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Spatial Variation of Water Quality Parameters in Gebeng Industrial Area, Pahang, Malaysia

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Abstract. The study was conducted to examine the physico-chemical parameters of surface water quality in the Gebeng Industrial area, Pahang, Malaysia. Water samples were collected monthly from the selected 10 sampling site in the study area. The selected parameters were analyzed based on *in-situ* and *ex-situ* analysis according to standard methods. The statistical software was used for data analyses. It was observed that, the non-point source pollutants were associated with runoff from construction sites of newly developed industrial areas and the point source contributing the major pollutants especially from industrial wastes. Low levels of dissolved oxygen (DO) and higher levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), ammoniacal nitrogen and selected heavy metals made the water pollution. According to Interim National Water Quality Standard (INWQS), the major part of the river specially the mid-region was categorized as class V (very highly polluted) while some part was found to be in class IV (highly polluted) and rest of class III (polluted) as well. Based on Malaysian Water Quality Index (WQI), the most stations except lower and uppermost were in class IV, and highly polluted.

Keywords: Water quality parameters, Water quality index (WQI), Chemical oxygen demand (COD), Biochemical oxygen demand (BOD), Gebeng Industrial area

1. Introduction

Quality of water is deteriorating all over the world in many ways. Anthropogenic activities are the main causes of water pollution. The end points of effluent discharged from industries are water bodies [1]. In Malaysia, the riverine ecosystem is of particular interest since river water provides about 98% of the country's water requirements [2]. Therefore, contamination of river and reservoir waters poses a serious health risk. According to Department of Environment (DOE), the biggest sources of industrial water pollution in Malaysia are food and beverage industries, chemical based industries, textiles, paper, palm oil and rubber processing industries [3]; [4]. Such rapid development of industries however has increased the water pollution level in Malaysia [5]. Rapid growth within the industrial sector, where more and more hazardous industrial wastes are being generated could damage to the environment when improperly treated and deposed. Industrialization in developing countries with an increasing demand for heavy metals results in a high emission of these pollutants into the biosphere. Heavy metal pollution in water bodies is a serious environmental problem, threatening the aquatic ecosystem and human health. Industrial pollution is a serious problem for the entire planet, especially in nations which are rapidly industrializing, like Malaysia.

Malaysia has a number of industrial estates all over the country of which Gebeng is one and main industrial area in Kuantan, Pahang. Since 1970s the area is increasing its industrialization. Including

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petrochemical, multifarious industries are been established in this area. The Tunggak, which is carrying wastes of the estate, is one of the important rivers in Pahang which is adjacent to this area. The real scenario is the rapid developments including the petrochemical industries generating effluents which contain high concentrations of conventional and non-conventional pollutants that deteriorating the water quality. Therefore, the study was conducted to determine water quality characteristics based on selected physico-chemical parameters.

2. Materials And Methods

2.1. Study Area

The Gebeng industrial area lies between 03°56′06" to 03°59′44" N and 103°22′41" to 103°24′47" E (Fig 1). It is located near Kuantan Port. The choice of sampling sites were based on location, land use pattern and site elevation. The Global Positioning System (GPS) was used to determine the actual coordinate of sampling stations and to reconfirm the location of stations during the subsequent sampling periods. A total of 10 sampling sites were selection for sampling.

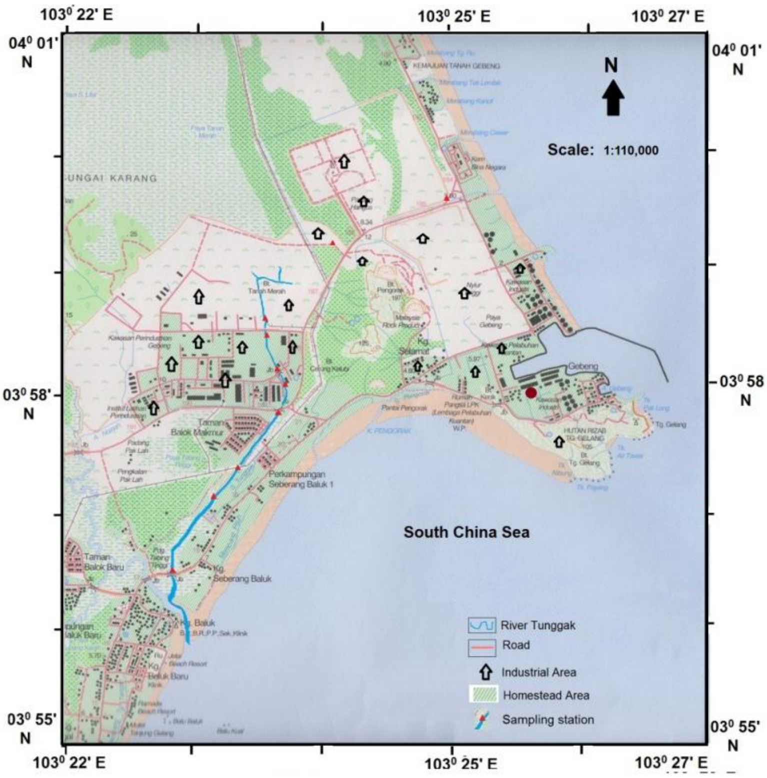

Fig. 1: Location of the study area

2.2. Sampling and Data Collection

Water samples were collected monthly from about 10 cm below the water surface using 500ml HDPE bottles. The dark BOD bottles (300 ml) were used for BOD samples. The samples were preserved and transported to the laboratory for analysis. The standard procedure was followed during the sampling time [6]. *In-situ* parameters such as, pH, temperature, dissolved oxygen (DO), turbidity, electrical conductivity (EC), and total dissolved solids (TDS) were measured during the sampling.

2.3. Laboratory Analysis

Selected ex-*situ* parameters were measured in accordance with standard procedures [6]; [7]. The selected heavy metals were determined using ICP-MS (Inductively Coupled Plasma Mass Spectrometry). The DOE-WQI index was used to classify stretches of the studied water bodies into classes, according to the system adopted by the DOE [8]; [9]).

2.4. Statistical Analysis

Statistical analysis was conducted using the statistical software (SPSS 16.0). The mean, standard deviation and analysis of variance (ANOVA) was done to determine the significant differences of the factors at different sampling stations in the study area.

3. Results and Discussion

3.1. In-Situ Parameters

Surface water temperature ranged from 26.16 ℃ to 35.24 ℃ among the stations. The mean temperature recorded was 28.78 ±1.07 ℃. The water temperature was within the normal limit of Malaysia [10] in the most of the stations, but the temperature at stations 6 to 8 were beyond the normal limit (Table 1). The pH values varied from station to station. The mean pH recorded was 6.23±0.52, and it ranged from 4.16 to 9.12. The highest pH value (9.12) was recorded in station 6 followed by station 5 and station 7. The highest pH was recorded due to the presence of industrial estate effluence consist of polymer, chemical, metal, gas and power industries. However, the average pH values at the most stations were found to be within the standard level of Malaysia [10]. On the contrary, the lowest value (4.16) was recorded at station 8 followed by station 9 and 10; these values were below the standard level. Perhaps the industrial effluents at the area of station 8 and 10 contained acidic substances and due to submerge condition the pH was also low at station 9 (Table 1)

Table 1: The range, SD and mean value of in-situ parameters at different sampling stations

Station No.	Geographical Location		Temperature (°C)	pH	Conductivity	DO (mg/L)	TDS (mg/L)	Turbidity (NTU)
1	03°56'35" N 103°22'32 "E	Range	27.05-30.17	5.66-7.02	14200-	2.62-4.40	9040-	7.69-22.50
		Mean	28.78±1.07	6.23±0.52	18013±4946	3.30±0.61	16137±76	16.66±6.41
2	03°57'19" N 103°22'60" E	Range	28.04-29.2	6.97-7.71	7700-13660	1.10-2.17	5160-7270	10.05-24.70
		Mean	28.55±0.59	7.28±0.34	10880±2836	1.58±0.41	6250±108	17.72±5.81
3	03°57'40" N 103°23'15" E	Range	29.01-29.81	7.32-8.40	1244-1800	1.33-1.80	650-869	9.78-20.70
		Mean	29.34±0.38	7.69±0.38	1395±207	1.69±0.36	767±112	13.70±3.90
4	03°57'54" N 103°23'23" E	Range	30.92-32.57	7.51-8.51	1119-1320	1.62-4.12	527-821	10.05-17.27
		Mean	31.74±0.75	7.95±0.35	1212±95	2.71±0.96	613±108	14.14±3.42
5	03°58'13" N 103°23'23" E	Range	30.92-33.1	6.96-8.95	1380-1630	1.93-3.91	642-748	11.26-34.50
		Mean	31.98±1.07	7.96±0.99	1505±107	3.12±0.91	700±50	23.44±12.0
6	03°58'34" N 103°23'14" E	Range	31.63-34.14	7.25-9.12	1423-1740	1.56-3.16	649-778	11.73-28.80
		Mean	32.88±1.35	8.01±0.76	1585±164	2.32±0.79	715±68	20.98±8.01
7	03°59'13" N 103°23'17" E	Range	33.2-35.24	6.77-8.60	923-1210	2.85-3.93	203-529	6.69-12.35
		Mean	33.78±0.88	7.65±0.62	1068±149	3.28±0.51	365±171	9.82±2.30
8	03°59'16" N 103°23'17" E	Range	32.5-34.1	4.66-5.42	51-58	2.78-4.25	19.6-24.8	4.83-10.06
		Mean	33.27±0.56	4.96±0.29	55±3.31	3.38±0.59	21.78±2.2	6.59±1.81
9	03°59'27" N 103°24'12" E	Range	26.16-27.4	4.23-6.70	20-27	1.93-3.05	7.7-8.7	2.10-6.02
		Mean	26.78±0.61	5.13±1.04	24±3.39	2.34±0.38	8.15±0.47	3.87±1.56
10	03°59'38" N 103°24'45" E	Range	31.12-31.75	5.14-6.40	713-787	2.36-3.01	333-379	7.7-12.24
		Mean	31.45±0.29	5.86±0.44	750±36.01	2.66±0.22	354±22.21	10.11±2.09

The conductivity values recorded from all the stations was within the normal limit except the stations 1, 2 and 3 (Table 2). It was probably due to the entering of saline water in those 3 stations during tide from the South China Sea [11]. The DO concentration was recorded very low at all the stations varied from 1.10 mg/L at station 2 to 4.40 mg/L at station 1. Based on DO concentration, all the stations were categorized as class III and IV according to INWQS threshold level for Malaysia surface water. The TDS concentration was recorded higher in the lower stations compare to the uppermost stations. Due to the tidal disturbance [11] higher amount of TDS was recorded at station 1. The TDS concentration was also higher at station 2 because of some agricultural activities adjacent to the station 2. The level of TDS at stations 7 to 10 were in permissible limits 500 mg/L [10]. The turbidity of water samples in the study area varied from 2.10 NTU at station 9 to 34.50 NTU at station 5 (Table 1). Overall, turbidity reading was normal level at station 9, whether rest of all contained higher value of turbidity according to the INWQS threshold level for Malaysian surface water [10].

3.2. Ex-Situ Parameters

All samples collected from sampling sites were analyzed in laboratory for determining the concentration of sulphate (SO_4^{2-}), NH_3-N, nitrate-nitrogen (NO_3-N), phosphate (PO_4^{3-}), BOD, COD and TSS. The highest sulphate value was recorded at station 1, 2 and 7. The location of stations 1 and 2 are near the sea [11] and some chemical industries are adjacent to station 7 which produced detergent and discharged sulphure reach effluents into the river flow. The concentration of NH_3-N varied from 0.25 mg/L at station 9 to 3.47 mg/L at 3. Those values that exceeded the INWQS threshold level; and the water of mid-stations were classified as class V [12]. The value of NO_3-N content was within the safe level (<0.4) [12] except station 5, 6 and 7; these stations were in the vicinity of industries including polymer, chemical, metal, gas and power, and wooden industries and received most of the effluents. From the study, the highest value of PO_4^{3-} (6.30 mg/L) was recorded at station 10, while the other stations contained relatively lower value of PO_4^{3-}. Overall, the PO_4^{3-} concentration was within permissible level at station 7, 8 and 9 [10]. The study showed that, the highest BOD (32.88 mg/L) was recorded at station 7 and the lowest (4.23 mg/L) at station 9. The values of BOD at all stations were beyond the permissible limit [10], and it was due to the discharge of industrial effluents to the river flows. The highest COD value was also recorded at station 7 and the lowest at station 9. According to INWQS, the water of mid-region was classified as class V (highly polluted) based on BOD and COD values. However, the level of COD was recorded safe at station 9 and 10 [10].

Results reveled that water in the study area was bearing chromium (Cr), cobalt (Co), copper (Cu), zinc (Zn), barium (Ba) and lead (Pb). The concentration of Pd was found to be higher at all stations compared to the threshold level [10]. The Cu concentration was beyond the threshold limit at station 1 and 7 (Table 2). The study also showed that, Co content was recorded higher at stations 1 to 6 and the Cr concentration was higher at station 8. The main sources of toxic heavy metals were possible wastewater and effluents from major industries, especially the chemical, polymer, metal, petrochemical gas and energy, and wooden industries that generated the organic and inorganic pollutants which ultimately contaminated the river water. However, the value of Zn and Ba content were observed below the permissible limit [10].

Table 2: Concentration of heavy metals (ppm) in the studied water samples

Stations	Cr	Co	Cu	Zn	Ba	Pb
1	0.0082	0.0926	0.4496	1.0717	0.0303	0.5415
2	0.0010	0.2243	0.0033	0.9441	0.0291	0.4956
3	0.0015	0.1740	0.0032	0.3431	0.0282	0.4827
4	0.0013	0.2502	0.0023	0.4778	0.0236	0.4801
5	0.0134	0.6191	0.0154	1.9435	0.0503	0.4937
6	0.0135	0.6716	0.2357	0.8405	0.0256	0.2323
7	0.0395	0.0000	0.4496	1.0003	0.0196	0.2349
8	0.0575	0.0003	0.0033	0.8810	0.0072	0.2305
9	0.0321	0.0920	0.0013	0.1400	0.0101	0.4896
10	0.0161	0.0000	0.3124	1.0003	0.0689	0.2283

3.3. Water Quality Index

Water quality index values were computed to classify and establish the status of water quality based on DO, BOD, COD, NH_3-N, TSS and pH concentration [13]. The highest value (61.95) was recorded at station 9 and the lowest value (38.35) at station 7. The calculated DOE-WQI score are shown in Table 3. The water quality of the study area varied with location of the sampling stations. The study revealed the station 3, 4, 5, 6, 7 and 8 were more affected by the industrial effluents. These stations are near to the different types of industries. These industries discharged various effluents and caused of higher pollutant at the mid-stations; on the other hand, station 9 and 10 are located close to existing the South China Sea, forested and urbanized area made the water less polluted [11].

Table 3: Classification of water in the study area based on DOE-WQI*

Sampling Station	DOE-WQI values	Water quality Class	Sampling Station	DOE-WQI values	Water quality Class
1	51.99	III	2	45.67	IV
3	45.35	IV	4	44.48	IV
5	43.36	IV	6	43.16	IV
7	38.35	IV	8	50.47	IV
9	61.95	III	10	53.18	III

*Class I ≥ 91.76; Class II = 75.36- 91.75; Class III = 51.68 – 75.36; Class IV = 29.61 – 51.67; Class V = <29.61

4. Conclusion

The physico-chemical study of the water quality reveled that the most of the water quality parameters were higher in study area. From the study results it is clear that station 3, 4, 5, 6, 7 and 8 (middle station) were more polluted compared to other sampling stations. These stations were polluted by the industrial activities. On the other hand, due to tidal interference at station 1 and 2 and less industrial activities at station 9 and 10 caused the less pollution in lower and upper stations. This study reveled that the major sources of pollutant were possibly the presence of different types of industries and their activities. Furthermore, the water quality status was affected by the land use pattern of its catchment area to contribute spatial variation. It is therefore recommended that all the industries that generate effluent and exceed the nation and international standards should treat it before discharging into the river stream. We also suggest that close monitoring of industrial activities should be ensure and emphasis also given on recycling of industrial waste to reduce the pollution level and their possible effects on the level of heavy metals pollutions.

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