Groundwater quality mapping of Yogyakarta City, Sleman, Kulonprogo and Bantul regency area of Yogyakarta Province

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Abstract. The groundwater quality is equally important as that of quantity. GIS is a powerful tool for representation and analysis of spatial information related to water resources. To attempt this goal, samples were analyzed for various physico-chemical and bacterial parameters such as pH, Electrical Conductivity (EC), nitrate, Fe, E. coli, etc have been estimated for all the sampling locations. The spatial variation maps of these groundwater quality parameters were derived and integrated through GIS. An interpolation technique inverse distance weighting was used to obtain the spatial distribution of groundwater quality parameters. The final map classified the groundwater quality in the study area. The results of this research show that groundwater contamination are occurred and the development of the management strategies for the aquifer system is vitally necessary.

Keywords: GIS, Groundwater, physicochemical parameters, spatial interpolation.

1. Introduction

Since 1970, Yogyakarta has been experiencing high population growth, putting immense pressure on the city to provide safe water to all residents [1]. Most of the water that is used is derived from shallow aquifers underneath the ground, however, in recent years; it has become apparent that increasing population has led to water scarcity in this province due to lack of sufficient groundwater reserves.

Groundwater quality maps are important to understand the distribution of water quality and Geographic Information System (GIS) has been widely used in mapping of groundwater for various objectives [2,3,4. The water samples analysed were adapted from 68 locations randomly distributed in the study area of environmental department ministry of Environmental monitoring well of year 2016. Considering the above aspects of groundwater contamination and use of GIS in groundwater quality mapping, the present study was undertaken to map the groundwater quality in Yogyakarta City, Sleman, Kulonprogo and Bantul Regency area. This study aims to visualize the spatial variation of certain physicochemical parameters through GIS and also GIS is used to assess the
existing condition of groundwater quality and the contaminated areas can be identified for further monitoring and management [5,6]. Geostatistical interpolation techniques utilize the statistical properties of the measured points [4,13]. In the present study is based on the analysis of groundwater samples collected from different sources like open well, tube well, and water supplied by Agriculture land and drinking purpose.

Figure 1. Location Map of the Study Area

2. Methods

2.1. Data Collection

This study is utilizing primary and secondary data. Primary data was collected from 36 field sampling (July 2018) in the study area. Secondary data sources are from 68 well taken from monitoring report of ministry of environmental of Yogyakarta Province [7], shown in Table 1. The detail data evaluated for this study can be seen in Appendix 1. The physic properties like temperature, conductivity, E, pH and alkalinity are analyses in the sampling site. The latitude and longitude of the sampling stations are taken from the hand held GPS. These latitude and longitude are converted into shape files in ArcGIS 10.3 software. Its utilities are used to generating the maps and making spatial comparisons of data. The maps spatially integrated and the analytical results of hydrological parameters show the study area water quality.

Table 1. Groundwater Quality Data of Sleman, Bantul, Yogyakarta City and Kulonprogo Regency
| No | G6 | 110.15848 | SMA Negeri 1 Wates | 6.9 | 110.38551222 |
| G7 | 110.14671 | 7.89418899 | SMA Negeri 2 Wates | 7.3 | 144.0 150 0.4 0.17 1.01 0.0 192.1 0.5 1.6 0.0 |
| G8 | 110.38032 | 7.80518006 | Kantor Kecamatan Pakualaman | 6.7 | 165.0 333 0.4 0.03 0.14 0.0 231.0 0.4 17.4 494.0 |
| G9 | 110.39198 | 7.80108086 | Kantor Walikota Kota Yogyakarta | 7.1 | 110.0 219 0.3 0.04 0.12 0.0 152.0 0.3 8.7 17.0 |
| G10 | 110.36226 | 7.78315000 | Kantor Kecamatan Jetis | 7.1 | 163.0 130 1.4 0.02 0.22 0.1 230.0 0.5 18.6 0.0 |
| G11 | 110.35571 | 7.78298333 | Kantor Kecamatan Tegalrejo | 7.0 | 196.0 389 1.0 0.03 0.18 0.1 273.0 0.4 19.9 2.0 |
| G12 | 110.34801 | 7.8107556 | Kantor Kecamatan Wirobrajan | 7.1 | 196.0 394 0.8 0.02 0.24 0.1 276.0 0.4 17.8 0.0 |
| G13 | 110.35594 | 7.80624444 | Kantor Kecamatan Ngemplan | 7.0 | 264.0 521 0.3 0.06 0.28 0.1 25.4 0.5 29.0 17.0 |
| G14 | 110.36285 | 7.80596835 | Kantor Kecamatan Kraton | 7.2 | 194.0 392 0.6 0.03 0.10 0.1 15.2 0.4 24.1 590.0 |
| G15 | 110.32369 | 7.89100000 | Dinas Perindagkop Kab Bantul | 8.9 | 253.0 426 0.3 0.17 0.45 0.1 16.1 0.5 31.2 0.0 |
| G16 | 110.34758 | 7.90511167 | Dinas Lingkungan Hidup kab Bantul | 7.0 | 213.0 418 0.8 0.04 0.08 0.6 15.6 0.2 29.7 44.0 |
| G17 | 110.34578 | 7.8974806 | Dinas Pertanian Pangan Kelautan Perikanan Kab Bantul | 6.8 | 210.0 457 0.2 0.02 0.12 1.0 14.7 0.3 25.6 30.0 |
| G18 | 110.34843 | 7.90547056 | Dinas Kependudukan Bantul | 7.0 | 229.0 450 0.1 0.03 0.12 0.5 5.9 0.1 27.7 0.0 |
| G19 | 110.34966 | 7.90480000 | Dinas Kab. dan Pariwisata Kab Bantul | 7.4 | 223.0 446 0.6 0.02 0.11 0.6 15.7 0.1 36.8 0.0 |
| G20 | 110.34917 | 7.9047417 | Dinas Perhubungan Bantul | 8.9 | 225.0 395 0.4 0.03 0.01 0.3 39.6 0.3 53.2 0.0 |
| G21 | 110.34841 | 7.9042111 | Dinas Pertanian Pangan Kelautan dan Perikanan Kabupaten Bantul | 6.9 | 198.0 507 6.9 0.05 0.19 0.1 14.2 0.4 15.9 188.0 |
| G22 | 110.35747 | 7.7857194 | Badan Perpust & Arsip Daerah DIY | 6.9 | 258.0 515 0.3 0.02 0.12 0.1 42.1 0.5 32.1 78.0 |
| G23 | 110.40203 | 7.7980722 | Dinas Sosial DIY | 8.7 | 223.0 443 0.7 0.15 0.09 0.1 22.0 0.4 24.8 89.0 |
| G24 | 110.35529 | 7.7831278 | Dinas Keselamatan DIY | 8.7 | 167.0 339 1.0 0.04 0.13 0.1 6.4 0.4 20.3 89.0 |
| G25 | 110.35636 | 7.7820194 | Badan Kepegawaian Daerah DIY | 6.7 | 180.0 357 0.9 0.14 0.13 0.1 18.1 0.5 18.2 390.0 |
| G26 | 110.36574 | 7.7955972 | BAPPEDA DIY | 7.4 | 386.0 768 1.7 0.28 0.10 0.1 48.9 0.6 50.0 294.0 |
| G27 | 110.36940 | 7.7955806 | BLH Kota Yogyakarta | 6.6 | 166.0 329 1.1 0.11 0.18 0.1 24.7 0.5 18.3 55.0 |
| G28 | 110.38449 | 7.7985750 | Dinas Kebudayaan DIY | 7.0 | 249.0 504 1.1 0.07 0.23 0.1 19.6 0.5 52.3 494.0 |
| G29 | 110.37300 | 7.7943056 | Kantor Kecamatan Dumirejan | 7.3 | 219.0 438 8.8 0.02 0.38 0.1 23.0 0.5 28.1 8.0 |
| G30 | 110.36603 | 7.8030694 | Kantor Kecamatan Gondokusuman | 6.9 | 224.0 111 1.8 0.02 0.04 0.1 10.3 0.7 14.8 38.0 |
| No. | Value | Description                                      |
|-----|-------|--------------------------------------------------|
| G31| 110.38763 | 7.8097389 Kantor Camat Umbulharjo               |
| G32| 110.39534 | 7.8179333 Kantor Kecamatan Kotagede              |
| G33| 110.37322 | 7.8179833 Kantor Kecamatan Mergangsan           |
| G34| 110.36603 | 7.8030694 Kantor Kecamatan Kandomanan           |
| G35| 110.36163 | 7.8208306 Kantor Kecamatan Mantriyeron          |
| G36| 110.36245 | 7.7865750 Dinamik PUPR & ESDM DIY               |
| G37| 110.37462 | 7.7839861 Dinamik Pariwisata Kota Yogyakarta    |
| G38| 110.38548 | 7.7962000 Dinamik Pertanian DIY                 |
| G39| 110.39121 | 7.8021306 Dasar dan Hasil Desain               |
| G40| 110.41556 | 7.7779306 Dinamik Perubahan DI Yogyakarta       |
| G41| 110.43109 | 7.7680167 Diklat KKN PMI                        |
| G42| 110.48944 | 7.7621472 Puskesmas Prambanan                   |
| G43| 110.44774 | 7.7880833 Puskesmas Berbah                      |
| G44| 110.44935 | 7.7586556 Puskesmas Kalsalab                   |
| G45| 110.40816 | 7.7566500 Puskesmas Depok II                    |
| G46| 110.43139 | 7.7749750 Puskesmas Depok IV                    |
| G47| 110.36253 | 7.8426639 SMA Negeri 1 Sewon                   |
| G48| 110.33908 | 7.8941417 SMA N 2 Bantul                        |
| G49| 110.33843 | 7.8947250 SMP Negeri 1 Bantul                  |
| G50| 110.31694 | 7.9058899 Dinamik PUPK Pab Bantul              |
| G51| 110.31730 | 7.8895417 Dinamik Sumber Daya Air Bantul        |
| G52| 110.33777 | 7.7830667 Puskesmas Gamping 2                  |
| G53| 110.32026 | 7.8007194 Puskesmas Gamping 1                  |
| G54| 110.30381 | 7.7766333 Puskesmas Godean 2                   |
| G55| 110.29158 | 7.7639639 Puskesmas Godean 1                   |
| G56| 110.30101 | 7.7191972 Puskesmas Sayegan                   |
| G57| 110.25271 | 7.7765306 SMK Muhammadiyah 2 Mjadun            |
| G58| 110.07473 | 7.8864917 SMP 1 Temon                          |
| G59| 110.07280 | 7.8795278 SMA Negeri 1 Temon                   |
| G60| 110.16431 | 7.8584111 SMP Muhammadiyah 1 Wates             |
| G61| 110.16798 | 7.8476528 SMK Negeri 1 Pengasih               |
2.2. Groundwater Quality Map
The base map was georeferenced and digitized by using ArcGIS 10.3 software and exported to ArcView software for spatial analysis. Spatial interpolation technique through Inverse Distance Weighted (IDW) approach has been used in the present study to delineate the distribution of water pollutants. The Inverse Distance Weighted (IDW) referred to as deterministic interpolation methods because they assign values to locations based on the surrounding measured values and on specified mathematical formulas that determine the smoothness of the resulting surface. This method uses a defined or selected set of sample points for estimating the output grid cell value.

2.3. Statistical Analysis
Cluster analysis were conducted using the SPSS version 16 software.

### 3. Results and Discussion
#### 3.1. Spatial Distribution Pattern of Groundwater Quality
The spatial and the attribute database generated are integrated for the generation of spatial variation maps of major water quality parameters Ec, pH, and temperature. Based on these spatial variation maps of major water quality parameters, an Integrated Groundwater quality map of Yogyakarta was prepared using ArcGIS 10.3. This integrated Groundwater quality maps helps us to know the existing groundwater condition of the study area. Electrical conductivity is the ability of a substance to conduct an electrical current, measured in microsiemens per centimeter (mS/cm). Ions such as sodium, potassium, chloride give water its ability to conduct electricity. Conductivity is an indicator of the amount of dissolved salts in a stream often is used to estimate the amount of total dissolved solids (TDS) rather than measuring each dissolved constituent separately. The range of electrical conductivity (EC) in the area is 110 to 1414 (Figure 2). pH is one of the important parameters of water and determines the acidic and alkaline nature of water. The pH of the good quality water ranges from 7.5 to 7.9. The pH of the samples was well within the prescribed standards for drinking water. The spatial variation map for pH was prepared and presented the pH of analysed sample varies from 6.1 to 6.4 (Figure 3). In this study, nitrate concentration in the groundwater is not exceeding the drinking water standard of 10 mg/L, except for 2 locations in Umbulharjo and Kotagede regency which shows the value of 12 mg/L (Figure 4). Umbulharjo region and Kotagede area was an agriculture and is a home industry area with high population density, respectively. Moreover, these area have shallow groundwater table of 3-5 m depth so it prones to contaminated by infiltrated anthropogenic pollutant sources. The mineral constituents that dissolved in water is a dissolved solids. The value of dissolved solids in natural water is usually < 500 mg/L. If it higher than than 500 mg/L is undesirable for drinking. TDS value was high because of the presence of sulphates (Figure 7), chlorides (Figure 8), bicarbonates, carbonates and calcium [8]. It can be removed by several techniques, such as: electro dialysis, RO (Reverse Osmosis) and distillation. It consist a wide variety of DOC constituent in various amounts because of the surface & subsurface water movement. Basically, it is based on concentration of NaCl, which in turn determine the

| Sample ID | Latitude  | Longitude | Ec (mS/cm) | pH | Temperature (°C) |
|-----------|-----------|-----------|------------|----|------------------|
| G62       | 110.16809 | -7.8437944| 7.3        | 368.0 | 315.0            |
| G63       | 110.17747 | -7.8538927| 7.2        | 406.0 | 326.0            |
| G64       | 110.36286 | -7.7544096| 6.6        | 191.5 | 429.0            |
| G65       | 110.32826 | -7.7326000| 7.0        | 151.0 | 432.0            |
| G66       | 110.32713 | -7.6582417| 6.6        | 805.0 | 467.0            |
| G67       | 110.28806 | -7.7006861| 6.8        | 170.5 | 479.0            |
| G68       | 110.37974 | -7.6539222| 7.2        | 102.9 | 590.0            |

Source: [7]
conductivity which has influenced on TDS. In the study area, it ranges between 102.9 to 805.5 mg/L (Figure 5). Fecal coliform may indicate contamination by human sewage or animal feces that could contain bacteria, viruses or organism that caused disease. People who is exposed to water with coliform contamination may exhibit diarrhea, fever and abdominal cramp, hepatitis or chest pain [9]. The study shows 64.7% of the total groundwater points is contaminated by fecal coliform (Figure 6). The Fe value in the study area is ranging from 0.003 to 0.3 mg/L (Figure 9). 11.78% of total groundwater points exceeds the standard value of 0.2 mg/L set to the drinking water. The lowest Fe concentration might appear in recharge areas and highest in discharge areas [10]. The study show that 61.7% of wells have manganese concentration higher than the Indonesian standard of drinking water 0.1 mg/L[12], while WHO-health based guideline of 0.05 mg/L [11]. It ranges from 0.02 to 1.22 mg/L (Figure 10). For Zn concentration, only one point exceed the drinking water standard of 5 mg/L with 13.24 mg/L. The minimum and maximum of Zn concentration is 0.014 and 0.97 mg/L, respectively, while distribution map is shown Figure 11. Fluoride (F) is ranging from 0.099 to 0.81 (Figure 12) which belows the drinking water standard of 1.5 mg/L.
Fig 6. Spatial distribution of Fecal Coliform

Fig 7. Spatial distribution of SO4

Fig 8. Spatial distribution of Cl

Fig 9. Spatial distribution of Fe

Fig 10. Spatial distribution of Mn

Fig 11. Spatial distribution Zn
3.2. Cluster Analysis of Groundwater Quality

There was an interesting finding where there is an increase of pH from 2016 to 2018 (Fig 13). The cluster analysis result was presented in dendogram using average linkage (between group). It groups 3 (three) cluster of sampling locations based on its groundwater quality characteristics (Table 2). Cluster1 group of sampling points has high biological contamination which evident by high fecal coli bacteria in the groundwater. Sampling points of 37 and 43 both have the most similar groundwater physicochemical and biological parameter. Meanwhile, sampling point nr.7 has very different groundwater quality among other sampling points. TDS and EC are three times higher than average all samples, respectively. While, chloride and sulfate are five times and eighteen times higher than average all samples, respectively.

Table 2. Average values of groundwater quality parameters of 3 (three) cluster

| Cluster | Sample Nr. | Average values |
|---------|------------|----------------|
|         | pH | TDS | EC | NO3 | Fe | Mn | Zn | Cl  | F  | SO4 | Fecal Coli |
| 1       | 1-6, 8-36, 38-42, and 44-68 | 6.94 | 237.72 | 431.34 | 1.27 | 0.06 | 0.23 | 0.09 | 35.98 | 0.42 | 26.20 | 163.20 |
| 2       | 37 dan 43 | 6.95 | 199.80 | 375.50 | 0.30 | 0.17 | 0.24 | 0.00 | 21.20 | 0.45 | 138.85 | 1.00 |
| 3       | 7    | 7.30 | 744.00 | 150.00 | 0.40 | 0.17 | 1.00 | 0.00 | 192.1 | 0.50 | 1.60 | 0.00 |
| Total Samples | 7 | 244.05 | 425.56 | 1.23 | 0.06 | 0.24 | 0.09 | 37.84 | 0.42 | 29.15 | 155.93 |
4. Conclusion

Groundwater is the primary sources of potable water in Yogyakarta province. It provides freshwater for domestic, agriculture, and industrial purpose. However, the pressure on groundwater is increasing, because of the high economic development and population growth. Moreover, large amount of ground water extraction has cause ground water pollution. Among these problems ground water survival. Therefore the identification, assessment and remediation of ground water pollution should be taken into serious consideration. In this present study the ground water of Sleman, Bantul, Yogyakarta City and Kulonprogo Regency for the year 2016 has been evaluated. The spatial distribution analysis of groundwater quality in the study area indicated that many of the samples collected are not satisfying the drinking water quality standards prescribed by the WHO and Indonesian Standard.

Cluster analysis result Further study needs to be conducted to make an effective groundwater quality management system and plans for the protection of quality of groundwater. Also, continuous monitoring and necessary groundwater quality improvement methodologies implementation is a must.

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