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Research paper

Seasonal-Spatial of Putrajaya Lake Water Quality Parameter (WQP) Concentration Using Geographic Information System (GIS)

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Abstract

This study presents the assessment of selected water quality parameters (WQP) distribution at Putrajaya Lake during the dry and wet season using spatial analysis. The WQP used in this study were dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia-nitrogen (NH3-N), total suspended solid (TSS), pH and temperature. Total thirteen water samples were obtained during both dry and wet seasons from May 2015 until March 2016 distributed throughout the areas. To explore the WQP distribution, Inverse Distance Weighted (IDW) was employed. The results have shown that mean values of WQ concentration during dry and wet season are varies accordingly. The highest value parameters of water quality during dry season which are COD (17.2 mg/L), DO (7.11 mg/L) and NH3N (0.94 mg/L). Meanwhile on the wet season, the highest values are recorded for BOD (5.27 mg/L), pH (7.62 mg/L) and TSS (18.4 mg/L) respectively. This has indicated that the concentration of WQP in the lake changed seasonally. Furthermore, among the WQPs; DO, TSS and COD have exhibited significant relationship between others for both seasons.

Keywords: *GIS; Putrajaya Lake; Water Quality Parameter (WQP); Wet and dry Season*

1. Introduction

High-intensity of land-use activities that occurred near to the lakes can be associated with the deterioration of lake water quality. This includes their watershed and an increase of population density in neighboring areas [1]. This had caused over exploitation of lake water resources and discharge of large volumes of pollutants into lakes water. Eutrophication of lakes and stream caused by the widespread of organic and inorganic pollutant which damaged the ecological system contributed to the environmental quality [2]. As water quality degrades it affects all the environment surrounding and also endangers human health [3].
Both natural and artificial lakes in Malaysia have multiple functions, whereas; almost 90 percent of the nation's water supply comes from the lakes and reservoirs. In addition, it serves as the source of water for domestic, industrial and agriculture; hydroelectric power generation; flood mitigation, navigation and recreation. It has found 90 lakes in Malaysia with total area covered is over 100,000 ha [4]. Huang (2015) [4] also concluded that there is scarce inventory on all lakes in Malaysia. More than 30 billion cubic meters of water based on states in Malaysia is produced from the lake. Lakes also is known as a home to a variety of biological species and freshwater fish industry. One of a very popular urban lake is located in Putrajaya which is also known as an 'Intelligent Garden City' [5]. At the heart of the region, lies the Putrajaya Wetlands with a natural landscape dominated by the Putrajaya Lake [5],[6]. Initially, the lake is designed for natural cooling system for city, recreation purpose, water sport and water transport [6],[7]. To preserve a lake's amenity and aesthetic values, water quality monitoring and maintenance of Putrajaya lake is regularly conducted under the authority of Putrajaya Holdings Sdn. Bhd, Lake & Wetland [7]. At the early of Putrajaya development, Wetland Park was designed as a natural cleansing function to treat pollutants coming from the upstream areas of the Putrajaya Lake's catchment. However, located in the middle of administrative and residential areas, with numerous anthropogenic inputs come into its ecological system cannot be avoided [5],[8]. It has been found that the emerging of pollution symptom has been show in the lakes as a result of development and human behavior. The sign of pollution is exhibited in the lake, where the indicators such as algal bloom, murky water, and dead fishes are visible in some parts of the lake [9].
The state of aquatic environment can be determined by using water quality and is an interesting point of study in determining both human impacts and natural processes in the environment [10]. The specific parameters used to determine the water quality are based on Water Quality Index formula (WQI) [1],[11],[12],[13] and Interim National Water Quality Standard for Malaysia (INWQS) [1],[12]. The parameters consist of dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia-nitrogen (NH3-N), total suspended solid (TSS) and pH [14]. In Malaysia, there is no specific national standard or index for lake water quality is available until 2014. Water quality standards and classification used are of surface water. There is no standards and index for lakes in Malaysia. Since lakes are located within a river basin (although lakes have their own lake basins). It is a normal practice, the analysis on lake water quality is executed based on the DOE's WQI classification, DOE Water Quality Classification based on Water Quality Index and National Water Quality Standards for Malaysia [15]. However, Putrajaya has developed its own standards and the details can be found in [4],[7].
In Situ measurement is commonly applied to determine the lake water quality status and provides relatively accurate analysis. Rap-

id urban and industrial development and any other anthropogenic activities the quality of water has decreased dramatically. Monitoring techniques using remote sensing and GIS are needed to manage all possible contamination that occurs and provides the effective action at all levels [13]. Though the ground sampling technique is accurate yet it consumed much of the time in data analyzing. Situ measurements is often restricted to selected sampling points, thus; limited on spatial and temporal for assessment and monitoring lake water quality [12],[13],[16]. In addition, the conventional methods do not have the capacity to express the spatial heterogeneity at the surface and subsurface levels of a lake [1]. Therefore, it limits the ability of investigating direct measurement of water quality parameters on a full scale at the surface and subsurface level, thus resulting in incomplete water quality assessment of water bodies [11], [12].

Therefore, this study aimed to analyse on selected water quality parameters at Putrajaya Lake during the dry and wet season. The study also has explored the distribution of WQP at study areas that provides insights to the surrounding development (i.e., land use) using spatial analysis.

2. Method

2.1. Study Site

The Putrajaya lakes and wetlands is a lake located in the centre of Putrajaya, Malaysia at 101.68911 E, 2.941942 N. Lakes and wetlands Putrajaya consist of a surface area of 6.5 km^2 and average depth of 6.6 m with wetlands of six arms with 25 cells covering about 2 km^2. This catchment division is only a small part of 2350 km2 Sungai Langat Basin. The location of this lake catchment at the southern part of Kuala Lumpur is surrounded by urban area with rapid development around it. Early of the development the area of Putrajaya Wetland, about 30% area of catchment managed by the authority meanwhile the other 70% is controlled by the existing land owner [17]. In this study, assessment of spatial-seasonal distribution was based on seven zone of land use as illustrated by [11] (Figure 1).

The study also has evaluated point-source impacts analysis based on different land use and development activities, historical conditions based on observation and the environmental impact potential resulting from the discharges. Land use occupied surrounding of Putrajaya Lake as classified in Figure 1. As illustrated the land use at upper north and upper east is occupied with botanical park, upper west is near to the residential area and meanwhile, upper west is near to the government offices and parks. Mixed development located in central wetland; where there were government offices, parks, residential areas and commercial areas

Fig. 1: The land-use zone used for assessing the magnitude of WQPs at Putrajaya Lake [11]

2.2. Data Acquisition and Method

WQ used in the study dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia-nitrogen (NH3-N), total suspended solid (TSS), pH and temperature. The WQPs data was obtained from May 2015 until March 2016 that represented the seasonality variation, during the southwest monsoon from May to September (dry season) and the northeast monsoon from November to March (wet season).

As for spatial analysis, Inverse Distance Weighted (IDW) was employed using ArcGIS software 10.3. The database for all spatial data was created using GIS interpolation according to the IDW method to obtain the spatial distribution of each of the selected water quality parameter. The shape file of the lake with the positions of sampling points, and the deterministic interpolation algorithm was used for the assessment of the geo-spatial distribution of the selected water quality parameters. IDW is a deterministic algorithm with a predetermined set of sampling at arbitrary locations. The predetermined points are used to calculate the unknown points with a weighted average [18],[19]. IDW was computed as function of distance between observed samples sites and the site at which the prediction has been made [20]. The formula of IDW method is as Equation 1 [21]:

$$\hat{z}\left(x_0\right)=\frac{\sum_{j=1}^{m} z\left(x_j\right)\cdot d_{ij}^{-k}}{\sum_{j=1}^{m} d_{ij}^{-k}} \quad (1)$$

Where, K is the distance between influence coefficient which is either 1 or 2. dij is the distance between the sampling locations j(xj) and non-sampled location i(xo). The maps are obtained by using the IDW interpolation method on water quality data for respective months. The result of the analysis shows changes on the maps which do not extrapolate beyond the minimum and maximum values of the experimental data. This allows clear presentation and easy analysing. Later, the WQPs for each sampling sites were analysed by calculating Pearson's correlation. The correlation coefficient was used to measure the strength of the relationship established between lakes WQPs over dry and wet season. The water quality parameters were evaluated for each of the interpolation techniques using Pearson's.

Water quality index method is used in based on DOE water quality index. The WQI used the National Water Quality Standard(NWQS) to classify the uses for the water body. The monthly averagf water quality parameter was based on the sampling site from Putrajaya lake and wetlands from 2015 until 2016 in Table 1.

Table 1 : Average lake water quality for each station for Putrajaya lake and wetlands from 2015 to 2016

Stations (Lakes & Wetlands)	pH	DO mg/L	BOD mg/L	COD mg/L	TSS mg/L	NH_3N mg/L	WQI
CW	7.20	7.03	4.40	16.08	12.4	0.11	53.44
LE2	7.09	6.04	4.13	14.50	17.67	0.47	40.02
UB2	7.20	5.10	4.67	16.42	25.42	0.28	51.22

UN8	6.95	6.20	4.75	31.76	16.25	1.48	39.10
UW7	7.62	12.16	4.21	13.75	16.30	0.28	53.91
PLa1	7.28	7.66	4.20	15.58	6.20	0.12	53.42
PLb2	7.30	7.60	4.20	15.50	6.12	0.11	51.58
PLc2	7.22	7.60	4.30	16.42	6.82	0.08	53.83
PLd2	6.96	7.43	4.27	16.63	6.3	0.105	53.43
PLe1	7.27	10.64	4.26	15.54	5.28	0.13	53.22
PLf1	7.26	7.41	4.16	14.92	4.72	0.18	52.65
PLf5	7.30	7.50	4.30	15.46	4.52	0.15	52.87
PLg2	7.27	7.40	4.06	14.56	3.85	0.14	53.40

The figure shows that, the average lake water quality of Putrajaya lake and wetlands for all the sampling points taken from 2015 to 2016. The pH of the aquatic system is an important indicator of the water quality that pollution emerged in the watershed. The unpolluted water bodies show near to neutral or slightly alkaline. Compared with DOE WQI showed that the pH at the sampling point UN8 is slightly acidic as it can be caused from the runoff of urban and agricultural activities during the sampling time. The rest of pH in all the sampling points are still in permissible range that states from DOE WQI guidelines [22].

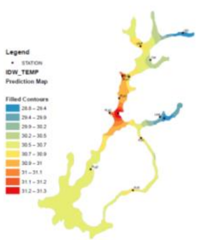
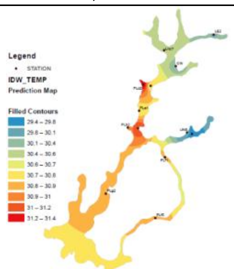
DO does not show a significant concentration from all the sampling except for sampling point UW7. DO values at UW7 showed a highest concentration at 12.16 mg/L. The high level of concentration is because of the water flowing at high velocity. As result, flowing water as the oxygen-rich water at the surface is constantly being replaced by water containing less oxygen creating an exchange of oxygen across air-water interface [23]. BOD ranging from 4.06 mg/L to 4.75 mg/L is still in permissible limits based from DOE WQI guidelines. This indicates that the organic pollutant in the water bodies is still in low concentration and does not adversely affect the water quality.

The average levels of COD from all the sampling points ranged from 14.50 mg/L to 31.76 mg/L. The range is still in acceptable range according to DOE WQI. The high level of COD at UN8 is 31.76 mg/L mostly due to runoff of the upper stream before entering the wetlands area. The runoff consists of agricultural, urban runoff and industrial discharge [3].

TSS showed concentration of dissolved organic and inorganic chemicals in water bodies and all the sampling stations in range of the sampling stations in range of 3.85 mg/L to 25.45 mg/L in acceptable limits based on DOE WQI. The maximum concentration of NH4N is 1.48 mg/L at UN 8. The high value of NH4N is likely due to effluent of sewage treatment from upstream and urban activities runoff [23].

3. Result and Discussion

The use of spatial analysis is important in establishing relationship between water quality parameters. This has been done by creating a prediction from the interpolated sample point values. These spatially referenced data were used to determine the contribution of each WQPs across the lake through GIS spatial distribution map. The analysis of WQP at the sampling station was put into perspective into spatial and seasonal. Figure 2 shows the Interpolated distribution of WQP Putrajaya lake for both dry and wet season over the period of May 2015-March 2016.

Seasonal / Parameter	**a) Dry**	**b) Wet**
Temperature		

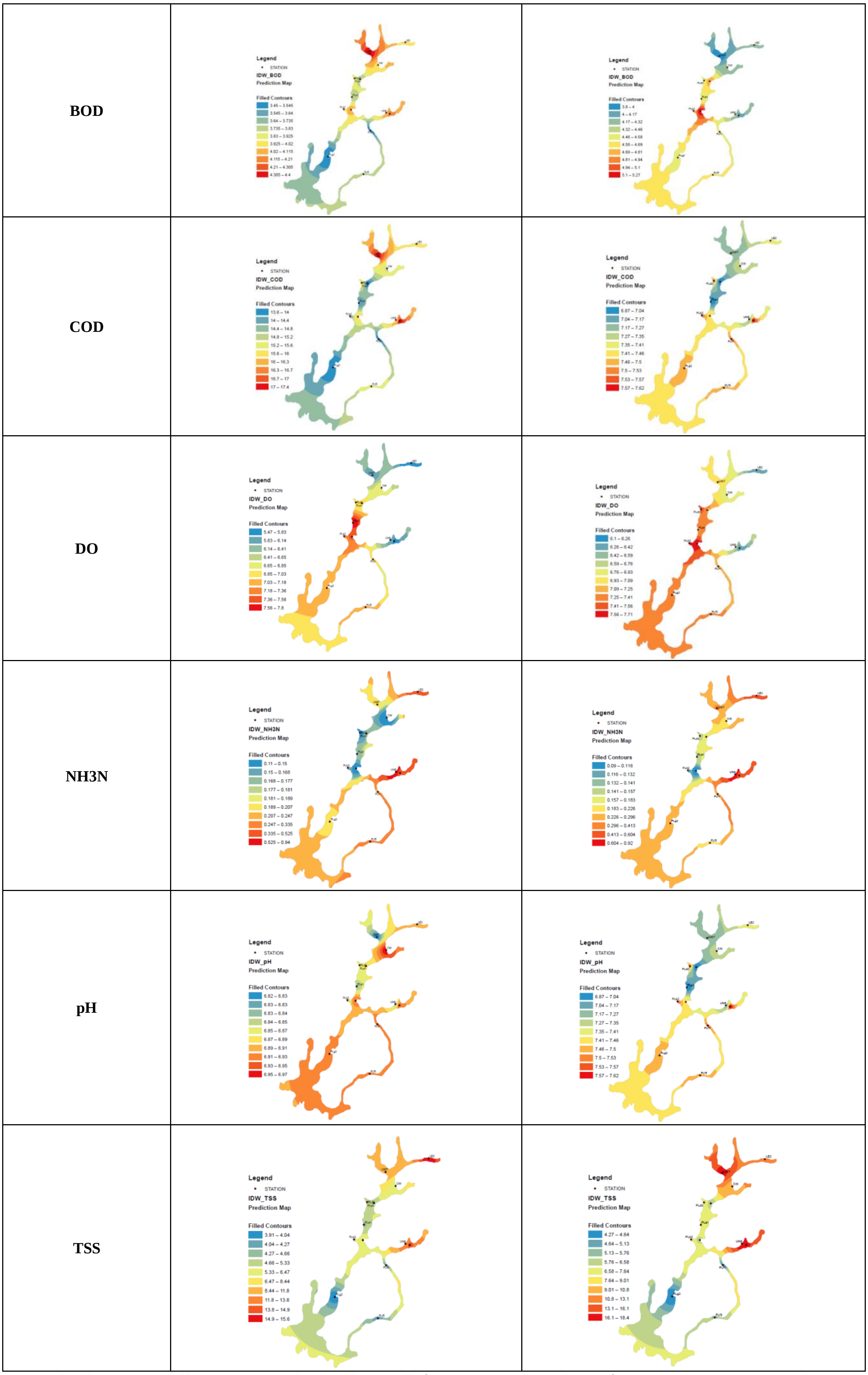


Fig 2: Interpolated WQP seasonally at Putrajaya Lake over the period of May 2015 until March 2016 for Temperature a) Dry season b) Wet season

The preliminary investigation and spatial analysis has shown the temperature for the lake is high for both seasons, which slightly exceeded from the standard set by Putrajaya Ambient Lake Water Quality Standard. The temperature exhibited was slightly higher on the wet season (31.37°c) and recorded (31. 29°c) during dry season respectively. BOD was recorded in range (3.45 - 4.4 mg/L) and (3.8 - 5.27 mg/L) for dry and wet seasons respectively and this can be interpreted exceeded from the standard set for BOD is 3 mg/l. During the wet season, surface the BOD concentration is highest (5.27 mg/L) as compared dry season where the highest value was (4.4 mg/L). The increasing of BOD values indicated that the availability of oxygen to living organism [24]. This maybe due to the maximum oxygen consumption by pollution load on the aquatic system. Increasing of BOD possibly because of excess nutrients from fertilizers flowed and settles down in the lake. The situation has led to the excess of nutrients in the lake and elevated the BOD level at the study areas. Thus, stimulate the algae growth which causes to oxygen consumption in water.

The following WQP used was DO concentration; it was found that the total DO is highest recorded over dry season was 7.11 mg/L. Meanwhile during the wet season the highest value was 7.71 mg/L. Both values slightly exceeded from permissible standard that should be (5-7 mg/l). The pH indicates the intensity of acidity and alkalinity and it measures hydrogen ions in water. Water which has pH value of more than 9 or less than 4.5 becomes unsuitable for use [25]. In the present study, water quality it is found to be within the permissible limit (6.5-9.0). The WQP of NH_3N, TSS and COD concentration also recorded is wit in the total concentration that was recorded over both seasons.

Spatially, the distribution of temperature is high at zone three during the dry season where the areas were occupied with administrative building. The high temperature was caused by thermoelectric power [26]. Meanwhile, the TSS concentration shows varies pattern for both season. During wet season the abundance of concentration is slightly higher as compared during dry season appeared at upper north and west which was occupied with residential, government office and park [27]. The WQP of DO concentration was distributed also at the central zone where the government office and park was located.

The correlation coefficient and their significant levels between all WQPs are presented in Table 1 and 2. Among the WQPs, DO, TSS and COD have exhibited obvious relationship between others significantly.

Table 2: Cross Correlation of WQPs of the Putrajaya Lake during the dry season

Parameter	TEMP	BOD	DO	TSS	pH	COD	NH3N
TEMP	1						
BOD	-0.26	1					
DO	**.822****	**-0.526**	1				
TSS	**.825****	**.611***	**.909****	1			
pH	-0.245	-0.256	0.017	-0.191	1		
COD	-0.413	**.871****	**-.647***	**.665***	-0.029	1	
NH3N	-0.43	0.088	-0.422	**.585***	-0.328	0.127	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Table 3: Correlation of WQPs of the Putrajaya Lake during the wet season

Parameter	TEMP	BOD	DO	TSS	pH	COD	NH3N
TEMP	1						
BOD	**.673***	1					
DO	**.926****	**.724***	1				
TSS	**-.759****	**-.703****	**-.909****	1			
pH	0.064	0.036	0.015	-0.097	1		
COD	0.064	0.036	0.015	-0.097	**1.000****	1	
NH3N	**-.653***	-0.406	-.621*	**.739****	-0.126	-0.126	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

From the Table 2 and 3, it shows that during both seasons, DO has produced strong relationship with TEMP (r=0.8) and (r=0.9) respectively. Normally, the increases in temperature has also led to the decreased of dissolved oxygen (DO) in the water, this happened due to the warmer water holds less oxygen than cooler water [28]. Furthermore, these decreases in DO are negatively correlated with biological oxygen demand (BOD) levels during dry season and vice versa for the wet season. BOD has been defined by EPA as the amount of oxygen that is consumed by microorganisms for decomposition of organic matter [29]. Higher BOD levels lead to a rapid depletion of oxygen in the stream which can cause aquatic life, to become stressed and suffocate. Sources of high levels of BOD include leaves, dead plants and animals, and animal manure [30]. As for WQP TSS, has produced strong relationship between TEMP, BOD and DO for both seasons, meanwhile negative correlation between were established over wet season.

The Putrajaya lake has been designed to meet with Class IIB of NWQS classification for recreational purpose. The wetland was created to treat surface runoff caused by development and agricultural activities from an upstream catchment before entering Putrajaya Lake. The wetlands are designed with different water levels in each of cells and the water flows through these wetlands cells before discharge into the lake which helps to achieve Class IIB. Putrajaya lake has facing challenging in maintaining the water quality as per standard. Rapid development and land use activities surrounding of the lake that had caused high pollutant load to be discharged into the wetlands. This has putting pressure to the existing lake system; and failed to act as filtration system before the water flows into the lake. UN8 showed Class IV which was very polluted because it showed pH, COD and NH3N at highest value. High level of COD and NH3N degrades the water quality of the water bodies [31]. WQI classifications of all the sampling stations were at Class III based on DOE-WQI [14].

The deterioration of lake water quality was caused by the nutrients such as nitrogen and phosphorus entering the lakes from storm water runoff or sewage discharge and also affected by lake physical characteristic, hydrology, land cover, land use and climate changes [32]. Land use surround the lake strongly determine the water quality of level. It appears that major developments are planned at surrounding of lake area is the main contributors of urban water runoff that degrade the water quality [11].

4. Conclusion

The study demonstrated that an interpolation technique is useful to indicate the distribution pattern of lake WQPs over dry and wet season. Further information on the WQP relationship between the parameters provides insight on the possible source of pollution and dependency among the variables. It is anticipated that the findings from this study will be a significant basis for application in other municipalities, thus leading to environmental sustainability in water quality monitoring.

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