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Relationship between WQI, heavy metal and sedimentation in Sg Kenau, Kuantan, Pahang using WQ-HeMeS Model

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Abstract. The purpose of this study is to investigate the relationship between water quality of river with heavy metal and sediment content in Sungai Kenau at Pahang using new developed model named WQ-HeMeS. Through this study, water quality has been analysed by using Water Quality Index (WQI) & National Water Quality Standard for Malaysia (NWQS). Water quality of river in Sungai Kenau have been observed by several test which are Dissolve Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Ammoniacal Nitrogen, Total Suspended Solid, Phosphorus and Nitrogen as Nitrate. Meanwhile, the sedimentation rate was determine using Schoklistch method and Duboy method. There are 2 condition for heavy metal considered in the analysis which are heavy metal in water and heavy metal in sediment. Heavy metal in water was tested using laboratory tools named as Atomic Absorption Spectroscopy (AAS) while heavy metal in sediment have been determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The classification of heavy metal in water have been done based on NWQS meanwhile heavy metal in sediment were observed based on Index of Geo-Accumulation and Metal Contamination Factor. After collecting all result from lab testing, the the relationship of water quality, sedimentation rate and heavy metal rate both in water and sediment was determine using generated model. Based on Malaysia WQI Standard, the result shown that water in Sungai Kenau is classified as Class I which means as for water supply, there are no treatment is necessary.

1. Introduction

Sungai Lembing area is located in a district of Kuantan, Pahang, East Coast of Peninsular Malaysia, about 45 km from University Malaysia Pahang (UMP) and 35 km from Kuantan town. There is a river called Sungai Kenau at this area which is estimated about 20.7 km length that cover the area of Sungai Lembing town, Kampung Kolong Pahat, Kampung Jeram Takar and Kampung Kuala Kenau.

Sungai Lembing area is famous as a tin mining since 1800's. At the early of 1900's, the Pahang Consolidated Company Limited, (PCCL), which was under British control had managed the operation of tin production until it had to be closed down in 1986 due to world tin prices collapsed high operational costs, drop in prices and low production [1, 2]. Since Sungai Lembing had been a tin mining location, there are high probability that the heavy metal such as tin, copper and lead deposited in Sungai Kenau and might affect the water quality of river.



Regarding to some issues, the water quality in Sungai Kenau have been affected. It had been reported that 500 ha of jungle in Hulu Sungai Lembing had been cut down indiscriminately without regard to the impact on the environment or the impact to tourism in the surrounding areas. The water of river also had turned murky due to deforestation. The Department of Environment decided to fine Mentiga Corporation Bhd due to violate the law on scheduled waste disposal [3]. In 2018, it had been report that 100 Sungai Lembing's resident had to use a murky water for their daily chore activity when their water supplies had been contaminated by logging activities. There were indeed logging activities which locate about 500 m from the water catchment area. The water seemed to be a murky, yellowish brown colour [4]. Moreover, flash flood in Sungai Lembing in 2014 had affected the quality of water in Sungai Kenau. It had been reported that flash flood was occurred due to clogged drainage system in town centre [5]. These issues have increased the sediment rate in Sungai Kenau and affect the quality of water since it is influenced by the concentration of total suspended solid.

The main objective of this research is to observe the water quality of Sungai Kenau based on parameter such as BOD, COD, TSS, Amoniacal Nitrogen, Phosphorus, and Nitrogen as Nitrate, pH level, temperature & turbidity and determine the class of water through Water Quality Index (WQI) and National Water Quality Standard (NWQS) [6]. The purpose of studies also to observe the correlation between water quality index, sedimentation rate and heavy metal contain in Sungai Kenau via the simulation of this new model.

1.1. Study area

Sungai Lembing is one of the tin mining town which is located 42 km northwest of Kuantan in Pahang, Malaysia. Sungai Lembing consists of few rivers and one of them is Sungai Kenau. It is located in Sungai Lembing start from (3° 49' 50.9988'' N , 102° 59' 40.8228'' E) and end at (3° 55' 57.342'' N , 103° 3' 2.7972'' E) about 20.7 km length. Sungai Kenau supply water to surrounding people and act as a protein source. Since the area of upstream of the river is inhabited and surrounded by indigenous people or 'Orang Asli' by generations, they use the river as their food supply by catching the fish and other aquatic life. Sungai Lembing also used to be a tin mining town since 1800's and the mining have been restored as an attraction for tourist. Sungai Lembing also surrounded by rainfall forest in which there are activities such as deforestation and logging for tree. Regarding to this matter, the quality of water in Sungai Kenau have been disturbed therefore the test have been conducted to investigate the quality of water. Figure 1 and 2 show the view of location of sampling point at Sungai Kenau which is labelled as Station 1 and Station 2. Details of coordinate for both stations were showed in figure 3 and listed in table 1.



Figure 1. Station 1 in Sungai Kenau.



Figure 2. Station 2 in Sungai Kenau.



Figure 3. Location of Sungai Kenau.

Table 1. Coordinate of station.

	Location	Latitude	Longitude
Sungai	Station 1	N 03°54'59.0''	E 103°02'00.2''
Kenau	Station 2	N 03°55'58.2''	E 103°03'00.6''

2. Methodology

Sample of water that had been collected was stored in chiller below than 4°C [7]. There were several tests had been conducted in-situ such as Dissolve Oxygen, flow, temperature, turbidity, salinity, conductivity and pH level. As for laboratory test, the sample first need to be through under preservation by different preservative technique for different type of test. As for water quality, the water sample was observed based on laboratory test such as BOD, COD, TSS, Phosphorus, Ammoniacal Nitrogen and Nitrogen as Nitrate. After getting all test's result, the water quality was determined via WQI and NWQS.

The results of test will be recorded and calculated based on equation (1) to indicate the status of water quality.

$$WQI = (0.22 * SIDO) + (0.19 * SIBOD) + (0.16 * SICOD) + (0.15 * SIAN) + (0.16 * SISS) + (0.12 * SIpH) \quad (1)$$

Where : $0 \leq WQI \leq 100$

The result of lab testing based on above parameter was inserted by user into the model. The model then calculated the index of water quality based on equation (1) to determine the class of water quality. Table 2 show the Water Quality Index by Department of Environmental, Malaysia. The water quality index helped to determine the classes of water quality in which to observe if the water is clean or contaminate. Table 3 show the water quality classes and uses that describe the suitable use of every type of water quality class. Other than WQI, the result that collected from in-situ and lab testing also had been analyzed based on NWQS. Table 4 (a) show the National Water Quality Standard by Department of Environmental, Malaysia which help user to observe water quality standard based on those parameters.

As for sedimentation rate, the sediment sample had been collected from study area. Laboratory test such as sieve analysis and particle density were conducted to observe the grain size of bed material. After obtaining the grain size of bed material, the sedimentation rate was analysed using Schoklistch (2) & Dubois (3) method [8].

$$g_s = \sum_{i=1}^n g_{si} = \sum_{i=1}^n i_b \frac{25}{\sqrt{D_{si}}} S^{\frac{3}{2}} (q - q_0) \quad (2)$$

$$g_s = \psi \tau_0 [\tau_0 - \tau_c] \quad (3)$$

Heavy metal content in water and sediment, the concentration of heavy metal was determined by using Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Heavy metal in water had been determined by NWQS that shown in table 4 (b) meanwhile heavy metal in sediment was determined by Index of Geo-Accumulation (4) & Metal Contamination Factor (5) [9]. Classification of sediment contamination is shown based on table 5 and table 6.

$$I_{geo} = \log_2 \frac{C_n}{1.5 \cdot B_n} \quad (4)$$

$$CF = \frac{C_{metal}}{C_{background}} \quad (5)$$

The water quality model (WQ-HeMeS) responsible to observe the correlation between water quality, sedimentation rate and heavy metal contain. The user needs to insert the data for water quality, sedimentation rate and heavy metal contain in sediment & water. As for water quality, after obtaining the result of laboratory and in-situ test, the user can insert the data in model in which the model will analyse the data and show the class of water based on WQI & NWQS. As for sedimentation, the user needs to choose to input the data through either Schoklistch or Duboys method. Meanwhile for heavy metal, as for heavy metal in water, the user needs to insert the data that obtained from AAS test into model. As for heavy metal in sediment, the user needs to insert the data of heavy metal concentration in sediment in which the model will analyse them based on index of geo-accumulation and metal contamination factor.

At the end, the graph that show the correlation between water quality, sedimentation rate and heavy metal was appeared. Figure 4 shows the flow chart of water quality model.

Table 2. Water Quality Index by DOE.

Parameter	Unit	Class				
		I	II	III	IV	V
AN	Mg/L	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
BOD	Mg/L	<1	1 – 3	3 – 6	6 – 12	> 2
COD	Mg/L	< 10	10 – 25	25 – 50	50 – 100	> 100
DO	Mg/L	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	Mg/L	> 7	6 – 7	5 – 6	< 5	> 5
TSS	Mg/L	< 25	25 - 50	50 - 150	150 – 300	> 300
WQI		< 92.7	76.5 – 92.7	61.0 – 76.5	31.0 – 51.9	< 31.0

Table 3. Water Quality Class and the Uses.

Class	Uses
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of above

Table 4 (a). National Water Quality Standard by DOE.

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
AN	Mg/L	0.1	0.3	0.3	0.9	2.7	> 2.7
BOD	Mg/L	1	3	3	6	12	> 12
COD	Mg/L	10	25	25	50	100	> 100
DO	Mg/L	7	5 – 7	5 – 7	3 – 5	< 3	< 1
pH	-	6.5 – 8.5	6 – 9	6 – 9	5 – 9	5 – 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatable	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
TDS	Mg/L	500	1000	-	-	4000	-
TSS	Mg/L	25	50	50	-	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform	count/100 ml	10	100	400	5000 (20000)	5000 (20000)	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Table 4 (b). National Water Quality Standard by DOE.

Parameter	Unit	Class			
		I	IIA/II B	III	IV
Al	Mg/L		-	(0.06)	0.5
As	Mg/L		0.05	0.4(0.05)	0.1
Ba	Mg/L		1	-	-
Cd	Mg/L		0.01	0.01*(0.001)	0.01
Cr (IV)	Mg/L		0.05	1.4(0.05)	0.1
Cr (III)	Mg/L		-	2.5	-
Cu	Mg/L		0.02	-	0.2
Hardness	Mg/L		250	-	-
Ca	Mg/L		-	-	-
Mg	Mg/L		-	-	-
Na	Mg/L		-	-	3 SAR
K	Mg/L		-	-	-
Fe	Mg/L		1	1	1 (leaf) 5 (other)
Pb	Mg/L		0.05	0.02*(0.01)	5
Mn	Mg/L		0.1	0.1	0.2
Hg	Mg/L		0.001	0.004(0.0001)	0.002
Ni	Mg/L		0.05	0.9	0.2
Se	Mg/L		0.01	0.25(0.04)	0.02
Ag	Mg/L	N	0.05	0.0002	-
Su	Mg/L	A	-	0.004	-
U	Mg/L	T	-	-	-
Zn	Mg/L	U	5	0.4	2
B	Mg/L	R	1	(3.4)	0.8
Cl	Mg/L	A	200	-	80
Cl2	Mg/L	L	-	(0.02)	-
CN	Mg/L		0.02	0.06(0.02)	-
F	Mg/L	L	1.5	10	1
NO2	Mg/L	E	0.4	0.4(0.003)	-
NO3	Mg/L	V	7	-	5
P	Mg/L	E	0.2	0.1	-
Silica	Mg/L	L	50	-	-
SO4	Mg/L	S	250	-	-
S	Mg/L		0.05	(0.001)	-
CO2	mg/l	O	-	-	-
Gross - α	Bq/l	R	0.1	-	-
Gross - β	Bq/l	A	1	-	-
Ra-226	Bq/l	B	< 0.1	-	-
Sr-90	Bq/l	S	< 1	-	-
CCE	μg/l	E	500	-	-
MBAS/BAS	μg/l	N	500	5000(200)	-
O&G (Mineral)	μg/l	T	40;N	N	-
O&G (Emulsified Edible)	μg/l		7000;N	N	-
PCB	μg/l		0.1	6(0.05)	-
Phenol	μg/l		10	-	-
Aldrin/Dieldrin	μg/l		0.02	0.2(0.01)	-
BHC	μg/l		2	9(0.1)	-
Chlordane	μg/l		0.08	2(0.02)	-
t-DDT	μg/l		0.1	(1)	-
Endosulfan	μg/l		10	-	-
Heptachlor/Epoxide	μg/l		0.05	0.9(0.06)	-
Lidane	μg/l		2	3(0.4)	-
2, 4-D	μg/l		70	450	-
2, 4, 5-T	μg/l		10	160	-
2, 4, 5-TP	μg/l		4	850	-
Paraquat	μg/l		10	1800	-

Table 5. Index of Geo-Accumulation.

Igeo	Igeo Class	Description of Sediment Quality
<0	0	Uncontaminated
0-1	1	Uncontaminated to Moderately Contaminated
1-2	2	Moderately Contaminated
2-3	3	Moderately to Strongly Contaminated
3-4	4	Strongly Contaminated
4-5	5	Strongly to Extremely Strongly Contaminated
>5	6	Extremely Contaminated

Table 6. Metal Contamination Factor.

Class	Cf value	Category
1	$C_f \leq 1$	Low Contamination
2	$1 \leq C_f \leq 3$	Moderate Contamination
3	$3 \leq C_f \leq 6$	Considerable Contamination
4	$6 \leq C_f$	Very High Contamination

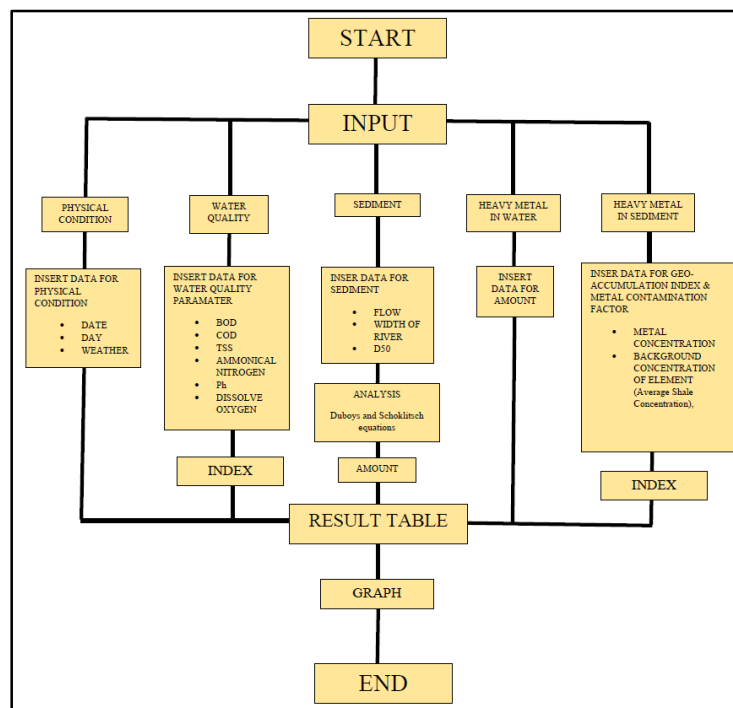


Figure 4. The flow chart of Water Quality Model.

3. Result and discussion

The sample had been collected at Oct 2019 and Feb 2020. Through in-situ and laboratory tests, the water quality of Sungai Kenau had been determined based on WQI and NWQS. The result of tests indicated that the water quality at both station in Sungai Kenau is classified at Class 1 which means the water is clean and no treatment necessary for water supply. Table 7 shows the water quality index and class in both station on October 2019 and February 2020. The water quality index in both stations is compare based on graph in figure 5.

The test for heavy metal had been done for sample of water on Feb 2020. As for heavy metal in water, classification have been done based on NWQS. There were 3 type of heavy metal that have been observed in which Iron, Copper and Lead. All these heavy metals were classified as Class 1 which mean the condition water being in natural state and safe. The classification of heavy metal in water is shown in table 8.

For heavy metal in sediment, classifications were conduct based on Index of Geo-Accumulation and Metal Contamination Factor. From the observation, the heavy metal such as Iron, Copper and Lead were being classified as Class 0 for Index of Geo-Accumulation which mean the sediment is uncontaminated. Meanwhile for metal contamination factor, the sediments were classified as Class 1 which mean it was categorized as low contamination. The classification of heavy metal in sediment is show in table 9.

Table 7. Water Quality Index in Sungai Kenau on Oct- 2019 & Feb-2020.

Station	Month	WQI	Class
1	Oct-2019	96.95	1
	Feb-2020	96.29	1
2	Oct-2019	93.68	1
	Feb-2020	96.57	1

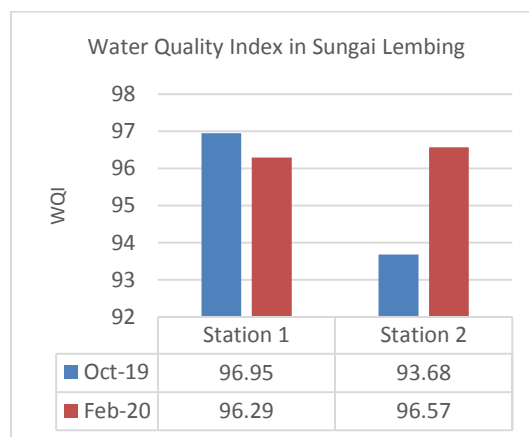


Figure 5. The water quality index graph comparison between Oct-2019 & Feb-2019.

Table 8. The Classification of Heavy Metal in Water at Sungai Kenau on Feb 2020.

Heavy Metal	Station	Concentration (mg/L)	Class
Iron	1	0.913	1
	2	0.65	1
Copper	1	0.008	1
	2	0.005	1
Lead	1	0.001	1
	2	0	1

Table 9. The Classification of Heavy Metal in Sediment at Sungai Kenau on Feb 2020.

Heavy Metal	Station	Concentration (mg/L)	Class of I_{geo}	Class of CF
Iron	1	552.7	0	1
	2	3190.3	0	1
Copper	1	0.2329	0	1
	2	1.4666	0	1
Lead	1	0.0732	0	1
	2	6.500	0	1

After getting all result of water quality, sedimentation rate and heavy metal contain both in water and sediment, the users will insert all the data into model to observe the class of water quality via WQI, Index of geo-accumulation and metal concentration.

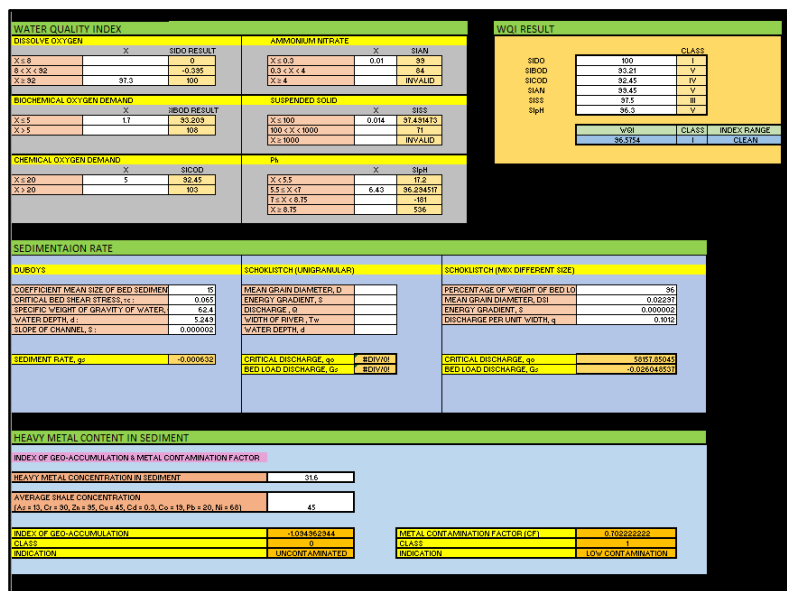


Figure 6. The model of water quality. The user will insert the data of water quality, sedimentation rate and heavy metal to observe the correlation between them.

Figure 6 shows that there are 4 part in the model. The upper left part is used as to analyse the Water Quality Index based on 6 parameters which are Dissolve Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solid, Ammoniacal Nitrogen, and pH level. The user needs to choose the range of their result and insert the value of sub-index into upper right part (orange part) in order to obtain the class of water. At the end, the water quality index was shown together with the description of class.

As for middle part, the sedimentation was calculated through Duboys & Schoklistch. The user needs to choose which method suitable depend to the size of the grain.

As for lower part, the users need to analyses the heavy metal in sediment based on Index of Geo-accumulation and Metal Contamination Factor. The user needs to observe the concentration of heavy metal in sediment through laboratory test first. In order to obtain the result, the user need to insert the data of heavy metal concentration and choose average shale concentration that suitable with the element. The result will appear after both data is inserted in which the model indicates whether the water it is uncontaminated or high contaminated.

Based on figure 7, there is a table in which the data of date, WQI, heavy metal concentration in water, heavy metal concentration in sediment and sedimentation rate need to be inserted by the users in order

to generate the graph that show the relationship between water quality index, sedimentation rate and heavy metal contains.

There are 4 type of graph shown in the model. The upper left graph shown the comparison of heavy metal contain between sediment and water. The users need to calculate the concentration of heavy metal through Atomic Absorption Spectroscopy in order to insert the data in the model. Meanwhile, the upper right graph shown the comparison between Water Quality Index and sedimentation rate. The lower left graph shown comparison between Water Quality Index and heavy metal rate. The lower right indicated the Water Quality Index, sedimentation rate and heavy metal rate.



Figure 7. The graph appear after the user insert the data.

4. Conclusion

In this conclusion, the water quality index plays an important role as indicator to the quality of water. In Malaysia, there are Water Quality Index (WQI) and National Water Quality Standard (NWQS) by Department of Environment to indicate the water quality here. Since Sungai Kenau is important as water and protein supply for residents there, it is a must to preserve the water quality. Based on WQI and NWQS, the water in Sungai Kenau was classified as class I which means the water was clean & uncontaminated and it does not need a necessary treatment as for water supply. For heavy metal in water and sediment, Iron record as the highest concentration compared to Lead & Copper. The content of Iron is the highest since the studies area located near with the mining area.

As for water quality model, the model simulation works effectively to analyses the relationship between water quality index, heavy metal content and sedimentation rate. This water quality model also can analyses the water quality faster compares to conservative calculation which need a long calculation. In other word, the water quality model helps to ease the task of users especially if the user needs to calculate lot of water quality index. The graph appeared also help the user to understand better the relationship between water quality index with heavy metal contains and sedimentation rate.

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