Surface Water Contamination Due To Industrial Activities in Gebeng Area, Kuantan, Malaysia

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***Abstract*—**Gebeng is a rapidly growing industrial area of Kuantan, Pahang, Malaysia. The water bodies are being affected by anthropogenic activities. Industrial effluents and waste water having contaminants are incorporated with river water regularly. The study was carried out to explore the pollution level and to find out human interference on river water quality. To conduct the research, surface water was collected from 10 different strategic locations of the river. The physico-chemical characteristics of water including temperature, pH, electrical conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), turbidity, nitrate, ammonia-cal-N, phosphate, sulphate and some selected heavy metals were measured by using standard methods. Statistical analyses were done by using SPSS software (version 16.0). The study showed that heavy metals such as Pb, Cu, Co, Cd and As concentrations were higher at station 4, 5, 6, 7 and 8 and more polluted, and at the downstream station 8, 9 and 10 were less polluted due to tidal interference. According to DOE-INWQS all stations were categorized as polluted (Class III to and V). Moreover, the most affected parameters were pH, DO, COD, BOD, ammonical nitrogen, nitrate and phosphate. Human activities especially treated and untreated industrial wastes as well as the effluents from the point and non- point sources increased the contamination levels of the studied surface water.

***Keywords*—** Gebeng, Surface water, Heavy metals, Pollutant.

I. Introduction

ALL livings things of this earth are largely dependent on water. Even 70% of living body is constituted with water [1].Surface water meet up about one third of the world's drinking water demand [2]. However, water has a substantial role in industry, agriculture and other human affairs. Though it is precious, it is very much neglected and the least cared resources of the earth. In Nigeria, a study of industrial effluents prevailed that inorganic pollutants are above the recommended limits [3]. Now a days, surface and sub-surface water as much as ground water are polluted by different ways. Water quality is being deteriorated day by day throughout the world through improper disposal of industrial wastes and effluents [4].If the effluents and wastes are not treated properly; the ground water will be polluted [5]. It is reported that about 97 percent of water demand for Malaysia are met up by surface water. A huge industrial dumping is going on in Malaysia. From the previous study, it revealed that higher biological oxygen demand (BOD), ammoniacal nitrogen (NH3-N) and suspended solids (SS) are present in the surface water of Malaysia [6].

As in the Gebeng area of Pahang, Malaysia the industries are developing fast, the surface water are increasingly contaminated due to lack of proper treatment procedures. The river water of the study area contains higher BOD, COD, TSS, Co, Cd, Cr, Pb and Cu. Therefore, monitoring and assessment of the Gebeng industrial area have to be taken to find out the present status of water quality [7]. formats for your particular conference.

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II. Materials And Methods

A. Study Area

Gebeng is a small town and main industrial area of Kuantan, the capital of Pahang. The town is located (Fig.1) near Kuantan port, situated about 20 km to the north of Kuantan city and facing the south China Sea. A large number of industries are active in Gebeng area, Kuantan, such as metal works factories, steel industries, petrochemicals, chemicals, palm oil mills, polymer, energy, oil and gas industries, coal mining, concrete industries, concrete ducting, pipe coating facility, chicken food, wood processing, detergent and air product. Two rivers namely Sungai Tunggik and Sungai Balok which covered almost all over the industrial region. Between the two rivers Tunggik is mainly affected by industrial throwing.

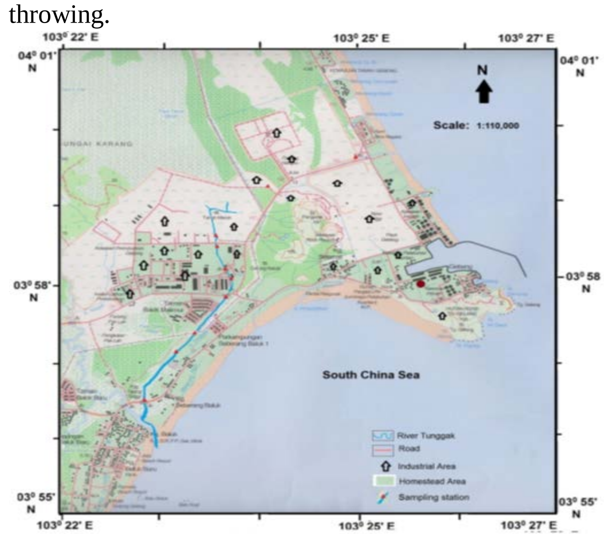

Fig.1 Map of the study area and sampling sites.

So, we have taken water samples from the different points of the Tunggik river.

B. Sampling and Preservation

Water samples were collected approximately from the 10 cm under the water surface using 500 ml HDPE bottles. The samples were collected for BOD at dark bottles (300 ml). Immediate after sampling the collected samples were inundated with icebox and later transferred to the laboratory and preserved in a refrigerator at below 4ºc temperature. Campaigns for the collection of contaminated water were performed on July, September and November 2012. Some parameters were determined instantly in the field from each sampling point. Temperature, dissolve oxygen (DO), electrical conductivity (EC), pH, turbidity and total dissolved solids (TDS) were the major parameters determined in situ by using YSI.

C. Laboratory Analysis

The BOD, COD, TSS, TDS, ammonia cal-nitrogen, nitrate, sulfate, and phosphate was analyzed by standard methods. The spectrophotometer model HACH DR2500 at specific wave lengths were used for the determination of COD, ammoniacal-nitrogen, nitrate, sulfate and phosphate [8], As, Ba, Cd, Cr, Co, Cu, Ni, Pb, Zn and other heavy metals were determined by using ICP-MS. Furthermore, TSS were analyzed gravimetrically after filtration with an adequate sample through a glass fiber filter and drying at 105^{o}c. BOD was determined as the difference between initial and 5-day readings. All the water samples were analyzed within 7 days of sampling.

III. Statistical Analysis

Statistical analysis was done by using SPSS software version16.0. Standard deviation, Mean and Correlation analysis (Pearson, 2 tailed) was also done to determine significant correlation among parameters by SPSS software.

IV. Results And Discussion

A. Temperature

The monthly studied surface water temperature varied from 26.53 ºc to 38.45 ºc, 28.40 ºc to 34.84 ºc and 27.53 ºc to 33.51 ºc as well as the average water temperature measured 31.44 ºc, 30.11 ºc and 30.02 ºc for July, September and November, 2012 respectively (Fig.2). The highest temperature (38.45 ºc) was recorded at station 5 in July 2012 due to the discharge of hot water and effluents from surrounding industries and for dry season. The lowest temperature was found at station 2 (26.53 ºc) because the site was surrounded by forest. The surface water temperature of all stations except site 5 was within the permissible limit. The average temperature (30 ºc) was recorded in the month of November 2012 (Fig.2) at rainy seasons, while in dry season, water temperature reached up to 38ºc due to low precipitation. However the average temperatures were within the recommended level of Malaysia [9]. The temperature of studied surface water showed a decreasing trend from July to November because of high rainfall. With the rise of temperature, the microbial activity increased and subsequently reduced dissolved oxygen [10]. Temperature of the surface water of Gebeng industrial area was positively correlated with BOD (r=0.676, p=0.025).

B. pH

It is an important parameter. The pH of the studied surface water varied from 4.28 to 7.76 with a mean 6.53. The monthly pH value of the samples was varied from 4.28 to 7.76, 4.62 to 7.74 and 4.44 to 7.15 in July, September and November (Fig.2) respectively. The highest pH was recorded 7.76.while the lowest value was (4.28), (class V, in accordance with Interim National Water Quality Standards, Malaysia). It revealed that pH of station 1, 2 and 3 were extremely acid to strongly acid. Nevertheless, pH of remainder stations were included slightly acidic to neutral (class-I). It was observed that the average pH values rose from rainy season to dry season (Fig 2). Sim [11] reported same findings by his studies. Statistical results exhibited that the pH was positively correlated with BOD (r=0.748, p=0.013) and Cr (r=0.648, p=0.043), on the other hand it was negatively correlated to Pb (r=-0.667, p=0.035).

C. Electrical Conductivity (EC)

The EC concentration was ranged from 0.02-25.22 µS/cm determined by in situ readings (Fig.2). and the average was 2.34 µS/cm. The greatest value 25.22 µS/cm was recorded at station 10 due to tidal influence, as the site is adjacent to the South China sea [12]. In contrast, the lowest concentration 0.01 µm/cm was measured at station 2 because the station was free from tidal intrusion and industrial interference. The EC values of stations 10 was belonged to Class V, while the remaining others sites were within the permissible ranges of INWQS. EC was positively correlated with TDS (r=0.999, p=0.000) and Sulfate (r=0.664, p=0.036) and Ni (r=0.777, p=0.008).

D. Turbidity

By turbidity is mean that the haziness of a liquid for the presence of particles. The average turbidity of the studied surface water was determined 27.92 NTU and it ranged from 0.33-139.01 NTU among sites. It varied from 2.93 to 82.00 at July, 0.33 to 55.40 at September and 5.56 to 139.10 at November 2012 (Fig.2). The higher turbidity was found at station 4 (139.01 NTU) in the month of November 2012, due to earth works and cleaning activities of surrounding area, and as a result highly weathered clayey soil mixed with water which increased the turbidity. For the raw water turbidity, the ministry of health, Malaysia has been prescribed the threshold level is 1000.00 NTU. The turbidity values of all sites were included into the permitting level [21]. Therefore, the turbidity values categorized into Class-I (according to INWQS). Turbidity was positively correlated with TSS (r=0.647, p=0.043) and COD (r=0.715, p=0.020)

E. Ammonical nitrogen (NH3-N)

The ammonical-nitrogen were found to be ranged from 0.45 to 3.43 mg/L in July, 0.42 to 1.58 mg/L September and 0.19 to 2.40 mg/L in November 2012 (Fig.2).The average value were 2.18 mg/L, 1.02 mg/L and 1.10 mg/L for July, September and November respectively. The high concentrations were recorded at site 1(3.43 mg/L), and 9 (3.26 mg/L) in the month of July because of dry season and more industrial wastes were accumulated at those stations, which increased the amount of ammonical nitrogen. The mean ammonical nitrogen of studied surface water was 1.43 mg/L. The average values of all sites except station 2 were included in Class IV and V (in accordance with INWQS). For supporting aquatic life, the threshold value of ammonical nitrogen for Malaysian surface water is 0.90 mg/L. From the correlation analysis it was found that ammonical N was positively correlated with dissolved oxygen ($r=0.668$, $p=0.0350$), but negatively correlated with pH ($r=-0.760$, $p=0.011$) and nitrate ($r=-0.761$, $p=0.0110$).

F. Nitrate

In general, nitrate is derived from the decomposition of organic matter by bacterial activity. It has been found to be ranging from 0.00 to 1.33 mg/L, 0.00 to 0.28 mg/L and 0.00 to 2.86 mg/L and monthly mean values were 0.31,0.15 and 1.19 mg/L. The average nitrate value was determined 0.62 mg/L (Fig.2) for the studied area.

The highest value 2.86 mg/L was found at station 6 and the result showed that nitrate content of station 5, 7 and 8 were also higher due to the vicinity of industry and addition of industrial components which contain nitrate. Das.J.et.al,.[2] studied with Lotic water quality, Cuttack, India and found higher nitrate content for industrial activities. Nevertheless, the lowest value (0.0 mg/L) was found at station 2 owing to the station is isolated from industrial interference. As nitrate concentration is below 3.7 mg/L, so it is suitable for drinking and eco –system but not good enough for emergency irrigation. Nitrate of the studied samples were negatively correlated with DO ($r=-0.748$, $p=0.013$).

G. Sulfate (SO4=)

The average sulfate values of water samples of present study were 172.73 mg/L in July, 52.63 mg/L in September and 172.26 mg/L in November, 2012. The sulfate concentrations were varied from 0.00 to 423.30, 0.00 to 203.33, and 0.00 to 1213.30 mg/L in July, September and November respectively (Fig.2). The mean concentrations of the studied samples were 132.54 mg/L. The highest value (1213.30 mg/L) was identified at station 10 during November/2012 as the site is the get way through pass over all the industrial wastes and effluents to the sea, while the lowest value (00.00 mg/L) was observed at station 2. Hem [13] stated that sulfate incorporated in watershed by anthropogenic activities such as waste discharges, fossil fuel and combustion processes. According to INWQS guideline 250 mg/L concentration of sulfate is suitable for the lives of water bodies. The average sulfate values of all stations are within threshold level of World Health Organization. Sources of sulfates are from weathering, volcanic eruption, fossil fuel combustion, mining activities and waste throwing [13]. Sulfate was positively correlated with EC ($r=0.664$, $p=0.036$) and TDS ($r=0.665$, $p=0.036$).

H. Phosphate

The PO43-levels of studied water varied from 0.02 to 35.40, 0.04 to 0.74 and 0.00 to 2.73 mg/L and the mean values were 4.08, 0.34 and 1.11 mg/L in July, September and November respectively (Fig.2). The highest value was recorded at station 1 (35.40 mg/L) at July that belonged to dry season while the lowest amount was determined at site 3 in November which included in wet season. Mean phosphate contents for studied surface water was 1.84 mg/L. The higher phosphate was due to wastes of detergent and other industries. The average range is above the permissible value and the concentrations of phosphate for most of the site are above the threshold levels. According to INWQS critical value for phosphate is 0.10 mg/L to support aquatic life. The phosphate concentration in the middle stations are comparatively higher due to wastes of detergent industries [14,15]. Excess phosphate in water may cause eutrophication and can reduce DO content. Correlation analysis showed that phosphate has a significant positive relationship with As ($r=0.970$,$p=0.000$).

I. Total Dissolved Solids (TDS)

TDS indicates the total content of dissolved solids in a fluid. The studied surface water collected from three months July, September and November 2012 which were included dry and wet seasons. The average monthly values were 6.02, 1.43, 11.50 mg/L and the TDS concentrations ranged from 0.04 to 41.30,0.05 to 2.65,0.05 to 76.16 mg/L in July , September and November respectively (Fig.3). The highest content (76.16 mg/L) of TDS at site 10 was recorded at wet season in November, while the lowest concentration (0.04 mg/L) was analyzed at station 2 in dry season. From the study it was found that the mean value of studied sample was 6.31 mg/L. In study, it was observed that TDS content was higher at site 10 in both dry and wet season. The TDS values of studied water were within the permissible limits as recommended by the World Health Organization (1984). The result showed that TDS value was positively correlated with EC ($r=0.999$, $p=0.000$) Sulfate ($r=0.665$, $p=0.036$) and Ni ($r=0.771$, $p=0.009$).

J. Total Suspended Solids (TSS)

If levels of TSS of a water body increase, its begins to lose the ability to support the diversity of aquatic life. The TSS was found to vary from 2.33 to 48.66 mg/L, 5.33 to 35.90 and 6.33. to 26.33 in July, September and November respectively (Fig.3). The average TSS of the studied water was found 15.33, 15.61 and 14.87 mg/L in July, September and November respectively. The highest TSS (48.66 mg/L) was noticed at station 6 , while the lowest value was found (2.33 mg/L) at station 1.The mean concentration of the studied surface water of the study area was calculated 15.27 mg/L.

According to the INWQS the critical levels of TSS values for the surface water of Malaysia varies from 25 to 50 mg/L. The TSS contents of studied samples were determined low and within the standard level of Malaysia. Water having high TSS is harmful for health [16]. It was observed that the total suspended solid concentrations were higher in station 1, 2, 3 due to the assemble of industrial wastes .Most of the results of TSS suggests that water quality is categorized in Class I and Class II. Department of Environment [17] revealed that the threshold value of TSS for the convenient of aquatic life in sweet water is 150 mg/l. It was found from the study that TSS was positively correlated with Turbidity (r=0.647, p=0.043), COD (r=0.661, p=0.037)and Co (r=0.798, p=0.006).

K. Dissolved Oxygen (DO)

DO content of the studied water found to be ranging from 1.53 to 5.38,1.52 to 6.26 and 1.36 to 6.03 mg/L while the average values were 2.88, 4.92 and 3.14 mg/L in July, September and November respectively (Fig.3). The highest value of DO (6.26 mg/L) at site 9 was recorded in September 2012 whereas the lowest value (1.36 mg/L) was analyzed for station 3, in the month of November 2012. In the study, it was noticed that the mean DO was 3.65 mg/L. The threshold value of DO for Malaysian surface water is from 3.0 to 5.0 mg/L. The average DO values of stations 5 (5.67 mg/L) and 7 (5.01 mg/L) were above the Malaysian standard level. On the other hand, DO values of other sites were determined below the Malaysian threshold value. DO is lower because for the decomposition of industrial wastes utilized oxygen and also depleting for cooling industrial effluents and hot water. The result showed that DO values were low from September to November (dry season to wet season). Ikusima et al.,[18] found the similar findings at the Tasik Bera lake, Malaysia during rainy season. DO was negatively correlated with nitrate (r=-0.748, p=0.013).

L. Chemical Oxygen Demand (COD)

COD proportion increases with the contamination level of water. The average COD of studied water collected from 10 sites during three months (July, September and November, 2012) were ranged from 11.15 to 64.93 mg/L (Fig.3) .The COD values measured from 17.30 to 126.00, 5.30 to 21.60 and 23.60 to 72.60 mg/L in July, September and November respectively (Fig.3). It was observed comparatively higher mean COD values from dry season to wet season. The high COD was determined at station 6, that included in IV in accordance with INWQS. Moreover, it was observed that those stations were surrounded by many industries and consequently a huge industrial throwing like wastes, hot water and effluents done, the surface water of those sites contained higher COD. However, on the the basis of INWQS, the COD concentrations of remaining sites were included in Class I and II which are within the Malaysian limit. The result exhibited that COD content increased for middle stations compare to others due to industrial interference. COD increased with the contamination of water [19]. It was showed from the correlation analysis that COD had a positive relation with TSS (r=0.661, p=0.037), turbidity (r=0.715, p=0.020), BOD (r=0.714, p=0.020) and Co (r=0.772, p=0.009).

M. Biological Oxygen Demand (BOD)

BOD is a parameter that measures the organic load as well as the pollution level for water bodies [20]. The average BOD concentrations found to vary from 21.48,7.81 and 11.57 mg/L, while the monthly BOD value ranged from 4.86-34.25, 5.90-9.28 and 7.50-18.85 mg/L in July, September and November respectively (Fig.3). The highest BOD (34.25 mg/L) was found at station 5 at dry season, owing to higher industrial discharges and more oxygen used for the decomposition of wastages whereas the lowest value (4.86 mg/L) was measured at station 2, because there was no scope for the intrusion of industrial water, wastes and effluents. The average BOD content of studied water was 13.62 mg/L. It has been found that in dry season comparatively higher BOD was observed than from wet season. At dry season, higher temperature and lower precipitation which result high BOD. In contrast at wet season, availability of water and lower temperature. In accordance with INWQS, the threshold value of Malaysian water is 6 mg/L, refer that the average BOD content of all studied samples were recorded above the permissible limit [21]. The average BOD concentrations classified the studied surface water into class III, IV and V. BOD was positively correlated with pH (r=0.748, p=0.013), temperature (r=0.696, p=0.025) and COD (r=0.714, p=0.020).

V.Heavy Metals Chromium (Cr)

The average Cr content of water samples was 0.0283 ppm and it ranged from 0.0051 to 0.0689 ppm (Table 1). The highest value (0.0689 ppm) was determined at station 3 and 4 during July/2012, while the lowest value (0.0051ppm) was observed at station 9 in November. Cr content of sites 3 and 4 were higher due to industrial processes. According to INWQS, the Cr concentration of all sites was categorized into class I and II. Nadeem-ul-Haque et al., [22] recorded extremely higher Cr and Pb in surface and ground water of the industrial areas of Karachi, Pakistan. The result showed that the Cr concentration of all stations in November were comparatively low, due to more dilution with rain water. Correlation analysis showed that Cr was positively related with pH (r=0.648, p=0.043), and negatively correlated with Pb (r=-0.756, p=0.011) and Ba (r=-0.717, p=0.020).

VI. Lead (Pb)

Lead content of the studied water samples found to be varied from 0.2285 to 0.6214 ppm with a mean value 0.4141 ppm (Table 1). The higher average Pb value 0.5597 ppm was recorded at station 1, due to industrial activities, while the lowest concentration 0.2285 ppm was observed at station 2. It was shown in Table 1 that Pb concentrations of all the sites were higher than threshold value [21] due to the presence of metal industries in studied areas which released lead particles by their industrial activities. The concentrations of Pb for all stations are included to class IV in accordance with INWQS.The study exhibited that Pb content of studied surface water was positively correlated with Ba (r=0.837, p=0.003) and Cu (r=0.679, p=0.031) and negatively correlated with pH (r=-0.667, p=0.035) and Cr (r=-0.756, p=0.011).

VII. Arsenic (As)

The average As amounts of the studied water samples was 0.0089 ppm. It was observed from the Table 1 that the Arsenic value of studied surface water ranged from 0.0020 to 0.0364 ppm. The highest figure 0.0540 ppm was recorded in station 10 at November 2012. It was showed that As concentrations of only site 10 was categorized in class III Furthermore, according to INWQS As contents of all stations except site 10 were categorized below the Malaysian limit and classified into class I and which is at natural levels. Anthropogenic activities were mainly responsible for As pollution at Portugal Rosario M.P. et al., [23]. Table-1 exhibited that the As concentrations of down streams sites were high compare to upstream. Rosario M.P. et al.,[23] showed the same trends with surface water at Portugal. As was positively correlated with phosphate (r=0.970, p=0.000).

VIII.Cupper (Cu)

The average Cupper concentrations of present study were 0.1642 ppm. The Cupper value of water samples measured from 0.0022 to 0.4756 ppm among 10 stations (Table 1). The highest value 0.4756 ppm was identified at station 1 during July/2012, because all coal wastes added from surrounding area, while the lowest value 0.0022 ppm was observed at station 9. Wogu et al., [24] observed higher Cu pollution due to industrial activities, in surface water of Warri River, Nigeria. It was observed that the Cupper concentration of 1, 6, 7 and 10 sites included into class IV while site 5 belonged to class III. Nevertheless, remainders (2, 3, 4, 8 and 9 stations) were categorized as class I in accordance with INWQS. The statistical analysis showed that Cu was positively correlated with Pb (r=0.679, p=0.031) and Ba (r=0.798, p=0.006).

IX. Barium (Ba)

The average Barium concentration of the studied surface water was 0.0501 ppm. It was shown in Table 1 that the Ba contents of water samples found to be ranging from 0.0070 to 0.1036 ppm. The highest result 0.1036 ppm was determined at station 7 during July/2012, because the station was close to industries and industrial wastes caused Ba accumulation, while the lowest value 00.0070 ppm was observed at November in station 3. From the data it was observed that the Ba contents of all stations were in natural levels that included in class I of INWQS. In the study, correlation analysis showed that Ba had a positive relationship with Pb (r=0.837, p=0.003), Cu (r=0.798, p=0.006) and negative relationship with Cr (r=-0.717, p=0.020).

X. Cadmium (Cd)

The average Cd content of the surface water of the study area was 0.0222 ppm. It was assumed from Table 1 that it ranged from 0.0012 to 0.3007 ppm. The highest value 0.3007 ppm was recorded at station 6 during July/2012 which is highly polluted, while the lowest value 00.0012 ppm was observed in November at station 10. From the result it showed that the Cd concentrations of all stations were higher at July. Due to dry condition and the lesser precipitation, industrial activities and especially the availability of the inflow of effluents caused the contamination of heavy metals like Cd, Cr, Pb, Zn, Ni and Cu [24].

The Cd values of all stations in July are higher and belong to class IV according to INWQS.

XI. Cobalt (Co)

The Co concentration of the studied surface water was 0.2668 ppm and the value found to vary from 0.0023 to 0.7361 ppm (Table 1).The highest amount (0.7361 ppm) was determined at station 5 due to wastes of catalyst using industries, alloy, paints, power plants, grinding and cutting tool factories. According to ministry of environment protection, USA, [25] permissible concentration of Co in surface water is 0.05 mg/L. So, the Cobalt concentration of studied samples for stations 2, 4, 5, 6, 7, 8, 9 and 10 were higher, whereas remaining sites (1 and 3) were within permissible limit. It was showed from the correlation analysis that Co had a positive relation on TSS (r=0.798, p = 0,006) and COD (r=0.772, p=0.009).

XII. Nickel (Ni).

The mean value of Ni in studied surface water was 0.0074 ppm and it varied from 0.0069 to 0.0104 ppm among sites (Table-1). The Ni content of all sites was below the threshold level and not affected by pollution. .According to INWQS (2008), it included into class I. The high value (0.0104 ppm) was recorded at station1, while the lowest value was found at site 6. Correlation analysis showed that Ni value of the studied surface water had a positive relationship with EC (r=0.777, p=0.008) and Ba (r=0.771, p=0.009).

XIII.Zinc (Zn)

Zn concentration of studied water samples ranged from 0.3204 to 1.975 ppm with an average value 1.177 ppm (Table1). The data showed that Zn content of all stations were within the permissible limit and the studied surface water were not polluted with Zn .It was categorized as class II and I, in accordance with INWQS.

Gebeng is a potential industrial zone of Pahang, Malaysia. Surface water from different points of the Gebeng industrial estate was collected on dry (July, 2012, September, 2012) and wet seasons (November, 2012). Among ten sites, one was encircled by forest and remaining nine was from different technical locations of the river. The laboratory analyses were conducted physico-chemical properties and for some heavy metals

From the study it was found that the pH of studied surface water was neutral to extremely acidic. .EC was included within recommended standard. It showed that the studied water having higher BOD, COD, NH_3-N, NO_3^-, PO4, Pb, Cd, Cu, Co and lower DO. Moreover, the higher TSS was found at sites 5,6,8 and 10,while the high TDS was recorded in stations 9 and 10, as much as higher turbidity was observed higher at station 4,6 and 10 due to industrial dumping. Furthermore, the amount of BOD and COD were determined comparatively high at station 3, 4, 5 6 and 9. Considering all results and data it could be said that the sites located at the vicinity of industry (5, 6, 7 and 8) contain higher contaminants and the concerned surface water were contaminated by industrial pollutants However, the results were differed on the basis of season, types of industries and sea water intrusion. The physico-chemical parameters and the studied results indicated that the industrial processes caused heavy metal contamination of the studied water.

The study revealed that emphasis should be given on proper treatment of industrial effluents and wastes to reduce the pollution status.In addition, sustainable industrialization approaches have to be taken for preservation and protection of surface water

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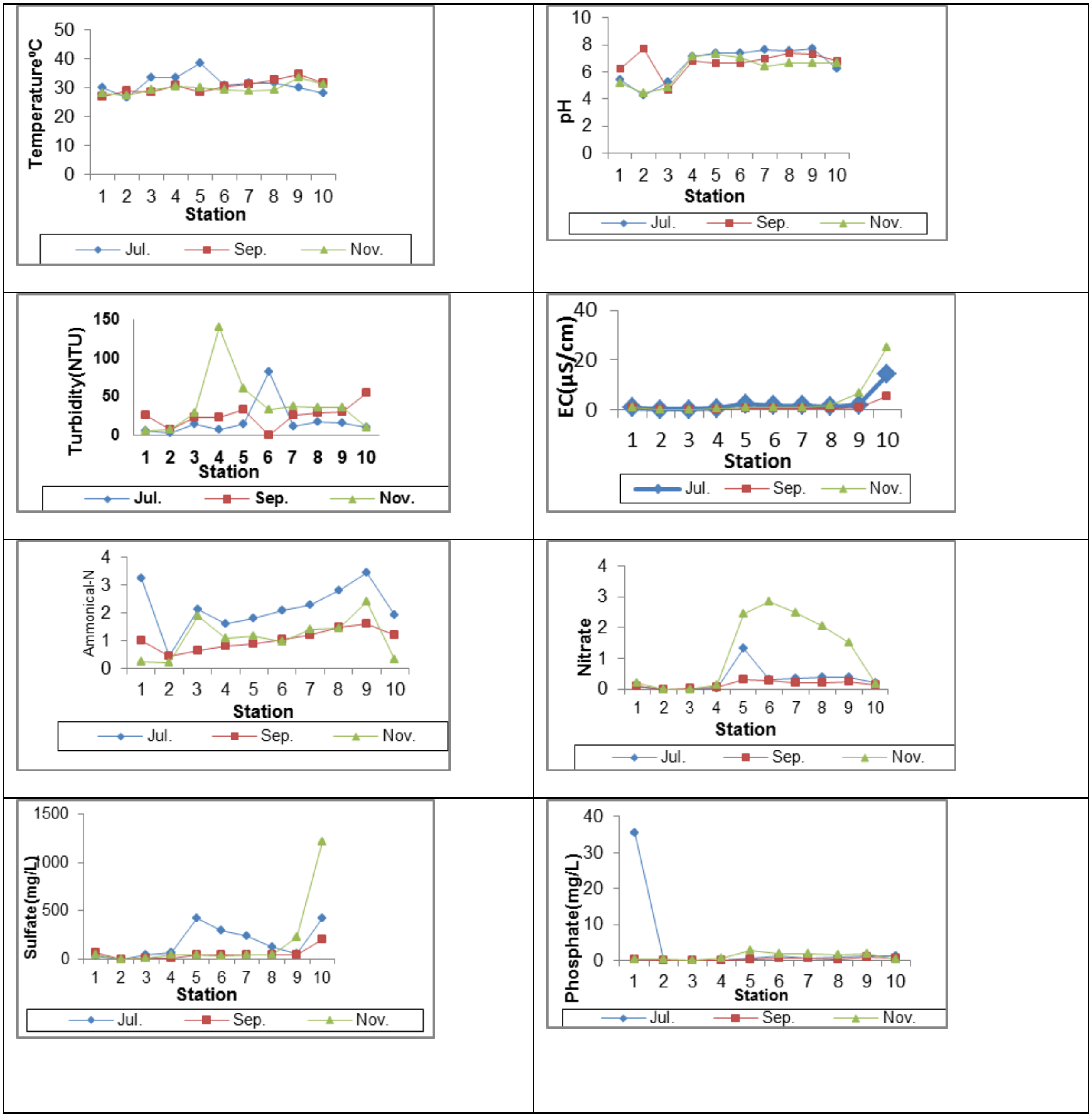
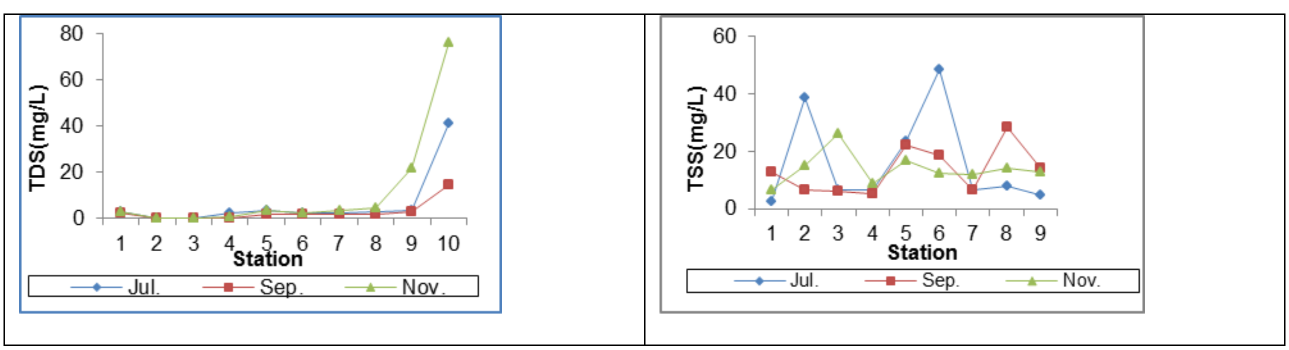


Fig.2 Concentrations of surface water properties including temperature, pH, EC, turbidity, ammonical-nitrogen, nitrate, sulfate and phosphate



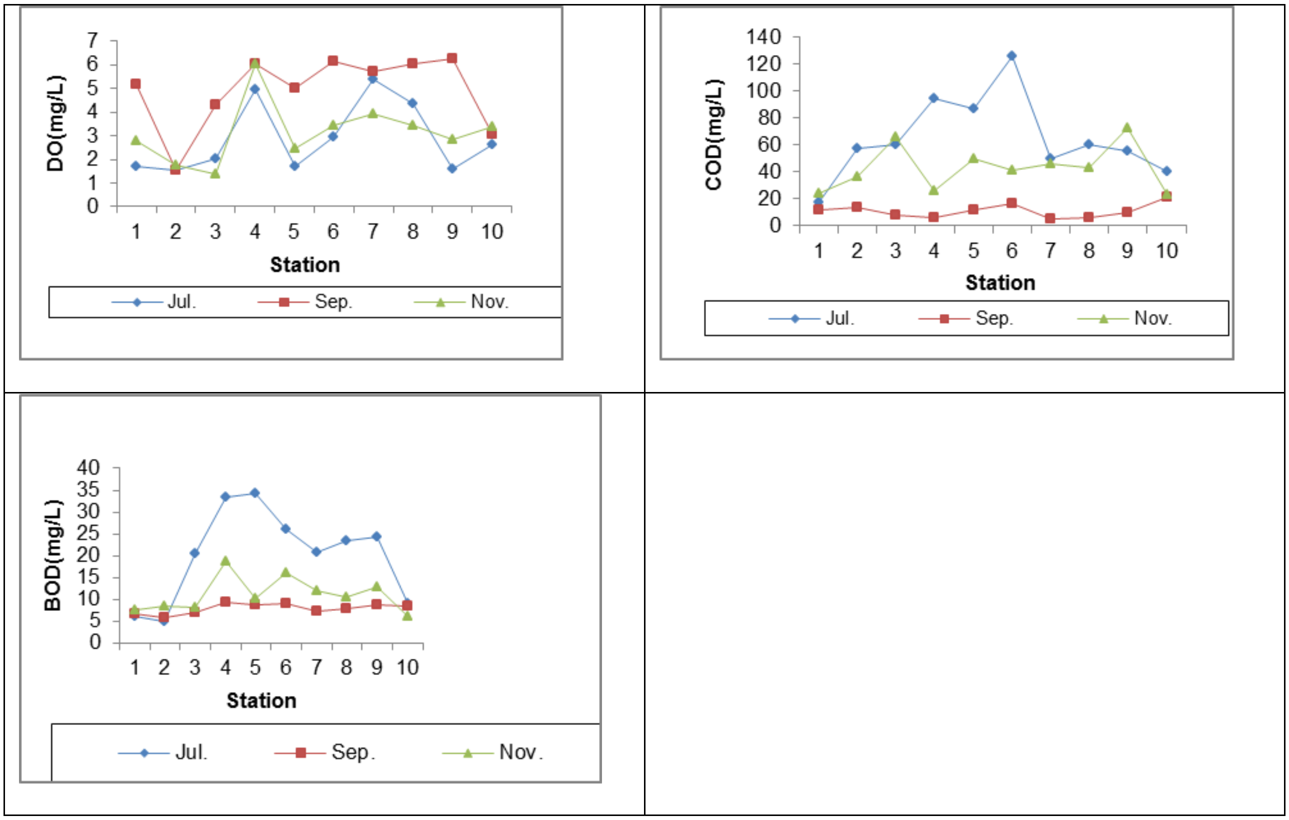


Fig. 3 Line graphs of 5 studied water parameters including TDS, TSS, DO, COD and BOD

Table 1. Heavy metal concentrations of studied surface water

S	location		As	Ba	Cd	Co	Cr	Cu	Ni	Pb	Zn
1	03° 59' 37" N 103°24' 46"E	R.	0.0020-0.0025	0.0433-0.0882	0.0013-0.0341	0.0023-0.0047	0.0209-0.0296	0.4551-0.4756	0.0102-0.0104	0.4775-0.6214	1.1935-1.8934
		Av	0.0022±0.0003	0.0688±0.0230	0.0112±0.0160	0.0031±0.0014	0.0246±0.0045	0.4659±0.0103	0.0103±0.0054	0.5461±0.0737	1.5834±0.3580
2	03°59'457"N 103°24'203"E	R.	0.0045-.0053	0.0269-0.0665	0.0222-0.0309	0.0892-0.0999	0.0432-0.0532	0.0159-0.0182	0.0087-0.0098	0.2285-0.2870	0.3204-0.3578
		Av.	0.0048±0.0004	0.0437±0.0200	0.0221±0.0156	0.0940±0.0054	0.048±0.0050	0.0171±0.0012	0.0091±0.0051	0.2615±0.0245	0.3375±0.01890
3	03°59 '16"N	R.	0.0038-0.0046	0.0070-0.0710	0.0018-0.0025	0.0093-0.0142	0.0607-0.0689	0.0076-0.0089	0.0083-0.0092	0.2372-0.2741	1.0321-1.9870
	103° 23' 18"E	Av.	0.0042±0.0004	0.0339±0.0330	0.0013±0.0160	0.0111±0.0027	0.066±0.0046	0.0087±0.0011	0.0087±0.0005	0.2561±0.0184	1.3055±0.5939
4	03°48' 55" N 103° 19' 20"E	R.	0.0065-0.0070	0.0083-0.0656	0.0014-0.0032	0.1574-0.1673	0.0411-0.0491	0.0047-0.0095	0.0088-0.0093	0.2389-0.2672	0.8879-1.5407
		Av.	0.0068±0.0003	0.0339±0.0290	0.0104±0.0005	0.1626±0.0049	0.0445±0.0042	0.0066±0.0025	0.0091±0.0003	0.2537±0.0142	1.1110±0.3722
5	03° 58'34" N 103°23' 17" E	R.	0.0089-0.0099	0.0201-0.0975	0.0017-0.0038	0.7109-0.7361	0.0198-0.0225	0.0196-0.0213	0.0076-0.0081	0.2532-0.2531	0.9408-1.7063
		Av.	0.0095±0.0005	0.0483±0.0427	0.0099±0.0161	0.7236±0.0130	0.0211±0.0014	0.0206±0.0090	0.0084±0.0021	0.2511±0.0035	1.4564±0.4540
6	03°58'13"N 103°23'23E	R.	0.0026-0.0045	0.0247-0.1116	0.0016-0.3007	0.7019-0.7187	0.0188-0.0298	0.2478-0.2631	0.0069-0.0082	0.4898-0.5237	1.6849-1.99753
		Av.	0.0035±0.0009	0.0569±0.0476	0.1037±0.1701	0.7116±0.0087	0.0247±0.0055	0.2537±0.0082	0.0074±0.0007	0.5079±0.0171	1.8626±0.1557
7	03°57'54"N 103°23'23"E	R.	0.0075-0.0081	0.0214-0.1036	0.0015-0.0337	0.2727-0.3065	0.0079-0.0213	0.4686-0.4721	0.0075-0.0085	0.4911-0.5129	0.4892-0.6298
		Av.	0.0078±0.0003	0.056±0.0426	0.0202±0.0140	0.2918±0.0173	0.0133±0.0071	0.4707±0.0019	0.0078±0.0005	0.4994±0.0118	0.5628±0.0705
8	03°57'40" N 103°23'15"E	R.	0.0067-0.007	0.2820-0.0899	0.0013-0.0305	0.1890-0.2139	.0095-0.0145	0.0052-0.0071	0.0074-0.0086	0.4802-0.5363	0.7153-0.8927
		Av.	0.0071±0.0035	0.0517±0.0334	0.0152±0.0181	0.1979±0.0139	0.0138±0.0040	0.0061±0.0009	0.0079±0.0006	0.5128±0.0291	0.7783±0.0992
9	03°57'19 "N 103°22'59"E	R.	0.0069-0.0083	0.0297-0.0829	0.0112-0.0331	0.3154-0.3537	0.0051-0.0172	0.0022-0.0049	0.0072-0.0086	0.4874-0.5011	0.9765-1.1079
		Av.	0.0075±0.0007	0.0488±0.0296	0.0165±0.0142	0.3314±0.0199	0.0128±0.0067	0.0034±0.0014	0.0081±0.0007	0.4929±0.0072	1.0474±0.0663
10	03°48'55" N 103°19'19"E	R.	0.0256-0.0540	0.0346-0.0937	0.0012-0.0314	0.0998-0.1953	0.0099-0.0132	0.3253-0.4255	0.0075-0.0084	0.5457-0.5783	1.6532-1.8452
		Av.	0.0364±0.0154	0.0592±0.0308	0.0115±0.0171	0.1409±0.0491	0.0141±0.0048	0.3892±0.0555	0.0081±0.0005	0.5597±0.0168	1.7255±0.1044

Table-2. Correlation analysis among various properties

	pH	EC	Tem.	TSS	TDS	Tur.	COD	BOD	NO3	SO4	PO4	DO	As	Pb	Cd	Co	Cr	Cu	Ni	Zn	Ba	NH3-N
pH	1																					
EC	0.86	1																				
Tem.	0.334	-0.228	1																			
TSS	-0.117	-0.148	0.09	1																		
TDS	0.74	0.999*	-0.231	-0.141	1																	
Tur.	0.332	-0.047	0.064	0.647	-0.045	1																
COD	0.421	-0.219	0.412	0.661*	-0.216	0.715	1															
BOD	0.748	-0.268	0.696*	0.052	-0.271	0.288	0.714*	1														
NO3	0.445	-0.018	-0.063	-0.572	-0.026	0.076	-0.329	0.101	1													
SO4	0.459	0.664*	0.373	0.247	0.665*	0.323	0.286	0.259	-0.09	1												
PO4	-0.324	-0.129	-0.121	-0.286	-0.123	-0.14	-0.547	-0.471	0.466	-0.274	1											
DO	-0.517	-0.235	-0.392	0.426	-0.236	-0.238	-0.022	-0.411	-0.748*	-0.364	-0.239	1										
As	-0.378	-0.294	-0.109	-0.178	-0.283	-0.047	-0.425	-0.44	0.368	-0.384	0.970**	-0.138	1									
Pb	-0.667*	0.222	0.154	-0.143	0.238	-0.487	-0.32	-0.341	-0.37	-0.027	0.349	0.061	0.313	1								
Cd	0.229	-0.17	0.513	-0.74	-0.161	-0.195	0.426	0.615	-0.3	0.007	0.176	-0.036	-0.13	0.32	1							
Co	0.126	-0.29	0.504	0.798**	-0.274	0.593	0.772**	0.464	-0.39	0.368	-0.175	0.021	-0.073	-0.01	0.309	1						
Cr	0.648*	0.046	-0.091	-0.295	0.014	-0.02	-0.119	0.228	0.517	0.09	-0.25	-0.174	-0.354	-0.756*	-0.332	-0.402	1					
Cu	-0.045	0.477	0.161	-0.327	0.486	-0.293	-0.166	-0.046	-0.03	0.257	0.38	-0.275	0.295	0.679*	0.551	-0.091	-0.43	1				
Ni	0.198	0.777**	-0.598	-0.286	0.771*	-0.018	-0.368	-0.383	0.243	0.325	-0.136	-0.109	-0.259	-0.27	-0.481	-0.598	0.418	0.063	1			
Zn	-0.061	0.339	0.309	0.287	0.334	0.187	-0.078	-0.218	-0.04	0.621	0.388	-0.159	0.298	0.27	-0.23	0.321	-0.11	0.294	-0.02	1		
Ba	-0.388	0.536	0.04	-0.008	0.557	-0.115	-0.1	-0.233	-0.21	0.291	0.289	-0.209	0.221	0.837**	0.294	0.117	-0.717*	.798**	0.016	0.341	1	
NH_3-N	0.619	0.108	-0.06	-0.572	0.097	0.074	-0.18	0.292	0.901**	0.032	0.051	-0.732*	-0.058	-0.52	-0.242	-0.147	0.674	-0.16	0.394	-0.263	-0.315	1