Water quality assessment for self-sufficient water resources for DKI Jakarta

by Ramadhani Yanidar

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Abstract. DKI Jakarta, Indonesia (106.22'42" S and 106.58'18"E) is passed by the 13 major rivers. However, only Krukut River, in South Jakarta has contributed 5.7% for supply the 60,27% coverage service of the10.178 million populations (2015). This paper is preliminary research to find the potential water resources for self-sufficient water supply. This study used multivariate analyzed of Factor Analyzed (FA) and Cluster Analysis (CA) for the archive river water quality data set covers the period from 2010 to 2015 from the Environment Department of DKI Jakarta. They selected the main pollution parameter and the potential raw water resources which necessary to study severely. The FA identified the two groups of water quality variables, which explain majority of the experimental data, and resulted organic pollutant as main factor that influenced DKI Jakarta river water quality. Therefore, BOD and COD used as main parameter for water quality further assessment. CA grouped 43 sampling sites into four clusters. 5 sampling locations on 4 rivers need further study for additional raw water sources.
Keywords: BOD, COD, cluster analysis, factor analysis, self-sufficient, water resources

1. Introduction

Jakarta is the capital of Indonesia which is a metropolitan city with 10.178 million populations of 2015. A River as a water resource is one of the natural resources which has a multipurpose function for human life and livelihood. Even though, Jakarta has 13 rivers in its administrative area, but there are no water resources meet the standard of raw water quality. However, only Krukut River, in South Jakarta has contributed 5.7% supply for the 60.27% coverage service of the 10.178 million DKI Jakarta's populations (2015). It needs to search a new raw water sources that can meet the standard raw water quality for additional production capacity to reach 100% coverage service water supply area by 2030 as National and SDGs goal. This paper is preliminary research to find the potential rivers that cross through Jakarta can be utilized as water resources for self-sufficient water supply in DKI Jakarta.

The river water has been contaminated because of the waste water discharge containing degradable organics, nutrients, domestic effluent, and agricultural waste [1]. The quality of surface water is threatened by a variety of pollutants from both natural such as precipitation inputs and erosion, and from anthropogenic sources [2], [3], [4].

Factor Analysis (FA) and Cluster Analysis (CA) technique as a multivariate analysis [5]. General Purposes of FA technique is to summarize the information contained in several original variables of a

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complex data set into new smaller data, with minimum loss information. CA is a reduction statistical method commonly used to classify objects into groups according to their similarity (nearness).

A river's water quality is combination of several interrelated compounds, which are subjected to local and temporal variations and affected by water flow quantity. In the last years, factor analysis (FA) and cluster analysis (CA) as a multivariate techniques, have been widely applied to facilitate in various surface water quality studies, including assessment the analysis of complex datasets to better understand the temporal and spatial characteristic of surface water quality [1], [4], [6], [7], [8], [9], [10]. The aim for this study was selected the main pollution parameter and the potential raw water resources which necessary to study conscientiously to find raw water resources for self-sufficient water supply in DKI Jakarta.

2. Research Method

2.1. Study Site and Collection of Water Quality Data

The DKI Jakarta extends from longitude 106.22'42" E to 106.58'18" E and latitude 5.19'12" S and 6.23'54" S. It is located about 7 m above mean sea level, covering an area of about 7,659.02 km^2. There are water quality monitoring data which consist of 85 sampling location of 19 Rivers published in the Regional Environment Status Book (SLHD) of The Environment Department of DKI Jakarta (*Dinas Lingkungan Hidup DKI Jakarta*) annually. In this research, the selection of physical and chemical of archive water quality data set was conducted. The 43 sampling locations of 11 rivers which allocation as B class for raw water and C class for fishery were chosen, as follows: Ciliwung, Kali Baru, Angke, Krukut, Mampang, Cengkareng, Grogol, Sepak, Pesanggrahan, Mookevart and Tarum Barat river (

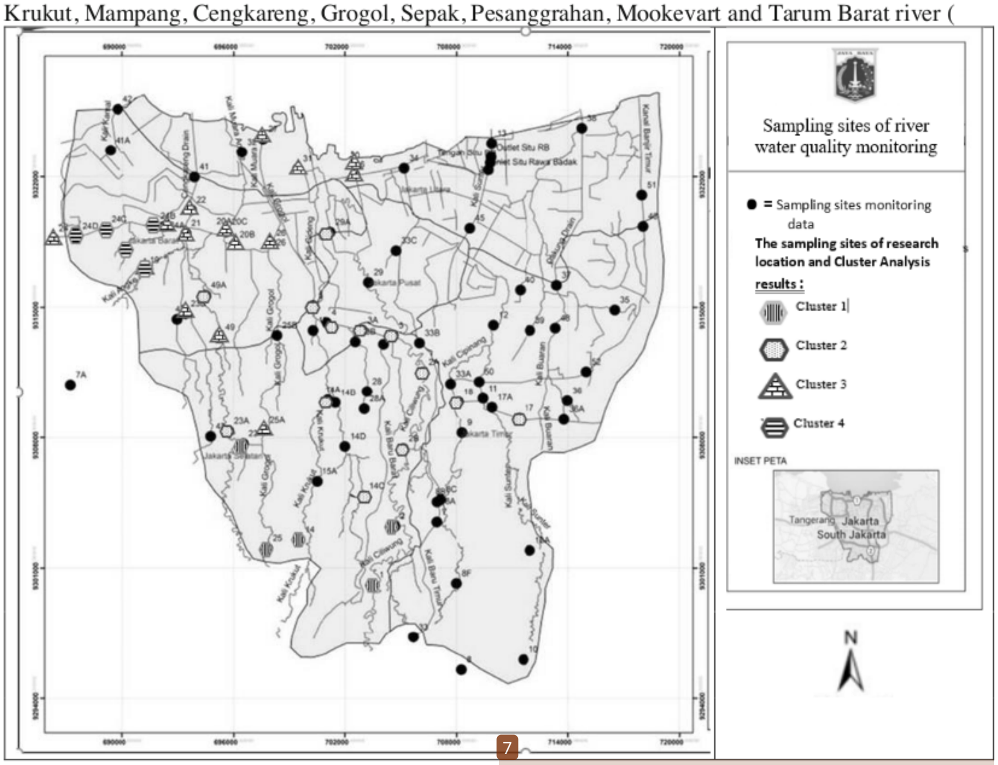

Figure). The archive data set comprise nine (9) water quality variables: Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solid (TDS), Suspended Solids (SS), and pH, Total Phosphor (TP), Ammonia (NH3) and Nitrite (NO2) which cover the period from 2011 to 2015 [11].

2.2. *Data Treatment and Statistical Analysis*

The data processing and multivariate statistical analysis used SPSS (ver. 23.0) with the following steps:

1) The z-scale transformation was applied to standardize the water quality data which expressed in different magnitudes and units.
2) The One-way ANOVA was used to analyze the significant seasonal differences in water quality.
3) The Bartlett's Test of Sphericity and Kaiser-Meyer-Olkin (KMO) was applied for Factor Analysis (FA) recommendation. It was used to explain the significance of the study and thereby illustrate the validity and suitability of the parameters being addressed through the FA. The FA identified the two groups principal component of water quality variables, which explain majority of the experimental data. The first VF, which indicated the most important parameters.
4) The Ward's method of hierarchical agglomerative Cluster Analysis (CA) was carried out to ascertain the multivariate similarity (the parameters were obtained from FA) between different sampling locations. the similarities and dissimilarities are quantified through Euclidean distance measurement and a dendrogram was the output of this CA process.

3. Results and Discussion

Before z-scale transformation, homogeneity of variances test results showed 2 of the variables i.e. TSS and NO_2 parameters were not homogeny and normally distributed, so the research variables which were choosen only BOD, COD, DO, pH, Total Phosphor, TDS and SS. Statistical descriptive for physicochemical characteristics recorded of the selected parameters for water samples in wet and dry seasons is presented in Table 1. Almost all parameters have average concentration exceed the raw water quality standard (class II), consequently, it needs further study to get the river water to meet the standard raw water quality. The mean values of BOD, COD, DO, pH, Total Phosphor, TDS and SS showed that they were not significantly difference between rainy season and dry seasons ($p < 0.05$). Only TP parameters in dry season was significantly higher than rainy season. This could be caused climate change effect that made the rainy and dry seasons cannot be ascertained.

Table 1. Statistical descriptive for physicochemical characteristics recorded in rainy and dry seasons.

Parameter	Units	Dry Season	Wet Season	F	p	Standar Class II	Standar Class III
Biological Oxygen Demand (BOD)	mg/L	22.98 ± 21.04	19.83 ± 13.00	0.698	0.406	3	6
Chemical Oxygen Demand (COD)	mg/L	76.97 ± 52.91	74.82 ± 48.01	0.039	0.844	50	100
Dissolved Oxygen (DO)	mg/L	2.71 ± 0.98	2.61± 0.68	0.401	0.528	4	3
Total Dissolved Solids (TDS)	mg/L	393.69 ± 519.28	428.84 ± 635.09	0.078	0.781	1000	1000
pH		7.19 ± 0.16	7.17 ± 0.19	0.751	0.389	6-9	6-9
Total Phosphorus (TP)	mg/L	1.43 ± 2.56	0.59 ± 0.47	4.423	0.038	0.2	1.0
Ammonia (NH3)	mg/L	8.19 ± 12.94	5.54 ± 6.34	1.450	0.232	-	-

The KMO value is 0.704 and the p-value is 0.000 (<0.05), the value falls in the "*more than enough*" category worthy for the benefit of factor analysis. The FA results corresponding vary factors (VFs) and factor loadings can be seen on Table 2. The two principal components with eigenvalues larger than 1 were retained, which explained almost 75.6% of the total variance in water quality data. The first principal component accounted for 50.34% of the total variance, whereas the other principal components accounted for variances of 25.2%, respectively.

The first VF which the most important parameters has 50.34% strong positive loading on BOD and COD and strong negative loading on DO. Thus, all information about 7 variables pollutant in the original on the 43 monitoring stations collected can be performed in the reduced space by 3 variables. It results organic compound (BOD and COD) as main factor that influenced DKI Jakarta river water quality. The decomposition of the organic pollutant reduced DO levels [12]. The presence of organic compound in water under normal conditions was indicated from BOD_5, COD concentration, then, the organic compound degradation consumed oxygen caused the very low available DO in water (Figure 1).

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The second VF has 25.2% strong positive loadings on NH3, TP, pH and moderate TDS. Ammonia and phosphate are natural parameters which accumulates easily in aquatic systems because it is a natural byproduct of organism's metabolism, but in the other hand, an indication that the system is out of balance when the presence of ammonia. The pH correlate positively with TDS, TP and NH3, but correlate negatively with DO in component (FVs) 1. Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances present in a liquid. Inorganic materials of ions commonly found in a river water. This may be the reason why they showed the strong positive loading in VF2 but they were not as main factors and support the BOD and COD concentrations. It reflected as natural rivers that was influenced by domestic pollutant activities.

The BOD, COD and DO concentration of each clusters are described on boxplot in Figure 2. It appears that cluster 1 has the lowest BOD and COD values and the highest DO value with small variance. The average BOD of Cluster 1 was 6.42–9.67 mg/L, and COD showed a range of 33.34–39.02 mg/L, and DO 3.63 – 4.23 mg/L. Cluster 2,3 and 4 the BOD and COD concentrations increase, but DO concentrations decrease. The results of this study indicate that the clusters were classified according to the characteristics of pollution sources in the locality or the water quality pollution level of the river [7].

The dendrogram of sampling sites obtained by Ward's method is shown in Figure 3 to analyse the similarities of water quality variation tendencies between the monitoring sites. CA made 43 sampling stations to be grouped into four main clusters. The Cluster 1 indicate 5 locations in 4 river i.e sampling location (SL) 1, and SL 2 in Ciliwung River, SL 14 in Krukut River, SL 23 Pesanggrahan River, and SL 25 in Grogol River which all of them are in upstream of the river. Cluster 2 consists of 16 sampling location in Ciliwung River, 2 SLs in Kalibaru river, 1 SL in Krukut River, Mampang and Sepak River, and each 2 SLs in Pesanggrahan and Tarum Barat River. The cluster 3 consist of 19 sampling locations in 9 rivers, but only 3 sampling locations in Mookevart river in cluster 4. The sampling locations of the Cluster Analysis results can be seen in Figure 4.

Table 2. Loadings of seven (7) water quality variables on two significant vary factors.

Variables	VF1	VF2
BOD	**0,954**	0,107
COD	**0,948**	0,140
DO	**-0,716**	-0,468
TDS	0,242	**0,648**
pH	-0,488	**0,713**
TP	0,451	**0,781**
NH3	0,154	**0,811**
Eigenvalue	3,524	1,767
%Total variance	50,344	25,242
Cummulative % variance	50,344	75,586

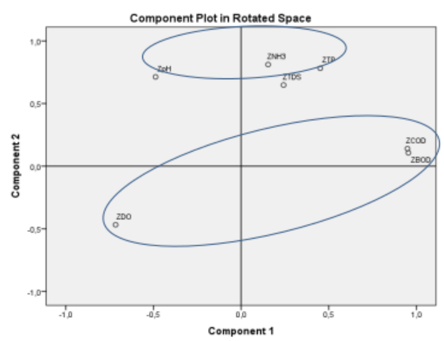

Figure 1. Principal component value of sampling sites data

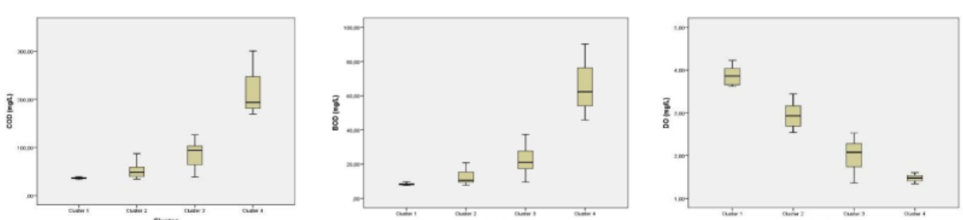

Figure 2.a) BOD concentration **Figure 2.b**) COD concentration **Figure 2.c**) DO concentration

Figure 2. Boxplot BOD, COD and DO concentration of sampling sites clusters.

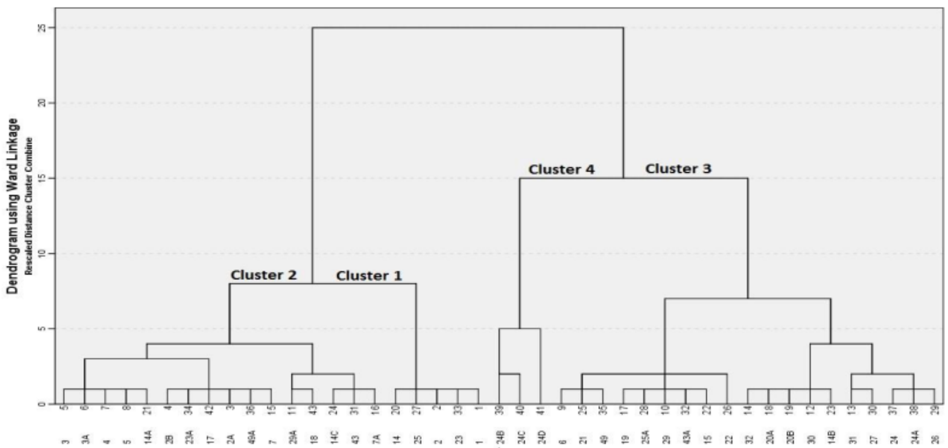

Figure 3. Dendrogram showing hierarchical clustering of sampling sites.

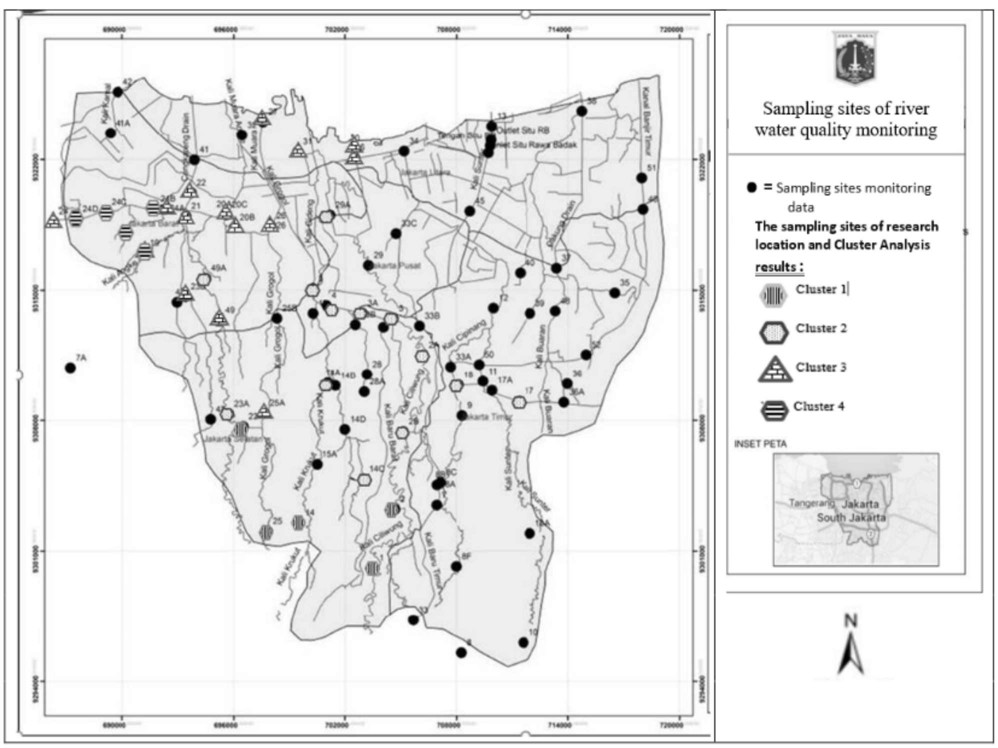

Figure 4. The sampling sites of water quality monitoring [11] and CA research data.

Pollutant sources in DKI Jakarta contribute to the river pollution process because the quality of downstream river water will decrease. Five locations in 4 rivers i.e Ciliwung, Krukut, Grogol and Pesanggrahan River which location in upstream of the river could be proposed as additional raw water sources with further study for quality, quantity, and continuity to meet water supply standard. Based on the above study results, it is necessary to further study the anthropogenic disturbance gradient depending on cluster, which described the water quality pollution level of the river. It is expected that a contribution will be made to data usage for efficient water quality management in terms of future watershed management.

DKI Jakarta will be proposed to adopt a model water supply coverage area by zoning of water services based on the location of the availability of raw water sources location. Depend on the Cluster 1 result, there will be 3 water supply services zones based on the availability of raw water sources location., ie the eastern zone which will be served by Ciliwung River, the middle zone will be served by Krukut and Grogol River, and the southern and western zones to be served by Pesanggrahan River.

4. Conclusion

The FA identified the two groups of water quality variables, which explain majority of the experimental data, and resulted organic pollutant as main factor that influenced DKI Jakarta river water quality. Therefore, BOD and COD used as main parameter for water quality further assessment. CA grouped sampling sites into four clusters. Five sampling locations on 4 rivers (Ciliwung, Krukut, Grogol and Pesanggrahan River) need further study which be proposed as additional raw water sources.

An objective interpretation of surface water physicochemical parameters and sharing as part of the effort identification location of rivers as raw water that necessary to study conscientiously are well provided by multivariate analysis.

DKI Jakarta will be proposed to adopt a model water supply coverage area by zoning of water services based on the availability of raw water sources location. This model will be influenced by the dynamics of urbanization and its impact on self-sufficient water sources which pass through the city. It expects this framework may impact raising public awareness to safe the water resources, in the sense that each resident is responsible for its local water sources.

Acknowledgment

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