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Study on the Effect of Leachates from Old Dumping Site on Water Quality of Sungai Batu in Taman Wahyu II, Selayang, Selangor

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Abstract: There are various cause of river pollution in Malaysia, one of them are sourced from dumping site. A study on water quality at Sungai Batu that located adjacent to the dumping site was being conducted where it was capped for more than 10 years ago and has been developed as housing estate namely Taman Wahyu II, that located in Selayang, Selangor. This study aims to assess the effect of leachate result from disposal site which practiced open dumping during the operation once upon a time on water quality. The purpose was to see whether there is a significant difference between station before and in study area through several parameters that was prescribed. Sampling process and analysis involving *in-situ* and *ex-situ* measurement which divide into two areas that is before study area and study area with a few physical parameters such as temperature, turbidity, conductivity and total suspended solid (TSS) and chemical parameter namely pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia-nitrogen and also phosphate. Sampling sediment and soil were carried out to analyze heavy metal that present in study area such as lead, cadmium, arsenic, zinc, copper and also manganese where these components usually present as pollutant in leachate. Statistical results from independent T-test showed significant differences ($p<0.05$) between station when water flow enter study area for turbidity parameter, conductivity, total suspended solid, DO, BOD, COD, Ammonia-nitrogen and phosphate. Statistical results from independent T-test for sediment analysis showed significant difference ($p<0.05$) for zinc between station before and in the study area. One-way ANOVA analysis on the other hand find out that arsenic heavy metal, zinc and manganese showed significant differences ($p<0.05$) between study area and the rest for soil sampling. BOD ratio to COD for station 4 which is nearby study area giving value 0.02 mg/l namely less than 0.1 mg/l where this value meet criteria to leachate which matured and this value shows leachate can be classified in category old leachate as this disposal site certainly was capped for more than 10 years and leachate that attended in body of water caused by this open dumping site. Water Quality Index (WQI) was upheld to every station and river near to the dumping site area categorized as Class IV where it is not suitable to be used as supply of drink water resources but only suitable for irrigation purpose.

Key words: Dumping Site · Leachate · Water Quality Index

INTRODUCTION

Malaysia is a country that is fast developing in line with Vision 2020 to achieve developed nation status. One of the results from the developments is the increments of solid waste quantity that produced every day. Solid waste production per-capita where increased two folds from 0.5kg / capita / day in early 1980 to 1kg / capita / day in 2001 Agamuthu [1]. The worrying part is waste disposal system that less systematic and effective for processing objective and that solid waste disposal which not only Malaysian nation in fact in Tropical country, almost 90% solid waste written off use open disposal site system Trankler *et al*. [2].

One of the important aspects in municipal solid waste management is the leachate which otherwise well managed will cause serious threat to environment because leachate production will enter the underground water flow and also surface water. Leachate is the liquid that drains or 'leaches' from a landfill; it varies widely in composition

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regarding the age of the landfill and the type of waste that it contains. It usually contains both dissolved and suspended material Azhar [3].

Study on 50 disposal site in Germany find out ammonia concentration does not show marked depreciation although after a 30 years closure. A survey result by Lee *et al*. [4] on two uncontrolled rubbish disposal sites in Korea found out that leachate contaminated body of water with COD content, ammonia and chloride in high concentration.

The present study aims to assess the effect of leachate result from disposal site which practiced open dumping during the operation once upon a time on water quality. Also the purpose was to see whether there is a significant difference between station before and in study area through several water criteria.

MATERIALS AND METHODS

Water sampling was being conducted for three times with 3 weeks interval between every sample with regard rain factor or not. Sampling time began at 9 o'clock in the morning to 12 noon. A few water quality parameters used to determine river water quality based on the objective of the study. Water sampling was divided into two namely analysis by *in-situ* and *ex-situ*. The parameter used to determined the quality of water included temperature (p*ortable* HI 8424 Hanna *instruments temperature meter)*, pH (p*ortable* HI 8424 Hanna *instruments pH meter)*, turbidity (*portable* 2100P HACH *Turbidimeter)*, total suspended solid, conductivity, dissolve oxygen (DO-*YSI 550A Dissolved Oxygen Meter)*, biological oxygen demand (BOD), chemical oxygen demand(COD),ammonia-nitrogen(NH_3-N) and phosphate.

Water Analysis by *in-situ*: In-situ measurement was carried out at study location and taken in depth around one meters from river water level which depends on accessibility. Parameters have that been chosen is pH, temperature, DO, conductivity and turbidity.

Water Analysis by *Ex-situ*: Ex-situ analysis was carried out by taking water sample in every sampling station to the laboratory for analyzing process. A few parameters was elected to at study Sungai Batu water's quality level effect from leachate that was generated from waste disposal site namely biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia-nitrogen (NH_3-N), total suspended solid (TSS) and phosphate.

Water Sample Preservation: To avoid biological or chemicals reaction that can change the natural homogeneity of water sample, the sample that has been taken would be analyzed immediately. It was stored in cold container or cool box that is structured as waterproof, acid-proof, rust resistant and strong in temperature between 4°C to 10°C for preservation purpose during transportation process to laboratory.

RESULTS

For studying the physical and chemical parameters the sampling stations has been divided into 2 groups namely a station before study area that consist of stations 1, 2 and 3 that was located in upstream and another station that located nearby the waste disposal site area that consist of stations 4, 5 and 6. The purpose of dividing the stations into 2 groups was to see whether there is significant increments or not for parameters that have been studied especially pollutants which residing within leachate when river water flow enter the study area namely river site next to Taman Wahyu II, Selayang which is a waste disposal site area. Table 1 and 2 showed analyzed results (average reading) that have been achieved in every physical and chemical parameter and also the average reading for station before study area, in study area and value p in table 3 and 4:

Pearson's Correlation test also being carried out to every water parameters that has been studied to observe the relation between parameters at sampling station whether it is significant or not.

Table 1: Physical parameters of water in the studied areas

Sampling Stations	Physical Parameters			
	Temperature (°C)	Turbidity (NTU)	Conductivity (mg/L)	Total Suspended Solid (mg/L)
1	26.6	9	3.2	68
2	27.5	32.3	4.4	72.3
3	27.1	48	9.5	98
4	26.5	71	9.5	128.7
5	27.5	66.3	11.2	104.3
6	28.5	32	22.8	94

Table 2: Chemical parameters of water in the studied areas

	Chemical			Parameter		
Stations	pH	DO(mg/L)	BOD(mg/L)	COD(mg/L)	Nitrogen-ammonia (mg/L)	Phosphate (mg/L)
1	6.77	4.57	0.71	4.3	0.24	0.16
2	6.98	4.16	0.86	14.7	2.50	0.62
3	7.02	2.01	2.25	25.3	4.04	1.53
4	6.81	0.78	3.75	170.6	8.91	2.55
5	7.06	0.58	3.43	143.3	8.20	2.49
6	7.27	1.69	3.25	94	7.65	2.13

Table 3: Average readings of physical parameters for stations before study area (1) and in study area (2)

Physical Parameter		Mean ± SD (µg/m³)	t value	p value*
Temperature				
Station	1	27.1±0.4		
	2	27.5±0.8	-1.234	0.24
Turbidity				
Station	1	29.4±16.7		
	2	56.1±18.9	-3.161	0.00
Conductivity				
Station	1	5.7±2.9		
	2	14.5±6.3	-3.820	0.00
Total Suspended Solid				
Station	1	79.4±14.1		
	2	109±15.5	-4.227	0.00

*significant value is $p < 0.05$. Indicator: 1-station before study area, 2-station in study area

Table 4: Average readings for stations before study area (1) and in study area (2)

Chemical Parameters		Mean ± SD (µg/m³)	t Value	p Value*
pH				
Station	1	6.9±0.1		
	2	7.1±0.2	-2.578	0.02
DO				
Station	1	3.6±1.2		
	2	1.0±0.5	5.937	0.00
BOD				
Station	1	1.7±1.3		
	2	3.1±0.7	2.854	0.02
COD				
Station	1	14.8±9.2		
	2	154.4±15.9	-22.868	0.00
Nitrogen-Ammonia				
Station	1	2.3±1.7		
	2	8.3±0.6	-10.260	0.00
Phosphate				
Station	1	0.9±0.6		
	2	2.4±0.2	-7.257	0.00

*significant is $p < 0.05$ Indicator: 1-station before study area, 2-station in study area

Table 5 showed results that have been achieved after correlation test analysis has been carried out to every parameter for chosen station (before study area and in study area).

Table 5: Correlation test analysis Pearson

	Parameters	Correlation Coefficient (r)	p Value*
Temperature	pH	0.893	0.02
	COD	0.992	0.00
Turbidity	Phosphate	0.858	0.03
	DO	-0.880	0.02
	COD	0.824	0.04
	Ammonia-nitrogen	0.821	0.04
Conductivity	pH	0.911	0.01
Total Suspended Solid	Turbidity	0.901	0.01
	Phosphate	0.904	0.01
	DO	-0.908	0.01
	COD	0.882	0.02
	Ammonia-nitrogen	0.875	0.02
DO	Phosphate	-0.987	0.00
	COD	-0.885	0.02
	Ammonia-nitrogen	-0.947	0.00
COD	Phosphate	0.916	0.01
	Ammonia-nitrogen	0.941	0.00
Ammonia-nitrogen	Phosphate	0.985	0.00

Table 6: Heavy metals in sediment samples of Sungai Batu, Selangor

Stations	Lead (ppm)	Cadmium (ppm)	Arsenic (ppm)	Zinc (ppm)	Mg (ppm)	Copper (ppm)
1	0.178	0.001	0.113	0.160	0.026	0.802
2	0.428	0.003	0.524	0.635	0.214	1.446
3	0.251	0.001	0.122	0.393	0.094	0.532
4	0.279	0.002	0.113	1.644	0.165	0.921
5	0.465	0.003	0.102	0.963	0.669	1.967
6	0.411	0.003	0.119	0.914	0.378	1.353

Table 7: Independent T-test analysis's for sediment samples

Heavy Metal		Mean ± SD (µg/m³)	t Value	p Value*
Lead				
Station	1	0.3±0.1		
	2	0.4±0.1	-1.074	0.34
Cadmium				
Station	1	0.0±0.0		
	2	0.0±0.0	-1.494	0.21
Arsenic				
Station	1	0.3±0.2		
	2	0.1±0.0	1.045	0.36
Zinc				
Station	1	0.4±0.2		
	2	1.2±0.4	-2.853	0.04
Manganese				
Station	1	0.1±0.1		
	2	0.4±0.3	-1.875	0.13
Copper				
Station	1	0.9±0.5		
	2	1.4±0.5	-1.197	0.29

*significant is $p < 0.05$ Indicator: 1-station before study area, 2-station in study area

Table 8: Analysis of heavy metals in soil samples in waste disposal site area Taman Wahyu II, Selayang, Selangor

Stations	Lead (ppm)	Cadmium(ppm)	Arsenic(ppm)	Zinc(ppm)	Manganese(ppm)	Copper (ppm)
1	8.125	0.058	1.304	9.319	6.682	4.609
2	1.379	0.008	1.139	5.797	5.577	0.800
3	1.806	0.019	0.803	4.832	8.465	0.601
4	0.035	0.000	0.005	0.101	0.034	0.014
5	0.036	0.001	0.039	0.150	0.083	0.018
6	0.018	0.000	0.009	0.089	0.046	0.015
7	0.023	0.000	0.051	0.052	0.101	0.011
8	0.018	0.000	0.013	0.043	0.066	0.003
9	0.030	0.000	0.058	0.029	0.059	0.004
10	0.022	0.000	0.032	0.087	0.069	0.014

Sediment sample taken at study station together with water sampling to study the concentration of heavy metal present in the area involved. Sampling station also has been divided into 2 parts namely area before waste disposal site that consist of station 1, 2 and 3 while station in waste disposal site area that consist of station 4, 5 and 6.Table 6 shows the trend of heavy metal before study area and at study area chosen.

Heavy metals that have been analyzed were lead, cadmium, arsenic, zinc, manganese and copper that there were often present in leachate. Plotted graph based on heavy metal concentration in sediment sample found that study area namely waste disposal site area at station 4, 5 and 6 showed a higher reading compared to stations before waste disposal site. Table 7 shows result from the analysis using an independent T-test.

Table 9: Characterization of leachates differs according to age of disposal site

Types Of Leachates	Young	Intermediate	Matured
Age of disposed site (year)	<1	1-5	>5
pH	<6.5	6.5-7.5	>7.5
BOD/COD (mg/L)	0.5-1.0	0.1-0.5	<0.1
COD (mg/L)	>15,000	3000-15,000	<3000
Ammonia-nitrogen (mg/L)	<300	NA	>400
Heavy Metal (mg/L)	>2	<2	<2

Table 10: Sungai Batu classification according to Water Quality Index (WQI)

Stations	IKA value	Classes
1	67	III
2	55	III
3	49	IV
4	37	IV
5	38	IV
6	40	IV

Soil samples were also taken in waste disposal site area by using equipment that is called Oguer. By using the same heavy metal parameters for sediment sampling, the sampling area were divided into 3 parts namely area that is the closest to river water flow which labeled as station 1, 2 and 3 and field areas in station 4, 5 and 6 and small mosque area with housing building in station 7, 8, 9 and 10.Table 8 shows the trend of metal graph that have been achieved in every sampling station in unit part per million (ppm).The sample was analyzed by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

DISCUSSION

Among water parameters that have been carried out in water flows before study area towards study area, all of them showed a significant increments in values. Although the statistical analysis using independent T-test showed no significant difference between station before study area and in study area with value $p>0.05$ for temperature however, according to earlier study water temperature could be rising and change according to the sun light intensity, time and also river depth factor. Water flow which flowed rapid from upstream to downstream and shading from tree which might have been degraded the water temperature Pauzi *et al*. [5] Ngoye and Machiwa [6] such as in station 1 that record a lower reading that low as much as 26.6 °C.

Turbidity is a common phenomenon to most of rivers in Malaysia. Turbidity often correlated with land used activity and also total suspended solid resultant effect from activity involved Munafo *et al*. [7]. Based on outcome of study that has been achieved, station 4 showed the highest value as much as 71 NTU. Based on the observation, area in station 4 contained of soil structure that relatively loose which might produced by the waste disposal site closure process that imperfect and this could become as contributing factor to the river turbidity where soil structure that relatively loose will cause land molecules to move into body of water especially when rainy day Suhaimi *et al*. [8].

Based on the obtained result conductivity parameter showed a significant increments when water flow drift into study area. Station 6 gave superlative reading and the drainage effluent goes directly into body of water which it came from plastic bottle recycling activity's purpose. The occurred changes in conductivity values showed availability of direct waste water disposal or other pollution into body of water which may influence the result Marryana *et al*. [9]. This shows that conductivity value increase when pollutant released into body of water like what had happened at station 6.

Beside that, suspended solid is referring to organic and also inorganic particles that residing within water. Organic particles consist of bacteria, protozoa, alga and others while for inorganic particles consist of silt, clay and portion of other types of land. Usually, river water turbidity was associated with suspended solid resultant from land use activity in river site. This established via survey results that achieved in station 4 which the reading value for total solid parameter suspended was the highest with value of 128.7 mg/l. While the achieved turbidity reading in station 4 also the highest with value as much as 71 NTU. Based on observation, station 4 located adjacent to waste disposal site area with availability land area that relatively loose structure and there was housing estate nearby. This soil structure is seen fairly simple to enter into body of water during the physical activity or rain which occurred. Apart from that, various sources that present from nearby population source such as domestic and organic waste material that can leverage on total solid value suspend that achieved.

Referring to WHO [10], pH did not give direct impact to human health but it is an important parameter that used in ascertaining water quality level that being studied. Based on the outcome achieved, pH value showed significant differences between station before study area and also in study area ($p<0.05$). pH value in station 1 was 6.77 while station 6 showed the highest pH value 7.27. If we reviewed at station 1environment, it was located nearby housing estate and road construction site where

there would be effluent that has been discharged came into body of water. With low pH value that was gained from this, it can be associated with drainage presence that issue domestic sewage waste into body of water Suhaimi *et al.* [8].

Oxygen solubility rate depends on several factors and one of them is eddy of water strength Mohd Rozali *et al*. [11]. Independent T-test showed value $p<0.05$ and this means a significant decline for oxygen reading dissolve between station before study area and within study area that give attention to waste disposal site area that is on stations 4, 5 and 6. Value of dissolved oxygen station (DO) was low because of sampling stations were situated within waste disposal site area. Waste disposal site area which had no efficient leachate treatment would caused water leach from the area percolate through land molecule and further enter into water flow. According to Abd Razak *et al*. [12], organic material contained in leachate would be experiencing oxidation process by microorganism and this activity require presence of oxygen pass cause DO value in water body to be low for area that has been polluted.

Value of BOD and COD usually inversely proportional with value of oxygen dissolves. Dissolved oxygen would be lower if BOD and COD value are high and vice versa. Biological Oxygen Demand (BOD) is oxygen demand entailment and is used for oxidation process and organic decomposition biologically (natural). While Chemical Oxygen Demand (COD) is demand on total oxygen that is used for organic pollutant oxidation process chemically.

Based on the outcome achieved obviously lead has a significant increments where low in station before study area and high in study area namely waste disposal site area (station 4, 5 and 6) where value $p < 0.05$ for independent T-test for both parameters BOD and COD. This indicates that the possibility of microorganism activity in study area due to polluting substance discharge (Abdul Razak *et al*. [12] and according to earlier study, COD concentration that was high at water environmental area which received pollutant in higher concentration.

This waste disposal site area seemed to contribute to high BOD and COD value because leachate which still produced through decomposition process although this disposal site already more than 10 years. All pollutant in leachate still had not achieved the climax concentration at the same time. When BOD to COD ratio in station had the highest reading value (station 4) calculated, value that achieved is as much as 0.02 mg /l namely less than 0.1 mg/l where this value meet criteria to leachate which matured and this value showed that the generated leachate staying in category old leachate as this disposal site certainly was capped more than10 years and leach that attended in this body of water are sourced from that.

The waste disposal site nearby also show that organic and inorganic material in this area are still exist and persistently behave because can exist in a long period of time although this disposal site already aged more than 10 years. This factor also showed risk on pollutant exposure to the surrounded housing area residents actually relatively high because pollutant that persistently behave have a long life span (half-life) that long and non-biodegradable. Characterizations of leachates which differ according to age disposal site are summarized in table 9:

Source: Alvarez-Vazquer *et al.* [13] Based on the result achieved, independent T-test found out that there is a significant increments with value $p<0.05$ where low zinc value in station before study area and the reading increase when sample sediment taken in study area. Analysis result from One-Way ANOVA also showed there is significant difference for soil sample that has been tested at study area with value $p<0.05$.WHO [10], polluted land with zinc usually occurs especially in zinc production area or disposal site and sewage result from industry of rock source.

Zinc concentration found was slightly high in station 2 and this may be attributed from current situation in that station which have rock dump and also land use activity that seen as a factor of why relatively high zinc concentration in that area compared to other different stations that located before study area. This area consist of relatively loose soil structure and this indirectly contributed to the presence of zinc which according to Abd Razak *et al*. [12] erosion process will cause mineral material and land carted to other places while for zinc it indirectly transported into body of water.

When independent T-test analysis undertaken for arsenic noted that there is no significant difference between areas before study and also in study area for tested sediment sample where value $p > 0.05$. However for soil sample that was taken in study area at station 1, 2 and 3 such as indicated in graph 2, that there is significant difference between station in study area compared to other areas where value $p < 0.05$ shows concentration of heavy metal increase when sampling station drew nearer to river water area and this showed movements of leachate that brought together arsenic came into body of water with availability value that can be detected at study area.

Based on independent T-test result for lead, there is no significant difference for sediment sample in river water flow before study area and in study area with value $p>0.05$. This case contrasts with soil sample that was tested where One-Way ANOVA test showed significant increments for soil samples in study area (station 1, 2 and 3) compared to the other stations where value $p<0.05$.

This showed that heavy metals still attended in soil samples that have been tested especially in area that was the closest with water body. This shows that the movement of leachate direct to river bring together lead heavy metal as pollutant which included before it crept into the air. This lead might be present from garbage that was banished in Taman Wahyu II waste disposal's site, Selayang, Selangor.

CONCLUSION

Sungai Batu water's quality study that has been carried out with aim to see the effect of leachate from waste disposal site on river water quality found to give positive results based on physical and chemical parameters concentration that achieved and favored with presence of heavy metal in sediment sample and also soil sample that has been tested.

Based on outcome of the study, the BOD and COD concentration in the study area remained in relatively high concentration for leachate that aged for more than 10 years which when BOD to COD ratio calculated, it gives value and indicated that this disposal site could be categorised remained in matured category by referring to study that was carried out earlier by Alvarez-Vazquer *et al.* [13] through characterization of leachates.

This study had successfully established that waste disposal site which practice open dumping able to generate leachate that can enter into body of water and reduce river water quality. More efficient and effective systems are needed to avoid more leachate incident that may enter into body of water especially to the river. More systematic management including leachate treatment need to be carried out if this waste disposal site wish to be closed and redeveloped for housing, recreation or for other purposes.

Sanitary landfills seem to be better and effective to tackle leachate problems and to reduce the disfavor smell from waste disposal because of systematic methane gas collection system and leachate treatment.

Six parameters have been used for calculating Sungai Batu water's quality index namely pH, dissolved oxygen(DO), BOD, COD, total suspended solid and also ammonia-nitrogen. Values for Water Quality Index were made to every station and classification at every sampling station indicated in table 10.

Source: Department of Environmental Malaysia [14] Study area namely area in station 4, 5 and 6 staying in class IV where the water in this area are only suitable to be used for irrigation purpose only. Site area with presence of waste disposal nearby water body is seen to become a contributing factor on reducing Sungai Batu quality's standard from class III to class IV.

REFERENCES

1. Agamuthu, P., 2001. Solid Waste: Principles and Management, with Malaysian Case Studies. University of Malaya, Kuala Lumpur.
2. Trankler, J., C. Visvanathan, P. Kurupan and Tubtimthai, 2005. Influence of tropical seasonal variations on landfill leachate characteristic-Result from lysimeten studied. Waste Management, 25: 1013-1020.
3. Abdul Halim and Azhar, 2008. Olahan Larut Lesapan Semi-Aerobik Menggunakan Penjerap Komposit Berasaskan Bahan Mineral Dan Organik [TD795.7. A994 2008 f rb]. PhD Thesis, University Sains Malaysia.
4. Lee, J.Y., J.Y. Cheon, H.P. Kwon, H.S. Yoon, S.S. Lee, J.H. Kim, J.K. Park and C.G. Kim, 2006. Attenuation of landfill leachate at two uncontrolled landfills. Environmental Geology, 51(4): 581-593.
5. Md. Pauzi Abdullah, Ainon Hamzah, Kong, Juin Mei and Cheah, Wai Leng, 2003. Land use effect on drinking water quality in side: Case study in Semenyih, Selangor D.E. Seminar Persekitaran proceeding, pp: 299-310.
6. Ngoye, E. and J.F. Machiwa, 2004. The influence of land-use patterns in the Ruvu River watershed on water quality in the river system. Physics and Chemistry of the Earth, Parts A/ B/ C, 29(15-18): 1161-1166.
7. Munafo, M., G. Cecchi, F. Baiocco and L. Mancini, 2005. River pollution from non-point sources: A new simplified method of assessment. Journal of Environmental Management, 77(2): 93-98.
8. Suhaimi Suratman, Norhayati Mohd Tahir, Mohd Riduan Azmi Mohd Alwi and Mohd Sabri Husin, 2002. Study on water quality in Sungai Marang, Terengganu. Simposium Kimia Analisis Malaysia proceeding 15th, pp: 60-67.

9. Marryana, L., S. Siti Aishah and K. Saiful Iskandar, 2006. Changes in profile of water chemistry with the establishment of forest plantation in a small forested catchment: International Journal of Forest Usufructs Management, pp: 10-16.
10. WHO, 2004. Guidelines for drinking-water quality. Vol. 1, Recommendations. 2nd. Ed. Geneva: World Health Organization.
11. Mohd Rozali Othman, Mohd Talib Hj Latif and Tai Siong Cake, 2006. Runoff as pollution indicator. Malaysia Journal of Analytical Sciences, 10(2): 191-196.
12. Abdul Razak Sederlan, Mohd Kamil Yusoff, Azizi Young and Ab. Aziz Abdul Latiff, 2003. Industrial activity and its impact on Sungai Merlimau water quality's standard, Malacca. Science journal and Technology Kolej University Technology, Tun Hussein Onn, (1): 41-51.
13. Alvarez-Vazquez, H., B. Jefferson and S.J. Judd, 2004. Membrane bioreactors vs conventional biological treatment of landfill leachate: A brief review, J. Chem. Technol. Biotechnol., 79: 1043-1049.
14. Department of Environmental, 2005. Malaysia. Surrounding World Quality Reports 2004. Kuala Lumpur: Natural Resources and Environment Ministry.