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**“Chemical Oxygen Demand Concentration and its Spatial Distribution for Rainwater of
a Small Area at Parit Raja, Batu Pahat, Johor, Malaysia”**

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Abstract

The purpose of this paper was to discuss rainwater quality based on chemical oxygen demand (COD) concentration and to map COD spatial distribution for an area of approximately 3.5 km x 3.0 km of Parit Raja, which is located at Batu Pahat, Johor, Malaysia. Rainwater samples were collected four times from June of 2007 to July of 2007 at eleven sampling stations. The measured COD concentration data were averaged and transformed into their common logarithms and then mapped through the application of kriging interpolation technique. The measured COD concentration was found ranging from 5.3 mg/L to 40.7 mg/L. The areas that received rainwater with high and low COD concentration were able to be identified and the presence of sources of rainwater contamination was suggested from observation on the developed COD spatial distribution map.

Keywords: chemical oxygen demand; rainwater quality; kriging; spatial distribution

1. Introduction

Rainwater harvesting has been practiced by some of the residents of Parit Raja, which is located at Batu Pahat, Johor, Malaysia, for many years. Rainwater has been used for the purpose of domestic usage even though the provision of water through piped networks is feasible. The main fresh water source to the domestic water supply in Batu Pahat, which is Sembrong River, was reported to be highly acidic and polluted in terms of Aluminum (Al), Iron (Fe) and Manganese (Mn) content [1]. Rainwater, therefore, may serve as a solution to the pollution of low pH and high amount of metals in the public water supply. Besides that, rainwater may also serve as a solution to flash floods that always occur in the area of Parit Raja after heavy and or continuous rainfall.

Rapid development and human activities such as industrial and traffic emission at Parit Raja, however, can deteriorate the quality of rainwater and make it unsafe for consumption. Air emission has been shown to affect rainwater chemical composition [7]. The quality of rainwater at Parit Raja has been studied by many researchers [2, 5 and 6]. Information in terms of spatial distribution patterns of contaminants in rainwater at Parit Raja, however, is still very limited. The spatial distribution pattern of contaminants is very useful since it can provide information on the locations that receive rainwater with high and low contaminant concentration.

The present study, therefore, aimed at (i) determining rainwater quality collected at Parit Raja based on chemical oxygen demand (COD) concentration and (ii) developing contaminants spatial distribution map by using COD

concentration data. The areas that receives rainwater with high and low contaminant concentration in the study area were identified from the analysis the developed COD contour map. The COD contour map was developed by using kriging interpolation technique. Tap water was also analyzed for COD for comparison purposes.

Chemical oxygen demand (COD) test is commonly used to determine the amount of organic pollutants found in water making COD a useful measure of water quality. Previous studies had reported COD concentration for rainwater at Parit Raja industrial area and Bangi, Selangor that were in the range of 27.56 to 33.2 mg/L [2] and 43 to 68 mg/L [9], respectively.

2. Methodology

2.1. Rainwater sampling

The present study was conducted for a small area of approximately 3.5 x 3.0 km at Parit Raja, inclusive of residential and industrial areas. Rainwater samples were collected four times from June of 2007 to July of 2007 at eleven sampling stations as shown in Figure 1. Sampling stations that were located close to the industrial area were Taman Pintas Jaya (S1), Industrial Area (S8), Universiti Tun Hussein Onn Malaysia (UTHM) Golf Field (S7) and UTHM Stadium (S6). The other seven sampling stations were located at Taman Bunga Raya (S2), Parit Hj. Abd. Kadir (S5), Parit Sempadan (S3), Parit Jelutong (S9), Parit Bengkok (S10) and Bandar Universiti (S11).

Rainwater samples were collected in plastic bottles that were placed at a high position above the land surface and free from trees and buildings. The samples were put into ice containers and transported to the laboratory for the analyses of COD. COD was analyzed at laboratory by using HACH DR 4000 spectrophotometer unit.

2.2. Development of COD contour map

COD contour map was developed through the application of kriging interpolation technique by using a geostatistical tool. COD estimation was made on a regular grid of 3516 x 3016 m. Equation 1 shows the experimental semivariogram $\gamma(h)$ used for the kriging estimation [4].

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \{z(x_i) - z(x_i + h)\}^2 \quad (1)$$

where h is the distance between locations x_i and $x_i + h$. A model variogram was then fitted to the experimental semivariogram. The features in semivariogram that were used for the analysis of

the spatial dependencies of COD data were sill, range and nugget.

Cross validation technique has been used to validate the quality of the COD kriged map. Cross validation statistics used in the present study involved the percentage estimation error (PAEE), computation of mean squared error (MSE) and relative mean square error (RMSE) [3 and 10]. Mean error (ME) [9] was also computed in addition to PAEE, MSE and RMSE.

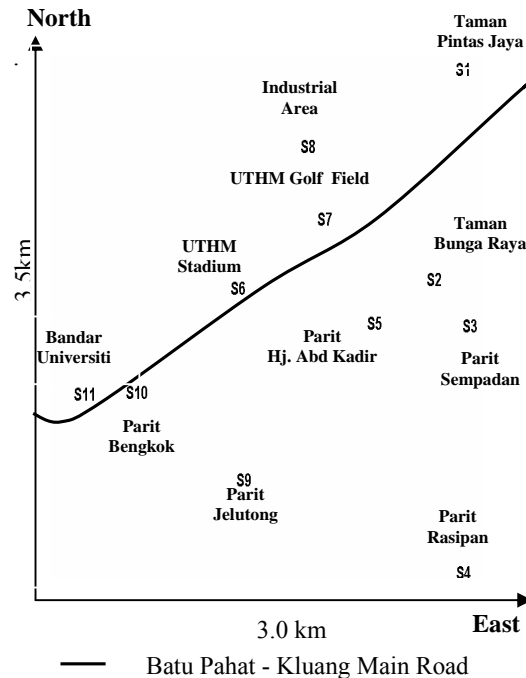


Fig.1. Sampling station locations (not in scale)

3. Results and discussion

The results of laboratory analyses and kriging interpolation are discussed below.

3.1. Chemical oxygen demand

Figure 2 shows the average COD concentration for rainwater sample collected at all the 11 observation stations and tap water. COD concentration in rainwater was ranging from 5.3 mg/L to 40.7 mg/L. Based on the COD concentration, the rainwater at the study area could be categorized under class III of the National Water Quality Standards for Malaysia.

Highest COD concentration was measured for rainwater samples collected at Parit Hj. Abd. Kadir while the lowest concentration was measured for rainwater samples collected at Parit Jelutong. From Figure 2, higher concentrations of COD were

measured for samples collected near the industrial area (Taman Pintas Jaya, Industrial Area, UTHM Golf Field, Taman Bunga Raya, and Parit Hj. Abd. Kadir) while lower COD concentrations were measured for samples collected at the residential areas (Parit Sempadan, Parit Jelutong, Parit Bengkok and Bandar Universiti).

COD concentration in rainwater was also compared with COD concentration measured in tap water. Higher COD concentration was found for tap water that was ranging from 23.7 mg/L to 79 mg/L. The quality of rainwater at the study area, therefore, is better than tap water based on the measured COD concentration.

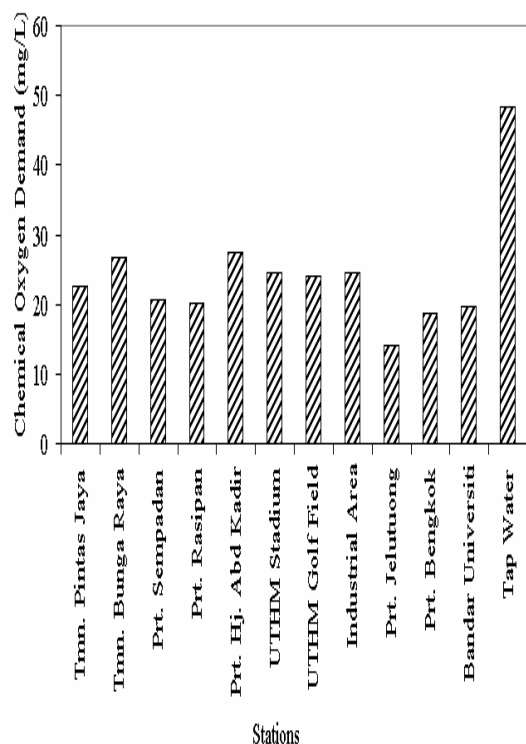


Fig.2. Chemical oxygen demand concentration

3.2. Cross validation results

Four different models were examined to fit the COD semivariogram data. The model that best fit the semivariograms of COD was exponential. Table 1 shows the features in semivariogram that were used for the analysis of the spatial dependencies of COD data. The ideal values for PAEE, MSE, RMSE and ME and the results of the cross validation analysis are shown in Table 2. The results shown in Table 2 indicate that the variogram model used for the development of COD contour maps was well selected.

Table 1. Characteristics parameters of fitted semivariogram of COD data

Parameter	Model	Nugget	Sill	Range
Chemical Oxygen Demand	Exponential	0	6.6E-3	2.2 E3

Table 2. Results of cross validation statistics (Ideal values of PAEE=0, MSE<sample variance, RMSE =0, ME=0)

Parameter	PAEE	MSE	RMSE	ME
Chemical Oxygen Demand	4.2E-1	3.4E-4	7.9E-1	6.1E-2

3.2. 1. COD spatial dependencies

Spatial dependencies of COD in terms of semivariogram parameters were examined. As can be seen in Table 1, COD showed a range of 2.2E03. Large range values for both COD indicated that this parameter is spatially dependence over long distances. Low sill values indicated low variability in COD data. The nugget and sill ratio for the COD were less than 25% which indicated that COD has a strong spatial dependence. Small nugget value for COD suggested less variation exist for this parameter at distances shorter than the smallest lag.

3.3. COD Contour Map

The developed log transformed of COD concentration contour is shown in Figure 3. COD concentration, as shown in Figure 3, decreases from a darker to a lighter area. From the observation on the log transformed of COD contour map, areas of highest COD concentration were observed at the area close to Parit Hj. Ad. Kadir (S5) and Taman Bunga Raya (S2) while the area of lowest COD concentration was observed at the area close to S9. These areas of highest and lowest COD concentration are shown by the darkest and the lightest area or peak in Figure 3, respectively. Higher COD concentration was observed at the northeastern part of the study area while lower COD concentration was observed at the southern part of the study area. The presence of the darkest peak on the log transformed of COD contour map suggested the presence of sources of rainwater contamination in the study area.

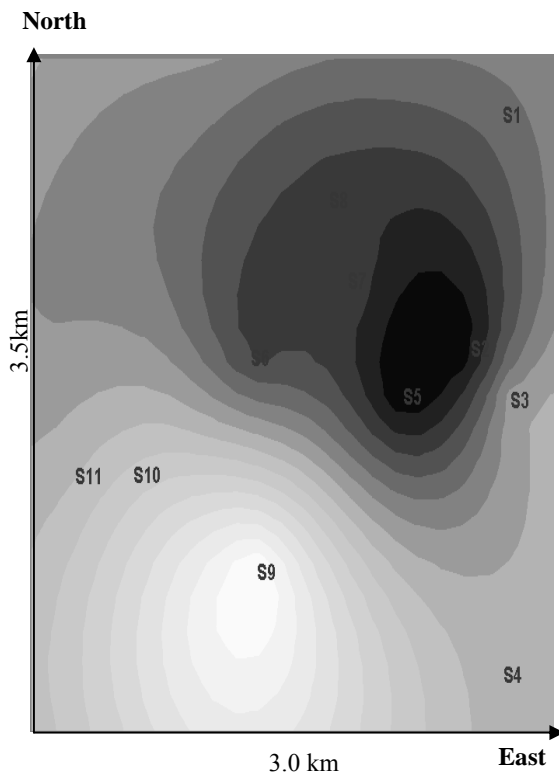


Fig. 3. Log Transformed COD Contour (\log_{10} mg per liter)

4. Conclusion

Rainwater of the study area could be classified under class III of the National Water Quality Standards for Malaysia based on the measured chemical oxygen demand concentration. The areas that received rainwater with high and low COD concentration were able to be identified from the developed contour map. The developed log transformed of COD concentration map showed that the area that received rainwater with higher COD concentration was the areas that were located close to the industrial area. The map also suggested the presence of sources of rainwater contamination in the study area.

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