SPATIAL VARIATION OF SURFACE WATER QUALITY AT GEBENG INDUSTRIAL ESTATE, PAHANG, MALAYSIA

M. A. Hossain, Sujaul Islam Mir, Nasly M.A., Zularisam. A.W. and Edriyana A. Aziz

Faculty of Civil Engineering and Earth Resources
University Malaysia Pahang
Highway Tun Razak, 26300 Gambang
Kuantan, Pahang, Malaysia
E-mail: ahossain2003@gmail.com

ABSTRACT: Gebeng is the main industrial area of Pahang, where, Tunggak is a strategic river. The anthropogenic impact on the river is as a result of rapid industrialization in Gebeng. This river is of particular importance in the study of surface water quality status because effluents from industries of Gebeng discharge into it thereby deteriorating the quality. Water quality parameters were analyzed across the river with the objective to disclose the spatial variation of the river water quality. To conduct the study, water samples were collected monthly from 10 sampling station across the river basin. The physico-chemical parameters were analyzed using APHA & HACH standard methods as well as the trace elements were determined using ICP-MS (Inductively Coupled Plasma Mass Spectrometry). Data analyses were done using SPSS statistical software. The study revealed that, pollution from non-point source was associated with runoff from construction sites of newly developed industrial areas and the point source contributing the major pollutants especially from industrial wastes. According to Interim National Water Quality Standard (INWQS) based on DO, COD, ammoniacal nitrogen and some selected trace elements, major part of the river specially the mid-region was categorized as class V (very highly polluted) while some part was found in class IV (highly polluted) and rest of class III (polluted) as well. Furthermore, classification of the river based on DOE-WQI showed that seven (7) stations (2-8) were in class IV (highly polluted); station 1, 9 & 10 were found to be polluted. So, from the study it is concluded that pollution is higher in the middle stations of the river compared to the upper and lower stream. This was due to less industry at upper stream and the tidal interference was present in lower stream and obviously the industrial wastes were mixing in the middle stations most.

Key Words: Water Quality Index (WQI), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen

1. INTRODUCTION

The earth is like a water planet [1]. It is the most delicate part of environment and is essential for human and industrial development. Due to rapid industrialization and population growth, the demand of fresh water rises tremendously in the last few decades [2]. Quality of water is deteriorating all over the world in many ways. Anthropogenic activities are the main causes of water pollution. The rate of pollution by anthropogenic activities is coupled with the ever-growing demands of water resources [3]. Industrial activities are producing most of the pollutant including organic matter, wastes and heavy metals. The natural and antrhopogenic metal contamination in aquatic ecosystem lead to the need of chracterizing their impact on environment [4]. Bounty of natural water resources make Malaysia as water rich zone; and it is contributing significantly to the socio-economic development of the country [5]. But the situation is not remaining unchanged; it is changing day by day with population growth, urbanization and

industrialization. According to the Environmental Quality Report 2009, 46% river water of Malaysia was polluted which was higher than previous couple of years [6]. Pahang is the largest province of Peninsular Malaysia. It is situated in the east coast area. Gebeng which is the main industrial area of Pahang is located near Kuantan Port; where the industrial development is growing rapidly. The wastes producing by the industries are mixing with the river water namely Tunggak. Tunggak is one of the important rivers in Pahang that adjacent to Gebeng industrial park. These industrial activities are generating effluents which contain high concentrations of conventional and non-conventional pollutants that deteriorating the water quality of the river. Therefore, the study was done with a view to identify the behavior of the water quality parameters and to disclose the spatial variation of the pollution status of the surface water in the study area.

2. MATERIALS AND METHODS

2.1 Study area and selection of station

The Tunggak river originated in uphill of Gebeng. Flowing over the industrial area it meets with another river named Balok; and they jointly fall into the South China Sea. The geographical location of the Tunggak river is $3^0 56' 06''$ to $3^0 59' 44''$ N and $103^0 22' 42''$ to $103^0 24' 47''$ E adjacent to the Gebeng industrial town holding several types of industries (Fig. 1). Stations selection was done considering the land use-pattern, point-sources of pollution, vegetation and river network. Total 10 stations were selected for sampling.

2.2 Sampling, Data collection and analysis

Water samples were collected monthly from pre-selected 10 stations. Three (3) samples were collected from identical 3 positions in every station for replication. BOD samples were collected using separate BOD bottle and during sampling, transportation and preservation, APHA & HACH standard procedure was followed [7-8]. Using YSI in-situ parameters such as, pH, Temperature, DO, turbidity, salinity, EC, and TDS were also collected during the sampling. For ex-*situ* parameters HACH spectrophotometer was used. TSS was analyzed by using gravimetric method and heavy metals were determined by using ICP-MS. All parameters were analyzed within 7 days of sample collection.

2.3 Data analysis

For data analysis SPSS statistical software was used. Mean, standard deviation and ANOVA and Principal component analysis was done using SPSS as it is the essential tool to identify the underlying factors which are not observable directly in database; but, the main aim of environmental research is to identify those factors influence in environment [9].
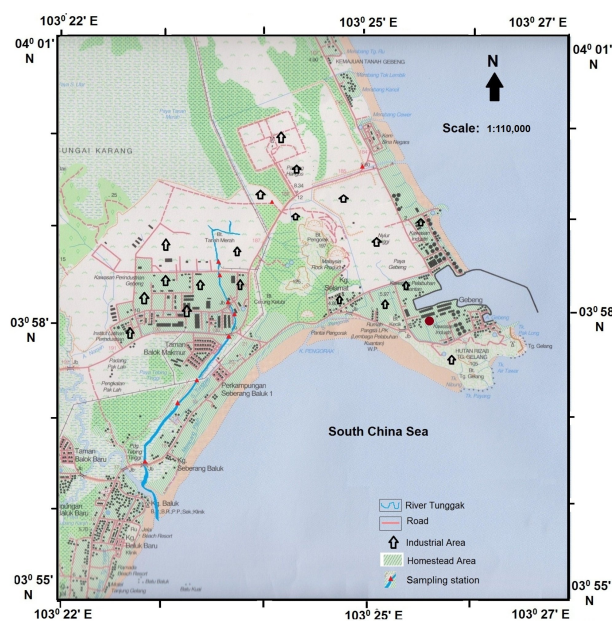

Fig.1.Location of the study area and sampling stations

3. RESULTS AND DISCUSSION

3.1 In-situ parameters

Water temperature of the river varied from 26.16^0C to 35.24^0C among the stations. In most of the stations temperature was within the normal limit of Malaysia [10] but the temperature of station 6 to 8 were beyond the normal limit (Table 1). Regarding pH the values varied from station to station. The highest pH value 9.12 was recorded in station 6 followed by station 5 and station 7. Those three stations received most of the effluents of the industrial estate consist of polymer, chemical, metal, gas & power industries. However, at most of the station average pH values were found within the standard level of Malaysia [11]. On the contrary, the lowest value 4.16 was recorded in station 8 followed by station 9 and 10; which were below the standard. Perhaps the industrial effluents at the area of station 8 and 10 contained acidic substances and due to submerge condition at station 9 pH was also low (Table 1)

Conductivity reading of the stations was mostly within the normal limit except the stations 1 to 3 (Table 2). This was perhaps because of entering the saline water in those 3 stations during tide from the South China Sea [12]. Concentration of DO recorded very low in all of the stations varied from 1.1 mg/L at station 2 to 4.4 mg/L at station 1 (Table 1). According to INWQS, Malaysia the stations were categorized as class III and IV based on DO concentration.

TDS concentration was higher in the lower stations compare to the uppermost. Station 1 and 2 contained higher amount of TDS due to tidal disturbance [12], forested area and there were some agricultural practices adjacent to the station 2. Meanwhile, TDS of station 7-10 were in permissible limits 500 mg/L [11] (Table 1). Regarding turbidity the estimated level varied from 2.1 NTU at station 9 to 34.5 NTU at station 5 (Table 1); only station 9 was found to be in normal level whether rest of all contained higher value of turbidity according to the INWQS, Malaysia [11].

Table 1: Range, mean and SD of in- situ parameters of the study areas with geographical location

Station No.	Geographical Location		Temperature (°C)	pH	Conductivity (µS/cm)	DO (mg/L)	TDS (mg/L)	Turbidity (NTU)
1.	03°56'35.04"N and 103°22'32.1"E	Range	27.05-30.17	5.66-7.02	14200-27080	2.62-4.40	9040-24300	7.69-22.50
		Mean	28.78	6.23	18013	3.30	16137	16.66
		SD	1.07	0.52	4946	0.61	7691	6.41
2.	03°57'19.44"N and 103°22'59.94"	Range	28.04-29.2	6.97-7.71	7700-13660	1.10-2.17	5160-7270	10.05-24.70
		Mean	28.55	7.28	10880	1.58	6250	17.72
		SD	0.59	0.34	2836	0.41	1088	5.81
3.	03°57'39.6"N and 103°23'14.64"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	7.69	1395	1.69	767	13.70
		SD	0.38	0.38	207	0.36	112	3.90
4.	03°57'54.18"N and 103°23'22.86"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	7.95	1212	2.71	613	14.14
		SD	0.75	0.35	95	0.96	108	3.42
5.	03°58'12.54"N and 103°23'23.28"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	7.96	1505	3.12	700	23.44
		SD	1.07	0.99	107	0.91	50	12.03
6.	03°58'33.6"N and 103°23'14.28"	Range	31.63-34.14	7.25-9.12	1423-1740	1.56-3.16	649-778	11.73-28.80
		Mean	32.88	8.01	1585	2.32	715	20.98
		SD	1.35	0.76	164	0.79	68	8.01
7.	03°59'13.44"N and 103°23'16.92"	Range	33.2-35.24	6.77-8.60	923-1210	2.85-3.93	203-529	6.69-12.35
		Mean	33.78	7.65	1068	3.28	365	9.82
		SD	0.88	0.62	149	0.51	171	2.30
8.	03°59'16.44"N and 103°23'17.46"	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	4.96	55	3.38	21.78	6.59
		SD	0.56	0.29	3.31	0.59	2.25	1.81
9.	03°59'27.42"N and 103°24'12.18"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	5.13	24	2.34	8.15	3.87
		SD	0.61	1.04	3.39	0.38	0.47	1.56
10.	03°59'37.62"N and 103°24'45.3"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	5.86	750	2.66	354	10.11
		SD	0.29	0.44	36.01	0.22	22.12	2.09

3.2 *Ex-situ* parameters

Collecting samples from sampling sites were analyzed in laboratory for determining the amount of sulphate (SO_4), NH_3-N, nitrate-nitrogen (NO_3-N), phosphate-phosphorus (PO_4^3), BOD, COD and TSS. Results showed that the amount of sulphate was the highest in station 1 followed by 2 and 7 (Fig. 2).It was due to station 1 & 2 near the sea [12] and 7 was adjacent with some chemical industries which

produced detergent and discharged sulphure reach effluents into the river flow. The amount of NH_3-N varied from 0.25 mg/L at station 9 to 3.47 mg/L at 3 (Fig. 3). The values were beyond the permissible limit of INWQS of Malaysia; and it categorized the water of mid-stations as class V [10]. NO_3-N level was within the safe level (<0.4) [10] except station 5 to 7 (Fig.3); those three stations received most of the effluents from the industries including polymer, chemical, metal, gas & power and wooden industries of Gebeng. From the analysis PO_4^{3-} recorded the highest 6.3 mg/L at station 10 (Fig. 3) while the other stations contained relatively lower concentration of PO_4^{3-}. Meanwhile, PO_4^{3-} amount was in permissible level at station 7 to 9 [11].
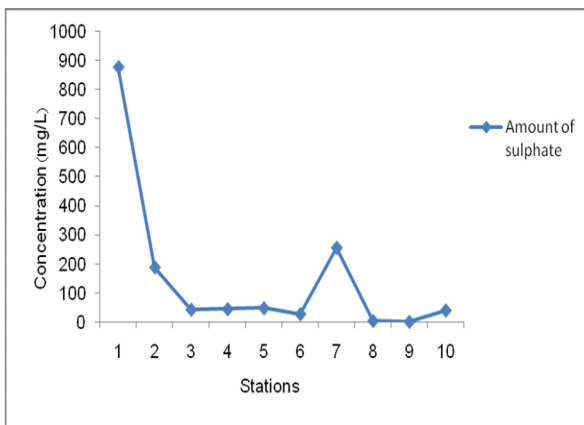

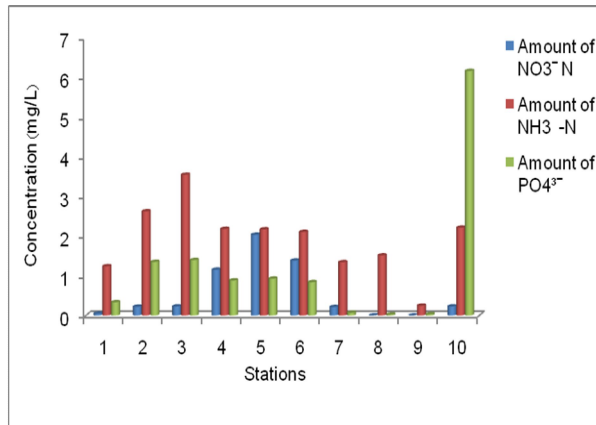Fig. 2 Variation of sulphate concentration among the station of the study area

Fig. 3 Variation of nitrate nitrogen, ammoniacal nitrogen and phosphate concentration among the station of the study area

Biochemical parameters BOD and COD concentration were determined and the result was analyzed. It revealed that, BOD was the highest 32.88 mg/L at station 7 and the lowest was 4.23 mg/L at station 9 (Fig. 4). The BOD values of all stations were beyond the permissible limit [11] and it was due to the discharge of industrial wastes to the river flow. In the same way COD was also maximum at station 7 and minimum at station 9 (Fig. 4). According to INWQS Malaysia, BOD and COD values categorized the water of mid-region as class V (highly polluted). However, COD level recorded safe at station 9 &10 [11].
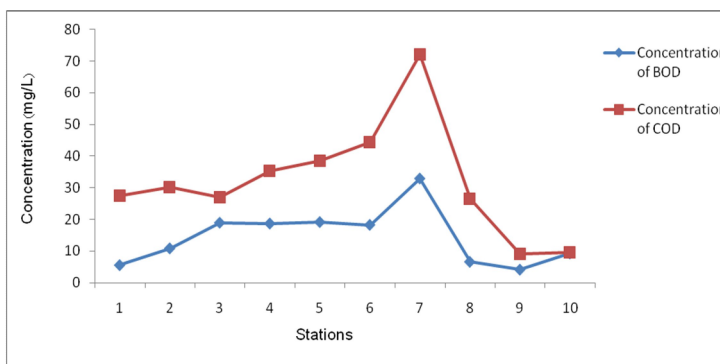

Fig. 4 Variation of the BOD and COD concentration among the study area

Heavy metals were determined by using ICP-MS (Inductively Coupled Plasma Mass Spectrometry). Result showed that water of the river was bearing chromium (Cr), cobalt (Co), copper (Cu), zinc (Zn), barium (Ba) and lead (Pb). The concentration of Pd found to be higher at all station compare to the permissible level [11]. Cu concentration was beyond the standard limit at station 1 and 7 (Table 2). The Table 2 also showed that, Co was recorded higher at stations 1 to 6 and Cr concentration was higher at station 8. However, Zn and Ba were observed below the standard limit of Malaysia [11]. Adjacent to the river the major industries are chemical, polymer, metal, petrochemical and gas & energy; those effluents bear the toxic heavy metal as a result polluting the river water of the area. Due to the addition of industrial effluents with the river water the quality of water deteriorated and based on the types of industry

pollution level of the river differ from station to station.

Table: 2: Heavy metal concentration in surface water of the study area (amount in ppm)

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

3.3 Water Quality Index

Water quality index values were calculated based on DO, BOD, COD, NH_3-N, TSS and pH concentration [13-15]. Water quality classification of the study area was done using the calculated WQI-values and demonstrated in Table 3. As can be seen, according to the DOE-WQI of Malaysia the water of the Tunggak river was classified as Class IV (highly polluted) except the lower station 1 and upper stations 9 & 10; which were found to be polluted (Table 3).

The water of the river at station 2 to 8 was found to be not usable except irrigation; and the water at station 1, 9 & 10 could be use for some specific fisheries only after intensive treatment [11]. The cause of higher pollution at mid-stations was due to the maximum wastes were adding at those stations as dense industrial activities were existing at the mid-region; on the other hand, at upper stations minimum industry and at lower station tidal interference made the water less polluted [12].

Table 3: River water quality classification of the study area based on DOE-WQI

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

Where, DOE-WQI value, ≥91.76 = Class I; 75.37- 91.75 = Class II; 51.68 – 75.36=Class III; 29.61 – 51.67 = Class IV and <29.61= Class V

4. CONCLUSION

This study revealed that the pollution level was comparatively higher in the middle stations because of maximum wastes discharged to those stations from the industries. On the other hand, due to tidal interference at lower stream and less industry at the upper stream caused less pollution in lower and upper stations. Considering the analytical results and data analysis it is clear that the major source of pollutant was the industrial activities. The variation among the stations was due to the presence of different types of industries. Again, the presence of forest, agricultural land, homestead and sea also contributed to the spatial variation. To reduce the pollution level of the river water close monitoring of industrial activities should be ensured and emphasis should also given on recycling of industrial wastes of their own before discharging to the river flow.

ACKNOWLEDGEMENT

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