International Journal of Civil Engineering and Geo-Environmental

Journal homepage:http://ijceg.ump.edu.my
ISSN:21802742

Assessment of Spatial Variation of Surface Water Quality at Gebeng Industrial Estate, Pahang, Malaysia

M. A. Hossain*, Sujaul Islam Mir, Nasly M.A., Edriyana A. Aziz

Faculty of Civil Engineering & Earth Resources, Universiti Malaysia Pahang, Malaysia

ARTICLE INFO

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

ABSTRACT

Gebeng Industrial Estate is the main industrial town 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 fulfill the objective, water samples were collected monthly from 10 sampling station and physico-chemical parameters were analyzed using APHA & HACH standard methods. Heavy metals were determined using ICP-MS. Data analyses were done using SPSS 16.0 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 INWQS, Malaysia 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 in 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. It is concluded that pollution is higher in the middle stations of the river compared to the upper and lower stream.

1. Introduction

The earth is like a water planet. 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 (Yisa and Jimoh, 2010). 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 (Charkhabi and Sakizadeh, 2006). Industrial activities are producing most of the pollutant including organic matter, wastes and heavy metals. The natural and anthropogenic metal contamination in aquatic ecosystem leads to the need of characterizing their impact on environment (Mary-Lou and Taillefert, 2008). Bounty of natural water resources make Malaysia as water rich zone; and it is contributing significantly to the socio-economic development of the country (Moorthy and Ganesan, 2012). 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 (DOE, 2011). 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

*Corresponding author. Mob: +6016-9888107
*Email address: ahossain2003@gmail.com

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 3056□ 06□ □ to 3059□ 44□ □ N and 103022□ 42□ □ to 103024□ 47□ □ E adjacent to the Gebeng industrial town holding several types of industries (Figure 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 (Andrew et. al., 2005; HACH, 2005). 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 16.0 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 (Towned, 2003).

3. Results And Discussion

3.1 In-situ parameters

Water temperature of the river varied from 26.160C to

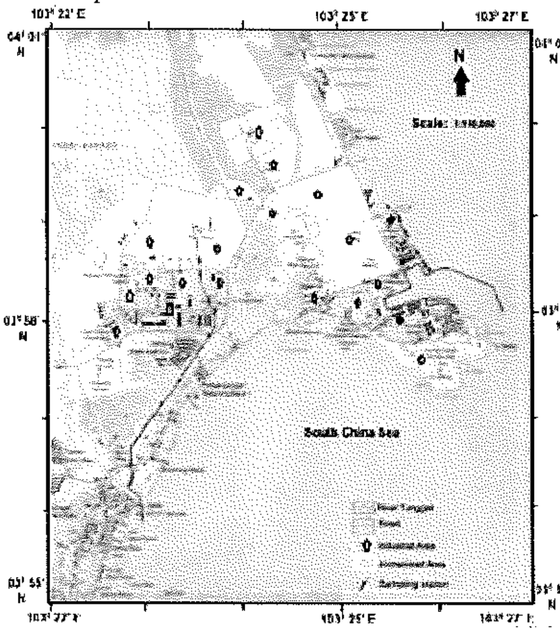

Figure 1: Location of the study area and sampling stations

35.240C among the stations. In most of the stations temperature was within the normal limit of Malaysia (Saad et. al., 2008), 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 (DOE, 2008). 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 (Haris and Maznah, 2008).

Station No.	Geographical Location	Stat. tools	Temperature (°C)	pH	Conductivity (µS/cm)	DO (mg/L)	TDS (mg/L)	Turbidity (NTU)
1.	03°56'35"N and 103°22'32"E	Range	27.1-30.2	5.7-7.0	14200-27080	2.6-4.4	9040-24300	7.7-22.5
		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"N and 103°22'60"E	Range	28.0-29.2	7.0-7.7	7700-13660	1.1-2.2	5160-7270	10.1-24.7
		Mean	28.55	7.28	10880	1.58	6250	17.72
		SD	0.59	0.34	2836	0.41	1088	5.81

	03°57'40"N	Range	29.0-29.8	7.3-8.4	1244-1800	1.3-1.8	650-869	9.8-20.7
3.	and	Mean	29.34	7.69	1395	1.69	767	13.70
	1 03°23'15"E	SD	0.38	0.38	207	0.36	112	3.90
	03°57'54"N	Range	30.9-32.6	7.5-8.5	1119-1320	1.6-4.1	527-821	10.1-17.3
4.	and	Mean	31.74	7.95	1212	2.71	613	14.14
	103°23'23"E	SD	0.75	0.35	95	0.96	108	3.42
	03°58'13"N	Range	30.9-33.1	7.0-9.0	1380-1630	1.9-3.9	642-748	11.3-34.5
5.	and	Mean	31.98	7.96	1505	3.12	700	23.44
	103°23'23"E	SD	1.07	0.99	107	0.91	50	12.03
	03°58'34"N	Range	31.6-34.1	7.3-9.1	1423-1740	1.6-3.2	649-778	11.7-28.8
6.	and	Mean	32.88	8.01	1585	2.32	715	20.98
	103°23'14"E	SD	1.35	0.76	164	0.79	68	8.01
	03°59'13.44"N	Range	33.2-35.2	6.8-8.6	923-1210	2.9-3.9	203-529	6.7-12.4
7.	and	Mean	33.78	7.65	1068	3.28	365	9.82
	103°23'17"E	SD	0.88	0.62	149	0.51	171	2.30
	03°59'16"N	Range	32.5-34.1	4.7-5.4	51-58	2.8-4.3	19.6-24.8	4.8-10.1
8.	and	Mean	33.27	4.96	55	3.38	21.78	6.59
	103°23'17"E	SD	0.56	0.29	3.31	0.59	2.25	1.81
	03°59'27"N	Range	26.2-27.4	4.2-6.7	20-27	1.93-	7.7-8.7	2.1-6.0
9.	and	Mean	26.78	5.13	24	2.34	8.15	3.87
	103°24'12"	SD	0.61	1.04	3.39	0.38	0.47	1.56
	03°59'38"N	Range	31.1-31.8	5.1-6.4	713-787	2.4-3.0	333-379	7.7-12.2
10.	and	Mean	31.45	5.86	750	2.66	354	10.11
	103°24'45"E	SD	0.29	0.44	36.01	0.22	22.12	2.09

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

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 (Haris and Maznah, 2008), forested area and there were some agricultural activities adjacent to the station 2. Meanwhile, TDS of station 7-10 were in permissible limits 500 mg/L (DOE, 2008) (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 (DOE, 2008).

3.2 Ex-situ parameters

Collecting samples from sampling sites were analyzed in laboratory for determining the amount of sulphate (SO4), NH3-N, nitrate-nitrogen (NO3-N), phosphate-phosphorus (PO43), BOD, COD and TSS. Results showed that the amount of sulphate was the highest in station 1 followed by 2 and 7 (Figure 2).It was due to station 1 & 2 near the sea (Haris and Maznah, 2008) and 7 was adjacent with some chemical industries which produced detergent and discharged sulfur reach effluents into the river flow. The amount of NH3-N varied from 0.25 mg/L at station 9 to 3.47 mg/L at 3 (Figure 3). The values were beyond the permissible limit of INWQS of Malaysia; and it categorized the water of mid-stations as class V. NO3-N level was within the safe level (<0.4) (Saad et. al., 2008) except station 5 to 7 (Figure 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 PO43- recorded the highest 6.3 mg/L at station 10 (Figure 4) while the other stations contained relatively lower concentration of PO43-. Meanwhile, PO43- amount was in permissible level at station 7 to 9 (DOE, 2008). TSS was observed almost below the standard level except at station 1and station 2. Water at these two stations was found loaded with TSS. At station 1 the concentration was 47.17 mg/L followed by 37.67 at station 2 (Figure 5). This was perhaps because of sea water intrusion, forested area and at station 2 there were some agricultural activities.

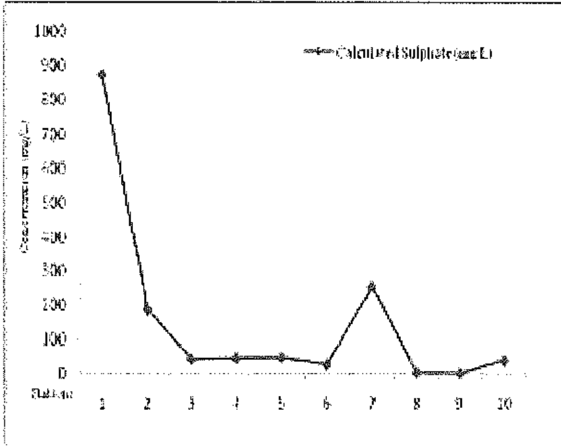

Figure 2: Variation of sulphate concentration among the stations of the study area

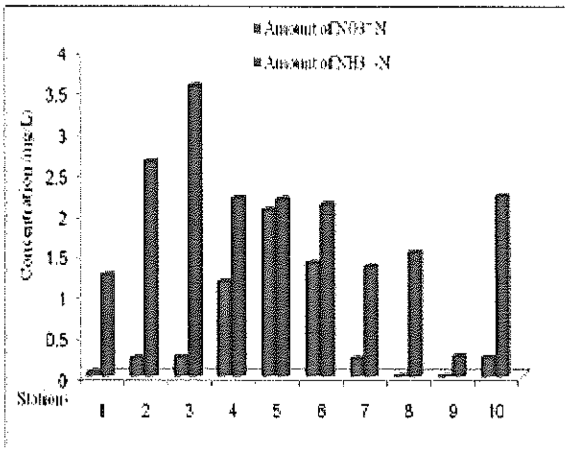

Figure 3: Variation of nitrate nitrogen and ammoniacal nitrogen concentration among the station of the study area

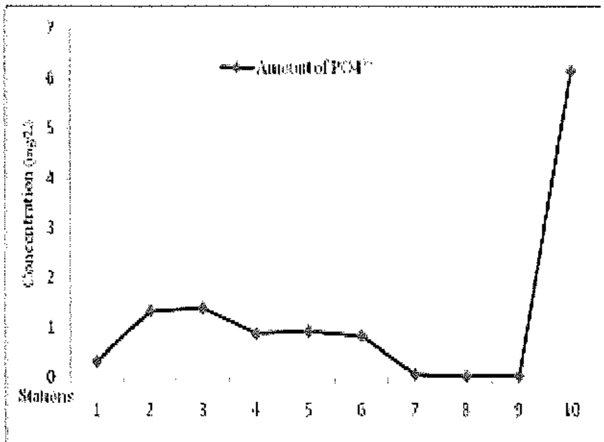

Figure 4: Variation of phosphate concentration among the stations of the study area

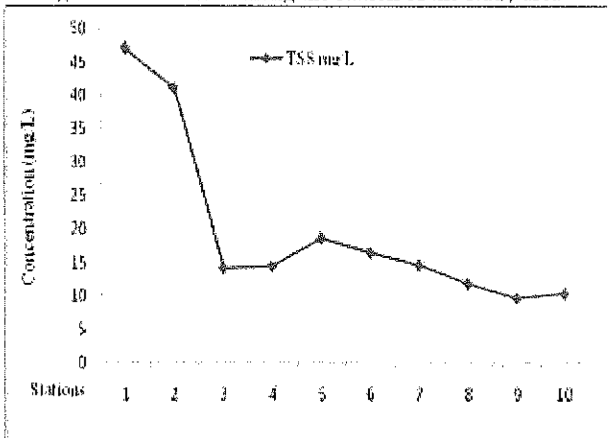

Figure 5: Variation of TSS concentration among the stations of the study area

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 (Figure 6). The BOD values of all stations were beyond the permissible limit (DOE, 2008) 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 (Figure 6). 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.

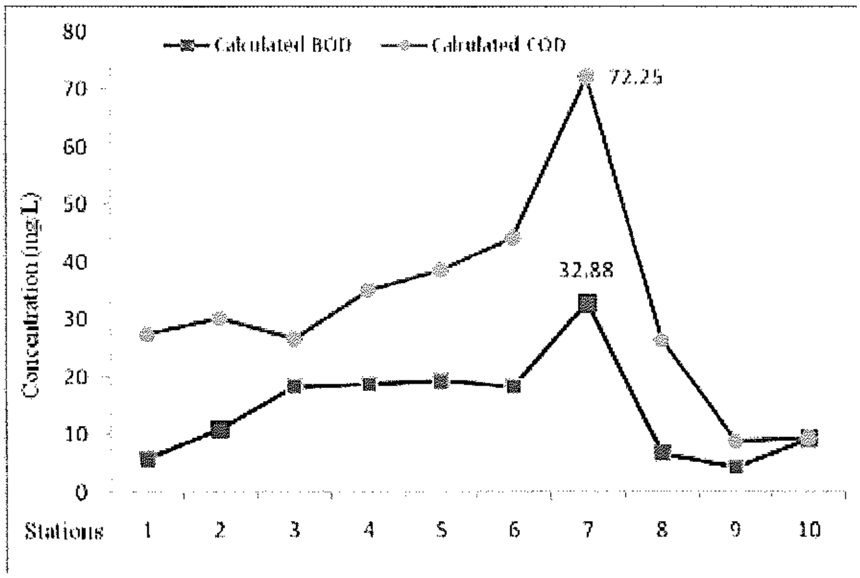

Figure 6: Variation of BOD and COD concentration among the stations of the study area

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 (DOE, 2008). 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. 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.

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

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

3.3 Water Quality Index

Water quality index values were calculated based on DO, BOD, COD, NH3-N, TSS and pH concentration (Norhayati, 1981; Yusuf, 2001 and Haque et. al., 2010). 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 (DOE, 2008). 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 (Haris and Maznah, 2008).

Sampling station	DOE-WQI values	Water quality class	Water quality status
Station 1	51.99	III	Polluted
Station2	45.67	IV	Highly Polluted
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	Polluted
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

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

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.

5. Acknowledgement

Authors are grateful to the University Malaysia Pahang and Faculty of Civil Engineering and Earth resources for research funding through the project RDU: 110354. We are also grateful to the laboratory personals for their cooperation during sample analysis.

References

A. H. Charkhabi and M. Sakizadeh (2006). Assessment of spatial variation of water quality parameters in the most polluted branch of the Anzali wetland, northern Iran, Polish J. of Environ. Stud, 15(3). Pages: 395-403.

Andrew D. Eaton, Lenore S. Clesceri, Eugene W. Rice, Arnold E. Greenberg and Mary Ann H. Franson, (2005). Standard methods for the examination of water and wastewater. American Public Health Association, Washington, USA.

Department of Environment, (2011). Chapter 3. River water quality. Malaysia environmental quality report, 2009, Kuala Lumpur, Malaysia.

Department of Environment,(2008). Interim National Water Quality Standards for Malaysia. Kuala lumpur, Malaysia.

HACH (2005). Water analysis guide. HACH Company, USA.

Hazzeman Haris and Wan Maznah, W. O. (2008). The effects of tidal events on water quality in the coastal area of Petani River Basin, Malaysia. International Conference on Environmental Research and Technology (ICERT 2008).

J. Yisa and, T. Jimoh, (2010). Analytical studies on water quality index of river Landzu, American Journal of Applied Sciences, 7(4). Pages: 453-58.

M. A. Haque, Y. F. Huang and T. S. Lee,(2010). Seberang Perai rice scheme irrigation water quality assessment. Journal - The Institution of Engineers, Malaysia. 71(4). Pages: 42-49.

Mary-Lou Tercier-Waeber and Martial Taillefert (2008). Remote in-situ voltammetric techniques to characterize the biogeochemical cycling of trace metals in aquatic systems. J. Environ. Monit., 10(1). Pages: 30-54.

M A Yusuf, (2001). PhD thesis: river water quality and ecosystem health in Langat basin, Selangor, Malaysia, Universiti Kebangsaan Malaysia.

Mohd Saad, Farah Naemah and Nik Abdul Rahman, Nik Norulaini and Abdul Kadir, Mohd Omar and Mohd Omar, Fatehah, (2008).

Norhayati Mustapha,(1981). Master's thesis: indices for water quality in a river. Asian Institute of Technology, Bangkok.

Project Report: Identification of Pollution Sources within the Sungai Pinang River Basin. Universiti Sains Malaysia. Available at http://eprints.usm.my/4907/Park Royal Penang, Malaysia. Pages: 595-599.

Ravichanddran Moorthy and Ganesan Jeyabalan, (2012). Ethics and sustainability: a review of water policy and management. American Journal of Applied Sciences, 9(1). Pages: 24-31.

Towned J., (2003). Practical statistics for environmental and biological scientists. John Wiley & Sons, New York. Pages: 221-228.