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Mapping Spatial Distribution of Copper, Dissolved Oxygen and Total Suspended Solids Concentration in Road Stormwater Drainage at Industrial Area

Nur Aina binti Mohammad[1], Mohd Hairul Khamidun[1*], Mohammad Ashraf Abdul Rahman[2], Mohd Erwan Sanik[3], Shakila Abdullah[4]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

[2]Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, 84600, Pagoh, Muar, Johor, MALAYSIA

[3]Centre for Diploma Studies,
Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, 84600, Pagoh, Muar, Johor, MALAYSIA

[4]Faculty of Applied Sciences and Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, 84600, Pagoh, Muar, Johor, MALAYSIA

*Corresponding Author

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Abstract: In present scenario, the urbanization area stormwater quality is decreasing due to human activities such as transportation movement and industrial development. This study was carried out to determine the concentration of water quality parameters such as pH, Dissolved Oxygen (DO), turbidity, Total Suspended Solids (TSS) and copper and to develop the spatial distribution mapping of pH, copper and TSS by using Surfer 8 software. Stormwater samples were collected within 4 weeks from 5 sampling points that had been identified. The experiment tested were conducted according to established technique of the American Public Health Association (APHA, 2012). The results showed that the range reading for pH was 6.48 to 7.60, DO was between 4.45 to 7.49 mg/L, turbidity was ranged 11.94 to 27.16 mg/L, TSS was 11 to 27 mg/L and copper was ranging from 0.19 to 0.27 mg/L. The spatial distribution mapping developed by Surfer 8 software and figure out the trends changing of water quality in the road stormwater drainage. The results showed that the drainage nearest to S3and S5 as most threatened by Cu and lower of DO concentration. The identification of spatial distribution in the study area helps stormwater management to be beneficial in decision-making processes.

Keywords: Copper, dissolved oxygen, total suspended solids, spatial distribution mapping

1. Introduction

Stormwater includes precipitation in the form of rain and snow, as well as melted ice and snow. Rainfall is the main contribution of stormwater in Malaysia [1]. Contribution of stormwater runoff are divided into two which are climate change and human activities. Changes in rainfall and temperature contribute to basin runoff, whereas urbanization of watersheds and the use of roads and highways lead to storm water runoff volume and decreased water quality [2]. Due to growth population in the urban areas, road network and accessibility are important infrastructure,

*Corresponding author: hairulk@uthm.edu.my

along with clean water, gas, power, drainage, sewage, and telecommunications [3]. In general, roadways in Malaysia have revealed the formation of pollutants such as chemicals, debris, fertilizers, vehicle fluids, debris from worn components, and heavy metals lead, zinc, copper, cadmium and others [1]. Thus, stormwater events cause water to flow on the surface, which washes away a range of pollutants during stormwater.in the drainage area and may sometimes have an effect on aquatic bodies.

Stormwater pollution has a negative impact on human health and environmental quality because of the amount and quality of garbage and pollutants carried by stormwater. Heavy metals are among the most harmful contaminants, since they have a devastating influence on the ecosystem and all creatures. Heavy metals such as copper, zinc, and lead may be found in considerable proportions in runoff from roofs, roadways, and parking lots, and these metals can have harmful effects on people when consumed. Aquatic species may get contaminated with metal ions, which can be integrated into food chains and concentrated to a point where they have an impact on their physiological status [4]. In addition, the contamination level surrounding Parit Raja, Johor Malaysia has increased due to the growing industrial area. Conventional and nonconventional pollutants in the industrial sector that are directly released into the drainage systems and cause water quality degradation [5]. In general, the wastewater that is discharged from industrial facilities is pollutant and had been disposed of in the surface waters which pose a direct or indirect threat to the quality of life of local people and health of aquatic ecosystem [6]. Anthropogenic input from industrial operations, such as wastewater discharge from electroplating smelting, corrosion of copper tubing, and metal engraving businesses, is a substantial cause of surface water pollution.

The aim of this research is to determine the concentration of water quality parameters pH, DO, Turbidity, TSS and the presence of copper in road stormwater drainage. Meanwhile, the spatial distribution mapping of copper, DO and TSS at selected sampling points is to figure out the trends changing in the road drainage using Surfer 8 software. Surfer 8 software has been developed as a powerful tool for 3D visualization, contouring, surface modeling programme and displaying spatial mapping data [7]. Therefore, the result can be used to comprehend the spatial for decision making in several areas including engineering and environmental fields. Hence, provide accurate information about surface water quality characteristics. At the end of this research, awareness on the importance of clean water had been highlighted to the public so that steps or precautions could be invented in the future to get a clean water and industrial utilization purposes in the present study.

2. Methodology

2.1 Study Area

The selected location of the research at road drainage KM50 Jalan Kluang that connected from Batu Pahat to Ayer Hitam. The details of the area are as tabulated in table 1 while fig. 1 depicted the 5 sampling points that located near to the industrial area, residency and education hub.

Table 1 - The sampling area with geographical coordinates at Parit Raja area and description

Sampling	Research Area	Geographical coordinates	Source of pollution
1	Education hub	1º51’15.0006’’N 103º5’30.0012’’E	Vegetation Area
2	Industrial Area 1	1º51’15.0006’’N 103º5’31.9992’’E	Vegetation and Industrial Area
3	Industrial Area 2	1º51’15.9978’’N 103º5’34.0002’’E	Industrial and Road Area
4	Industrial Area 3	1º51’16.9986’’N 103º5’38.0004’’E	Industrial and Road Area
5	Main Road (Traffic light area)	1º51’15.9978’’N 103º5’34.0002’’E	Vegetation and Road Area

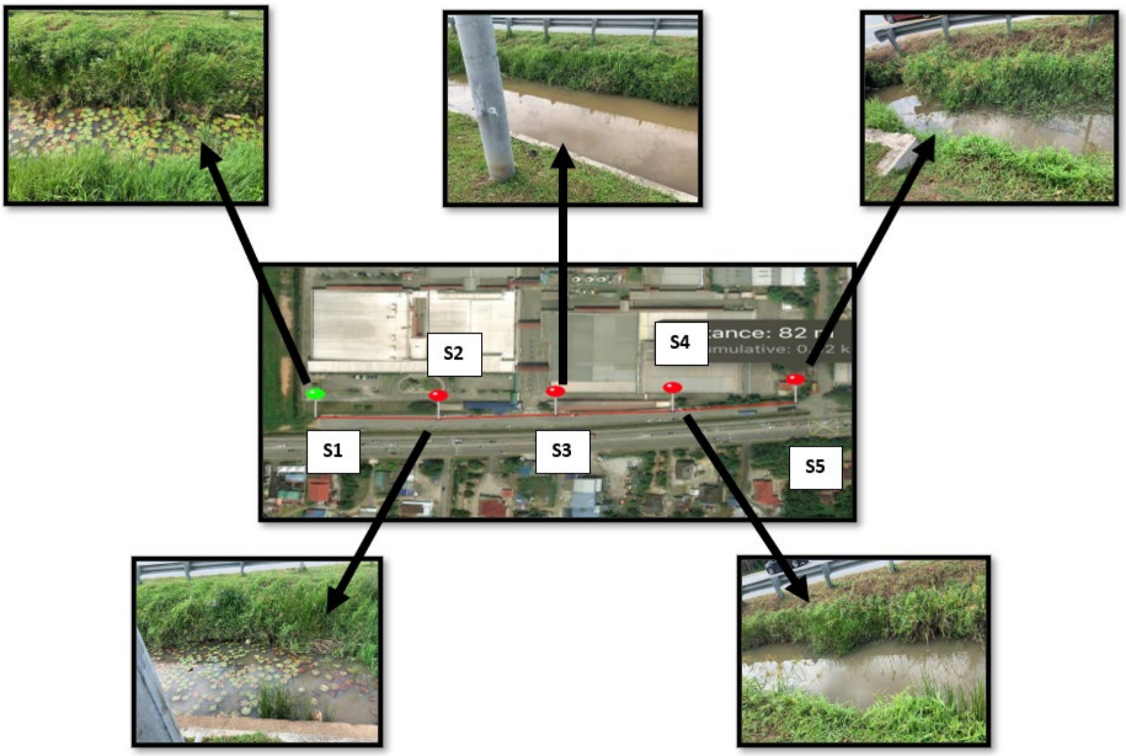

Fig. 1 - Sampling points location in along the main road and industrial area

2.2 Water Sampling

Water sampling were collected from 5 sampling points as mentioned in table 1. 500ml HDPE bottles were used to collect water samples for physical and chemical analysis by manual grab techniques since this procedure is simple and often uses where the minimal equipment requirements and field workers to handle. Water samples were preserved in reference to the American Public Health Association standard method as tabulated in table 2 [8].

Table 2 - Storage and maximum holding time of samples (APHA 2012)

Parameter	Storage	Maximum Storage
Copper	Room temperature	Preserved sample 6 months
DO	Refrigerate (<6ºC) in dark	8 hours
TSS	Refrigerate (<6ºC) in dark	28 days
pH	Analyses immediately	Determine in situ if possible or upon arrival in laboratory
Turbidity	Refrigerate (<6ºC) in dark	Up to 48 hours

2.3 Water Quality Analysis and Mapping

The water quality parameters measured in this study were pH, turbidity, DO, TSS and copper. Standard methods were used for sample collection, preservation and analysis of different water quality parameters. The samples were tested for contamination using physicochemical method at Micro Pollutant Research Centre (MPRC) and environment laboratories as described in standard method for water examination by APHA. The determination of this parameter TSS and copper was carried out using the spectrophotometer (HACH DR6000) [8],[9]. Meanwhile, turbidity and pH were measured using pH meter and Turbidimeter. Results of analysis were discussed and compared to the National Water Quality Standard (NWQS).

The coordinates and selected parameter values of each sample were the data inputs used in this analysis for each sampling site. Surfer 8's associated programme and spreadsheet for data entry, which includes the easting value, northing value, and elevation The location and elevation of the sample spots shown in the table 1 and fig.1 were used for data entry. The elevation of each stormwater sample was substituted by the water quality parameters such as turbidity value, concentration of DO and copper concentrations.

3. Result and Discussion

Table 3 illustrates the average value for stormwater drainage quality analysis of parameter involved. In regard of pH, turbidity, DO, TSS and copper parameter, all samples comply with recommended NWQS standard limit as shown in table 4. Thus, the parameter of DO and copper exceeded the limit class II in NWQS while the parameter TSS and turbidity were compared to the class II and pH in class I of NWQS.

Table 3 - Stormwater drainage quality analysis of parameter involved

Parameter	Unit	Point 1	Point 2	Point 3	Point 4	Point 5
pH	-	6.48 - 6.80	7.07 - 7.33	7.20 - 7.45	7.25 - 7.50	7.30 - 7.60
Turbidity	NTU	18.84 - 21.32	11.94 -27.16	16.66 - 21.86	13.14 - 18.89	18.83 - 20.76
DO	mg/L	5.22 - 7.12	4.45 - 7.49	4.48 - 7.11	4.80 - 6.88	4.66 - 6.94
TSS	mg/L	13 - 17	12 - 18	10 - 22	11 - 27	12 - 20
Copper	mg/L	0.21 - 0.26	0.23 - 0.26	0.24 - 0.27	0.22 - 0.25	0.19 - 0.24

Table 4 - Comparison to the NWQS criteria

Parameter	Unit	Min	Max	Average	Recommended NWQS
pH	-	6.48	7.60	7.04	6.5 – 8.5 (≤ class I)
Turbidity	NTU	11.94	27.16	19.55	50 (≤ class II)
DO	mg/L	4.45	7.49	5.97	5 – 7 (> class II)
TSS	mg/L	10	27	18.5	50 (≤ class II)
Copper	mg/L	0.19	0.27	0.23	0.02 (.> class I)

3.1 Relationship Between Concentration of Water Quality Parameters and Weeks Sampling

Fig. 2 (a) shows a relationship between concentration of water quality pH and weeks sampling. From the figure, it can be observed that the pH readings for stormwater drainage were between pH 6.48 until pH 7.60. In general, pH readings were obeyed the maximum permissible limits in NWQS (Table 4). pH is a relevant parameter in water treatment systems, because chemical reactions are intensively affected by these parameters [10]. The pH level rises as a consequence of the consumption of dissolved carbon dioxide by photosynthetic algae, which causes the concentration to rise [9]. However, the pH range obtained were appropriate for aquatic life cause too much of acidic water is bad for vegetation and the livelihood of aquatic. Consequently, it is crucial to keep the pH of aquatic ecosystems within this range, since both high and low pH levels may be harmful to nature [4].

Turbidity values varied between 11.94 and 27.16 NTU (see Fig.2(b)) which recorded the high turbidity in S2. These concentrations were within the permissible limits of NWQS and categorized as class II. Turbidity is often caused by suspended particles such as silt, plankton, clay, organic waste, and other tiny or decomposing creatures. The presence of these suspended particles that settled in the water reduced the water's clarity. The murkier water is attributed to the higher sediment concentration [11]. High turbidity might associate to the microbial contamination and attributed to the effluent from excessive precipitation, organic contaminants and road runoff in which a high suspended matter content [12]. The best results can be obtained by measure immediately without altering the pH and temperature and to minimize the microbiological decomposition of solids by refrigerate the samples. Turbidity levels enhance by stream flow, surface runoff, and overland movement in natural waterways [13].

Fig.2 (c) shows DO concentrations of water samples analyzed ranged from 4.45 to 7.49 mg/L. Overall, the values acceptable levels of NWQS which was more than 3 mg/L as well as categorized under class II. Low concentration of DO was reflected to the increased of organic contamination [14]. In general, oxygen enters the solution of surface waters as a consequence of its diffusion from the surrounding atmosphere and the process of photosynthesis that occurs in aquatic plants. In most cases, the breakdown of organic matter in water will result in the consumption of DO [4].

TSS in stormwater can also be due to natural sources as sewage, urban runoff and industrial waste permissible limit [5]. According to the Fig.2(d), the TSS value was ranged between 10 until 27 mg/L. High TSS presence in the S4(W2), these might decrease the quality and affected the taste of the water. Suspended matter was affected by weathering processes. Therefore, mechanical procedures like filtration or slow settling should be applied to remove suspended matter rather than chemical procedures [15]. In most cases, soil erosion which is often surrounding environment to the human activities (mining, deforestation and plantation) takes into account the source of suspended particles. The high TSS concentration in the drainage attributed to the anthropogenic activities and runoff with high suspended matter [16].

The copper concentrations were ranging between minimum 0.19 mg/L at sampling point 5 (in week 2) and maximum 0.27 at point 3 (in week 4) (Fig.4(e)). Overall, the range of the Cu was class II whereas 0.02 mg/L exceeded the standards level in NWQS. Some of the metals deposited from industry and road runoff flush away the metals through the drainage. Fluctuation concentration of Cu probably cause by variation traffic volume, rainfall event and drainage characteristics [13]. Moreover, Cu can inhibit the activity of nitrifying and denitrifying bacteria, thus decreasing the nitrogen removal capacity of stormwater. Excessive amount of Cu in drainage can accumulate in the tissues of living organisms and is toxic to many aquatic organisms [17].

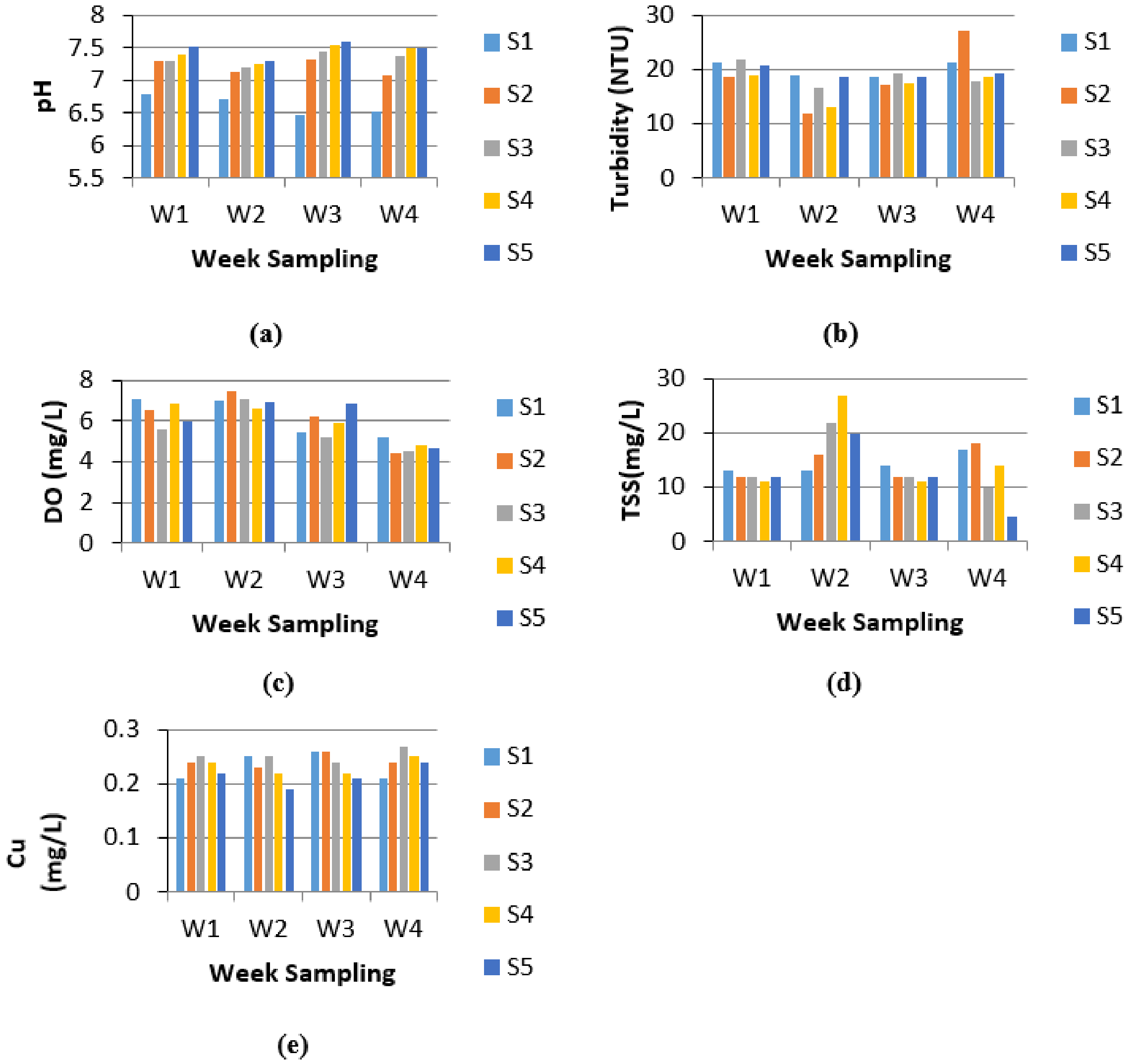

Fig. 2 - Distribution of values for (a) pH; (b) turbidity; (c) DO; (d) TSS; and (e) Cu in road drainage from 5 sampling points in 4 weeks

3.2 Spatial Distribution Mapping of the Concentration Dissolved Oxygen, Total Suspended Solids and Copper

The contour maps depicted in Fig. 3 is the distribution of DO. In reference to the figure, high concentration zone occurred in W1 and W2. In contrast, concentration map for W3 and W4 showed that DO concentration slightly reduce to the left area of drainage but still higher than safe limit. Decreasing of concentration of DO in W3 and W4 due to the high temperature because low rainfall event occurred for those weeks. The rate of biological oxidation was speeds up a during the sunny days. Also, the DO values changes throughout the day and night because of the photosynthesis and breathing. The quantities of DO give relevant information about the water quality and the stability of numerous organic and inorganic pollutants.

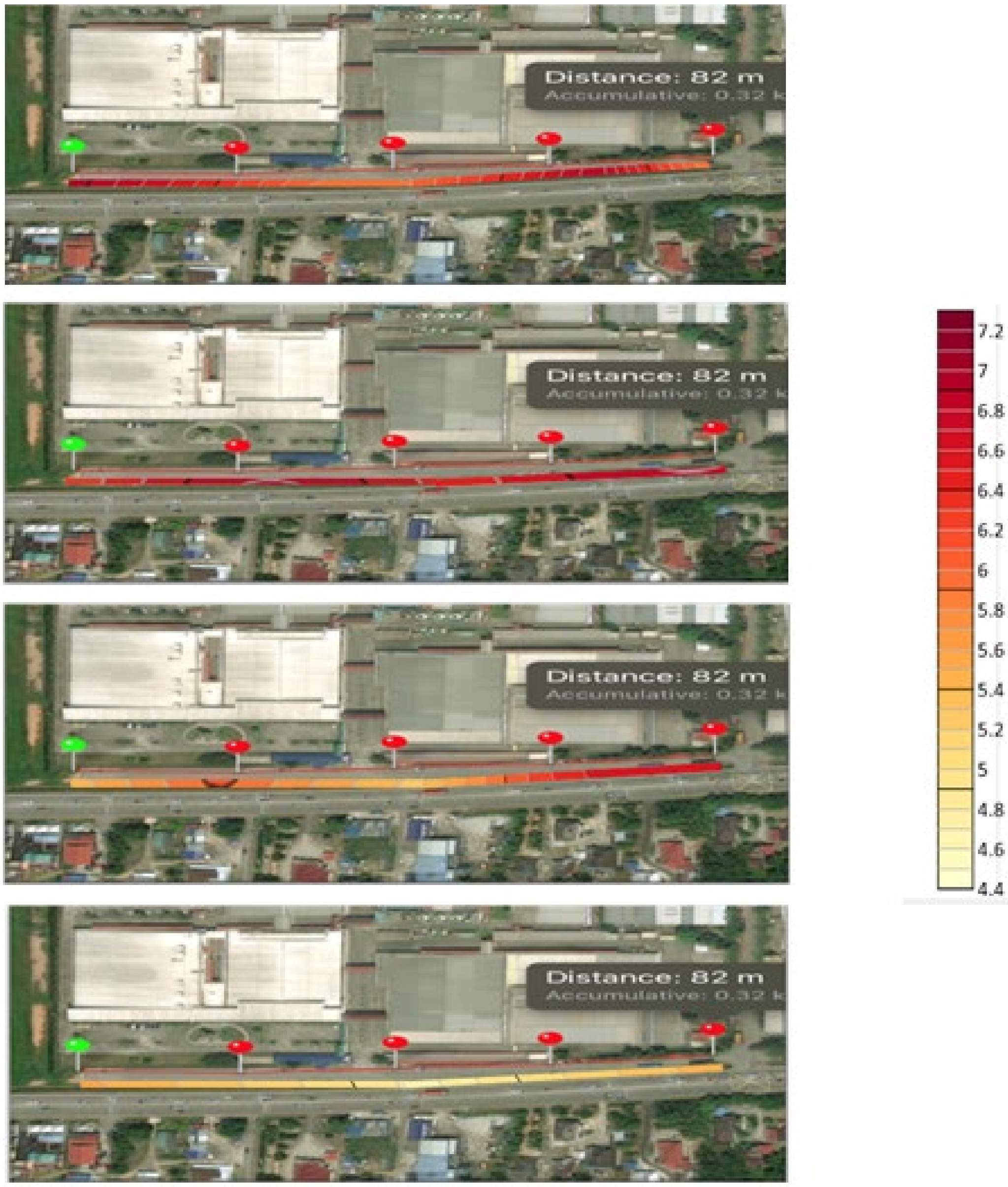

Fig. 3 - Spatial distribution mapping of DO in road drainage

The contour maps of the distribution of TSS is shown in Fig 4. The overall spatial distribution of TSS at the study area showed increasing tendency in W1, W2 and W3 and deceasing on S3 towards the down part of road stormwater drainage. The increasing of TSS might be attributed to the loading and deposition of pollutants from surface water runoff such as vehicle exhaust emissions, vehicle parts, road salt, road paint and soil material [18]. Vegetated filter, including swales, were also affect the reducing TSS value in S1 and S2 area. In general, TSS value is considered might harmful in higher quantities.

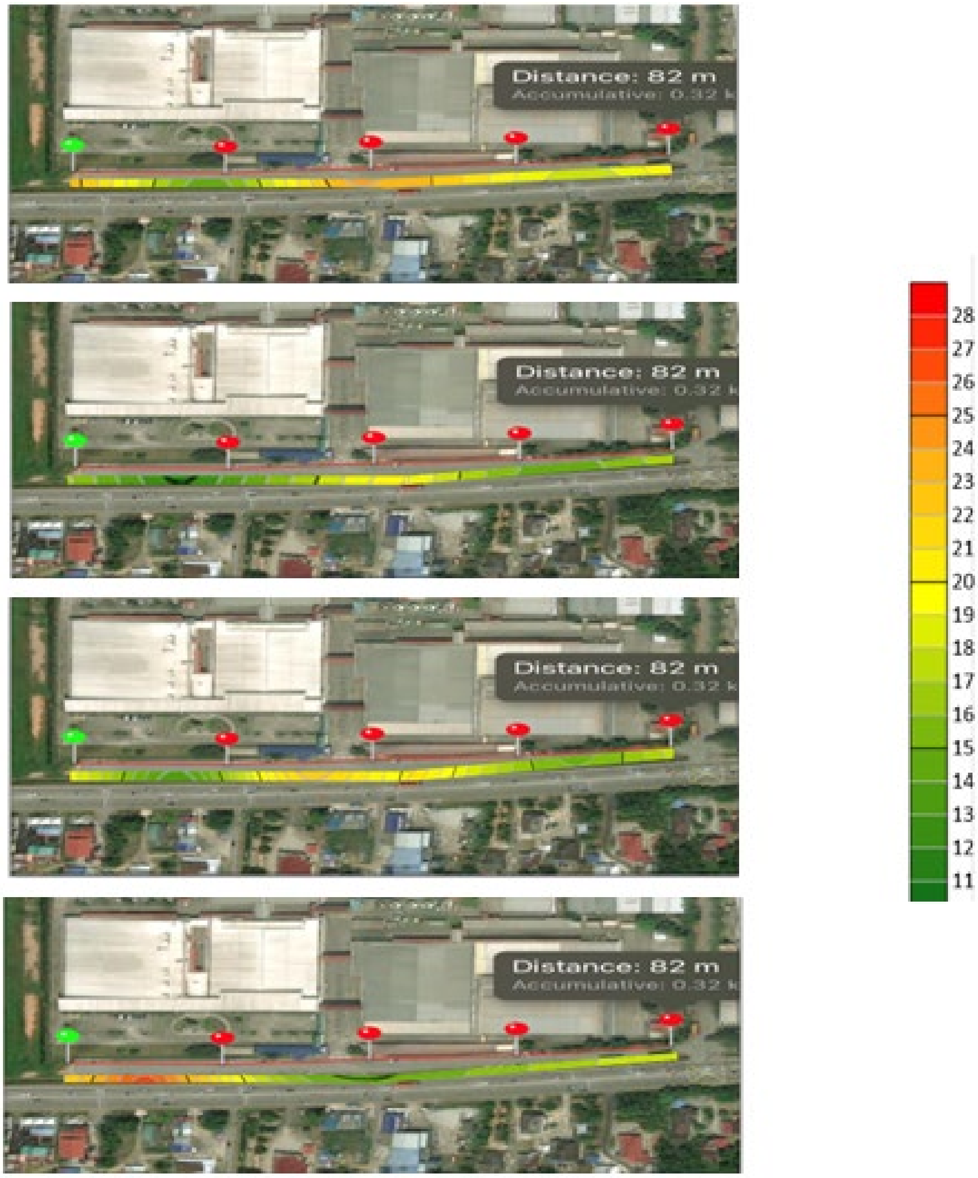

Fig. 4 - Spatial distribution mapping of TSS in road drainage

The contour map for concentration of Cu in road drainage is shown in fig.5. The maps show high concentration zone occurred in S3 for W1 to W4. Volume traffic and near to the industry can be considered as factor affecting water quality in road stormwater drainage due to emission of Cu that deposited on roads and washed off by runoff water. In contrast, concentration map for W1 and W4 was slightly reduce in left area drainage while in W2 and W3 reduced in right drainage and almost reached to the maximum safe limit. Due to the variety species of vegetation in the drainage, it had adsorbed the pollutants and decreased concentration of Cu [19]. Thus, water need conventional treatment for water supply and sensitive aquatic species in the drainage.

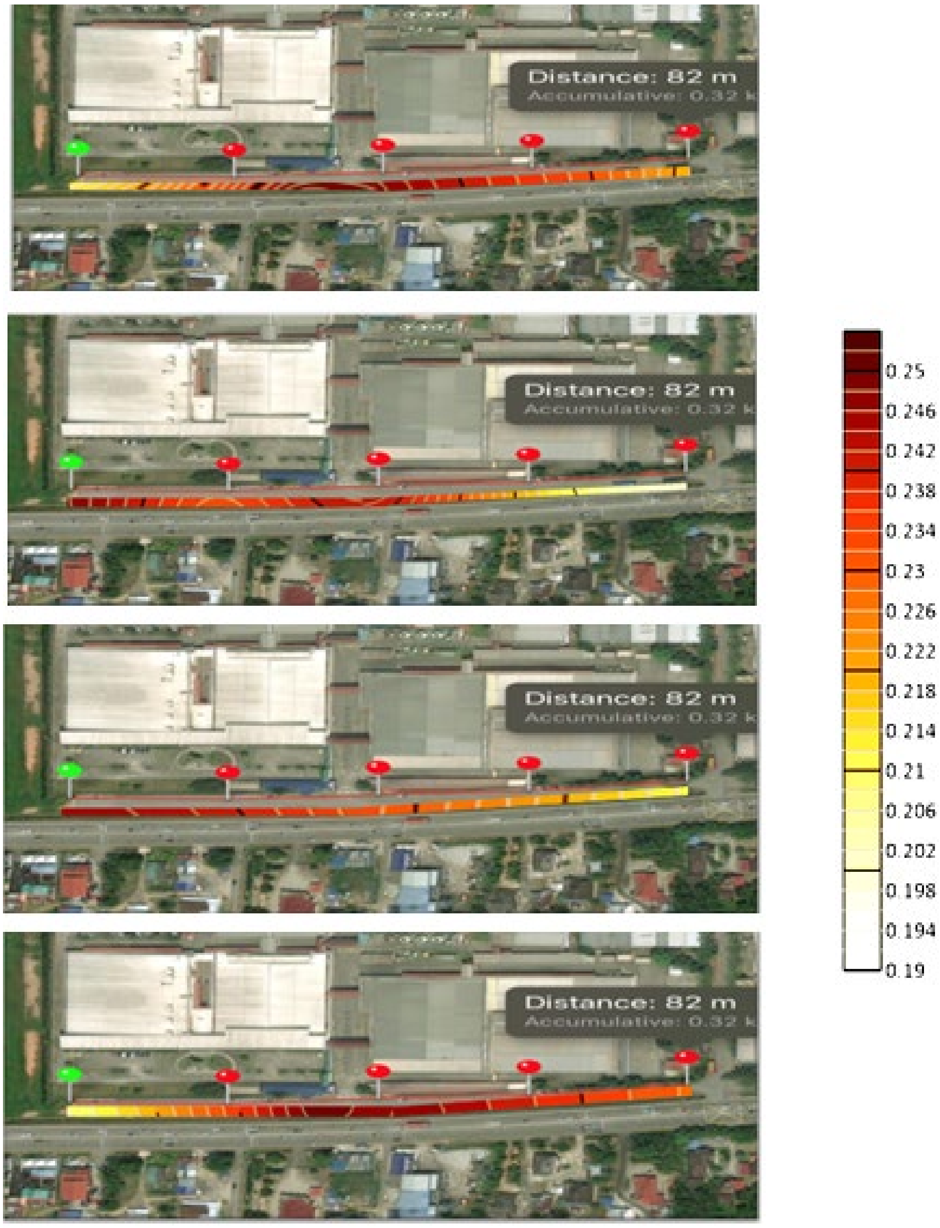

Fig. 5 - Spatial distribution mapping of Cu in road drainage

4. Conclusion

In regard of pH, turbidity, DO, TSS and Cu, all sample complied with recommended criteria set by NWQS. While parameter DO and Cu, exceeded the class II and class I standard limit in NWQS. Traffic volume, industrial wastes, weather, land and plant around the stormwater drainage were some possible factors that influenced the pollutants in road stormwater drainage that unsuitable for human consumption. This shows that treatment and awareness are needed. For this reason, sustainable management practices need to be implemented in the industrial region of Parit Raja in order to safeguard surface water from the pollutants produced by industry and road runoff. The Surfer 8 software proved to be a useful tool in conducting spatial analysis and providing an interpretation of the groundwater quality. The research had shown that Surfer 8 paired with analysis were useful for evaluating and mapping the quality of stormwater drainage in the industrial areas at Parit Raja, Johor. This software is believed to be helpful in the stormwater management, the identification of spatial distribution in the study area and should be beneficial in decision-making processes. In conclusion, the effectiveness of this study and information about the quality of water need to be upgraded from time to time. There are some proposals that should be taken into account for the purposes of further research and the effectiveness of these study. Stromwater drainage quality needs to evaluate the effect of different heavy metals such as ferum, magnesium or aluminum. Next, understanding the relationship between quantity of water and water quality; and effectiveness of water treatment systems in reducing pollutants in the road stormwater drainage.

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