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# Spatial Distribution of Water Quality Index in Stormwater Channel: A Case Study of Alur Ilmu, UKM Bangi Campus

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**ABSTRACT**

**Objective**: The present paper aims to provide an overview of current status of water quality by analyzing spatial distribution of water quality index (WQI) in Alur Ilmu.

**Method**: WQI is used to outline large amount of water quality data into simplest term in water quality classification. The stormwater channel was in-situ monitored and the water samples were ex-situ analyzed seasonally (both dry and rainy seasons) from thirteen stations along the stormwater channel. Six selected parameters, namely dissolve oxygen (DO), pH, ammoniacal nitrogen ($NH_3N$), total suspended solid (TSS), biological oxygen demand (BOD) and chemical oxygen demand (COD), were used to determine WQI. Spatial analysis was conducted based on the thematic maps which were generated using geostatistical approach whereby Kriging models were used for the mapping of WQI along Alur Ilmu.

**Result:** From the WQI analysis, dry season (68.85 - Class III) is lower than that of rainy season (75.94 - Class III). The comparison of seasonal WQI spatial distribution analysis shows AL5 is the most influential point for source of pollution along Alur Ilmu during dry season.

**Conclusion**: From the Kriging models, the water quality in Alur Ilmu can be determined which is beneficial for the planners and decision makers to device policy guidelines for effective management of stormwater in the campus.

**Keywords:** *spatial analysis, Water Quality Index, Alur Ilmu, stormwater channel, kriging*

## 1. Introduction

Rapid urban development and climate change have posed great challenges to stormwater quality management at different geographic condition (University of Bristish Columbia (UBC), 2014; Marsalek & Schreier, 2009). Increasing impervious areas with the rapid urban development has resulted flashier stormwater runoff from heavy rain falls, carrying pollutants namely suspended solid, oil and grease, pesticide, organic matter, domestic waste into stormwater channel (Marsalek et Al., 2008; Brezonik & Stadelmann, 2002). These natural phenomena and human activities contribute to the degradation of stormwater quality and pollution when discharged into the nearest inland water bodies, namely streams, rivers and lakes (Thomas & Reese, 2003).

In managing stormwater quality, it is necessary to have information on water quality data and the source of pollution. Point source pollution is easier to access and monitor because pollutants are discharged from a specific location such as municipal and industrial waste discharges. Non-point source pollution is normally contributed by agriculture practice, surface runoff, sediment deposition, which requires a more comprehensive investigation to identify for its production (Chansheng & Carlo, 2010). Spatial distribution study of water quality is an alternative way that able to provide precise knowledge of pollution source in stormwater with minimum time and cost (Ghafouri & Swain, 2005). This method predicts by interpolating the values of a constituent area of interest in a location where it is not measured based on measurement taken at other location (Curriero, 2007; Murphy et al., 2010).

Alur Ilmu stormwater channel is vulnerable to point and non-point sources of pollution because its location is close to human activities. Infrastructure developments and anthropogenic activities along the stormwater channel may cause serious environmental problems to Alur Ilmu. Previous water quality study on Alur Ilmu has determined the level of water quality parameters, namely Dissolve oxygen (DO), Ammonical Nitrogen ($NH_3$-N), total suspended solid (TSS), chemical oxygen demand (COD) and biological oxygen demand (BOD) for water quality index (WQI) as well as other water quality parameters. WQI study was conducted to identify the level of acceptance of water quality for human use and environmental health (Department of Environment Malaysia (DOE), 2007). Further study was conducted on TDS, DO, BOD, COD, $NH_3$-N, TSS to measure Event Mean Concentration (EMC) (Din et al. 2012) for pollution loading and discharge pattern by the building construction located at Alur Ilmu upstream. Another water quality study (Afina et al., 2015) has compared the variation of water quality value between stations during non-rain day and rainy day. However, until now there is no study been done on spatial distribution of WQI in Alur Ilmu stormwater.

In this paper, the spatial distribution of WQI in Alur Ilmu was studied to enable environmental manager to target the pollutants as close as possible to their source of origination (Ghafouri & Swain, 2005). The six abovementioned parameters were selected for WQI study during rainy and dry seasons using in-situ monitoring and ex-situ analysis. Water quality parameters were interpolated for their comprehensive coverage and range of geochemical complexity from simple to highly complex water quality parameters (Murphy et al., 2010). This study used water quality modeling (WQM) for a better decision making tool to improve and sustain Alur Ilmu stormwater quality.

# 2. Materials and Method

## 2.1. Study area

Alur Ilmu extends in the middle of the main campus of Universiti Kebangsaan Malaysia (UKM), receiving water from Permenant Reserved Forest and Natural Education Forest (Hutan Simpan Kekal dan Hutan Pendidikan Alam) UKM. In 1970s, the natural stream of Alur Ilmu was modified into concrete stormwater channel without changing its flow (Din et al. 2012). It serves as irrigation control for rain water, ground water and any type of fluid discharged along the campus into the Langat River, Selangor, Malaysia (Mazlin et al., 2005). Water quality studies on Alur Ilmu were conducted since 1999. The reported WQI of Alur Ilmu has decreased with time from Class II (Chong, 1999) to Class III and has reached Class IV in March 2012 (Din et al., 2012). Alur Ilmu is susceptible to water pollutants from nearby natural phenomenon and human activities, i.e infrastructure developments and anthropogenic activities. Existing sediment trap were built at Ghazali Lake at the Alur Ilmu upstream has reached beyond its capacity due to downpour and erosion caused by the previous building construction thus sediment accumulated and overflowed the trap during heavy rain. This has changed Alur Ilmu water quality and existing discharge pattern (Din et al. 2012). Moreover, surface runoff brings pollutants during rain and discharges from nearby pavements, buildings and cafeterias, contributing to water quality deterioration.

This study focuses on Alur Ilmu upstream which extends to 500 m long and width ranges 5 m starting from Ghazali Lake to Silt Collection Tank. Thirteen stations were assessed based on water quality for point and non-point sources pollution along Alur Ilmu upstream and each station's GPS coordinate was recorded using Garmin Etrex 20. The GPS coordinate for each station was used in map interpolations for spatial distribution of WQI in the stormwater channel. Six water parameters were selected for this analysis namely Dissolve Oxygen (DO), Ammoniacal Nitrogen ($NH_3$-N), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD).

The study area is shown as the light blue colored region in Figure 1. The area was selected to identify source of pollution in Alur Ilmu upstream and also to eliminate complication of spatially interpolating within nonconvex, or irregularly shaped, regions (Curriero, 2007). Interpolation of WQI data were conducted using Surfer® 11 software.

### 2.2. In-situ monitoring and Ex-situ analysis

In-situ monitoring was conducted during rainy and dry seasons. Six water quality parameters were studied for WQI in this research. Parameters such as $NH_3$-N, pH and DO were monitored in-situ using YSI Multiparameter Sonde for the thirteen stations. Ex-situ analysis was conducted for Total Suspended Solid (TSS), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD). The six parameters were calculated for WQI for each station based on National Water Quality Standards for Malaysia (Department of Environment Malaysia (DOE), 2007).

### 2.3. Water quality modelling and data treatment

Interpolation of WQI data was conducted using Surfer® 11 software. Below is the general linear regression model (Eq. 1), showing how WQI data treated via interpolation (predicted) for notation purposes. {y(s1) , . . . , y(sn)} represent a set of observed WQI value at the station expressed by s1 , . . . , sn. Likewise, Y(s0) expresses corresponding water quality at an unsampled (unmonitored) location s0 for interpolation. Weight of the observed data is expressed as w(si) and $\hat{Y}(s0)$ represents interpolated value for Y(s0) (Murphy et al., 2010).

$$\hat{Y}(s0) = w(si)y(si) \quad \ldots\ldots (1)$$

Kriging is a geostatistics method using statistical optimal spatial interpolation of given values to unsampled location (Murphy et al. 2010). The WQI data for thirteen stations in the Alur Ilmu was interpolated using geostatistical kriging method. Below is the linear equation model of Kriging (Eq. 2). s expresses a generic spatial location expected to be different over some domain of interest, Y(s) is the result of interest measured at s. X1(s) expresses a potential covariate indexed by location s which may have more than one covariate. β1 is the covariate's associated regression effect and ε(s) is the random error term. The current study focuses on WQM-generated concentration of the 6 selected WQI parameters namely DO, $NH_3$-N, TSS, pH, COD and BOD. Using Kriging method, the parameters can be generated for all locations within the area, representing as the covariate [X1(s)]. The expected value of a parameter (i.e β0 + β1[Modeled DO(s)] ) is different by location and is a function of the WQM-generated concentration. Residual error term is accounted for expected value which deviates in value and varies spatially. In Kriging, accounting for a spatial varying expected value has lessened the concern regarding station in a flowing water body.

## 3. Results

Table 1 shows Alur Ilmu WQI data during dry and rainy seasons for thirteen stations. WQI values were obtained based on WQI calculation of the 6 selected water quality parameters (9). During rainy season, WQI ranges from 79.52 – 71.7 (Class II and III). The highest WQI is at AL4 (Inlet 2) with 79.52 - Class II and the lowest WQI is recorded at AL13 (Silt Collection Tank) with 71.71 (Class III). The results show Alur Ilmu upstream is generally slightly polluted during rainy season. During dry season, WQI value ranges from 79.12 – 51.36 (Class II to IV), low values for most of the stations except AL1, AL2, AL3 and AL13. The highest WQI is recorded at AL1 (Ghazali Lake) with 79.12 (Class II) and the lowest WQI is recorded at AL5 (Canteen) 51.36 (Class III) during dry season. The results show that water is slightly polluted during dry season for all the stations except at station AL5 (FST café) whereas AL12(EcoNiaga) is recorded as polluted. Average WQI of dry season (68.85 - Class III) is lower than that of rainy season (75.94 - Class III), indicating that extensive treatment is required if the water were to be used for water supply.

Figures 2 show the contour map to display spatial distribution of WQI along Alur Ilmu upstream during rainy and dry seasons. The red color on the map indicates low WQI (polluted) while the blue color on the map indicates high WQI (clean). The contour map of rainy season shows high WQI along the stormwater channel except for station AL2 (Main Inlet), AL7 (Biology Building), AL10 (Economy and Business management Building), AL11 (Mathematic Building), AL13 (Silt Collection Tank). However, the contour map of dry season demonstrates a different variation of distribution pattern whereby the highest WQI is observed at the south of the stormwater channel and started to decrease drastically in WQI after station AL4 (Inlet 2) to AL13(Silt Collection Tank). The lowest WQI are recorded at stations AL4 (Inlet 2), AL5 (FST Café), AL12 (EcoNiaga) and AL8 (Car Park).

## 4. Discussion

The contour maps for both rainy and dry seasons are spatial heterogeneous in spatial distribution of WQI along Alur Ilmu upstream. Comparatively, higher average WQI is obtained during rainy season compared to dry season which indicates better water quality obtained during rainy season. Din et al. (2012) found that high rainfall intensity causes high water velocity and high discharge volume decreases pollution loading in Alur Ilmu at a certain time. This study shows that high rainfall intensity is able to dilute pollutants in Alur Ilmu.

There are a total of nine pollution sources that lower WQI in the study area, five stations are identified during rainy season and four stations are identified during rainy season. During rainy season, four stations are detected as point source which are AL2 (Main Inlet), AL7 (Biology Building), AL10 (Economy and Business management Building), AL11 (Mathematic Building) and only one station is detected as non-point source which is AL13 (Silt Collection Tank). The concentration of suspended solids is recorded high at AL2 (main inlet) where the station is facing sediment deposition, dead leaves and branches, soil thus lowering WQI. At station AL7 (Biology Building), AL10 (Economy and Business management Building) and AL11 (Mathematic Building), surface runoff from heavy rain collecting oil, sediments, debris and flow into the station's inlets, hence discharge into Alur Ilmu. Water discharged from toilet and laboratory building in UKM are channeled into UKM's sewage oxidation pond and are not connected to Alur Imu (Mazlin et al., 2005).

**Table 1.** WQI Value, WQI Class and Pollution Status during Dry and Rainy Seasons for 13 Stations along Alur Ilmu Upstream.

| Stations | Description | Longitude | Latitude | WQI Wet season | WQI Class | Status | WQI Dry season | WQI Class | Status |
|---|---|---|---|---|---|---|---|---|---|
| AL1 | Ghazali Lake | 2.9219861 | 101.7817889 | 76.90 | II | S.P | 79.12 | II | S.P |
| AL2 | Main Inlet | 2.9227833 | 101.781675 | 73.11 | III | S.P | 76.34 | III | S.P |
| AL3 | Inlet 1 | 2.9226806 | 101.7817306 | 77.85 | II | S.P | 78.12 | II | S.P |
| AL4 | Inlet 2 | 2.92285 | 101.7817944 | 79.52 | II | S.P | 61.26 | III | S.P |
| AL5 | FST Cafe | 2.9230278 | 101.7818667 | 78.42 | II | S.P | 51.36 | IV | P |
| AL6 | Retention pond | 2.9234722 | 101.7818139 | 78.13 | II | S.P | 66.23 | III | S.P |
| AL7 | Biology Building | 2.923625 | 101.7819861 | 73.47 | III | S.P | 68.46 | III | S.P |
| AL8 | Car Park | 2.9239780 | 101.7819970 | 76.74 | II | S.P | 62.42 | III | S.P |
| AL9 | Geology Building | 2.9242810 | 101.7820720 | 77.21 | II | S.P | 73.13 | III | S.P |
| AL10 | Economy and Business management Building | 2.9245940 | 101.7821030 | 74.56 | III | S.P | 68.65 | III | S.P |
| AL11 | Mathematic Building | 2.9248440 | 101.7820580 | 73.56 | III | S.P | 73.49 | III | S.P |
| AL12 | EcoNiaga | 2.9250780 | 101.7820280 | 76.10 | III | S.P | 58.88 | III | P |
| AL13 | Silt Collection Tank | 2.9251780 | 101.7819190 | 71.71 | III | S.P | 77.53 | II | S.P |
| | Average WQI | | | 75.94 | III | S.P | 68.85 | III | S.P |

*S.P = Slightly polluted, P = Polluted*

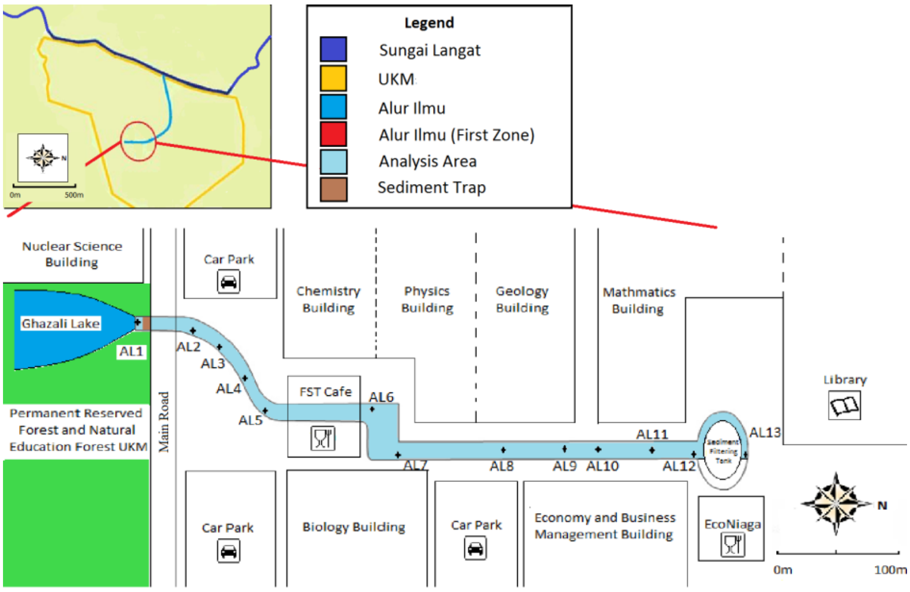


**Figure 1.** Alur Ilmu upstream and nearby buildings.

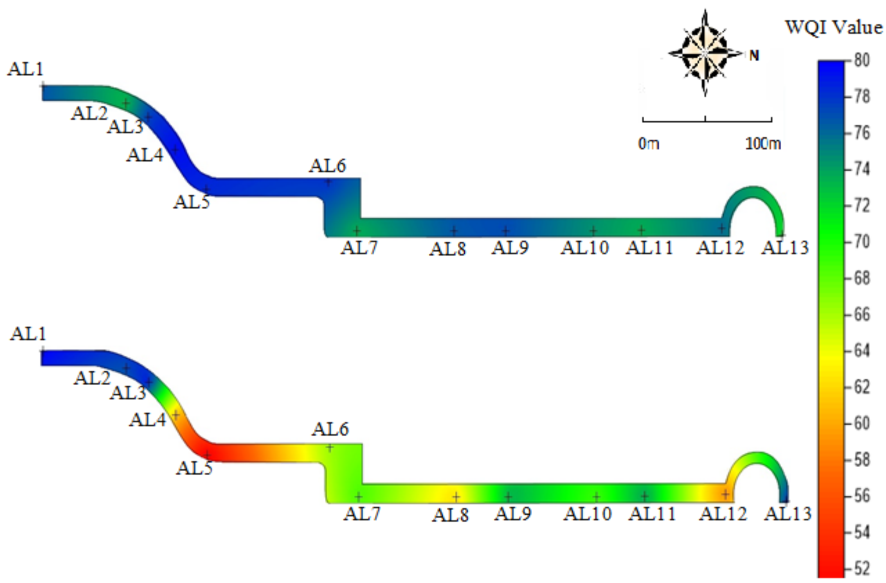


**Figure 2.** Kriging models of WQI during raining season (above) and dry season (below).

WQI at station AL13 (Silt Collection Tank) is low because the filtering tank is functioning to prevent sediment from flowing further into the downstream of Alur Ilmu, hence most of the pollutants are accumulated here during rainy season.

During dry season, Alur Ilmu receives clean water, which can be seen at AL1 (Ghazali Lake), AL2 (Main Inlet) and AL3 (Inlet 1). But as moving to downstream, the water quality in Alur Ilmu is degraded. AL4 (Inlet 2), AL5 (FST Café), AL12 (EcoNiaga), AL8 (Car Park) are detected as pollution sources during dry season. Minimum rainfall intensity during dry season creates stagnant water or even backwater to which no transporting energy to flow sediments and other pollutants downhill but accumulating most pollution in Alur Ilmu at the point source. AL5 (FST Café) and AL12 (EcoNiaga) are the major pollution sources to the Alur Ilmu. Poor maintenance of water and oil pipes of the cafes has caused leakage which allows pollutants such as oil and grease as well as nutrients entering Alur Ilmu. It is in an agreement with the study conducted in 2015 (Afina et al., 2015) showing that EcoNiaga is the main point source pollution that contributes to high concentration of BOD, COD, TSS, turbidity and oil and grease in Alur Ilmu.

## 5. Conclusion

The average WQI in Alur Ilmu during dry season (68.85 - Class III) is lower than that of rainy season (75.94 - Class III), indicating that extensive treatment is required if the water were to be used for water supply. The study provides stormwater monitoring data and computer modeling in spatial interpolation for the use of stormwater quality management in Alur Ilmu. The results of the study can be used as an effective tool for solving environmental problems such as pollution control at point sources, provide knowledge in maximizing the capacity of water treatment system for strategic coverage and being able to determine water quality level in specific area in a short time and low cost for analysis.

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