CHAPTER 7

WATER QUALITY CONDITION IN RECREATIONAL FOREST

Result

Generally, the impact of forest recreation on water quality is quite difficult to detect, as compared to soil compaction and loss of vegetation where their losses are not only readily noticeable, but also that they can be easily related to the intensity of forest recreation. Nevertheless, changes in water quality do occur and are usually transient in nature. Water quality changes are generally not easily related to specific cause but rather being attributed to the many harmful uses of water that occur simultaneously. Survey includes the collection of data comparing both physical (temperature, pH, turbidity, electrical conductance) and chemical (dissolved oxygen) properties of water in Sg. Batu within the Sg. Tua FRA, as they react to different intensity of forest recreation (lightly, medium, heavily used and control).

Regular grab sampling for turbidity and *in-situ* measurements for water temperature, pH, conductance and dissolved oxygen are taken, at predetermined locations adjacent to the recreational sites, both upstream and downstream of Sg. Batu, in order to establish their reactions to water quality. The differences in their readings will be attributed to the water quality measurements from that site (Chapter 4- Methods and Materials). Analysis of results is undertaken using the S-Plus 2000 MathSoft, Inc. computer programme.

Temperature

Water temperature is a measure of the intensity of heat stored in a volume of water. In this respect, factors affecting water temperature in Sg. Batu, Selangor can be attributed to the effects of radiation absorption, cooling by air-water temperature differences and the degree of exposure to direct sunlight. Water temperature in this study is measured in degrees of Celsius (°C). Mean water temperature for the lightly, medium, heavily recreational used and control sites are 25.8°C, 25.9°C, 26.0°C and 25.9°C respectively. Application of analysis of variance (ANOVA) test at significance level of $p = 0.05$, confirms the non-significance of water temperature between lightly, medium, heavily recreational used and control (Table 24). The stability of water temperature between the four recreational use may be due to the shading effects of forest canopy, which lined both sides of the river thereby reducing surface water exposure to direct sunlight. The high hills that surround the Sg. Tua FRA conveniently act as a buffer in keeping both ambient and water temperature lower. The cooling effect of intense rain and together with increased heat loss due to wind in surface layer of water, which are quickly dissipated by turbulence and disturbance, further reduce water temperature. In addition, water turbulence not only reduces light penetration, but also absorbing light energy thereby lowering of water temperature. Although there are variations in water temperature between the different recreational used (lightly, medium, heavily and control), but their differences are not significant, which imply that water temperature is not dependent on recreational intensity.

pH

pH of water refers to its hydrogen ion activity and is expressed as a logarithmic of the reciprocal of its acidity. It is measured by a electrometer connected to two electrodes. The electrode potential or pH is a function of the hydrogen ion

Table 24. ANOVA Result of Water Temperature

	treat	rep	Residuals
Sum of Squares	0.203958	0.035000	1.294167
Deg. of Freedom	3	2	42

Residual standard error: 0.1755377
Estimated effects are balanced

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)	Dif
treat	3	0.203958	0.06798611	2.206375	0.1014658	NS
rep	2	0.035000	0.01750000	0.567933	0.5709869	NS
Residuals	42	1.294167	0.03081349			

concentrations in water. The mean pH for the four recreational sites; lightly, medium, heavily used and control are close to neutrality with measurements of 7.03, 7.04, 7.03 and 7.05 respectively. Application of ANNOVA test at significant level of $p = 0.05$, confirms that the pH between the four different recreational used are non-significant (Table 25). The near neutral pH among the different recreational used (lightly, medium, heavily and control) are a surprise since precipitation has a mean pH of 5.6 due to the solubility of atmospheric carbon dioxide by rain. The fast flowing Sg. Batu may have provided the flushing effect necessary to advect and disperse the concentration of hydrogen ion acidity throughout the water body, thereby contributing to the near neutrality in pH between the different categories of recreational use. These together with more alkaline groundwater infusion containing a higher proportion of silicates and bicarbonate, from the overlain Kuala Lumpur Limestone Formation, may have further neutralised the pH to near neutrality. As forest canopy lined both sides of Sg. Batu, the increased leachate from fallen leaves may have also contributed to the increased in water alkalinity and together, these could have explained the mild overall alkalinity measured at the four recreational used sites (replicated thrice per site for each category

Table 25.. ANOVA Result of pH

	treat	rep	Residuals
Sum of Squares	0.00397500	0.00167917	0.09113750
Deg. of Freedom	3	2	42

Residual standard error: 0.04658262
Estimated effects are balanced

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)	Dif
treat	3	0.00397500	0.001325000	0.6106158	0.6118748	NS
rep	2	0.00167917	0.000839583	0.3869154	0.6815442	NS
Residuals	42	0.09113750	0.002169940	-		

of recreational used, while four samples are collected from each site) though not significantly different between them. Nevertheless, the mean pH values for these recreational sites fall within the interim standards for drinking water and domestic use (Anon, 1986).

Electrical Conductance

The electrical conductance of Sg. Batu waters reflects its overall ionic concentrations and is expressed as micro-Siemens per distance (μS/cm). The amount of current conducted is proportional to the concentration of ions in solution. Mean conductance readings for the lightly, medium, heavily recreational used and control are relatively homogeneous, as reflected by their mean conductance measurements of 30.1 μS/cm, 30.2 μS/cm, 30.1 μS/cm and 30.2 μ S/cm respectively. These readings around the value of 30.15 μS/cm suggest the dilution effects of ionic contents by groundwater intrusion, which indicate that the water quality of Sg. Batu is relatively clean. Application of ANNOVA test at significant level of p=0.05 confirms that it is non-significant between the different recreational used (Table 26). The stability of Sg.

Table 26. ANOVA Result of Electrical Conductance

	treat	rep	Residuals
Sum of Squares	0.00397500	0.00167917	0.09113750
Deg. of Freedom	3	2	42

Residual standard error: 0.04658262
Estimated effects are balanced

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)	Dif
treat	3	0.00397500	0.001325000	0.6106158	0.6118748	NS
rep	2	0.00167917	0.000839583	0.3869154	0.6815442	NS
Residuals	42	0.09113750	0.002169940			

Batu's ionic composition irrespective of recreational used, could be attributed to the underlying riverine bed-rock dominated by silica and bicarbonate

Dissolved Oxygen

Measurement of dissolved oxygen in river water is one of the most frequently and most important of all chemical methods available for the investigation of the aquatic environment. Dissolved oxygen provides valuable information about the biochemical and biological reactions going-on in water, as well as being crucial for microbial activities. Thus, dissolved oxygen is a measurement of environmental factors affecting aquatic life. Dissolved oxygen is measured by oxygen sensitive electrodes (anode and cathode) encased in the electrolytic filled housing and separated from water and an oxygen permeable membrane. Oxygen then diffuses through the membrane and the electrolyte solution to the electrodes, and the electrical current generated is recorded on the meter. Units of measurement used in this study are mg/litre. Mean dissolved oxygen measurements of lightly, medium, heavily recreational used and control sites are 7.3 mg/lit, 7.2mg/lit, 7.1 mg/lit and 7.2 mg/lit respectively. Application of ANOVA Test at significance level of p=0.05 confirms the existence of significant differences between the four recreational used namely, lightly, medium, heavily and control (Table 27).

MCT is conducted at significant level of p=0.05 to test the level of interactions between the difference recreational categories of lightly, medium, heavily and control and the results are presented in Table 28. Results indicate that significant differences occur between lightly and two other used categories; medium and heavily, as well as between control and heavily used. This would indicate that more oxygen will be required to support microbial activities in the oxidation of organic matter and inorganic exudates associated with medium and heavily used sites than in the lightly recreated sites. As oxygen is used up, the amount of dissolved oxygen remaining in the water is much less in the medium and heavily used sites as compared to the control and lightly recreated sites. The same reasoning can be used to explain the significant differences in dissolved oxygen contents between control and heavily used sites. It means that the higher the intensity of recreational use, the greater the amount of oxygen is required to oxidise the pollutants from the medium and heavily used sites. As such, less dissolved oxygen is available in the waters associated with the medium and heavily used sites as compared to the lightly used sites.

However, there is no significance in dissolved oxygen values between control and lightly and medium recreational used sites, as well as between medium and heavily

Table 27. ANOVA Result of Dissolved Oxygen

	treat	rep	Residuals
Sum of Squares	0.2622917	0.0150000	0.3908333
Deg. of Freedom	3	2	42

Residual standard error: 0.09646531
Estimated effects are balanced

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)	Dif
treat	3	0.2622917	0.08743056	9.395522	0.0000715	S
rep	2	0.0150000	0.00750000	0.805970	0.4534418	NS
Residuals	42	0.3908333	0.00930556			

Table 28. MCT Result of Dissolved Oxygen

95 % simultaneous confidence intervals for specified
linear combinations, by the Tukey method

critical point: 2.675
response variable: DO

intervals excluding 0 are flagged by '****'

	Estimate	Std.Error	Lower Bound	Upper Bound	
A-B	0.1080	0.0394	0.00299	0.2140	****
A-C	0.2080	0.0394	0.10300	0.3140	****
A-D	0.0917	0.0394	-0.01370	0.1970	
B-C	0.1000	0.0394	-0.00534	0.2050	
B-D	-0.0167	0.0394	-0.12200	0.0887	
C-D	-0.1170	0.0394	-0.22200	-0.0113	****

(where A, B, C, D representing lightly, medium, heavily and control used respectively)

used sites. This can be explained by the presence of aquatic plants, which add oxygen into the water through photosynthesis, thereby giving the non-significant measurements. In addition, some of the sites where measurements were taken are less exposed to direct sunlight, thereby encouraging better atmospheric oxygen absorption since temperature is inversely proportional to oxygen absorption. Together, these could explain the non-significant differences between them

Nevertheless, the overall results do indicate a mild deterioration of water quality in respect of dissolved oxygen contents in Sg. Batu. The results can also be used to pin-point the source of pollution relative to the different recreational intensities.

Despite the significant differences in dissolved oxygen between the four recreational used, their mean dissolved oxygen contents for the four recreational used categories range between 7.1 mg/lit and 7.3 mg/lit, which is still sufficiently rich in oxygen to support aquatic life.

Turbidity

Suspended solids and turbidity are quite similar in a way that both reflect the amount of undissolved materials in water and therefore affect its physical quality. Due to its strong co-relation with suspended solids, turbidity is often referred to as an index for suspended solids concentration (Hem 1988). Turbidity in this study is measured using a Hach Portable Turbidimeter (Model 2100P) which uses a light beam to pass through a sample solution and light scattered by the suspended sediments are captured by photocells and is expressed as Nephelometric Turbidity Unit (NTU). Mean turbidity measurements for lightly, medium, heavily recreational used and control are 4.93 NTU, 5.01 NTU, 5.00NTU and 4.69 NTU respectively. Application of ANNOVA test at significance level of $p=0.05$ confirms the non-significance between the different recreational used sites (lightly, medium, heavily and control) (Table 29).

As part of Sg. Tua FRA, Sg. Batu is a protected area whereby logging in the surrounding forested compartments is prohibited. The existing vegetation acts as a good buffer against the erosive impacts of rainfall. The surface soil which contains a high

Table 29. ANOVA Result of Turbidity

	treat	rep	Residuals
Sum of Squares	0.0232896	0.0109292	0.2065292
Deg. of Freedom	3	2	42

Residual standard error: 0.0701239
Estimated effects are balanced

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)	Dif
treat	3	0.0232896	0.007763194	1.578732	0.2087415	NS
rep	2	0.0109292	0.005464583	1.111284	0.3386196	NS
Residuals	42	0.2065292	0.004917361			

density of roots and covered by thick litter, is highly absorbent and have the capacity to infiltrate rainwater with a much higher rate than rainfall intensity. As a result, the overland flow into the river in usually not observed, except in heavy storms. As such, the water flowing into the Sg. Batu is of relatively high quality. The gentle flowing Sg Batu can be attributed to the easy gradient of underlying bed-rock as reflected by the relief ratio of 0.27, which reduces turbidity further. This could explain the non-significant differences between the different recreational used sites (lightly, medium, heavily and control). Nevertheless, the mean turbidity measurements for the different recreational used sites, are still within the international.standards for Class 1 water of 5 NTU (Anon, 1986), where the water quality is classified to be suitable for both recreational use and consumption, if treated by conventional methods

Sg. Batu Watershed

Sg. Batu watershed is oblong with the circulatory ratio of 0.67 (Table 30). In addition, the oblong features are complemented by the high elongation ratio of 0.91 (Table 30). The value of the elongation ratio usually varies from 1.275 when the

Table 30. Watershed Characteristics of Sg. Tua FRA

Parameter	Sg. Tua FRA
Area (ha)	208.7
Length (m)	1,800
Width (m)	1,250
Relief (m)	480
Total stream (m)	10,025
Length/mainstream-Sg. Batu (m)	1,150
Slope of mainstream (°)	3.26
Perimeter (m)	6,275
Relief ratio	0.27
Elongation ratio	0.91
Form factor	0.18
Circularity ratio	0.67
Drainage density	0.51

watershed is a circle to 1.128 when it is a square (Zavoianu, 1985). The watershed also has a form factor of 0.18. The basin shape criteria of Sg. Batu watershed further confirmed that the watershed is oblong. Based on Strahler's (1964) stream classification, the watershed is drained by 2 nd order stream. The total stream length of 10,625 km coupled by its drainage density of 0.51 (Table 30) is comparable to the behaviour of other watersheds of Bukit Tarek, and Berembun both in Negeri Sembilan and Jengka watershed in Pahang (Saifuddin, 1994), and Benchah watershed also in Pahang (Anon, 1996). Drainage density is an important parameter, as it provides details on watershed in terms of run-off potential. A high drainage density may not necessary mean an increase in run-off , since drainage density has an inverse relationship with maximum discharge (Carlston, 1963; Patton and Baker, 1976). The steepness of Sg. Batu watershed can be adequately described by the relief ratio and slope of main stream. However, this watershed seems to have a lower relief ratio of 0.27, as compared to Jengka (0.32-0.38), Pahang, but higher than Berembun (0.15-0.18) and Bukit Tarek (0.18-0.19) watersheds both from Negeri Sembilan (Saifuddin, 1994), and Benchah (0.12-0.15) in Pahang (Anon, 1996).

It is against this background, that the water quality parameters identified in this study such as water temperature, pH, dissolved oxygen, conductance and turbidity are discussed.

Discussion

The majority of FRA in Peninsular Malaysia and of particular interest is the Sg. Tua FRA, are water based. As such, the presence of water is often regarded as a fundamental requirement for forest recreation not only as a medium for the activity itself, but also to enhance the recreational setting. Recreation in Sg. Tua FRA generally involve one or more activities such as, swimming and fishing which are often combined picnicking, while campers prefer to have swimming and fishing opportunities available with to them. These recreational activities are normally associated with bodily contact with water and as a result, some pollution will occur. Because of such intensive uses of water, it needs to be of relatively high quality. Douglass (1990) reported that swimming, fishing and picnicking have been encouraged by improvement on water quality, whereas Brown et al. (1992) also elucidated that rivers have wider appeal based on scenic qualities while at the same time providing a desirable setting for camping, hiking, picnicking and other land based activities. There are also others who would prefer combining hiking and nature study, with water body available to them for passive appreciation or to add to the scenic quality of the surroundings. Douglass (1990) also echoed these observations and elucidated that even land based activities are enhanced by nearby water that provides for a secondary activity or as an improvement on the recreational setting. In contrast to the earlier expectation of high water quality, the latter activities can tolerate reasonable water quality. In this respect, water provides for a diversity of recreational experiences, some requiring direct use of water (swimming and fishing) while other users only requiring the presence of water (camping, picnicking, hiking and nature study) to supplement some other activities. Guided by such varying expectations of water quality in forest recreation, it still has to fulfill certain quality limitations to be termed as "safe" water, in order to continue attracting visitors to FRA.

Water temperature needs to be relatively lower than the surroundings in order to provide relief to visitors. A difference between water and ambient temperatures of between 5°C-6°C would be a welcomed relief from the tropical humidity. Water temperatures of Sg. Batu range from 25.7°C-26.1°C, a 5°C-7°C lower than the average range of ambient temperatures of between 30°C-32°C. However, few long term temperature records for humid tropical rivers are available for comparison. The consistency of water temperature conditions in Amazonia has been described by Fittkau (1964, 1970), who gives a mean value of 24.5°C with diurnal and seasonal variations of only about 1°C. Bishop (1973) in his description of water temperature in the nearby Sg. Gombak, Selangor reported that Sg. Gombak behaved similarly, although the variation was slightly greater because of altitude differences. Lai and Amat Ramsa (1993) also reported that water temperatures in Sg. Congkak, Selangor are generally within 1°C-7°C of the forest environment. A number of other related studies have also shown that woodlands stabilise or decrease stream temperatures (Macan, 1958; Gray and Edington, 1969) while deforestation is known to increase both maximum readings and fluctuations in temperature, especially in low volume streams (Macan, 1958; Likens et al., 1967; Bruijnzeel and Critchley, 1994). This increase in water temperature is most likely to be the result of direct exposure of water to sunlight (Macan, 1958; Likens et al., 1967; Lai and Amat Ramsa, 1993). Bishop (1973) also observed that water temperatures in the lowland were stable with some differences caused by rain and prolonged cloudy weather.

The decrease in water temperatures of Sg. Batu, as compared to the surrounding ambient temperatures is due to the shade provided by the forest vegetation which lined both sides of the river. As a result, the water surface area is less exposed to direct sunlight, thereby causing a decline in water temperature.

Another reason is the water turbulence of Sg. Batu, which has the ability to incur energy absorption, thereby contributing to the decline in water temperature. These results are analoguous to those reported by Bishop (1973) for Sg. Gombak, Selangor. Wind velocity disturbing the water surface, is another factor in influencing the evaporation rate. Through wind evaporation, the water surface is cooled down considerably, thereby causing a decline in water temperature. However, Bishop (1973) has reported that temperature loss through wind velocity is not a significant factor in the tropics, since air movements within the forest are negligible and if occur, only at low velocity, which are generally confined to the lowlands except during rainstorms.

Another reason in lowering of river temperature can be attributed to precipitation which is characterised by variability of occurrences and intensities. Precipitation generally absorbs solar radiation energy and thereby, acting as cooling agent upon entering the river water and this result in the lowering of the water temperature. Together, these are the factors influencing a lower water temperature of Sg. Batu. The findings of non-significant differences in water temperatures between the different recreational used sites in this study can be attributed not only to the stability of water temperature in Sg. Batu, but also to that the water temperature is independent of recreational use.

In summary, water temperatures of Sg. Batu are generally stable with small differences caused by rain and prolonged cloudy weather. Mean temperature ranges are narrow for all the four categories of recreational use, as are their replicates. Water surface exposure, effects of shade, water turbulence, heat exchange (evaporation loss) and precipitation are important factors in contributing to the decline of water temperature in Sg. Batu, which is a major river within the Sg. Tua FRA, Selangor.

pH values are relatively uniform throughout the length of Sg. Batu, Sg. Tua FRA, Selangor, as reflected by the measurements taken along the length of Sg. Batu. The range of pH values for the four categories of recreational use (lightly, medium, heavily and control) are between 6.99-7.14 pH unit with mean pH values of between 7.03-7.05 pH unit. An acceptable range for pH values for forest recreation would be from a pH of 6.0 on the acid side of neutral to a pH of 8.5 on the alkaline side (Anon 1962), while water that is any more acid or alkaline than that suggested would cause inconvenience to swimmers (Douglass, 1990). Wall and Wright (1977) also reported that biological life in water is influenced by pH values and its optimal range is between

6.7-8.8 pH unit. Since the pH values for the four categories of recreational use in Sg. Batu, Sg. Tua FRA fall between 6.99-7.14 pH unit, these are well within the optimal pH range to support biological life.

The mean pH values for the four categories of recreational use (lightly, medium, heavily and control) ranged between 7.03-7.05 pH unit, are close to neutral. These are similar to those observed by Bishop (1973), who reported that the greatest range of pHs measured along the Sg. Gombak, Selangor was only 0.8 pH unit with a mean value close to 7.00 pH unit. It can be inferred that the waters of Sg. Batu are not only relatively "safe" for biological life, but also that the near neutrality in pH, makes the water also relatively "safe" for swimming since water being too acid (<pH 6.0) or too alkaline (>pH 8.5) can cause skin irritation to swimmers (Douglass, 1990).

Another reason for the near neutral pH of Sg. Batu can be attributed to its relief ratio of 0.27 and coupled with sufficient volume of groundwater dictated by a drainage ratio of 0.51, have provided the flushing effects for the advection and dispersion of hydrogen ion throughout the waterbody, rendering the near neutral pH readings for Sg. Batu.

Since Sg. Tua FRA comprises of undistrubed forest, surface flow from precipitation into Sg. Batu is minimal due to high infiltration capacity of the forest root mat and the high density litter layer. As a result of absorbance and filtration of surface flow sediments, water flowing into Sg. Batu are of relatively high quality in terms of pHs. These factors are also applicable to Sg. Gombak, as reported by Bishop (1973). As such, most of the surface flow of Sg. Batu comes from groundwater infusion from the overlain Kuala Lumpur Limestone Formation, which is rich in silicates and bicarbonates ion, thereby bringing down the water pH to near neutrality. The alkaline leachate from fallen leaves along Sg. Batu is another contributing factor in neutralising the hydrogen ion to near neutrality.

The non-significant differences in pHs between the four categories of recreational used (lightly, medium, heavily and control) imply that the river water pHs are not duly affected by recreational use.

In summary, the pHs of Sg. Batu is near to neutral and it is both "safe" for maintaining biological life and are within the interim standards for drinking and domestic use. Wind velocity, evaporation rate, groundwater infusion from parent materials and lechate from fallen leaves are important factors in contributing to the overall mild alkalinity of waters of Sg. Batu.

Low turbidity with high conductance is generally associated with clear and relatively pure water respectively. There must also be sufficient amount of dissolved oxygen in the river water not only to oxidise the suspended solids and inorganics, but also to support aquatic life. In Sg. Batu, with the exception of dissolved oxygen content, the other parameters of water quality, such as turbidity and conductance show non-significant differences in their measurements, between the four categories of recreational use (lightly, medium, heavily and control). These values range from 4.79 NTU-5.21 NTU with mean values between 4.93 NTU-5.01 NTU, while for conductance they range between 35.8 μS/cm-36.4 μS/cm with mean values of between 36.1 μS/cm-36.2 μS/cm. The mean turbidity values are well within the interim standards for Class 1 Water of 5NTU (Anon, 1986), while for conductance their mean values for the four categories of use are well below the 1000 μS/cm interim standards for the classification of clean water (Anon, 1986). As such, the turbidity and conductance values of Sg. Batu waters are more than acceptable for recreational use.

A relief ratio of 0.27 provides a gentle gradient which Sg. Batu flows through the Sg. Tua FRA. This relief provides the gradient necessary for the swift flow of Sg. Batu waters, interceded with turbulence, minor turbidity and high conductance.

Another factor in lowering turbidity and increase conductance is the effects of forest cover. The role of forest in water absorbance and filtering of sediments have been well documented by Macan (1958), Bishop (1973) and Bruijnzeel and Critchley (1994). They have reported that forest through evapotranspiration, and increased infiltration through its high density root mat and thick litter layer have drastically reduced run-offs. As a result, the overland flow which is virtually the single agent for the transportation of sediments and other form of pollutants into rivers are generally not observed, except in severe storms. As a result, the overland flow of water into Sg. Batu is relatively clean and hence low turbidity and high conductance. The results are analogous with those of Bishop (1973) in his study of Sg. Gombak in Selangor.

In forest, it is the removal of undergrowth, litter layer and canopy that accelerate the erosion process (Bruijnzeel and Critchley, 1994) which contribute to high concentration of non-point pollutants in stream water. Since Sg. Tua FRA is a protected forest area for recreation, logging is prohibited and as a result, high quality flow of Sg, Batu waters is recorded. As a consequence, the water is low in turbidity and high in conductance.

Another factor affecting turbidity and conductance in Sg. Batu is that sufficient quantity of water is available to keep pollutants diluted, thereby ensuing minimal turbidity and good conductance. In this context, Sg. Batu carries not only sufficient quantity of water, as indicated by the drainage density of 0.51 but also sufficiently fast-flowing due to the relief ratio of 0.27, to keep the pollutants both diluted and dispersed throughout the water-body. As reported by Douglass (1990) streams, creeks and rivers should have a flow-through rate of 500 gallons for each user-day. This turnover rate of water must occur daily in the area in use to prevent pollution (Douglass 1990)

In summary, overland flow of water in Sg. Batu though small in volume, is of relatively high quality due to the absorbance and filtration of sediments by forest cover and litter layer. As a result, the waters of Sg. Batu mainly derived from groundwater intrusion from the overlain Kuala Lumpur Limestone Formation, are of relatively high quality and rich in silicates and bicarbonates ions, hence low in turbidity and high in conductance. In addition, the swift flowing Sg. Batu backed by a relief ratio of 0.27 and drainage ratio of 0.51, have provided a flushing effect for the advection and dispersion of pollutants throughout the water-body. The non-significant differences in turbidity and conductance between the different levels of recreational use (lightly, medium, heavily used and control) indicate that the turbidity and conductance of Sg. Batu water are not affected by degree of recreational use.

Oxygen gas dissolves freely in fresh waters. Oxygen may be added to the water from the air or as a by-product of photosynthesis from aquatic plants in the presence of sunlight. Dissolved oxygen measurements for the four categories of recreational used (lightly, medium, heavily used and control) range from 6.9 mg/l-7.4mg/l with mean range of 7.1mg/l-7.3 mg/l. Despite the narrow range, significant differences in dissolved oxygen content of Sg. Batu waters exist between the different levels of recreational use, especially between lightly and medium, lightly and heavily, as well as between control and heavily recreational used. The results support the observation that increased recreational activities tends to cause some pollution to water quality, which lead to higher depletion of oxygen by respiring organisms, as well as inorganic chemical reactions in Sg. Batu. As more oxygen is depleted with increased recreational intensity, the less the amount of oxygen is available within the waters of Sg. Batu. Hence the occurrences of significant differences in dissolved oxygen content. This observation is similar to those reported by Wetzeel and Likens (2000) that as oxygen is added into the water through atmospheric absorption, oxygen in water is being depleted by respiring organisms and by inorganic chemical reactions. Dissolved oxygen content measurements in Sg. Batu, are in support of this observation.

In addition, the range of dissolved oxygen content measurements for Sg. Batu is between 6.9mg/l-7.1mg/l for the four categories of recreational use (lightly, medium, heavily and control) and these values are much higher than the minimal of 5mg/l of dissolved oxygen required for freshwater fish (Anon, 1962). Since fish retreat downwards to cooler waters during the day, the fish must have adequate supply of oxygen at deeper levels (Anon, 1962). Oil from outboard motor can decrease oxygen supply since 3.3 grams of oxygen are consumed in the oxidtion of 1.0 gram of oil (Barton 1969). Nevertheless, oxygen content of the first few centimetres of a lake may be depleted and this has been shown to decrease phytoplankton production (Wall and Wright, 1977).

Aquatic plants will only grow as long as sunlight can penetrate through the waters. This is evident in Sg. Batu, especially in the more exposed medium and heavily recreational used sites where there are ample growth of aquatic plants especially within the upper one to one and half metres of water, as compared to the control and lightly used sites which are more shaded. Aquatic plants through photosynthetic process add oxygen to water, which could explain the non-significant differences in dissolved oxygen content between control and lightly used, medium and heavily used, as well as between medium used and control sites. This observation is similar to those reported by Bishop (1973). He observed that the removal of tree cover along Sg. Gombak, Selangor caused growth of some seasonally rich periphyton (algae), as indicated by a good coating of diatoms especially in riffles of Sg. Gombak, which restored some of the oxygen loss as a result of oxidation of organic sediments.

In Sg. Batu aquatic growth, especially near to the medium and heavily used site are observed within one to one and half metres of the water surface. Light penetrating the water surface could have caused the aquatic plants to proliferate through photosynthesis. This observation is similar to those findings of Douglass (1990). He reported that the penetration or topogenic zone for light to stimulate growth of aquatic plants varies between five and ninety feet in depth according to the amount of suspended materials and stains present in the waters. He further added that generally most aquatic plants lived within the upper ten feet of waters and they do not add oxygen directly to the lower strata of water.

Wall and Wright (1977) in their studies of recreational lakes in Ontario, Canada, added that oxygen solubility varies inversely with temperature, while Bishop (1973) reported that in Sg. Gombak a decrease in dissolved oxygen content is related to an increase in water temperature. Wetzeel (1983) and Hutchinson and Scott (1988) further added that the amount of dissolved oxygen in water is dependent upon water temperature, pressure and concentration of various ions. Guided by the results from the study, water temperatures of Sg. Batu are not only stable, but also are non-significant between the four categories of recreational used. Similarly, the concentrations of various ions are stable, as reflected by the pHs and conductance measurements. Hence, any increase in dissolved oxygen content in waters of Sg. Batu, can be attributed to the different intensity of use (lightly, medium, heavily and control) since water temperatures and concentration of various ions are stable.

In summary, despite the narrow range of dissolved oxygen content within Sg. Batu, there are significant differences between the four categories of recreational use (lightly, medium, heavily and control). On one hand, the increase in recreational intensity has led to a decrease in dissolved oxygen content, as a result of oxidation of organic sediments, as well as to support inorganic chemical reactions. On the other hand, exposed areas along Sg. Batu has led to the growth of aquatic plants and periphyton (algae) in riffles which are capable of restoring some of the oxygen loss during oxidation and chemical reaction stages.