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Spatial Autocorrelation of Inorganic Compound in Groundwater

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Abstract: *The water quality at a location is influenced other locations. Characteristics of groundwater quality in some locations were spatially auto correlated. Such as in Jakarta, Indonesia, if the water source in one location is polluted so can lead to polluted water sources at a different location which close together. This research was analyzing the content of inorganic compounds in Jakarta, Indonesia. The analysis was performed using spatial methods to obtain the relationship among locations of ground water quality. The samples were ten locations in East, West, Central, North, and South Jakarta. Spatial methods conclude that there were spatial autocorrelation in inorganic compounds of groundwater in Jakarta, specifically in Cadmium (Cd). Moran's I test shows that there are dependencies of Cd among 10 samples at α = 10%. Meanwhile, Mn, CN, Cr, and Pb haven't dependencies. By LISA test, there were the first sample in West Jakarta and seventh sample in East Jakarta which significant affects with other location at α = 5%. P value in area west, north, and east of Jakarta were lower than others. So, the samples in these areas have dependencies than in south area.*
Keywords: *Inorganic Compound, Spatial Autocorrelation, Moran's I, LISA*

I. Introduction

Water quality in accordance with the requirements of health is important in improving the quality of life. Ministry of Health [1] states that one of the Indonesia health indicators which are still difficult to achieve was an increase in the percentage of population with access to drinking water quality. Achievement in 2011 is 42.76%, while the target is 68% in 2014. Furthermore, the [2] states that statistics bureau have found a number of 47.71% of households have access to safe drinking water. Following that in 2010 and 2011 fell to 44.19 percent and 42.52%. Meanwhile in Jakarta in 2010, there is 87% of households get drinking water quality. Research from [3] also shows that Cadmium (Cd) and Manganese (Mn) of ground water in Jakarta, Tangerang, and Bekasi, Indonesia were higher than the values recommended by PAK-EPA and WHO or the standard of Indonesian Ministry of Health.

Information from [4] states that 82% of the source water in Jakarta, Indonesia were supported by Jatiluhur reservoir. Meanwhile ammoniac of these reservoir are relatively high due to contaminate. This causes the supply of raw water to the Greater Jakarta increasingly polluted. This indicates that the water quality at a location is influenced other locations. Characteristics of groundwater quality in some locations were spatially auto correlated. This is shown by the dependency among locations of the water quality. If one of the locations has polluted groundwater adjacent the other locations will also be contaminated as well. This is in accordance with the first law of geography proposed by Tobler.

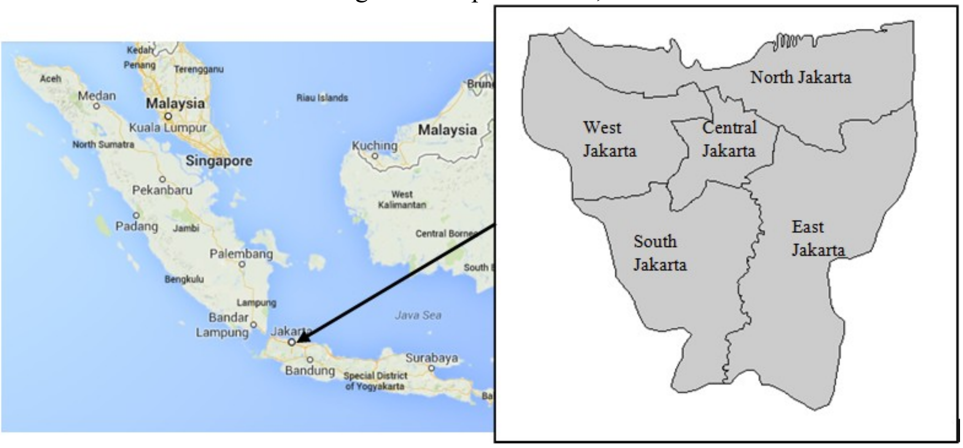
To illustrate the pattern of the relationship between water qualities among locations can use the spatial method, the spatial autocorrelation. Some testing in the spatial autocorrelation is Moran's I, Geary's ratio, and the Local Indicator of Spatial Autocorrelation (LISA) [5]. The research about spatial autocorrelation conducted by [6] about the Moran's I for the identification and mapping patterns of relationships poverty in East Java. Furthermore, [7] in analyzing the factors that influence the incidence of diarrhea in Tuban, East Java. Spatial autocorrelation also can be perform by mapping, such as [8], [9], and [10].

Based on the analysis of inorganic substances that have been done previously, the study aims to analyze the content of inorganic compounds in Jakarta, Indonesia. The analysis is performed using spatial methods to obtain the relationship among locations of ground water quality.

II. Methodology

The samples were obtained from research of Tanty, Bekti, Herlina, and Nurlelasari (2014), specifically in Jakarta, Indonesia. The total samples were 10 locations in 5 regions of Jakarta: West Jakarta, North Jakarta, East Jakarta, South Jakarta, and Central Jakarta (see Figure 1). Jakarta region is in 5° 19' 12" - 6° 23' 54" south latitude and 106° 22' 42" - 106° 58' 18" east longitude. Testing of inorganic compound was done in laboratory of Padjadjaran University. There inorganic compound consist of Manganese (Mn), Chrome (Cr), Cyanide (CN), Lead (Pb) and Cadmium (Cd).

Figure 1. Map of Jakarta, Indonesia



Data analysis consists of spatial dependency (autocorrelation) test: Moran's I and local indicator of spatial autocorrelation (LISA). Spatial dependency test consist of Moran's I test which use to perform autocorrelation between observations or location. The hypothesis test for Moran's I is no autocorrelation as null hypothesis and the statistics test is in (1). *Var (I)* is the variance of Moran's I and E (I) is the expected value. Reject null hypothesis if $Z_{test} > Z_{\alpha/2}$ (or P value < α.) and there is a spatial autocorrelation.

$$Z_{test} = \frac{I - I_o}{\sqrt{\text{var}(I)}} \quad (1)$$

LISA test used to identify locally autocorrelation coefficients or spatial correlation in each locations. The formula autocorrelation for i location is (2).

$$\mathbf{I}_i = z_i \sum_{\text{i}=1}^{\text{n}} w_{\text{ij}} z_{\text{j}} \quad (2)$$

z_i is the standardize data and w_{ij} is weighted matrix between i and j location. The null hypothesis is no autocorrelation among location i and its neighbors. The statistics test is in (3). Reject null hypothesis if $Z_{test} > Z_{\alpha/2}$ or P value < α.

$$Z_{test} = \frac{I_i - I_o}{\sqrt{\text{var}(I_i)}} \quad (3)$$

III. Results and discussion

Jakarta has a population density of 15,085.82 people/km^2. The condition is very dense population of this course will be directly proportional to the amount of septic tank located in Jakarta. Statistics bureau shows that almost all areas of Jakarta has experienced water pollution, especially East Jakarta, West and North that are in addition to the dense population. There are 49 of 267 villages which have water pollution. Generally, it because people and industry activities. Because that water pollution, so the main water source is from bottled water and PDAM.

Distribution patterns of inorganic compounds in ground water are presented in Figure 1. On the water content of Manganese (Mn), an area that has high levels of Mn was in the South Jakarta, which is up to 3.5 mg/l. Furthermore, the low rate was spreads in all areas of Jakarta. Average Mn was 1.600 mg/l (see Table 1). Regulation of the Minister of Health no. 492/Menkes/IV/2010 stated that standard value of Mn is 0.5 mg/l. Based on this, it can be concluded that the Mn does not meet water quality standards, as all samples are worth more than 0.5 mg/l.

Meanwhile the levels of Cyanide (CN), regions with high levels CN was in Central Jakarta, a few in East Jakarta, North Jakarta and West Jakarta. This shows that a pattern of CN was higher when getting to the center. However, based on the requirement of drinking water quality standards are 0.07 mg/l, then CN in Jakarta still meet water quality standards. Locations which have high Chrome (Cr) were South and Central Jakarta. A lead (Pb) level was high in Central Jakarta. As well as CN, Cr and Pb levels are also still meet water quality standards.

As the levels of Mn, all the samples still had higher levels of Cadmium (Cd) which is above standards. The highest levels were in the West and East Jakarta. While, there are the lowest around Central Jakarta, as in North Jakarta, South Jakarta, West Jakarta and close to the Center. This suggests that the pattern is smaller toward the center.

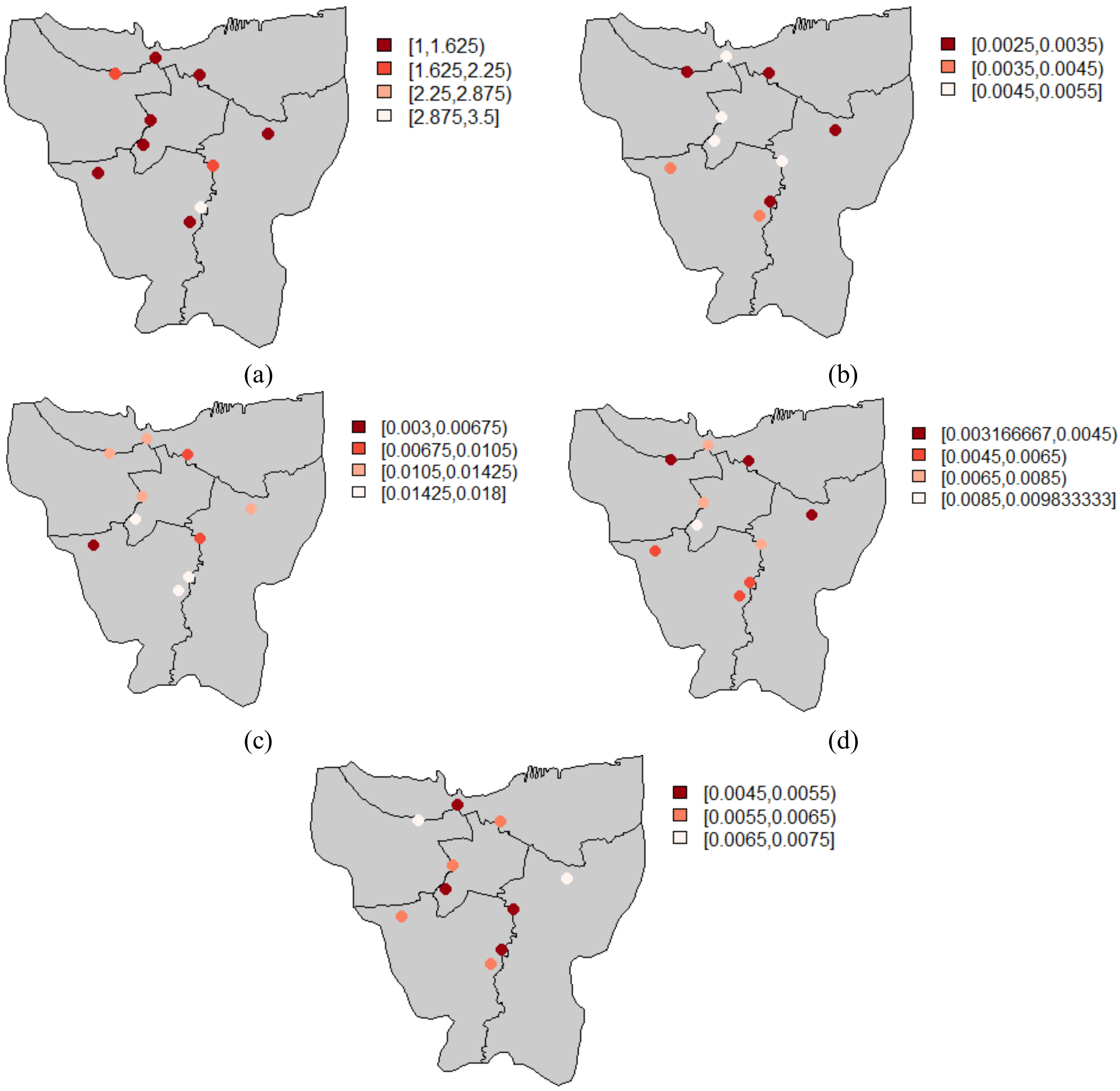


Figure 2. Pattern of Inorganic Compound in Groundwater Jakarta, a) Mn, b) CN, c) Cr, d) Pb, e) Cd

Table 1. Characteristics and Standard Quality of Inorganic Compounds

Characteristics	Mn	CN	Cr	Pb	Cd
N	10	10	10	10	10
Mean (mg/l)	1.6100	0.0040	0.0120	0.0060	0.0058
Standard Deviation	0.7187	0.0009	0.0045	0.0020	0.0008
Minimum (mg/l)	1.0000	0.0030	0.0030	0.0040	0.0050
Maximum (mg/l)	3.5000	0.0050	0.0180	0.0090	0.0070
Standard quality	**0,5**	**0,07**	**0,05**	**0,01**	**0,003**

Autocorrelation test by Moran's I

This test aims to determine the spatial dependency or autocorrelation about inorganic compounds of groundwater (Mn, CN, Cr, Pb, and Cd) among samples or locations in Jakarta. The type of weighting used is standardizing matrix. The location of the sample with a distance between 0^o to $0,13^o$ was code to 1. The distance was calculated by Euclidean distance. Hypotheses used are:

Ho: $\mathbf{I} = 0$ (no dependencies among inorganic compounds)

H_1: $\mathbf{I} \neq 0$ (dependencies among inorganic compounds)

Table 2. Moran's I Test of Inorganic Compounds

Inorganic Compounds	I	P value
Mn	**-0.117**	**0.870**
CN	**-0.172**	**0.336**
Cr	**-0.130**	**0.733**
Pb	**-0.178**	**0.280**
Cd	**-0.217**	**0.079**

The results can be seen on Table 1. By α = 10%, Cd has P value 0.079 which less than 10%. Then the conclusion is there are dependencies of Cd among 10 samples. Cd in one sample was influenced or affect with other samples. This conclusion is appropriate with the pattern in Figure 1(e). Cd was getting smaller towards to center. Moran's I coefficient is -0.217. It shows that there is negative autocorrelation between locations (or samples). Locations that have low Cd has neighboring with locations that have high Cd. Otherwise, locations that have high Cd has neighboring with locations that have low Cd.

Autocorrelation test by LISA

The next test is also conducted at each location dependencies using Local Indicator of Spatial Autocorrelation (LISA), especially for Cd. The result in Table 3 shows that there are two samples which significant affects with other location. There were the first sample in West Jakarta and seventh sample in East Jakarta. This is indicated by the P value which is less than α = 5%. Significant means that the presence of spatial autocorrelation on the location of the nearest sample. Such as the first sample with Cd 0.007 is relatively larger than the others. This sample was affects in the nearest samples. The results of LISA test also can be map in Figure 3. The P value in area west, north, and east of Jakarta were lower than others. In south area, the P value was higher than others. So, it can be conclude that samples in west, north, and east area more have dependencies than in south area.

Table 3. LISA Test of Inorganic Compounds

Sample	Locations	Latitude	Longitude	Cd	Ii	Zi	Pvalue
1	West Jakarta	-6.145392	106.782909	0.007	-0.64286	-2.07534	0.038*
2	South Jakarta	-6.229456	106.768001	0.006	-0.0625	0.312134	0.755
3	North Jakarta	-6.146263	106.854466	0.006	-0.00794	1.008996	0.313
4	East Jakarta	-6.222646	106.865716	0.005	-0.12698	-0.15523	0.877
5	Central Jakarta	-6.205858	106.806651	0.005	-0.12698	-0.15523	0.877
6	West Jakarta	-6.184274	106.812615	0.006	-0.00794	1.008996	0.313
7	East Jakarta	-6.196331	106.912183	0.007	-0.79592	-3.34171	0.000*
8	South Jakarta	-6.271095	106.846428	0.006	-0.03061	0.392817	0.694
9	North Jakarta	-6.131378	106.81672	0.005	-0.28571	-0.85203	0.394
10	South Jakarta	-6.257913	106.855645	0.005	-0.08163	0.143849	0.887

Note : *) significant at α=5%.

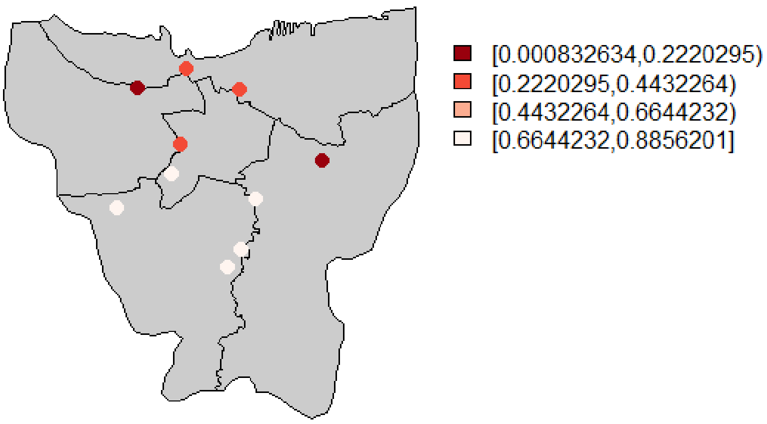


Figure 3. Mapping of LISA Test (P value) Cd in Jakarta

IV. Conclusion

Spatial methods in this research conclude that there are spatial autocorrelation in inorganic compounds of groundwater in Jakarta, specifically in Cadmium (Cd). Moran's I test shows that there are dependencies of Cd among 10 samples. Meanwhile, Mn, CN, Cr, and Pb haven't dependencies. Cd in one sample was influenced or affect with other samples. Cd was getting smaller towards to center. By LISA test, there were the first sample in

West Jakarta and seventh sample in East Jakarta which significant affects with other location at $\alpha = 5\%$. The P value in area west, north, and east of Jakarta were lower than others. In south area, the P value was higher than others. So, the samples in west, north, and east area more have dependencies than in south area.

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