TROPICAL AGRICULTURAL SCIENCE

Variations of Electrical Conductivity between Upstream and Downstream of Langat River, Malaysia: Its Significance as a Single Indicator of Water Quality Deterioration

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ABSTRACT

This paper investigated the potential of using a single chemical parameter namely electrical conductivity (EC) as an indicator of water quality pollution in relation to dissolved oxygen (DO) and suspended solids (SS) which are two of the parameters included in the calculation of Water Quality Index (WQI) in Malaysia based on current scenario. In this study, nine periodic samplings at eight sampling sites along a tropical river which included the polluted downstream and the unpolluted upstream of the Langat River, were conducted between March 1998 and January 1999. The consistent results for the nine month samples (negative and significant correlation between EC vs. DO, and positive and significant correlation between EC vs. SS), indicated that EC could be potentially used as a single chemical parameter to indicate the water quality of tropical rivers such as the Langat River of Malaysia. It is also recommended that EC should be included in the revised WQI in Malaysia in future, in order to better reflect the mineral-related pollution/composition and of the water samples.

Keywords: Electrical conductivity, Langat River, Malaysia

INTRODUCTION

Currently, the Malaysian Water Quality Index (WQI) is based on six water parameters (dissolved oxygen (DO), pH, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solids (SS) and ammoniacal nitrogen (AN) (DOE, 2007; WEPA, 2012). This WQI with the chosen six parameters is an opinion-poll formula and this formulation was based on consultations by a panel of experts on the choice of parameters and on the weight to each parameter (DOE, 1985). Although WQI enables large amount of water quality data to be reduced to a single index value

with its index score (Gupta *et al.*, 2003), there are limitations in the use of WQI and this has been clearly reviewed by Zainudin (2010). According to Zainuddin (2010), indexes by design contain less information than the raw data that they summarize. The major weakness of WQI is that it is not a comprehensive index to quantify all the water quality constituents.

A particular sampling site may be calculated as being a 'good' WQI score but the water quality could be contaminated / deteriorated by other water parameters/ contaminants which are not included in the calculation of the WQI which are only based on six water parameters. For instance, heavy metals such as Cd and Pb , which may be carcinogenic top living organisms (Kromhout *et al.*, 1985), are not included in the calculation of present Malaysian WQI. Subsequently, a good WQI score at a particular sampling site does not necessarily mean that water quality was always in an acceptable level. Hence, further check on the water quality parameters listed in the Interim National Water Quality Standards for Malaysia (INWQS) (WEPA, 2012) should be conducted.

The distribution and abundance of benthic macroinvertebrate of tropical rivers could be potentially influenced by a lot of biotic and abiotic factors. However, owing to limited time and facilities, some researchers limit the measurement of physico-chemicals to only some easy and measurable parameters that are highly dependent on the availability of the sampling devices. If we had only measured a few water quality parameters, can they still be used to indicate the quality of the river water?

The inclusion of electrical conductivity (EC) as one of the parameters in the calculation of WQI is always not found in the literature except for a few cases. Banoeng-Yakubo *et al*. (2009) included nine water parameters in the determination of WQI including EC and assigned three parameters (EC, NO_3^-, and F^- as assigned the highest weight (value 5) because of their importance in the water quality assessment. According to Dojlido and Best (1993) and Welch *et al.* (1998), EC can be used as a measure of sulfate, bicarbonate, and chlorides of calcium, magnesium, and sodium therefore basically EC can be used as a measurement of the ability of an aqueous solution to carry an electrical current (Das *et al.,* 2006). Only Das *et al*. (2006) proposed the use of electrical conductivity as an indicator of pollution in shallow lakes but not in tropical rivers yet.

Earlier, Azlina *et al.* (2006) documented the anthropogenic impacts on the biodiversity of macrobenthic invertebrates and water quality between the upstream and downstream of the Langat River while Yap *et al.* (2005) reported on the nitrate levels in the Straits of Malacca. However, detailed study on a single parameter such as EC, as an indicator of water quality pollution, has not been discussed widely in the literature. This could be due to the fact that the more chemical parameters are included, the better and more conclusively could the data be interpreted. However, from the present

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study, if all the other physico-chemicals are normalized, the use of the single EC could be a potential parameter for water pollution studies.

This is an interesting point if more sampling sites and regular samplings are included to study the above question. Therefore, the objective of this study is to find out the relationships between EC vs. dissolved oxygen (DO) and EC vs. suspended solids (SS) and to discuss the potential use of EC as a single indicator of water quality deterioration.

MATERIALS AND METHODS

Description of the study area

Samplings were conducted over nine months (March, April, May, June, July, August, October and November of 1998 and January 1999) at the Langat River Basin which is located in Selangor, Peninsular Malaysia (Fig.1). The water flows from the upstream area in Hulu Langat until Kuala Selangor at the downstream area where the Langat River becomes the main river in the basin which flows in a southwesterly direction and drains into the Straits of Malacca. The Langat
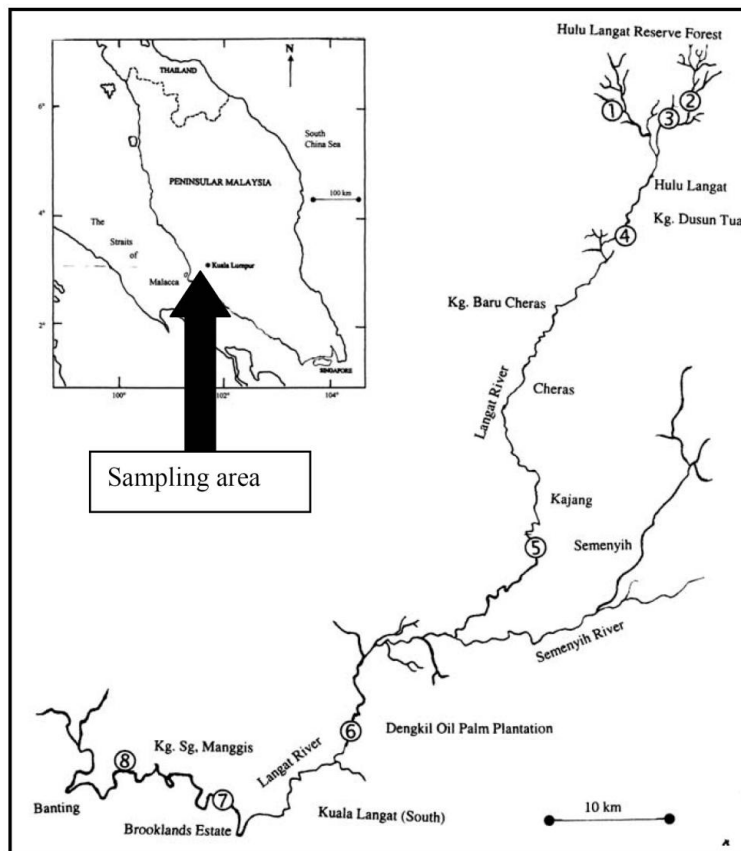

Fig.1: Sampling area along the Langat River, Peninsular Malaysia.

River Basin is located between 101°25' and 101°54' of the Greenwich meridian.

The upstream stations covered Stations 1-4 while the downstream covered Stations 5-8. Azlina *et al.* (2006) reported that that the upstream and downstream of the Langat River were clean and polluted parts of the river, respectively. The first station was located in the Chongkak River . This river is used for camping and picnicking especially during the weekends. The second station was located near the Orang Asli village in Hulu Langat. The third and fourth stations were located at the Lopo River and Kampung Batu 17 in Hulu Langat, respectively . The water was clean and clear and it was used by some villagers for washing and bathing. The common characteristics of stations 1-4 were the presence of cobbles and pebbles and sometimes sand and gravel. There was generally high vegetation coverage at the four upstream sampling stations.

The fifth station was located at Section 4 of the township of Bandar Baru Bangi. The sixth station was located at the Dengkil Oil Palm Plantation and the water could be heavily polluted since colour of the river water was brownish. The seventh station was located at the Brooklands Oil Palm Estate close to a paper factory. The sediment was of a muddy type. The eighth station was located at Telok Dato' near Banting. The river water was milky, smelly and it was likely to contain a lot of suspended matter that could be due to sewage pollution. The substrata of the downstream sampling sites comprised of muddy sediment.

Water Quality Measurement

Three replicates of the EC were obtained by using a YSI meter Model 33 and DO by a YSI oxygen meter Model 57. Suspended solids (SS) was calculated based on the standard method procedures (APHA, 1989).

Data Analysis

All the data were transformed by $\log_{10}(x+1)$. The data transformation was performed to stabilize the variance so that the data frequency distribution was close to the normal distribution (Zar, 1996). T-test and Spearman's correlation analysis (CA) was carried out based on the transformed data by using STATISTICA 99" Edition (version 5.5).

RESULTS AND DISCUSSION

From this study, there are two major points to support the use of EC as a single chemical indicator of water quality. Firstly, from Table 1, the polluted downstream of the Langat River (Azlina *et al*., 2006) had significantly (P< 0.05) higher EC values (154-301 µS/cm) and SS (200-1145 mg/L) and significantly (P< 0.05) lower DO concentrations (0.97-4.15 mg/L), than those in the clean upstream stations (EC: 29.0-46.0 µS/cm; SS: 4.50-25.0 mg/L and DO: 7.69-10.03 mg/L). Anthropogenic inputs at the downstream of Langat River could be attributed from sources including 1) *wastewater* from sewage treatment plants (**point source** pollutants), 2) *wastewater* from septic systems and drainfield on-site wastewater treatment and disposal systems (**point source** pollutants), 3) *urban runoff*

TABLE 1
The T-test results from comparisons of mean [Suspended solids and dissolved oxygen in mg/L, electrical conductivity in µS/cm] between upstream (stations 1-4) and downstream (stations 5-8) of the Langat River. N= 4.

Parameter	Periods	Upstream (st 1-4)	Downstream (st 5-8)	Significance level
Electrical conductivity	March 1998	36.4	178.8	P< 0.05
	April 1998	43.3	154.9	P < 0.001
	May 1998	41.0	186.5	P < 0.01
	June 1998	39.2	243.3	P < 0.01
	July 1998	42.4	247.8	P< 0.05
	August 1998	46.9	168.0	P> 0.05
	October 1998	37.0	301.3	P< 0.001
	November 1998	29.0	126.8	P> 0.05
	January1999	29.8	210.4	P< 0.05
Suspended solids	March 1998	4.50	231	P < 0.05
	April 1998	8.67	534	P < 0.05
	May 1998	24.9	270	P < 0.05
	June 1998	25.0	209	P < 0.05
	July 1998	8.92	200	P< 0.01
	August 1998	19.3	632	P< 0.001
	October 1998	5.67	132	P< 0.05
	November 1998	13.5	1145	P< 0.05
	January1999	18.0	132	P< 0.05
Dissolved oxygen	March 1998	7.98	3.89	P < 0.05
	April 1998	10.00	3.13	P < 0.0001
	May 1998	7.69	3.02	P < 0.01
	June 1998	10.03	3.42	P < 0.00
	July 1998	9.64	2.12	P< 0.001
	August 1998	8.19	4.15	P< 0.001
	October 1998	8.33	0.97	P< 0.001
	November 1998	8.40	2.54	P< 0.001
	January1999	7.85	3.97	P< 0.001

from roads and 4) *agricultural runoff* of water draining agricultural fields typically has extremely high levels of dissolved salts (Dojlido and Best, 1993). According to INWQS for Malaysia (DOE, 2006; WEPA, 2012), EC is classified as I (Water supply I - Practically no treatment necessary) and IIA (Water supply II – Conventional treatment required) for a value of 1000 µS/cm while 6000 µS/cm for Class IV (Irrigation). Therefore, the present ranges of EC values (29.0-301 µS/cm) are all classified as Class I.

When compared to other reported studies on EC, the present EC values (29.0-301 µS/cm) are lower than those reported by

Banoeng-Yakubo *et al.* (2009) for surface river waters in the Volta region (Ghana), EC as 787-806 µS/cm. However, their values are below the WHO standard for EC (1500 µS/cm) (Banoeng-Yakubo *et al.*, 2009), which is considered to be unsuitable for agricultural use (Dojlido and Best, 1993). Zhang *et al.* (2012) reported that EC ranged from 43.9 to 2830 µS/cm and 96.8 to 2680 µS/cm for surface water and groundwater, respectively, in Songnen plain, Northeast China. Positively, they concluded that EC is also a good index to ion concentrations and for the assessment of water quality. The present EC values are also lower than that (875 µS/cm) the groundwaters in the Kathmandu Valley (Nepal) (Pant, 2011).

Secondly, from Table 2, EC values correlated negatively and significantly with DO (R= -0.739 to R= -0.895, P< 0.001) and correlated positively and significantly with SS (R= 0.594 to R= 0.775, P< 0.001). These correlation coefficients indicated that EC is a potential water quality indicator. From Fig.2, the comparison between EC and DO showed a negative pattern with each other. A higher EC would be followed by a decrease in the DO of the river water. The negative relationships between EC and DO were consistent in all the nine sampling periods. Therefore, this supports the use of EC as a single indicator of water quality of the river water.

The use of EC as a single indicator of water quality of the river water is also well supported by some literature. For instance, EC is one of the important water parameters in the determination of surface water quality such as in Jakara River (Nigeria) (Mustapha *et al.*, 2012). Mustapha *et al.* (2012) also found that positive correlations between EC and SS. Moreover, Ouyang *et al.* (2006) reported that the lower St. Johns River, located in northeast Florida (USA), with contaminants such as nutrients, hydrocarbons, pesticides, and heavy metals, had significant correlations between EC vs. DO as R= -0.91 in spring, R= -0.80 in summer, R= -0.40 in fall and R= -0.90 in winter. They concluded that EC was always one of the most important parameters in contributing to water quality variations for all four seasons. This clearly showed that mineral and nutrient related EC was negatively affected by the physical parameter DO and thus in support of the present findings on the tropical Langat River. The presence of dissolved ionic substances could potentially increase the EC value in water (Pant, 2011). The increased ionic concentrations are practically caused by increments of different ionic substances including organic matters containing ionic charges, metallic ions, nitrate, and ammonium ions (Dzwairo *et al.*, 2006).

Eh Rak *et al.* (2010) reported that water discharge at Mengkibol River showed negative relationships with EC and DO. They suggested that a high water discharge will not influence the EC and DO values of the river water. However, they found a positive relationship between river discharges and turbidity, where turbidity levels of the water were influenced by river discharges of the rivers. Therefore, if EC is to be used as a single indicator of water
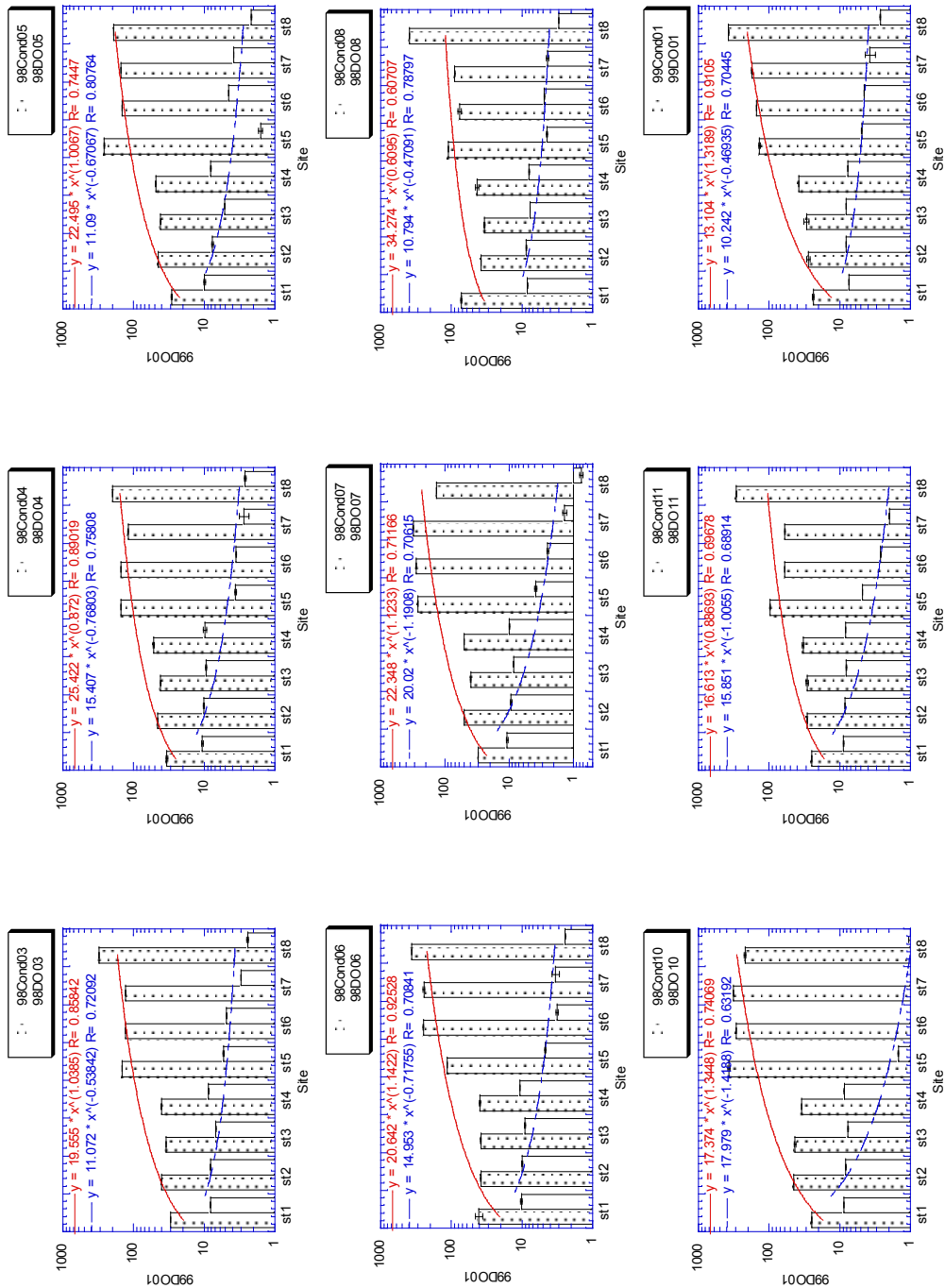
Fig.2: Variation of electrical conductivity (µS/cm) and dissolved oxygen (mg/L) from the upstream to the downstream of the Langat River

TABLE 2
Spearman's correlation coefficients based on log10 (mean +1) of suspended solids (SS), dissolved oxygen (DO) and electrical conductivity (EC) in the water samples collected from March 1998 to January 1999, at the Langat River.

March 1998	N= 24	DO	SS
	EC	-0.739***	0.632***
	DO	1.000	-0.809***
April 1998	N= 23	DO	SS
	EC	-0.810***	0.715***
	DO	1.000	-0.752***
May 1998	N= 22	DO	SS
	EC	-0.895***	0.775***
	DO	1.000	-0.655***
June 1998	N= 24	DO	SS
	EC	-0.817***	0.673***
	NDO	1.000	-0.604***
July 1998	N= 24	DO	SS
	EC	-0.773***	0.772***
	DO	1.000	-0.911***
August 1998	N= 24	DO	SS
	EC	-0.791***	0.594***
	DO	1.000	-0.762***
October 1998	N= 24	DO	SS
	EC	-0.829***	0.728***
	DO	1.000	-0.831***
November 1998	N= 24	DO	SS
	EC	-0.878***	0.730***
	DO	1.000	-0.860***
January 1999	N= 24	DO	SS
	EC	-0.845***	0.693***
	DO	1.000	-0.635***

Note: Level of significance: ***$P< 0.001$.

quality, the discharge is not contaminated by mineral and nutrient related pollutants.

The use of EC as an indicator of water quality deterioration in general was also reported in the literature. Das *et al.* (2006) reported that water quality is closely linked to many physical and chemical aspects of a lake. They found that EC was a thermophysical property of lake water which has a strong interrelationship with pollution levels. Therefore, measured values of EC indirectly indicate the level of pollution in lake waters. Moreover, measurement of EC is much easier than direct measurement of total dissolved solids (TDS), thus easing for pollution monitoring of river waters.

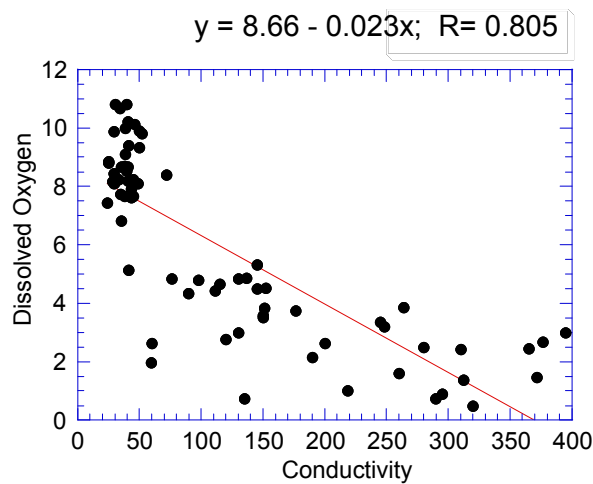Owing to SS can be attributed to industrial wastes, wastewater discharges,

Fig.3: Overall relationship between electrical conductivity (µS/cm) and dissolved oxygen (mg/L) from the upstream to the downstream of the Langat River.

erosion from urban runoff and agricultural land (Liebl, 2009), the positive relationship between EC and SS found from this study could be related to all the above anthropogenic wastes and activities. Since SS is one of the major pollutants in Malaysia with the sources for SS were mostly earthworks and land clearing activities (WEPA, 2012), there is a reason to use EC as a single and effective indicator of mineral-related parameter in Malaysian rivers, because EC is significantly and positively correlated with SS.

CONCLUSION

Since it is much easier and faster to measure EC than to measure all the anions and cations, highly positively correlated with SS and negatively correlated with DO, the use of EC as a single indicator of water pollution in tropical rivers is proposed. The present finding has provided evidence

that EC should be included in the revised Water Quality Index in Malaysia in future, in order to better reflect the mineral-related pollution/composition and of the water samples.

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