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Assessing of water quality and sedimentation problems in Lata Sungai Limau, Malaysia

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ABSTRACT

Sedimentation problem and water quality deterioration are the occurrences happened along the river basin especially at main river basin in Malaysia. The main objective of this study to review the sedimentation problems and water quality deterioration level in the Lata Sungai Limau, Terengganu, Malaysia. 11 sampling stations were chosen from upstream until downstream. There are four mains contributed in this study such as water quality parameters, distribution of sediment grain size, concentration of total suspended solids (TSS) and river discharge (*Q*) respectively. From leave-one-out method showed chemical oxygen demand and TSS are the most importance water quality variables with river discharge (*Q*). The formation of sediment load per day falls between 53.540 kg/d (Station 2) and 1,164.394 kg/d (Station 5) for all sampling stations contributed. The result showed the sizes of sediment recorded phi –0.011 and phi 0.768 with very rough particle sizes which are between phi 1.00 and phi 0.00. All parties involved need to take responsibility and be more aware to environmental deterioration and awareness. This research conducted to enlighten the public about the importance of the environment, especially river basins.

Keywords: Sedimentation; water quality deterioration; Lata Sungai Limau; suspended sediment; leave-one-out method

1. Introduction

The development of anthropogenic activities and climate changes phenomenon around the river basins are much more sensitive negatively impacts to the unsustainability of environmental. Basically, there are familiar with the anthropogenic effects along the river basins such as urbanization, tourism sector, agriculture, industrialization, deforestation, and residential construction.

River and lake play a very necessary role as water resources supply in everyday life. There are a few uses of

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river water such as agricultural, industrialization, drinking water, tourism, domestic usage, and hydroelectric source. The unstable of river equilibrium along the river basin in Malaysia caused by the unregulated domestic sewage, agricultural, industrialization fields, residential construction, sewage disposal and urbanization around the river basins which are the major pollution sources [1–5] . The increasing amount of chemical pollutants and the level of water quality deterioration caused by the changes in development along basins [6–11].

Fig. 1 shows the land use distribution (%) in Besut, Terengganu, 2015. This study more focus to the promote contribution to increase the sustainable development in conservation and preservation to protect and stabilize the environmental biodiversity and ecosystem. The unbalancing of management characteristics will give negative respond to river and lake basin management institutions [12–15]. The potential integrated river and lake management suggest a necessary precautionary approach in developing and implementing lake management interventions. Besides that, the environmental researcher teams should be fully understanding the levels of sustainability capacity of ecosystem and biodiversity along basins. It is an important critical preserve and conserve to protect the environmental biodiversity and ecosystem with better environmental awareness policy decisions. This study more focuses specifically on the major existing environment in Lata Sungai Limau, Jabi, Besut and its basin including the climate characteristics, hydrological characteristics, air quality, topography and geomorphology of the lake and river system. These factors influencing the water quality of the river system [16–20].

In Malaysia, based on the environmental annual report issued by the Department of Environment, there are mainly anthropogenic factors from development around the basins causing river pollution deterioration such as sedimentation problems, water quality problems and flooding phenomenon in Malaysia namely land use development, urbanization and climate changes. The water quality, sedimentation problems, and river system changes are sensitivity to various factors that affect the environment. These situations also occur in some rivers in Malaysia, and those examples show us that Malaysian rivers are now facing tremendous transformation caused by anthropogenic activities that later contribute to pollution. We are concerned about water quality status and sedimentation problems not only because water is required by cultures and industries but also because it is a fundamental assessment in the environment [21,22].

The characteristic features of the climate in Lata Sungai Limau generally are uniform temperature, high humidity, and high-intensity rainfall. Fig. 2 shows the climate and precipitation data were obtained from the Malaysia meteorological department and department of irrigation and drainage (DID) which covered the overall district showed the climate characterized by the Asian monsoon system. The generally seasonal variation of rainfall in Terengganu River basin can be divided into two main types such as the rainfall intensity event occurs starting September to February (Northeast monsoon month – wet season) and the relatively dry event starting May to October which received relatively lower than the other months (normal season).

Besides that, technically, riverbank erosion can be occurring due to several factors that become a contributor to the erosion to happen. Among the factors are the loss of soil particles on river banks due to streamflow, landslide due to the increment of bank slope, erosion due to turbulence of the streamflow and finally the side erosion that causes the structure of the bank collapsed. River geometric factors include the cross-section for minimum geometrical such as width, depth, cross-section, meander length, and hydraulic variable include riverbank slope, minimum friction, and minimum streamflow that affect the bed erosion and

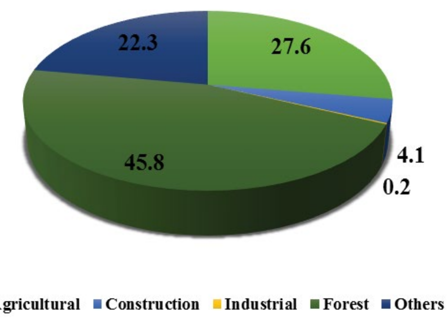


Fig. 1. Land use distribution in Besut, Terengganu, 2015.

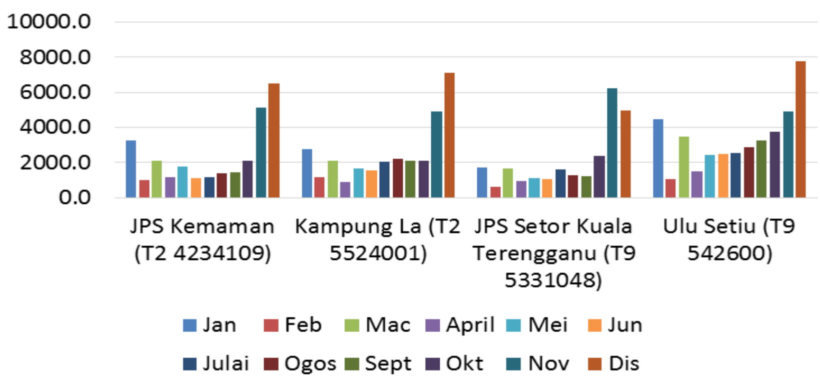


Fig. 2. Distribution of rainfall intensity from January 2011 until December 2010, Terengganu.

sedimentation. In the end, the shape of the river geometry profile can be elaborate as a physical shape of a river whether it is plain or groove due to the pressure of the bed surface transverse flow that led to erosion and sedimentation [21–23].

The process of deposition of sediment depends on the velocity of the river flow and river discharge. Basically, at the downstream areas have the discharge value and water velocity higher than upstream areas. These hydrological factors triggered a higher amount of sediment load (SL) deposited production. This deposition process depends on the process of erosion, transport, and deposition. The coarse sediments affect the potential erosion while the fine sediments affect the chemical content of dissolved and suspended solids. One of the essential functions of sediment is to carry of nutrients and pollutants in the flow of the river. The sediment production depends on the rate of the side and riverbank erosion. Then, higher water velocity and increasing frequency of rainfall triggered the erosion activity and intensity of sediment production. Generally, the high rate of speed and volume of water caused higher erosion rates [24,25,42]. Besides that, from this study the researcher also describes sediment properties and suspended sediment concentration, to determine the relationship of status water quality and river discharge recorded and to identify the factors of sedimentation problem in the study area.

2. Study area and research methodology

2.1. Study area

Lata Sungai Limau was selected as the study area because the areas along this Besut River basin were developing and suffered from the destruction of houses and properties. There are forested areas cover more than 50% of the land use in the District of Besut. Besut River is a major river drain that flows toward the eastern part of Kuala Besut. There are a few active anthropogenic activities along this river basin such as eco-tourism facilities, farming, logging, industrialization and residential. These anthropogenic activities are negatively affected to the river basin and caused the river erosion and increasing the amount of sediment deposited into the river Following figures are the location (downstream, middle stream and upstream) of the study catchment and river network (Table 1 and Figs. 3 and 4).

2.2. Water samples and hydrological analysis

The water samples were collected from 11 sampling stations which are covered from downstream to upstream areas of a river basin. The collection and analysis of water samples for the determination of loading were following internationally accepted protocols. Hence, water samples collection and preservation were conducted following the Global Environment Monitoring System (GEMS) for Water Operational Guide (endorsement from United Nations Environment Programme, World Health Organization, United Nations Educational, Scientific and Cultural Organization, and World Meteorological Organization for water samples collection and preservation), World Health Organization, 1987 and the ISO 5667 series. All the sample polyethylene was labeled before site collection and that had been soaked and cleaned using hydrochloric acid. Three replicate samples were taken randomly at each station were labeled according to the sampling area. The samples were

Table 1
Location of sampling station at Lata Sungai Limau, Jabi, Terengganu, Malaysia (2018)

Sampling station	Longitude	Latitude
Station 1	102°34′ 11.6″ E	5°38′ 11.2″ N
Station 2	102°34′ 11.5″ E	5°38′ 18.3″ N
Station 3	102°34′ 10.8″ E	5°38′ 20.6″ N
Station 4	102°34′ 11.6″ E	5°38′ 23.9″ N
Station 5	102°34′ 14.7″ E	5°38′ 28.4″ N
Station 6	102°34′ 25.1″ E	5°38′ 30.3″ N
Station 7	102°34′ 31.9″ E	5°38′ 32.82″ N
Station 8	102°34′ 35.4″ E	5°38′ 36.7″ N
Station 9	102°34′ 41.1″ E	5°38′ 34.7″ N
Station 10	102°34′ 45.8″ E	5°38′ 31.6″ N
Station 11	102°34′ 19.0″ E	5°38′ 29.2″ N

(a) (b) (c)

Fig. 3. (a) Downstream, (b) middle stream, and (c) upstream of study location at Lata Sungai Limau, Jabi, Terengganu, Malaysia. (2018).

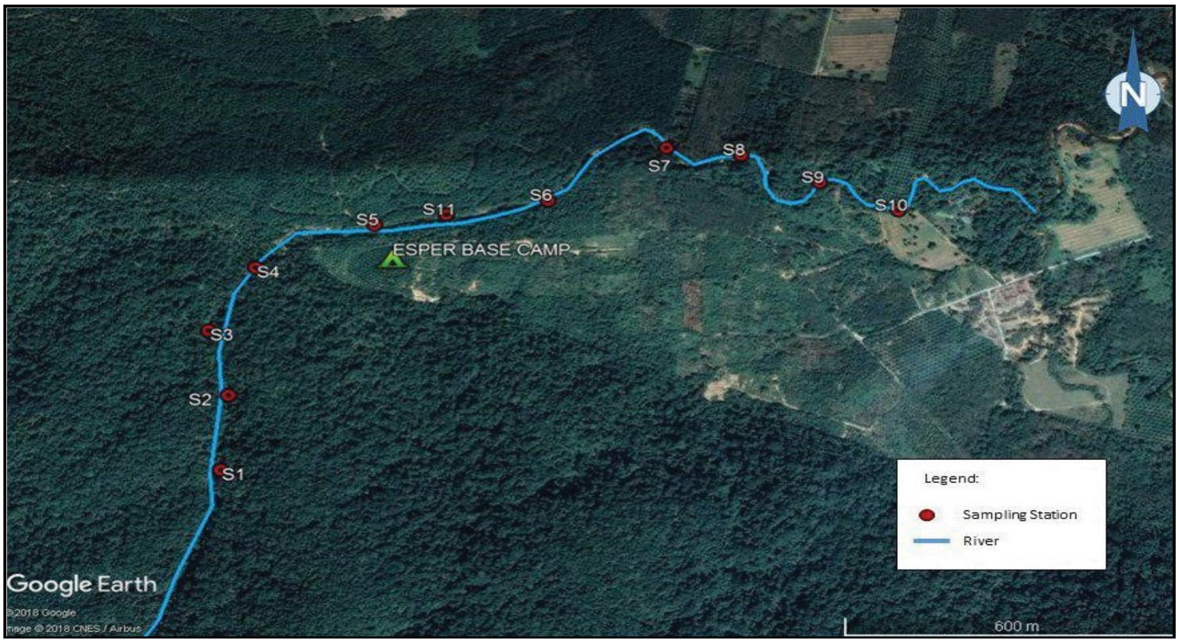


Fig. 4. Map of sampling station at Lata Sungai Limau, Jabi, Terengganu, Malaysia. (2018).

collected by directly filling the water sample container from the surface body and by decanting the water from a collection portable device. While, analytical methodologies were following standard methods for the examination of water and wastewater, American Public Health Association (APHA) [26]. The testing laboratory is an ISO 17025 accredited laboratory for all the parameters to be analyzed.

2.3. In-situ analysis

The discharge or flow rate was determined using the middle section method (hydrological Procedure No 15: river discharge measurement by current meter DID). Figs. 5a and b show the typical cross-section of a river and the streamflow speed was measured using a current meter portable, flow meter (model FP101). It is recognized that the methodology adopted in the study presents several limitations for the degree of accuracy of the loading estimates. Fig. 6 shows the illustrated the river discharge measurement.

The measurements of in-situ parameters were dissolved oxygen (DO), pH, and ammoniacal nitrogen (NH_3–N) using the water-quality multiprobe model DO meter YSI 58. Biochemical oxygen demand (BOD) check meter used to determine the level of BOD. This multiprobe meter portable was calibrated before field sampling. Fig. 7 shows the water quality in-situ parameter measurement.

2.4. Ex-situ analysis

All the sample preparation and preservations follow based on the standard procedures provided by APHA and the United States Environmental Protection Agency (USEPA) Methods. For laboratory analysis, at least 500 ml water sample for each station was needed to measure the concentration of total suspended solids (TSS) and chemical oxygen demand (COD) measurement. Besides that, about 100 g of sediment samples were collected using sediment scoops and sediment grab and then the samples will be analyzed based on the procedure of Gerald and Kenneth, 1982 [25,27].

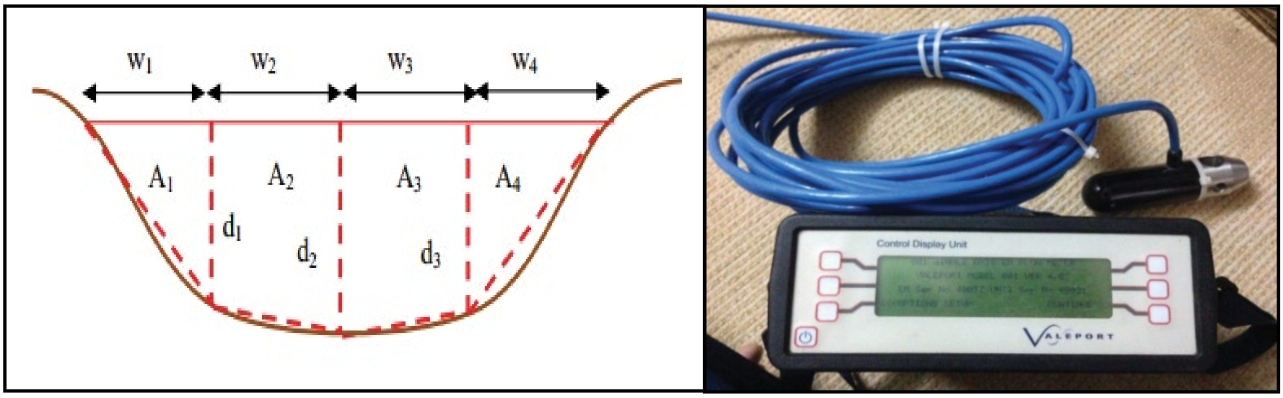
2.5. Water quality in-situ parameters

The parameter of TSS analyzed using a gravimetric method (refer to APHA and USEPA). There are about 250 ml water sample was needed for each study area (each sampling station). Eq. (1) showed the formula used to measure the value of TSS [27–29]. COD test (methods for chemical analysis of water and waste, EPA -600/4-79-020, USEPA, method 410.1).

$$\begin{aligned}\text{TSS} = {} & \{(\text{Weight of membrane filter} + \text{Dry residue}) - \\ & \text{Weight of membrane filter}\}\ (\text{mg}) \times 1{,}000/ \\ & \text{Volume of filtered water (mL)} \\ = {} & \text{mg/L}/1{,}000/1{,}000/1{,}000 \\ = {} & \text{tonne/L}\end{aligned} \tag{1}$$

2.6. Sediment grains size analysis (Procedure of Gerald & Kenneth, 1982 & Udden-Wentworth method)

The statistic value of median, mean (M), standard deviation (SD), skewness (S) and kurtosis was determined based on the sediment grains size analysis (Procedure of Gerald and Kenneth, 1982. Then, the Udden-Wentworth method, the arithmetic ordinate graph used the weight of the sample. In the x-axis scale unit of a micrometer (μm) and the y-axis is the cumulative percentage scale (0%–100%) by a linear scale. The higher or lowest size of sediment depends on the roughness and fineness of the sample composition [30,31].



(a) (b)

Fig. 5. (a) Theoretical of discharge measurement by a cross-section of the river and (b) current meter portable, flow meter (model FP101).

(a) (b) (c)

Fig. 6. (a) Width measurement, (b) depth measurement and (c) velocity measurement.

Fig. 7. Water quality in-situ parameters measurement instruments.

3. Results and discussion

3.1. Hydrological analysis

Table 2 shows the distribution of river discharge at Lata Sungai Limau, Jabi, Terengganu, Malaysia, 2018 which highest values especially at station 1 (downstream area) and the lowest value recorded at station 10 (upstream area). The measurement of river discharge depends on the measurement of flow velocity [32].

The changes in riverbanks or river width affected the level of six parameters of water quality characteristic TSS in the river basin. The hydrological cycle, biological cycles, global biogeochemistry, biodiversity, unstable ecosystem, and climate changes are the main factors caused water quality deterioration and sedimentation problems. The increase the erosion rate, rainfall intensity, higher river velocity, and river discharge will trigger the higher amount production of suspended solids, turbidity, total dissolve solid which are became the river more shallow and give a negative impact on the ecosystem and the biodiversity around the river basin [33,34].

3.2. Water quality parameters analysis

Water quality parameter analysis is defined as a technique of the chemical, physical and biological characteristics of water. From the few preliminary water quality level studies in Lata Sungai Limau proved there are high values of COD and TSS in middle and downstream areas as compared with the upstream areas. The reverses were true for the NH_3–N and DO values (Fig. 8). The main sources of pollutants were possibly waste products and effluent which from development activities contaminated along the river basin. The results presented here provide a baseline reference on future monitoring for the next development activities of the Besut River basin.

The sedimentation rates and water quality changes include damage to the biodiversity communities ecosystems affected by the hydrological changes. The leave-one-out method was carried out in this study as one of the statistical analysis to determine significant water quality parameters with river discharge (Table 3). From this linear relationship, the analysis showed the percent contribution of DO is highest than other variables (29.75%). The highest concentration of DO in river water depends on the velocity of water, the velocity depends on the intensity of rainfall. The higher discharge value and higher the water velocity, the higher the amount of concentration DO [35,36]. The highest percent contribution than other parameters is COD (33.8%) and TSS (13.08%). Studies showed the wastes from these activities were characterized by high organic content leading to high COD and TSS values as a result of the

Table 2
River discharge (Q) values at Lata Sungai Limau, Jabi, Terengganu, Malaysia (2018)

Station	Discharge (Q) (m^3/s)	Discharge (Q) (m^3/d)	Discharge (Q) (L/d)
Station 1	3.121	2,69,654.4	2,69,612,928
Station 2	0.252	21,772.8	21,764,160
Station 3	0.280	24,192	24,192,000
Station 4	0.214	18,489.6	18,495,648
Station 5	1.248	1,07,827.2	1,07,814,240
Station 6	0.304	26,265.6	26,307,072
Station 7	0.151	13,046.4	13,039,488
Station 8	0.362	31,276.8	31,271,616
Station 9	0.330	28,512	28,493,856
Station 10	0.115	9,936	9,899,712
Station 11	0.156	13,478.4	13,519,526.4

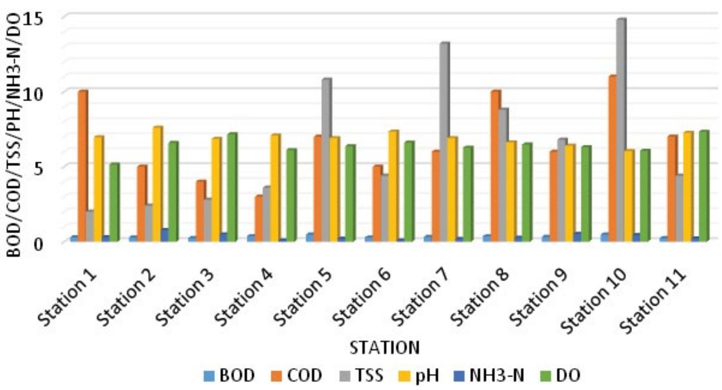


Fig. 8. Distribution of water quality parameters at Lata Sungai Limau, Jabi, Terengganu, Malaysia. (2018).

decomposition processes [37,38]. From the result showed the downstream and middle stream areas more polluted than upstream.

3.3. Sedimentation problems

3.3.1. Estimated suspended load

Based on hydrological basic stated the concentration of TSS increased from the upstream stations to the downstream stations. From scientific hydrological research, TSS is one of the indicators to measure the sedimentation problems. TSS is the concentration amount of solid-phase material suspended in a water-sediment mixture on the surface of the water [38–40].

Table 4 shows the discharge value (Q) at station 1 and station 5 at the downstream and middle stream areas recorded the highest values at 3.121 and 1.248 m^3/s, respectively, the lowest values at station 10 with 0.115 m^3 which at the upstream area. The highest daily suspended sediment production in a river basin (Besut River basin) was caused by the highest discharge value and the highest suspended solid. The result showed the highest daily suspended sediment production recorded at station 5 (1164.394 kg/d) and station 1 (539.226 kg/d). Based on this result proved, the suspended SL production depends on the energy of river flow [41–45].

3.3.2. Sediment grain size

The dendrogram of the locations of different sites along Lata Sungai Limau applied for sediment grain size. It shows that the monitoring locations can be grouped into four clusters (Table 5 and Figs. 9a and b). Cluster 1 is formed by the sites station 1, station 4, station 5, station 7, station 9, station 10, and station 11. Cluster 2 is covered by the station 2 and station 8. Cluster 3 included by the sites station 3 and station 6. From the classification showed mostly sediment grains size in Lata Sungai Limau classified as very rough correspond and coarse sediment needed higher flow energy at stations which nearby the development areas along Besut River basin. This clustering method based on environment procedure generated three clusters as the sites in these groups have natural backgrounds and homogeneous characteristics. Besides that, the sedimentation problems along Besut River basin including Lata Sungai Limau area is still not critically level but it is increasing caused by the uncontrolled land use activities along the river basin.

Table 3
Input importance variables in a linear relationship to predict river discharge (Q) at Lata Sungai Limau, Jabi, Terengganu, Malaysia (2018)

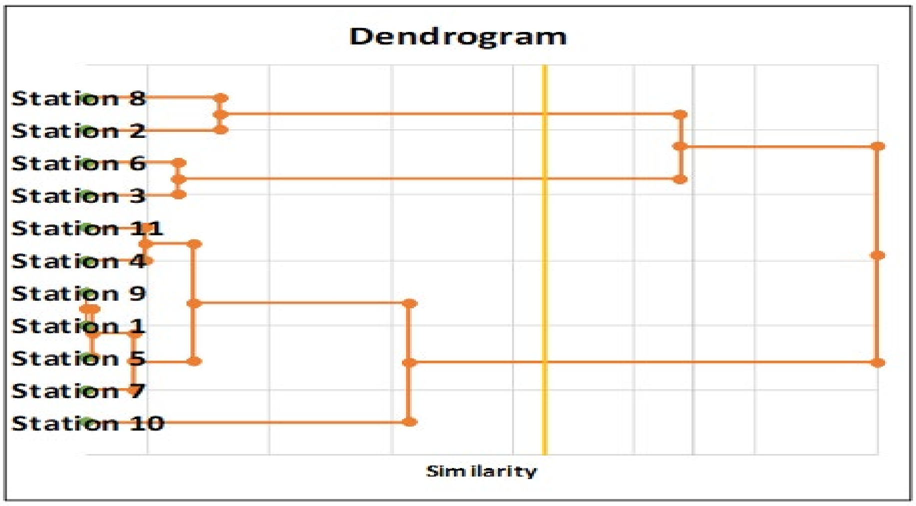
R-square reference = 0.726			
Leave variable	R-square leave variable	R-square difference	Percent contribution (%)
DO	0.535	0.191	29.75
BOD	0.712	0.014	2.18
COD	0.509	0.217	33.8
NH_3–N	0.719	0.007	1.09
TSS	0.642	0.084	13.08
pH	0.597	0.129	20.0
Total	3.714	0.642	100

Table 4
Estimated suspended load in the Lata Sungai Limau, Jabi, Terengganu, Malaysia (2018)

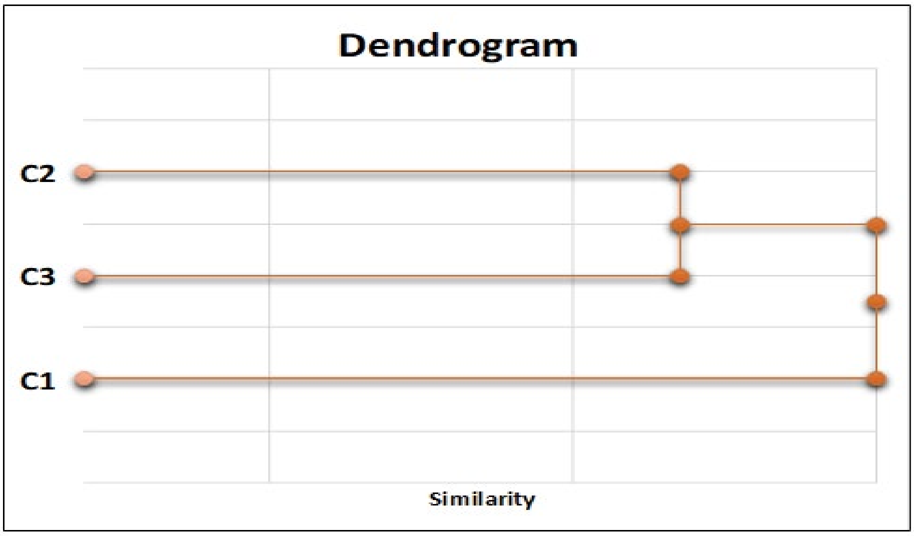
Station	TSS (mg/L)	TSS (kg/L)	Estimated discharge, Q (m^3/s)	Estimated Q (L/d)	Estimated TSS (kg/d)
Station 1	2	0.000002	3.121	2,69,612,928	539.226
Station 2	2.4	0.00000246	0.252	21,764,160	53.540
Station 3	2.8	0.00000286	0.280	24,192,000	69.189
Station 4	3.6	0.00000360	0.214	18,495,648	66.584
Station 5	10.8	0.0000108	1.248	1,07,814,240	1164.394
Station 6	4.4	0.00000440	0.304	2,6307,072	115.751
Station 7	13.2	0.0000132	0.151	13,039,488	172.121
Station 8	8.8	0.00000880	0.362	31,271,616	275.190
Station 9	6.8	0.00000680	0.330	28,493,856	193.758
Station 10	14.8	0.0000148	0.115	9,899,712	146.516
Station 11	4.4	0.00000440	0.156	13,519,526.4	59.486

Table 5
Distribution sediment grains size at Lata Sungai Limau, Jabi, Besut, Terengganu, Malaysia (2018)

Parameter/ station	Mean	Standard deviation	Skewness	Kurtosis
Station 1	0.222 (Rough grain)	0.800 (Moderately sorted)	1.627 (Very fine)	–0.186 (Very platykurtic)
Station 2	0.489 (Rough grain)	0.873 (Moderately sorted)	1.599 (Very fine)	0.393 (Very platykurtic)
Station 3	0.768 (Rough grain)	0.838 (Moderately sorted)	0.074 (Medium)	–0.175 (Very platykurtic)
Station 4	0.517 (Rough grain)	0.830 (Moderately sorted)	0.862 (Very fine)	–0.700 (Very platykurtic)
Station 5	–0.011 (Very rough grain)	0.548 (Moderately well sorted)	1.293 (Very fine)	–0.750 (Very platykurtic)
Station 6	0.764 (Rough grain)	0.847 (Moderately sorted)	0.077 (Medium)	0.380 (Very platykurtic)
Station 7	0.507 (Rough grain)	0.834 (Moderately sorted)	0.851 (Very fine)	0.391 (Very platykurtic)
Station 8	0.496 (Rough grain)	0.859 (Moderately sorted)	0.417 (Fine)	0.804 (Platykurtic)
Station 9	0.250 (Rough grain)	0.798 (Moderately sorted)	1.584 (Very fine)	–0.162 (Very platykurtic)
Station 10	0.210 (Rough grain)	0.841 (Moderately sorted)	1.259 (Very fine)	0.817 (Platykurtic)
Station 11	0.750 (Rough grain)	0.558 (Moderately well sorted)	1.028 (Very fine)	–0.051 (Very platykurtic)



(a)



(b)

Fig. 9. (a and b) Dendrogram showing a different cluster of sampling stations located at Lata Sungai Limau, Jabi, Terengganu, Malaysia. (2018).

4. Conclusion

These sedimentation problems and water quality deterioration caused by the increase of sediment production on the river bed. These problems will cause serious drastic changes in hydrological characteristics and water quality status along the river basin. The environmental integrated management should be taken by the government and public communities to sustain the equilibrium of the ecosystem and biodiversity. The effectiveness of these mitigating measures also depends on the awareness, preservation, conservation and legal enforcement to prevent the sedimentation and water quality problems around the river basins.

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