUNDWATER FROM SOME DUG WELLS.

Parameter	**Unit**	**Sample**				
		CD-S1	CD-S2	CD-S3	CD-S4	CD-S5
		Loc 2	*Loc 21*	*Loc 25*	*Loc 47*	*Loc 48*
Color	TCU	ttd	10	2	ttd	ttd
Turbidity	NTU	7	1	2	1	2
TSS	mg/l	2	1	9	12	8
Cl	mg/l	11	28	32,8	47,8	28
SO_4	mg/l	32	37	43	38	26
HCO_3	mg/l	204,4	62,17	384,3	362,9	244
Na	mg/l	10,58	10,82	94	116	60
K	mg/l	8	17	18	12	13
Ca	mg/l	41	73	45,57	46,57	35,02
Mg	mg/l	4,8	5	22	18,86	12,82
Fe	mg/l	0,376	<0.0098	<0.0230	<0.0230	<0.0230
Zn	mg/l	<0.0041	<0.0041	<0.0041	<0.0041	<0.0041
Mn	mg/l	0,1468	<0.0129	<0.0129	<0.0129	<0.0129
NO_3	mg/l	0,22	2,23	6,35	32,04	3,65
NH_3	mg/l	0,0146	0,008	0,0105	0,0053	0,0038
PO_4	mg/l	0,72	4,0859	0,9396	5,4908	1,1382
DO	mg/l	4,8	5	3,8	3,6	3,8
BOD	mg/l	4,3	2,3	4,1	4,5	3,9
COD	mg/l	16	12	16	16	16
pH				6,9	6,9	7
Chemical type		Ca- HCO_3	Ca- Cl, SO_4, HCO_3	Na, Ca, - HCO_3		

Chemical types of groundwater in the study area are variable. Putra (2011)[3] said that the water in this area has chemical types of HCO_3 - SO_4 , HCO_3 - NO_3 and NO_3 - HCO_3 - SO_4. In contrast to this researcher, the primary data in this study showed that the type of water chemistry is dominated by bicarbonate anion, consists of Ca - HCO_3; Ca - Cl,SO_4,HCO_3; Na,Ca - HCO_3 in wells and Na,Mg - Cl,HCO_3 on spring. Groundwater under study has the potential contamination which is low - medium (Listyani & Isjudarto, 2013)[5]. Type of groundwater chemistry is highly dependent on the aquifer Merapi volcanic rocks, especially from Yogyakarta Formation and influenced by some of the sources of pollution household or farm, for example in phosphate and nitrate .

TABLE II. TESTING RESULT OF PHYSICAL/CHEMICAL CHARACTERISTICS OF GROUNDWATER FROM SOME DEEP WELLS AND KADIPURO SPRING.

Parameter	**Unit**	**Deep groundwater sample**			**Spring sample**
		Sleman 1	*Sleman 2*	*Bantul*	*Kadipuro CD-M1 (Loc 52)*
Na	mg/l	187	67	80	119
K	mg/l	14	10	15	12
Mg	mg/l	36,33	14,48	21,81	33,92
Ca	mg/l	48,48	24,24	35,96	33,06
Cl	mg/l	131,4	11	35	94
HCO_3	mg/l	305	140,3	225,7	292,8
SO4	mg/l	65	46	41	75
Fe	mg/l	0,8659	1,1278	1,842	<0.0230
B	mg/l	tt	tt	tt	
Zn	mg/l	0,0168	<0,0022	0,006	<0.0041
Mn	mg/l	0,2457	0,1679	3,227	<0.0129
TDS	mg/l	511	187	278	
pH		7	6,7	6,7	7,6
Turbidity	NTU	5	7	47	2
Color	TCU	19	15	13	7
NO_3	mg/l	0,46	1,83	0,17	<0.05
NH_3	mg/l	0,0024	0,0012	0,002	0,0187
PO_4	mg/l	2,1133	0,576	4,223	1,0184
Chemical type		Na,Mg - Cl,HCO_3	Na,Ca,Mg - SO_4,HCO_3	Na,Ca,Mg - HCO_3	Na, Mg - Cl, HCO_3

Shallow groundwater in the study area has a type of bicarbonate anion chemistry, with a variety of cations Na, Ca and Mg which are dominant. Figure 3 shows the variation of the chemical type. In general, the dominance of Ca ions occur in the northern part of the study area, whereas further south, in line with groundwater flow, Na ion is increased. However , the bicarbonate ion remains the dominant anions in the groundwater.

Characteristics of chemical types of deep groundwater are more difficult to see about their development. Fig. 4 show that the type of hydrochemicals in the deep groundwater varies randomly. Groundwater with type of Ca,Mg - HCO_3 scattered in several places, in the west, east, north and south. The dominance of chloride ions appear in several locations, in the north until the middle part of the study area. It showed that groundwater evolution was also quite long although in the catchment areas at the north.

Shallow groundwater is generally not long ago fallen into the subsurface. The dominance of bicarbonate ions show that shallow groundwater is young age groundwater, with mixing as dominant hydrochemical process. Compared to shallow groundwater, the deep groundwater chemical types are more leads to the enrichment of anions sodium, supported by their

dominance of chloride ions in some places. This shows that the groundwater flow in the trip should be longer and farther. According to the tri linear diagram of Piper, the processes of mixing and leaching are much more common in the deep groundwater .

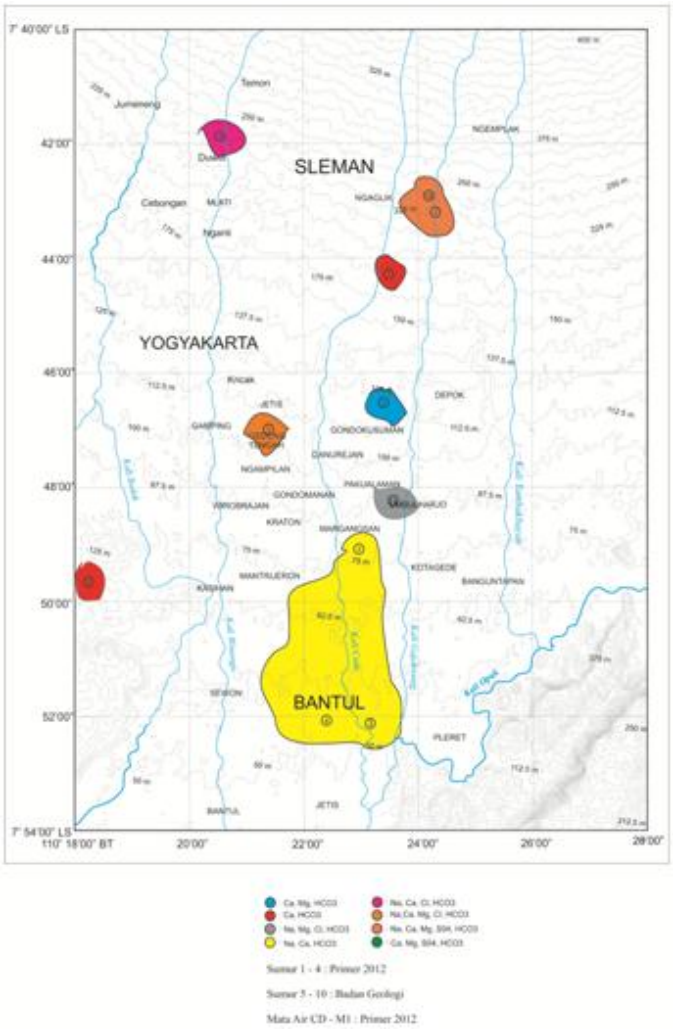

Figure 3. Hydrochemical map of shallow groundwater in research area.

V. CONCLUSION

Groundwater system in the study area is included in Yogyakarta Groundwater Basin. From the surface data is known that local hydrogeological study prepared by a group of Yogyakarta and Sleman Formations aquifer. Catchment areas are in the northern part of the study area that is around the peak to the slopes of Merapi while discharge areas is on own research area on the lower slopes to the foot of Mount Merapi. Type of shallow groundwater chemistry is dominated by sodium calcium - bicarbonate water, consists of Ca - HCO_3; Ca - Cl , SO_4, HCO_3; Na,Ca - HCO_3 whereas the type of chemistry of deep groundwater is more varied (Na,Mg - Cl,HCO_3 ; Na,Ca,Mg - SO_4, HCO_3 and Na,Ca,Mg - HCO_3. Groundwater from the spring which was found has the type of Na,Mg - Cl,HCO_3. Hydrochemistry types are highly dependent on the aquifer Merapi volcanic rocks, especially from Yogyakarta Formation through the process of mixing and leaching.

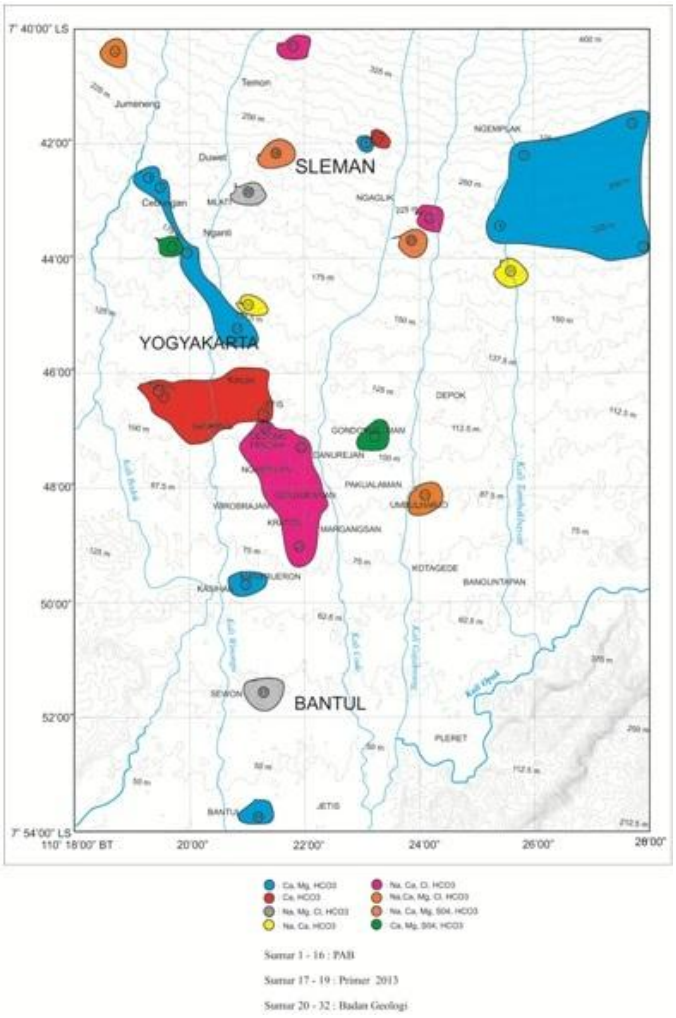

Figure 4. Hydrochemical map of deep groundwater in research area.

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