DEVELOPMENT OF POSSIBLE INDICATORS FOR SEWAGE POLLUTION FOR THE ASSESSMENT OF LANGAT RIVER ECOSYSTEM HEALTH

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Abstract. The pollution of the Langat River at Kajang was examined in terms of domestic sewage discharge. The effects of domestic sewage were studied. The water quality data obtained from effluents discharged at two selected sites along the Sungai Langat was used to develop indicators for sewage pollution. A model based on the Pressure-State-Response (PSR) concept was suggested for the development of possible indicators for the Langat River for the management of sewage discharge.

Abstrak. Pencemaran Sungai Langat di daerah Kajang diteliti dari segi perlepasan kumbahan domestik. Kesan kumbahan domestik ke atas sistem sungai dikaji. Data kualiti air daripada dua tapak perlepasan kumbahan domestik di sepanjang Sg. Langat digunakan untuk mengembangkan penunjuk bagi pencemaran kumbahan. Satu model yang berasaskan konsep tekanan-keadaan-rangsangan (PSR) dicadangkan untuk tujuan pembentukan penunjuk yang sesuai untuk pengurusan perlepasan kumbahan domestik di Sg. Langat.

Keywords: water quality, water analysis, ecosystem health framework, river basin management.

INTRODUCTION

The sources of the Langat River pollution are identified as industrial discharge (58%), domestic sewage from treatment plants (28%), construction projects (12%) and pig farming (2%) [1]. Attempt has been made by the Jabatan Alam Sekitar Selangor to resolve the problem of water pollution. The 'Sub-Group Activity' concept was implimented where water quality monitoring of various polluting sources was carried out in addition to law enforcement and river pollution education and awareness activities. The aim was to improve the WQI of the Langat River to class II level [1].

Pollution of the Langat River is strongly correlated with the population increase[2] and water deficit problem in the Basin is further aggravated by river pollution. In the year 2000, the Langat River was classified as average polluted overall (water quality index, WQI = 36-89). Except for the upstream at the Hulu Langat area before Sg. Lui where the river pollution is still relatively low and WQI is in class I, the downstream section of the Langat after the tributaries Sg. Balak and Sg Batang Benar is polluted with WQI reaching class III to IV [1].

The rapid infrastructure development in the Langat Basin in general has caused increase in population. The current population of the Langat Basin is close to 1 million but by 2020 it is expected to exceed that of the adjacent Klang Basin, which has a population of two millions currently. The rapid development of the area and increase in population has put pressure on the river ecosystem. Particularly obvious is water deficit and river pollution. Because the Langat and Semenyih Rivers are the main sources of potable water for both the Langat and Klang Basins, increase in population in the Basin is predicted to cause water deficit by 2010[2].

Clearly, the rapid development and population increase in the Langat Basin has resulted in tremendous stress on the ecosystem health of the Langat River. Protecting the ecosystem health of the river will require an integrated approach. Such an approach should take into consideration of various aspects of water pollution, no only water quality but also socio-economic factors. This is best examined through the use of indicators through the concept of river ecosystem health.

Several criteria have been suggested for the assessment of ecosystem health. These include ecosystem stress, ecosystem dysfunction, organization, resilience, maintenance of ecosystem services and damage to neighboring systems[3,4]. With reference to a river ecosystem, ecosystem stress refers to the contamination of a river by substances, e.g. various chemicals that can cause stress to aquatic life. The frequent occurrence of pollution will lead to the inability of the river to provide services such as good quality water for the purpose of potable water supply and hence the river is said to suffer from ecosystem dysfunction. As a result of pollution stress, the interdependence nature of the biotic and abiotic components of a river ecosystem is disrupted and this results in poor organization of the river ecosystem.

The continuous degradation of water quality of the Langat River is a concern for the public and policy makers, and is also a sign of a stressed ecosystem. It is generally recognized that river pollution is brought about by the discharge of all kinds of effluents, particularly effluent from domestic sewage, industry and from construction sites located along the Langat River. Although, the possible impact of effluent discharge on the water quality of the Langat River is somehow ‘established’ through the use of water quality index and classification of river formulated by DOE, this is by no means has addressed the real issue of pollution by effluent. Attempt to identify the source of the pollution is difficult not to mention quantifying the amount of effluent discharged into this river. Detailed mapping of effluent sources and quantification of discharge is likely to be costly, time consuming and such information may quickly become irrelevant to pollution control as the source may disappear as soon as they are ascertained.

To address such a problem, other concepts of river pollution control and management should be examined and such concepts should be consistent with ecosystem health. Karr[4] has suggested that ecosystem health can be assessed by using multimetric index and index of biological integrity. One approach is to employ an indicator or index suitable for each effluent. The indicators used may follow the Pressure-State-Response model of the OECD approach[5].

The indicator/indicators for effluent contamination are not necessary physicochemical based (e.g. water quality) but they also can encompass other quantities such as biological and even social economical values. It is important that these non-water quality based indicators should be examined with reference to water quality as they may yield sub-indices that can be substitutes for the many water quality indicators, and thus simplify further the process of obtaining the overall index for effluent pollution. In this work, a concept for the management of effluent pollution in the Langat River utilizing indicators as tools is suggested. The concept is discussed with the application of some water quality data collected from the study of sewage contamination.

Experimental

Study areas

Effluent that contributed to pollution of the Langat River included in this study is sewage discharge. The study areas for each effluent source and water quality parameters examined are shown in Table 1.

Table 1. The source of effluent and water quality examined.

Location of sewage source	Water quality variables studied
Oxidation ponds along Bukit Mewah, Kajang via Sg Jeluh. Oxidation ponds near UKM at Bangi, direct discharge to Langat River.	Temperature, dissolved oxygen, pH, conductivity, turbidity, BOD, COD, phosphate, nitrate, ammonical-nitrogen, chlorophyll, *E. coli* and total coliform.

Kajang and Bangi areas are selected for domestic sewage pollution studied because of the likely impact of sewage discharge from sewage treatment plants with oxidation pond system. In the Kajang site, a tributary of the Langat, i.e. the Jeluh River was also examined. The Jeluh River collects all effluent from sewage treatment plants in the Kajang Town before it is discharged into the Langat River. Five water sampling stations were fixed along the Jeluh River (JL1 – JL5) and two were at Langat River (LG1 and LG2), i.e. before and after the confluence with Jeluh River. In addition to that, the effluent from a major oxidation pond in the study area (OXK) was also sampled for water quality analysis. The study area is shown in Figure 1.

The Bangi sampling site is approximately 8 km downstream to the site and Kajang. Four water sampling stations were selected. Two samples were taken from source of discharge, i.e. two oxidation ponds (OXB1 and OXB 2) which discharged effluent directly to the Langat River. One water sampling station was chosen at 500 m upstream to the input of the sewage effluent (LG3) and another station (LG4) at 1 km downstream from source of discharge. The sampling site is depicted in Figure 2.

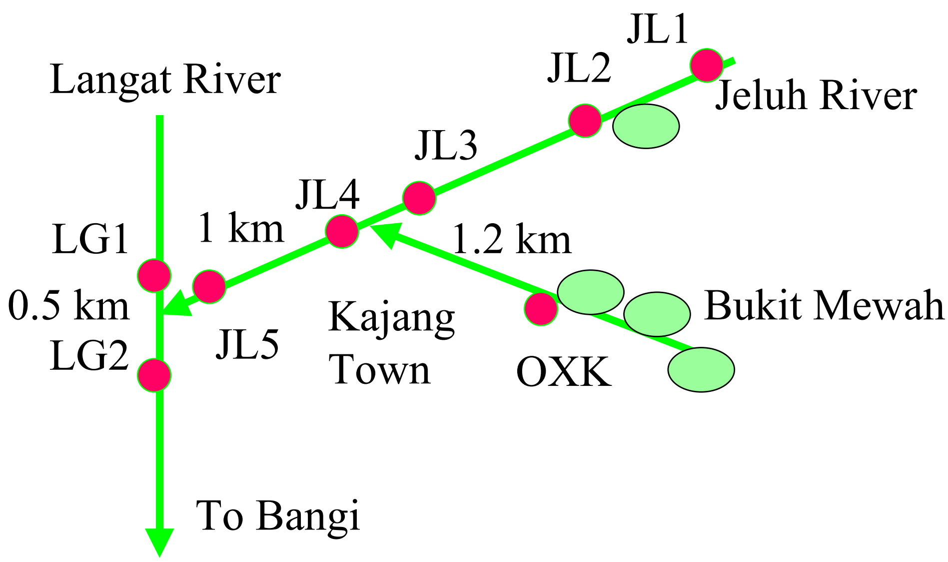


Figure 1. The location for the study of sewage impact on the Langat River at Kajang

Water sampling

Water samplings were performed in 2002-03 and 10 samplings were carried at most of the stations. Physicochemical water quality parameters such as dissolved oxygen (DO), pH, conductivity (Cond), temperature (T) and turbidity (Turb) was measured on site with portable meters. Samples for the analysis of chemical oxygen demand, nitrates, orthophosphates and ammoniacal nitrogen were filtered through a 0.45 µm membrane before preserved in appropriate acids down to pH 2 and stored at 4^oC until analyses were carried out. For biochemical oxygen demand (BOD), coliform bacteria and chlorophyll content of the water, the samples were chilled and the analysis was carried out immediately (< 3 h) without any sample preservation and treatment.

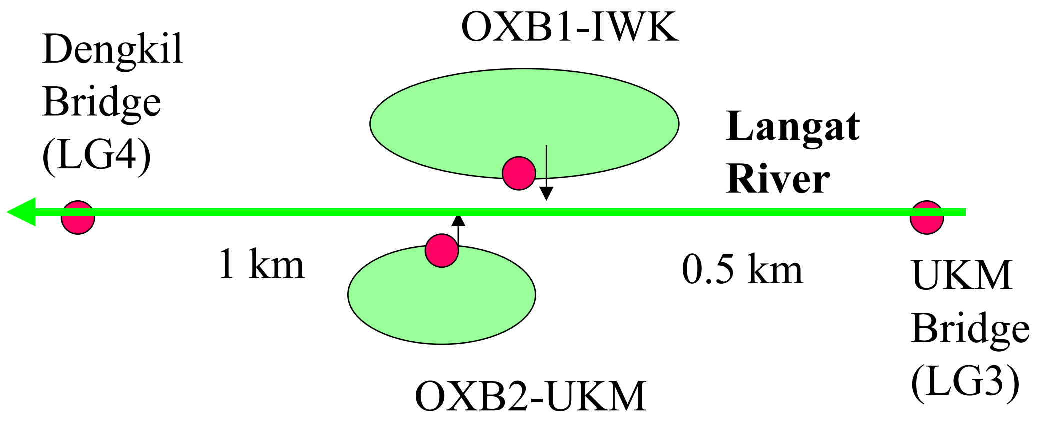


Figure 2. The location for the study of sewage impact on the Langat River at Bangi.

Water analysis

All water analysis methods followed standard procedures[6]. The COD content of the water samples was determined by open reflux with potassium dichromate followed by titration with iron(II) ammonium sulphate. Dissolve phosphate was analysed by the ascorbic acid method using a spectrophotometer at 880 nm. The cadmium reduction procedure was employed for the determination of nitrate (using the NitraVer 5 Pillow Power (Hach)). The colour complex formed from the reduction of nitrate was measured at 543 nm using a spectrophotometer. Ammonia in samples was first distilled and then followed by reaction with Nessler's reagent where the absorbance of the colour formed was measured with a spectrophotometer.

BOD was determined after incubation for 3 days at room temperature (~ 30^oC) by measuring the difference of DO in the sample before and after incubation with an oxygen probe. Coliform bacteria (E. coli and T. coli) were determined using the membrane filtration method and incubation in lauryl sulphate broth. Chlorophyll was determined after cells was collected in cellulose membrane filter of 0.45 μm and then extracted with acetone where the extract was measured using a spectrophotometer.

Results and Discussion

A framework for ecosystem health of the Langat River

The framework of the exercise is to view the river as a life-support-system where the Langat River is a provider of water as an important commodity for life. The indicator concept should allow pollution and ecosystem risks and effects management, so that the carrying capacity of the river as a water resource is not reduced.

Peterson[5] has mentioned the PSR (Pressure-State-Response) model from OECD as a basic concept of developing a management tool for several life support systems, including water quality. The model attempts to define the pressure (or stress) on the system and the current condition (state) of the system. As a result of the stress, the possible impacts are established and relevant responses to the stress and impact are evaluated. Each of the pressure, state, impact and response sector can be represented by one or more indicators.

Based on the PSR model, various indicators can be assigned with weights and values before an index related to water pollution can be derived. This will require input of water quality and also socio-economic data. The derivation of an index based on indicators will need some understanding of the relationships between various water quality indicators and non-water quality data especially socio-economic data source.

The final aggregated index will be useful as a decision management tool for assessing ecosystem health of a river based on multimetric indicators.

Establishing indicators for effluent pollution of the Langat River.

Based on the PSR model, the following are identified as indicators (Table 3) for the contamination of the Langat River by effluent discharge resulted from the activities studied.

Table 3 . The various indicators and their measures proposed for the PSR model

	Indicators	**Measures of indicators**
Pressure	Water pollution	Water quality index
State	Water quality	Water quality parameters
	Water resource	Number of polluted/unpolluted river
Response	Environmental policies	Number of policy formulated
	Environmental laws	Number of related laws gazetted.
	Policy implementation	Number of policy implemented
	Land management	Area of land cleared

The pressure indicator will focus mainly on water pollution although other indicators are also discussed. For the state indicator, the water quality will be considered here. All the selected indicators are used to construct an overall index (E) that could summarize the effects of all forms of effluent pollution to the Langat river. By using an aggregation model, index E is influenced by sub-indices for sewage (S), other effluents sources such as Q, G, etc. Thus E may be written as:

$$E = aS + bQ + cG + \ldots \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where a, b and c are weights given to the influence of each effluent on the index E. The effluent impact index, E, will provide information on the impact of activities that produce and release effluent to the Langat River. This index is a decision making tool for the development and location of effluent discharge industries, including residential and commercial centres in the Langat River Basin.

But the determination of the sub-indices S, Q and G in equation (1) is a complex matter and they should be based on the water quality indicators or other non-water quality indicators listed in Table 1 if they can be correlated with water quality changes.

Using sewage effluent as an example, for the development of the sub-index, S, which assess the impact of sewage on a river, several water quality parameters determining the characteristics of the sewage are required. Each of this parameter can be used as an indicator. For example, value of S may depend on ammonical-nitrogen (NH3), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved phosphate (PO4), *E. coli* (ECOL), chlorophyll content and surfactant (SUR), i.e.

$$S = NH3 + BOD + PO4 + COD + ECOL + CHOL + SUR \qquad \ldots\ldots\ldots\ldots\ldots (2)$$

However, each indicator is expected to be dependent on other factors such as distance from the river (D) and the number of sewage treatment plants (T) in a certain stretch of the river. Therefore,

$$S = NH3 + BOD + PO4 + COD + ECOL + CHOL + SUR + D + T \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

At this stage, other social-economic factors may also be introduced to equation (3). Thus, the population of an area (i.e. degree of urbanization) and the amount of expenditure on sewage treatment can be considered.

It is no doubt that with many indicators included in the calculation, equation (3) will increase in complexity and this may make the whole exercise of employing sub-index and indicators as tools of effluent management unworthy! However, some indicators such as those based on social economy or the number of treatment plants may be used alone without directly involving water quality parameters to establish S. But the relationships of these indicators with the water quality state indicators must be verified before replacing the water quality indicators. Even among the many water quality parameters that characterized a typical sewage effluent, one or two representative parameters may be sufficient as indicators. The same kind of argument may be applied to determine the sub-indices Q and G shown in equation (1).

Data synthesis

The indicator approach will be proposed here for the purpose of management of effluent discharge to the Langat River and assess the ecosystem heath of the basin. Physicochemical indicators (water quality parameters of effluents) will be used solely for deriving the overall sub-index, E, for effluent impact.

Only data on water quality were obtained from this study although other non-water quality data are also useful. There was no secondary data available and therefore, primary data were measured on site. The water quality data for the Sg. Jeluh, Sg. Langat and oxidation pond discharge are shown in Tables 4 to 6.

Table 4: The physical variables of water quality from the Sg. Jeluh (stations JL), Langat (stations LG) and oxidation pond effluent (stations OX)

	T (^{o}C)	**DO (mg/L)**	**pH**	**Cond (μS/cm)**	**Turb (NTU)**
JL1	27.7±1.0	3.28±1.2	6.97±0.8	0.07±0.01	38.0±19.7
JL2	27.7±1.0	3.16±1.3	6.93±1.1	0.11±0.02	56.0±20.2
JL3	28.5±1.1	2.95±1.2	7.71±0.3	0.12±0.02	31.0±11.4
JL4	29.1±1.2	2.86±1.1	7.60±0.9	0.15±0.03	35.7±10.1
JL5	27.6±0.5	3.36±1.2	7.76±0.3	0.15±0.03	32.3±11.7
OXK	29.2±1.2	2.18±0.6	7.94±1.0	0.26±0.03	26.0±11.8
LG1	27.1±0.6	3.54±1.1	7.49±0.1	0.07±0.03	358.7
LG2	27.0±0.5	3.64±1.9	6.17±2.1	0.11±0.05	357.3
OXB1	29.9±0.8	1.78±1.73	7.30±0.18	320.9±33.0	206.6±22.6
OXB2	28.9±1.5	3.98±1.03	7.41±0.09	251.8±39.4	204.4±74.0
LG3	28.4±0.7	4.20±0.67	6.75±0.13	145.5±20.0	89.5±6.18
LG4	28.3±0.4	3.92±0.51	6.83±0.30	128.6±5.50	104.5±26.2

Table 5: The organic and nutrient contents of the Sg. Jeluh (stations JL), Langat (stations LG) and oxidation pond effluent (stations OX).

	BOD (mg/L)	**COD (mg/L)**	**PO4 (mg/L)**	**NO3 (mg/L)**	**NH3-N (mg/L)**
JL1	1.75±0.93	NA	NA	2.75±1.45	NA
JL2	1.86±0.97	NA	NA	3.26±3.25	NA
JL3	1.78±0.73	48.2±14.5	0.28±0.02	4.31±6.12	0.31±0.20
JL4	1.69±0.96	76.5±20.5	0.36±0.02	4.27±5.57	0.36±0.18
JL5	1.79±0.95	76.5±13.9	0.34±0.03	4.04±5.60	0.46±0.41
OXK	1.31±0.52	72.7±10.8	1.80±0.29	2.99±0.53	0.65±0.49
LG1	2.24±0.47	75.3±11.1	0.10±0.01	2.66±0.97	0.11±0.05
LG2	2.57±1.28	53.8±11.7	0.11±0.01	2.09±1.15	0.16±0.04
OXB1	4.3±1.5	29.12±14.99	0.85±0.36	3.33±3.72	4.22±1.78
OXB2	3.6±1.1	30.63±6.35	0.55±0.29	1.58±0.78	6.62±1.35
LG3	3.9±1.0	25.73±4.22	0.14±0.06	3.77±0.96	0.43±0.06
LG4	3.1±0.2	22.02±3.85	0.19±0.16	2.74±1.41	0.56±0.04

Table 6: The biological variables of water quality of the Sg. Jeluh (stations JL), Langat (stations LG) and oxidation pond effluent (stations OX).

	Chlorophyll (μg/L)	***E coli* (x 10^6 CFU)**	**T. coliform** (x 10^6 CFU)
JL1	26.53±11.33	4.45±4.04	2.81±0.06
JL2	29.31±15.91	2.23±0.42	4.79±1.05
JL3	16.79±10.50	0.48±0.11	1.80±0.54
JL4	25.66±12.06	1.08±0.10	4.62±0.05
JL5	22.91±9.62	0.83±0.01	3.43±1.68
OXK	107.59±104.8	1.36±1.47	6.65±7.71
LG1	9.48±5.87	0.15±0.02	1.35±0.10
LG2	13.01±1.69	0.23±0.02	2.69±0.79
OXB1	409.1±196.0	5.24±8.53	89.3±129.3
OXB2	1023.5±876.3	8.03±13.31	38.1±63.6
LG3	64.1±45.7	36.25±25.13	395.3±736.3
LG4	89.9±58.2	58.58±33.00	153.5±118.9

The data synthesis is based on examining the trend of changes of water quality parameters apart from their concentrations, which is compared against accepted standard values for water pollution. Table 4 summarizes all the maximum values of water quality data from the pollution sources and their possible use as indicators.

Table 7. Water quality parameters investigated for the sewage discharge source and their maximum levels measured.

Water quality parameters	Max. concentration	Class based on INQWS	Suitability as indicator
PO4 (mg/L)	6.6	III	/
NO3(mg/L)	3.5		X
NH3 (mg/L)	2.0	IV	/
BOD (mg/L)	4.3		X
COD (mg/L)	112.4	III	/
Chlorophyll (μg/L)	1023		X
E. coli (x10^6 cfu/100mL)	2.4	V	/

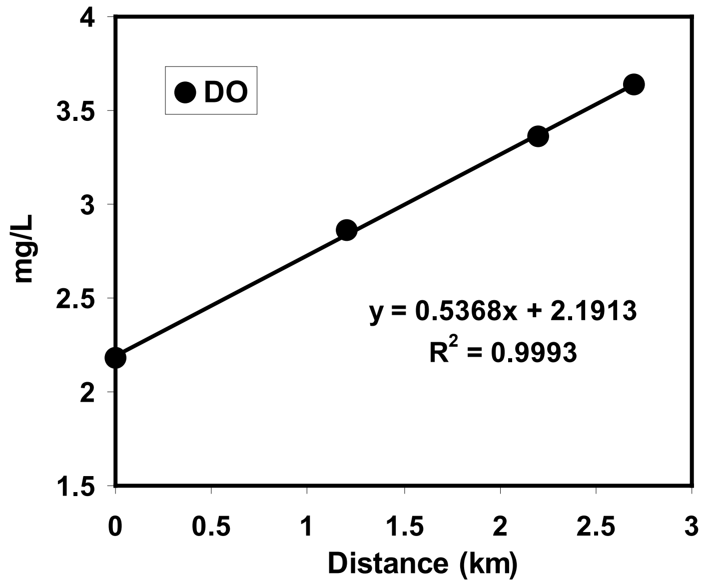
/ = Suitable as indicator for water pollution
X = Not suitable as indicator of water pollution

From Table 7, the indicators that can be used to construct the sub-indices of the effluent are selected based on their impact to their Langat River. This is established by comparing with the value measured with standard Class III values from Interim Water Quality Standards of Malaysia (INWQS). If the value found in the effluent is very much higher than that recorded in the Langat River, it is also a choice of indicator because there will be impact on the Langat River. For sewage, several water quality parameters that are closely related to the effluent characteristics are selected as indicators. These water quality parameters are then used to construct the sub-index S or the sewage impact sub-index. Therefore for S, after selection of indicators based on INWQS is:

S = NH3 + PO4 + COD + ECOL …………………………(4)

The values for NH3, PO4, COD and ECOL can be transformed into numerical values by comparing with existing water quality standards such as that of INWQS. Refer to Table 7, by comparing with standards of the INWQS, the NH3, PO4, COD and ECOL values are in Class III, IV, III and V respectively. Thus, NH3, PO4, COD and ECOL are represented respectively as numerical values of 3, 4, 3 and 5 in equation (4). Chlorophyll content (CHOL) in equation 3 is omitted because no INWQS value is available for comparison.

Studies on the effect of sewage contamination at the Kajang area with station OXK, which received domestic sewage discharge from several oxidation ponds as the main source of effluent and JL4, JL5, and LG2 as the downstream stations showed that most of the values of the water quality parameters diminished as the effluent moved away from the source (Figures 3-5) except that of DO, which increased as the pollution effect diminished. Therefore, the impact on the Langat River is expected to reduce if the source is located far away from the main river. There are strong correlation between the distance (d) from the source and the reduction in concentrations (C) of certain water quality parameters (Table 8).



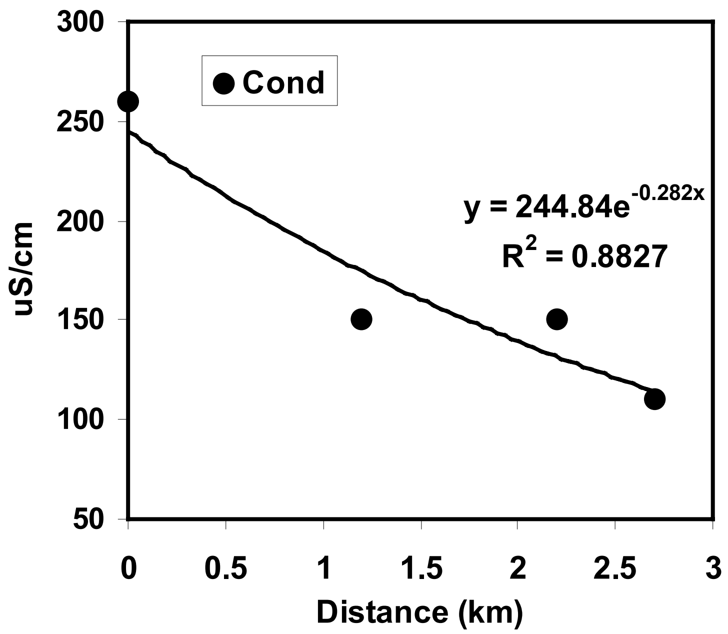


Figure 3. The changes of physical water quality variables with distance from the source of sewage discharge.

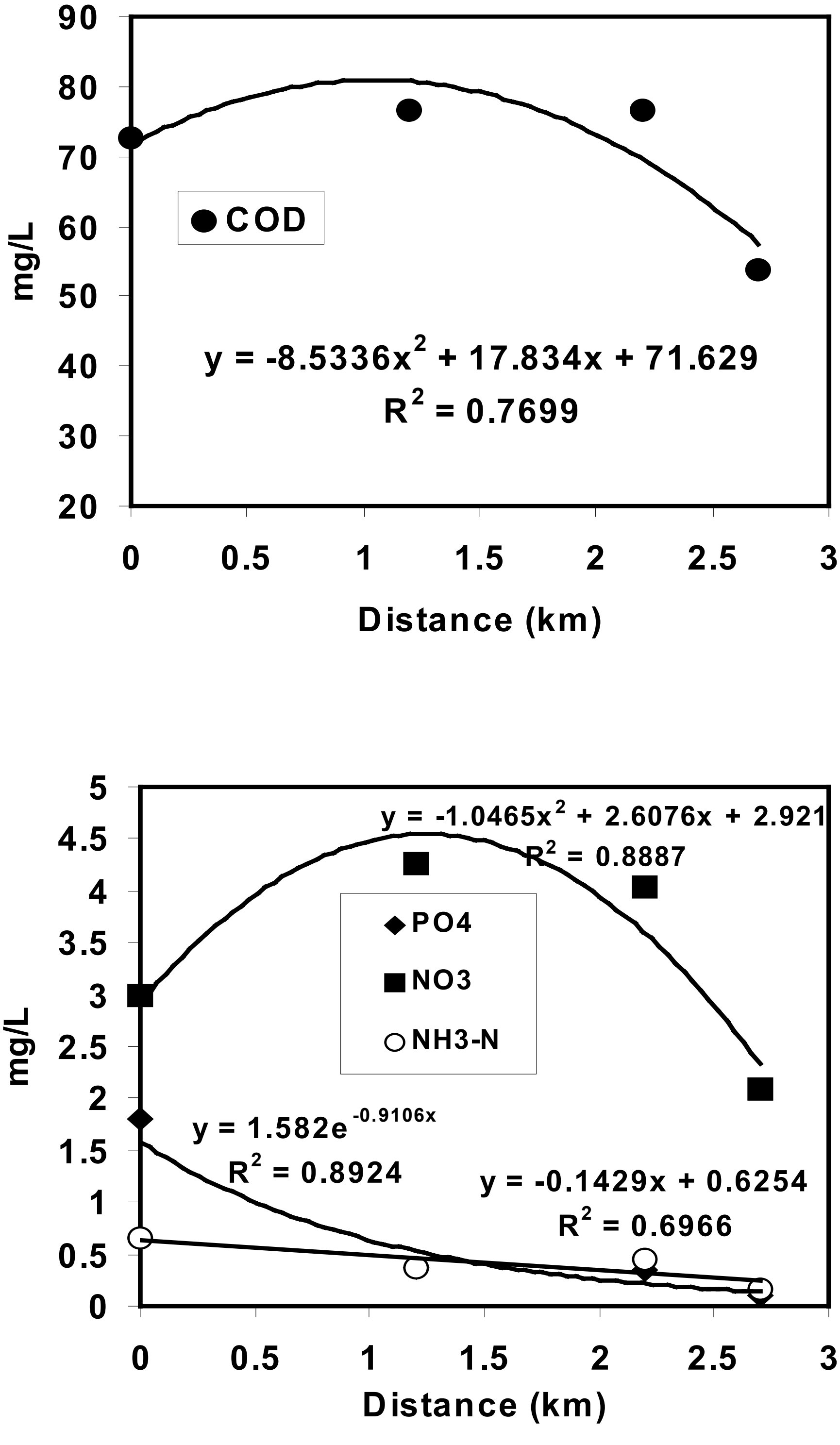
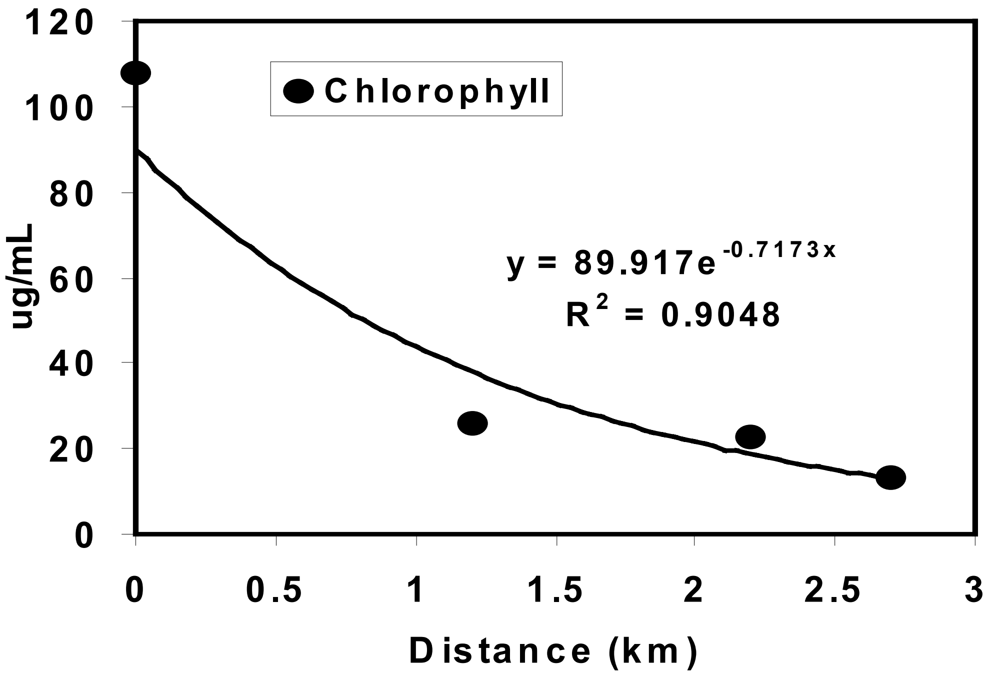


Figure 4. The changes of some chemical water quality variables with distance from the source of sewage discharge.



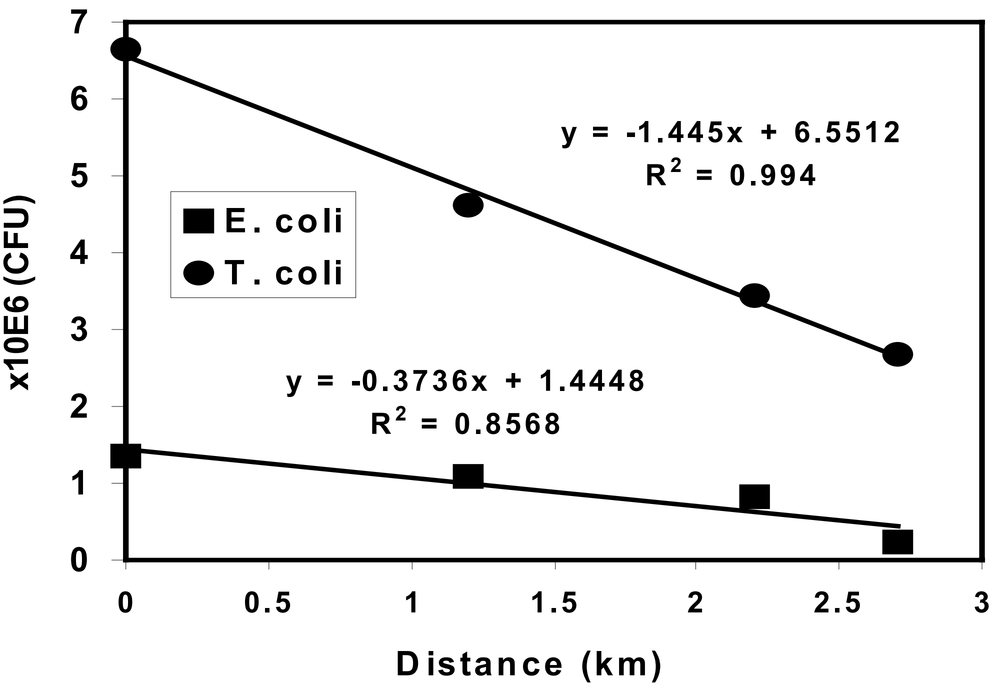


Figure 5. The changes of biological water quality variables with distance from the source of sewage discharge.

Table 8. The relationship between distance from the sewage source and the concentration of some water quality parameters for Sg. Jeluh and Langat at Kajang.

Parameter	Relationship between distance, d & concentration, C (n =4)	Correlation coefficient (r)	Factor for index S
COD	$d = -8.5C^2 + 17.8C + 71.6$	0.88	u
NH3-N	$d = -0.14C + 0.62$	0.83	W
PO4	$d = 1.5\ e^{-0.91C}$	0.94	X
E. coli	$d = -0.3C + 1.4$	0.92	y
Cond.	$d = 244\ e^{-0.28C}$	0.94	
NO3	$d = -1.0C^2 + 2.6C + 2.9$	0.94	
T. coli	$d = -1.4C + 6.6$	0.99	
Chlorophyll	$d = 89.9\ e^{-0.72C}$	0.95	

To take into account the effects of distance of the effluent source from the main river on the index S, the factor for reciprocal of u, w, x, y are include in (4)

$$S = 3u^{-1} + 4w^{-1} + 3x^{-1} + 5y^{-1} \qquad \text{…………….(5)}$$

Where u, w, x and y are factors relating to the diminishing of pollution effect, which depends on the distance of the effluent source from the river. The relationships in Table 8 for COD, NH3-N, PO4, CHOL and ECOL may be used to characterize the factors u, w, x and y that are embedded in equation (5). Thus, the value of d is taken into account when considering the location of the sewage treatment plant or source.

Based on equation (5), the value of S is now determined by the INWQS of the chosen indicators and also the reciprocal of the distance (i.e. the value of d) the river situated from the source of the sewage. Thus, if the value of S will be smaller even the water quality at the sewage source is poor as long as the river is located far from the source (reciprocal term for d). This means that, the smaller the value of the sewage sub-index, S, the least will be the impact of the river by the sewage source in terms of phosphates, COD, ammonia and E. coli. The sub-index S also has important implication when location of a sewage treatment needs to be decided in a heavily populated residential or commercial area.

Further simplification of the expression for the sewage sub-index, S, is possible because strong relationships existed between the conductivity values measured and PO4 or NH3-N indicators (Table 9). Similarly, chlorophyll indicator may be replaced by turbidity and the indicator *E. coli* replace by total coliform since the relationships between these parameters are strongly correlated (Table 9). Although both conductivity and turbidity are water quality that can be determined very easily compared with PO4 or NH3-N, using them as replacements should be caution because many other factors can affect their values apart from PO4 or NH3-N.

Table 9. The relationship between several water quality parameters from the sewage studies

Parameter pair	Relationship (n = 14)	Correlation coefficient
Cond-NH3-N	$[NH3\text{-}N] = 0.04\ e^{0..02[Cond]}$	r = 0.93
Cond – PO4	Cond = 96.0 ln[PO4] + 307.3	r = 0.85
CHOL-Turb	CHOR = 44.2 ln[Turb] - 110.6	r = 0.84
ECOL-TCOL	TCOL = 10.9 [ECOL] – 9.6	r = 0.98

Evaluation of non-water quality based indicators

Indicators other than water quality parameters should be examined to determine whether there exist some relationships between them and the water quality parameters. One of them is the number of sources situated along the river. For sewage, more sources mean higher level of impact and pollution, and this may be related to population and the degree of urbanisation in the vicinity of the Langat River. Both population and the degree of urbanisation can be indicators themselves to replace the water quality parameters if they are strongly related to water quality.

Other social-economic indicators that may be included are expenditure on sewage treatment facilities and maintenance. Higher expenditure implies better sewage treatment facilities and hence less likely in water pollution. It is important that these non-water quality base indicators should be examined with reference to water quality as they may yield sub-indices that can be substitutes for the many water quality indicators, and thus simplify further the process of obtaining the overall index for effluent pollution.

The state of ecosystem health of Langat River - Strategic responses

From the studies, it is obvious that the Langat River ecosystem is under stress from the discharge of effluents particularly domestic sewage. The largest stress is the present of coliform bacteria and PO4. However, the source of ecosystem stress by coliform bacteria can not be ascertained because its link to sewage discharge is not conclusive. But the stress caused by PO4 showed close relationship to sewage discharge. The Langat River, particularly from the middle stretch onwards has suffered from ecosystem dysfunction to some extent. Because of the Class III and IV status of the river, it is no longer functioned as potable water source and the water could not be used for recreational purpose. Whether the Langat River ecosystem is resilient enough to withstand all the stresses imposed on it is still waited to be seen as effort is on the way to rehabilitate the River to Class II status. Certainly the pollution of the Langat ecosystem by effluent discharge has caused damage to neighboring ecosystems, especially the human society which depends so much on the River as potable water source. Such damage is not only stress from water rations but also economical from the increase cost of water treatment.

Many strategic responses have been put forward to arrest the degrading ecosystem health of the Langat River. One example is the 'Sub-Group Activity' by the DOE of Selangor[1]. The concept is useful in continuous water quality surveillance and to deter illegal discharge of effluents by various operators through law enforcement and prosecution. However, to get to the root of the problem, there is a need to understand the degradation of the Langat River ecosystem health in a holistic manner because the ecosystem health damage has its source in the rapid development and increase in population of the Langat Basin.

Conclusion

Linkage of ecosystem health to all the biotic, abiotic and social-economic factors must be established if the ecosystem health of the Langat River is to be improved. Therefore, the use of indicators and indices to simplify the complexity of the problem are useful. This work has demonstrated that as least the water quality aspect of the ecosystem health can be simplified through construction of indices. It shows that the poor water quality is not only related to sewage discharge, it is also dependent on the location of the sewage source and also the number of treatment plants. This implies that location of treatment plants or residential areas from the Langat River are important in reducing ecosystem stress to the river apart from a constant surveillance of water quality and prevention of illegal discharge through law enforcement. With the incorporation of socio-economical data, the concept of a total ecosystem health management can be realized.

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