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Research paper

Classification of Sedimentation Problems Level Using Environmetric Method at Terengganu River, Malaysia

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Abstract

This study was implemented to prove the sedimentation problem. The technique of analysis of primary data obtained which determine according procedure Gravimetric method, Gerald & Kenneth and the scale Udden - Wentworth which included median, mean, standard deviation, skewness, and kurtosis. The results showed the highest average of TSS (mg/L) is 67.2 (wet season) and 128.2 (dry season). While the highest TUR is 43.57 (wet season) and 21.57 (dry season). The statistical analysis of the phi value obtained showed the size of sediment grains is dominated by the rough size (phi -0.10 to phi -0.30) and very rough (phi -0.30 to -1.00) which signify the production of sedimentation behavior. The statistical analysis proved the weak regression relationship between TSS, TUR, river discharge (Q) and skewness caused by the anthropogenic factors and uncertain climate changes. The Agglomerative Hierarchical Clustering (AHC) enabled to group 29 monitoring sites into a few groups (sand mining area, industrial and development of socioeconomic, agricultural and farming, residential and domestic waste). The contributors of sedimentation problems from unsustainable land use and climate changes which are effectively trapping the bed sediments, backflow that carries out high sediments.

Keywords: *Terengganu River; Sedimentation; Gravimetric method; National Water Quality Standard (NWQS); Agglomerative Hierarchical Clustering (AHC).*

1. Introduction

River is one of important environmental sources which are highly valuable heritages that are unsurpassed. The river water continues to be able to sustain the needs of water for all human beings and other organisms in the world. The river water also plays as an important asset for economic resources, development and urbanization [1-3]. The municipal discharge, land use, eroded soils which are major factor of human activities around the Sungai Terengganu Catchment evaluating the quality and quantity of water bodies. It is highly recommended that erosion and sedimentation control measures be constructed at the appropriate areas before any commencement of development activity. There are many factors of environmental concerns affected by the detached, transported and deposited of sediment in the soil erosion process. The increasing of suspended sediment concentrations (SSC) deposited in drain and rivers will decrease the light penetration and photosynthesis process and increase the costs of water treatment and detract aesthetically of water body. The premature filling of impoundments and exertion of large Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) on the water triggered by deposition of sediment in water bodies. Sediment also acts as a transport through absorption caused more environmentally damaging pollutants. Sedimentation problems is contains of water pollutants were influences the health of the river. There are three main processes of formation of sediment were erosion, transport and deposition which are interact along the river basin from the upstream to downstream areas [4-6]. Terengganu River considered polluted when the composition or condition of its waters are directly or indirectly modified due to human activity such as residential development, domestic sewage, agricultural activities, industrial development, tourism and urbanization are among the major pollution sources influencing the in the equilibrium of the rivers.

2. Study Area

Terengganu River or Sungai Terengganu is the main river in the Terengganu which starting from Kenyir Dam, Hulu Terengganu and ending in Kuala Terengganu. 29 research stations that has been determined using DGPS which covered from downstream to upstream along Sungai Terengganu Catchment representing the length of the Sungai Terengganu (Table 1 and Figure 1). The samplings were carried out in January 2016 (Wet season) and July

2016 (Dry season). The primary data obtained from the field work and laboratory analysis. This research more focused on the analysis of sedimentation processes that occurred impact of anthropogenic, geomorphology and climate changes factors. The movement process of sediment is a main factor to the problems that occurred in the management of the river. Sungai Terengganu's ability will decrease which resulting geometric shape on the riverbed changes and eventually the floods can occur caused by sedimentation process. As the flood water receded, the lake water level dries out, reaching its lowest water levels in March to June. At this period, the water stays shallows with sedge-covered mud banks for up to six months until the rains came again. The climate of the equatorial climate of Peninsular Malaysia, which is characteristic by moderate average annual rainfall, temperature and humidity.

Table 1: Location of Research Stations at the Terengganu River, Terengganu

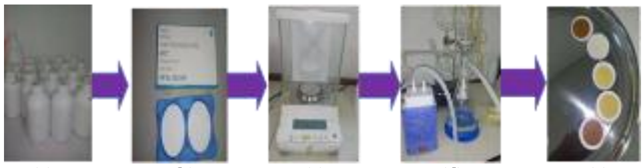
Sampling Stations	Latitude	Longitude
Station 1	5°20'23.93"N	103° 8'21.92"E
Station 2	5°19'26.55"N	103° 6'20.14"E
Station 3	5°19'40.59"N	103° 5'56.80"E
Station 4	5°18'48.53"N	103° 5'12.22"E
Station 5	5°18'32.74"N	103° 5'12.42"E
Station 6	5°17'7.75"N	103° 5'50.67"E
Station 7	5°16'14.99"N	103° 3'3.64"E
Station 8	5°13'9.00"N	103° 1'32.70"E
Station 9	5°12'42.04"N	103° 1'40.09"E
Station 10	5° 7'37.61"N	103° 2'9.46"E
Station 11	5° 4'8.14"N	103° 0'31.30"E
Station 12	5° 3'22.80"N	102°58'43.16"E
Station 13	5° 4'39.67"N	102°57'58.26"E
Station 14	5° 4'37.96"N	102°56'41.24"E
Station 15	5° 3'48.46"N	102°56'10.96"E
Station 16	5° 2'26.86"N	102°55'46.47"E
Station 17	5° 1'55.10"N	102°55'37.24"E
Station 18	5° 3'54.70"N	102°56'28.08"E
Station 19	5° 4'37.88"N	102°57'4.74"E
Station 20	5° 3'43.35"N	102°58'16.48"E
Station 21	5° 4'8.88"N	103° 0'8.50"E
Station 22	5° 4'31.96"N	103° 0'25.47"E
Station 23	5° 8'2.35"N	103° 2'21.33"E
Station 24	5°11'2.74"N	103° 2'35.85"E
Station 25	5°12'36.82"N	103° 1'50.56"E
Station 26	5°13'26.72"N	103° 2'21.83"E
Station 27	5°16'37.05"N	103° 4'38.05"E
Station 28	5°17'37.90"N	103° 5'29.09"E
Station 29	5°18'57.56"N	103° 5'27.17"E

Fig. 1: Map of Research Stations at the Terengganu River, Terengganu, Malaysia

3. Methodology

3.1. Laboratory Experiment

The Gravimetric method was used to analyse the Total Suspended Solid (TSS) which measured in mg/L. 250 m/L of water sample required for each research station. The measurement of TSS was carried out by weighing the membrane filters (0.45 µm diameter pores) (Figure 2). The disturbance of water flow had to be kept at a minimum error to avoid the measurement of deposition of suspended solids. In (1) showed the formula to calculate the TSS.



(a) (b) (c) (d) (e)

Fig. 2: a) Sample water b) Membrane filter c) Electronic weighing d) Filtration apparatus with vacuum pump e) Dried membrane filter

$$TSS\ (mg/L) = \frac{(WMAF - WMBF)\ mg \times 1000}{\text{Volume of filtered water (ml)}} \quad (1)$$

where WMAF = Weight of membrane filter after filtration and WMBF = Weight of membrane filter before filtration [5].

Nephelometer (HACH 2100Q Portable Turbidimeter) (Figure 3) used to monitor and measure turbidity parameter which reported in Nephelometric Turbidity Units (NTU) which is a measurement of the intensity of light being scattered when light is transmitted through a water sample. Turbidity consists of suspended material in water, causing cloudy appearance. The higher of turbidity will decrease the amount of sunlight able to penetrate the water and decrease the photosynthetic rate. The procedure according [7] following on the standard procedures provided by United States Environmental Protection Agency (USEPA) Methods; adjusting the nephelometer at 100 using 40 NTU. Then transfer the sample into the nephelometer tube. See to it that the sample did not contain any air bubble during measurement. Read out the value on the scale. If the sample processed an NTU greater than 40, dilute it using distilled water and repeat the procedure as described above.

Fig. 3: The measurement of turbidity parameter (turbidity meter) (*HACH 2100Q Portable Turbidimeter, USA*)

The sediment samples were collected using sediment scoops and sediment grab for each research station. There are three replicate samples were taken at each station (right, left and middle parts of river) (Figure 4a), the analysis of bed sediment grains size particle and texture deposited bottom sediment and riverbanks used to classify the type of sediment. The firstly is the drying process, the sediment was dried using room temperature (Figure 4b). After dry the sediments, the sediment will be crush using a mortar pestle (Figure 4c). Then the sample weighed with 100g using the electronic weighing to sieve for 10 until 15 minutes using mechanical shakers (Figure 4d). The size of trays used are 2mm, 0.25mm, 0.125mm, 0.63mm and 0.44mm (Figure 4e). The technique of analysis used follow the procedure of [8], the scale of size of sediment followed [9]. All the sediment samples will be classified by size and others characteristics. Then, the samples which have been alienated will be weighed using the electronic weighing (Figure 4f). The Udden-Wentworth Method and the Arithmetric ordinate graph with the x-axis scale unit of micrometer (um) and the y-axis is the cumulative percentage scale (0 to 100%) by a linear scale are applied.

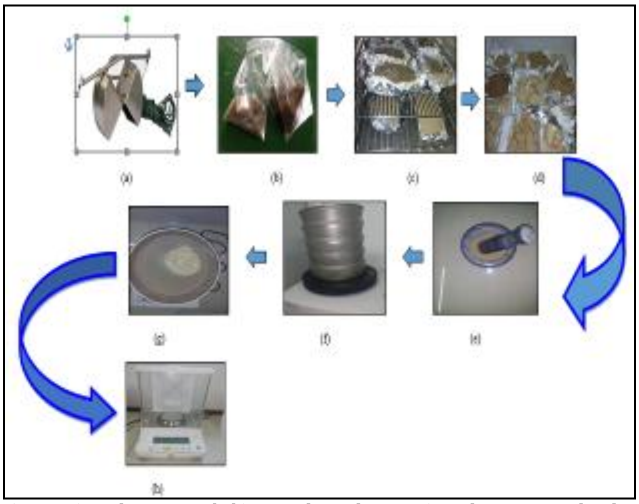


Fig. 4: a) Sediment Grab b) Sample Sediment c) Sediment was dried at room temperature (d) the dried sediment (e) Mortal pestle (f) Mechanical shakers (g) The sediment was sieved (h) The sediment will be weighed using the electronic weighing

3.2. In- Situ Analysis

The measurement of cross section of the river discharge (Q) which is product of velocity and cross section area (A). The cross section area is derived from the product of depth (d) and width (w) (Figure 5, in (2)-(4)).

Cross Section Area = $\sum$ A1 + A2 + A3 + A4.
$A1 = 1/2\ (L1 \times D1)$
$A2 = L2\ [(D1 + D2) / 2]$
$A3 = L3\ [(D2 + D3) / 2]$
$A4 = 1/2(L4 \times D3)$ (2)
River Discharge (Q)
$Q = vA$, atau $Q = ½\ vA$
$Q = m^3$ /second (3)
$Q = m^3$/second x 86400 second/day x 1000 L/m^3
= L/day (4)

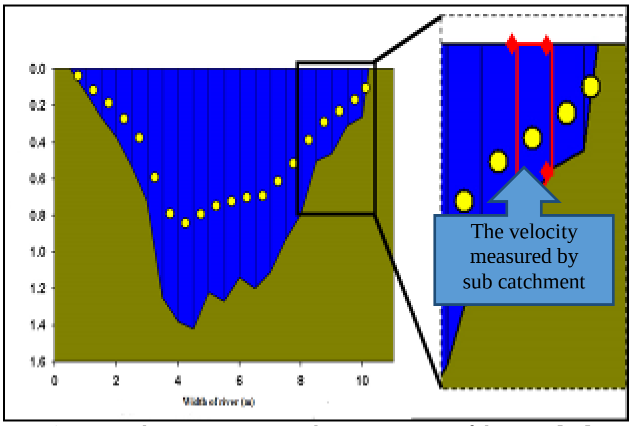


Fig. 5: Discharge measurement by cross section of the river [10]

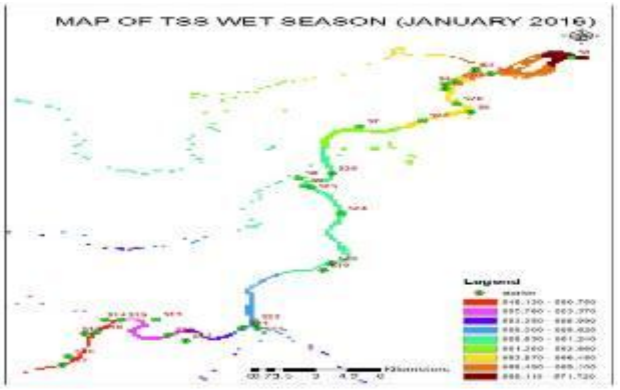
3.3. Statistical Analysis

The statistical analysis methods applied for the sedimentation problems and classification using Environmetric Method (Cluster Analysis (CA)). CA was employed to investigate the grouping of the distribution of sediment grains size for sampling sites (spatial) and determine the clustering group of generated based on similar characteristics and natural backgrounds of land use activities around Sungai Terengganu Catchment. The regression and correlation analysis used to identify the relationship characteristics between whole primary data set for dry season and wet season water quality level by excluding the less significant parameters with a minimum loss of original information. All data analysis was carried out using XLStat2014 and SPC XL licensed software for Microsoft Excel.

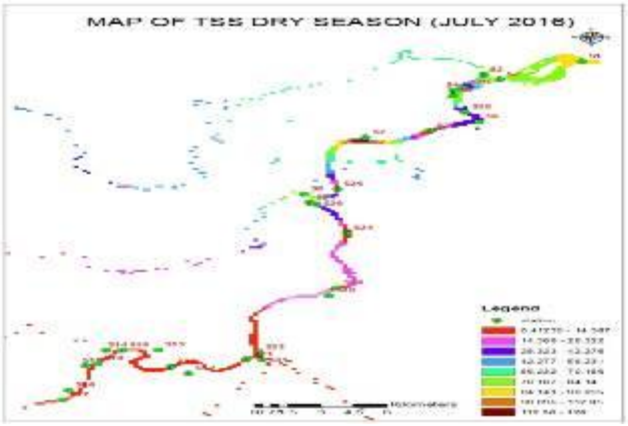
4. Results and Discussion

4.1. Descriptive Analysis

Basically, increased the value of Q will increased the production of TSS and TUR. Then, the intensity of rainfall, anthropogenic activities around the river basin, erosion, climate changes, geomorphology factors and other factors will affects the sediment production. The density of water in forest canopy is the main role towards reducing the surface erosion which contributes to sediment load in Terengganu River. TSS production and erosion rate will increase because the higher flow contains with strong energy to move the higher concentrated the suspended sediment load compared to the low flow level. TSS is one of indicator parameter to determine whether the status of water quality clean, moderately polluted or contaminated and to estimate the level of suspended sediment load. TSS classified the river in Class I, II, III, IV or Class V, based on the National Water Quality Standard (NWQS). The maximum and minimum distribution of TSS during wet season and dry season 0.4 mg/L ± 67.2 mg/L and 0.4 mg/L ± 128.2 mg/L respectively. The value of TSS on dry season showed higher range compared wet season Station 7 (middle stream) on dry season recorded the highest amount of TSS level compared the maximum amount during wet season effected by *El Nino* phenomenon on January 2016 [11].
The difference distribution of TSS at Terengganu River effected by the anthropogenic, geomorphology, climatology and hydrological cycle [12-15]. The stations at upstream of Sungai Terengganu showed the highest value of river discharge and stations at downstream indicated the lowest value. Based on hydrological theory proved the water velocity in the elevated upstream is higher than the downstream (Figure 6 (a) (b)). The excess water flows out of Lake Kenyir into the Terengganu River especially during the November until January. Then, the difference of the depth and width of the river will influence the flow rate value of the river. Relatively, there are natural hydrological correlations between the Q and TSS, river discharge rate is one of the main factor affected movement or concentration of TSS. Basically, the lower level of velocity, the higher amount of sediment production. The increasing the value of Q will increased the sediment deposition concentration. However, the frequency and intensity of rainfall, land use activities around the basin, climate changes, erosion and other factors will also affects the TSS production [6, 16-17]. The average turbidity concentration for all sampling stations on January 2016 (wet season), ± 0.4 NTU to ± 43.57 NTU. The range of distribution of TUR for July 2016 (dry season), ± 0.82 NTU to ± 21.57 NTU. The results showed the TUR distribution trends are the same as the TSS distribution trends, which are higher values in the downstream and middle - stream of the Sungai Terengganu Catchment than the upstream part (Figure 7).

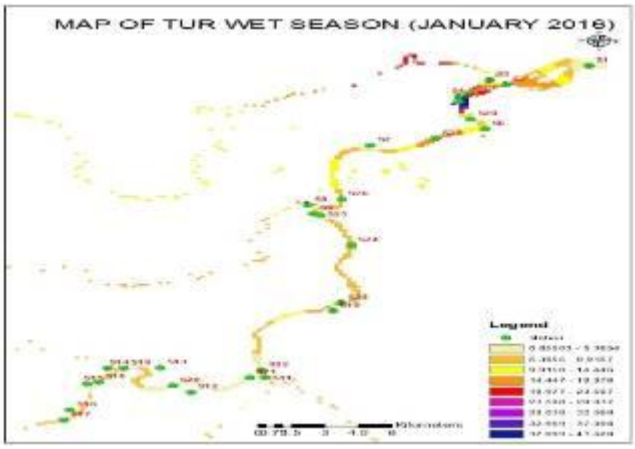


(a)

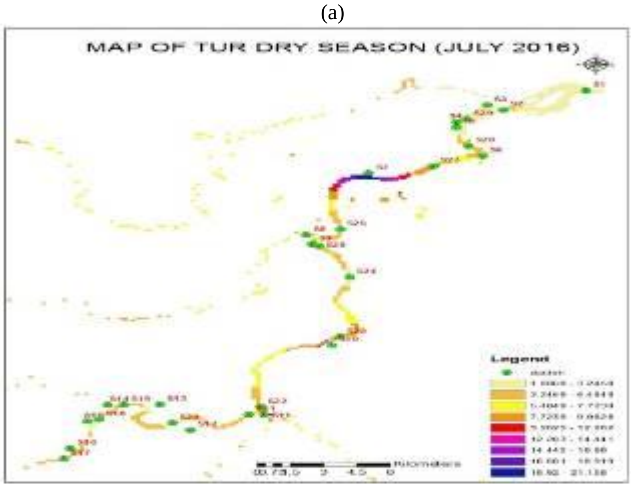


(b)

Fig. 6: Interpolation of Total Suspended Solid (mg/L) along Sungai Terengganu Catchment during (a) Wet Season and (b) Dry Season



(a)



(b)

Fig. 7: Interpolation of Turbidity (TUR) (NTU) along Sungai Terengganu Catchment during (a) Wet Season and (b) Dry Season

4.2. Statistical Analysis

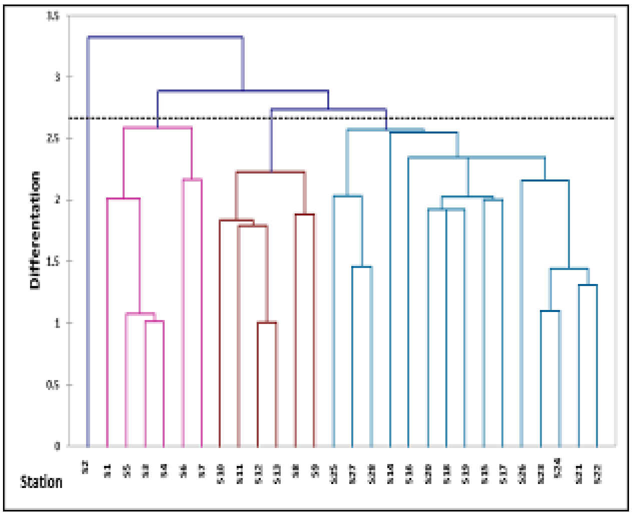
The dendogram of the locations of different sites along Sungai Terengganu applied for sediment gain size. It shows that the monitoring locations can be grouped into four clusters (Table 2, Table 3 and Figure 8 (a) (b))). Cluster 1 is formed by the sites S1, S3, S4, S5, S6 and S7 represents the very rough correspond to the high level of sedimentation problems. These station situated around the sand mining activities area which are from downstream until mid-stream, rural area of Sungai Terengganu Catchment. Cluster 2 (S2) represents the medium sediment grain size correspond to the medium level sedimentation problem sites. These stations lie in the industries and development of socioeconomics areas, closer into municipal pollution and land use activities such as construction and development. The cluster 3 (S8, S9, S10, S11, S12 and S13) represents the fine sediment grain, cluster 4 (S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28 and S29) represent the very fine sediment grains. These stations which are mostly downstream which correspond by agricultural and farming activities, urbanization areas, domestic sewage and residential. Water pollution in the urban areas mainly comes from municipal sewage system and strom-water drainage. Agriculture activities and orchard plantation contributed to the high amount of the organic pollutants and can be categorized as highly polluted area which proved by the value of TSS very high in these clustering areas at S7, S5, S6 and S8. From the result, the sediment size distribution very rough and coarse sediment needed higher flow energy at stations which nearby the sand mining activities. The clustering procedure generated four groups/clusters in a very convincing way, as the sites in these groups have similar characteristics and natural backgrounds. The main causes of sedimentation problems around the Sungai Terengganu Catchment is the uncontrolled land use activities such as sand mining project [1].

Table 2: Clustering of Station Based on the Sediment Grain Size in the Sungai Terengganu, Terengganu

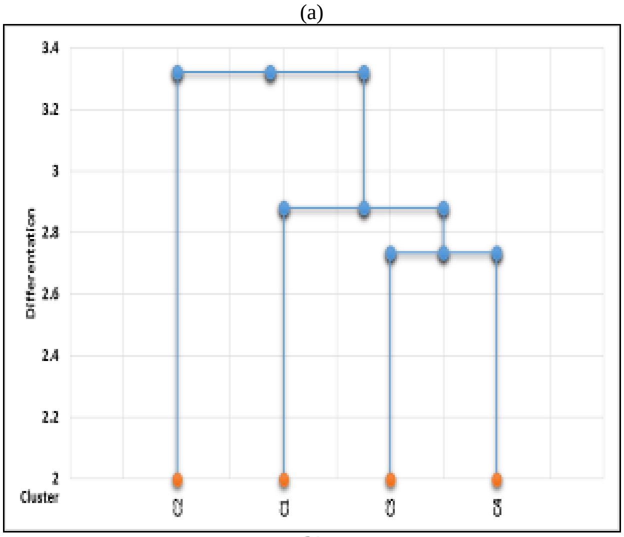
Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Median	-0.888	1.685	1.643	1.934
Mean	1.045 (Medium Grain)	1.416 (Medium Grain)	1.308 (Medium Grain)	2.261 (Fine Grain)
Standard Deviation	1.325 (Poorly Sorted)	0.801 (Moderately Sorted)	1.022 (Poorly Sorted)	0.811 (Moderately Sorted)
Skewness	0.914 (Medium)	-0.632 (Very Rough)	0.170 (Fine)	0.330 (Very Fine)
Kurtosis	2.636 (Very Leptokurtic)	3.659 (Extremely Leptokurtic)	2.885 (Very Leptokurtic)	3.731 (Extremely Leptokurtic)

Table 3: The Classification of Land Use Activities Based on Sediment Grains Distribution at Sungai Terengganu Catchment, Terengganu

Class Classification	Sampling Station
Class 1 (Sand Mining Area)	S1, S3, S4, S5, S6, S7
Class 2 (Industrial and Development of Socioeconomics Areas)	S2
Class 3 (Agricultural and Farming Areas)	S8, S9, S10, S11, S12, S13
Class 4 (Residential and Domestic Waste Areas)	S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29



(a)



(b)

Fig. 8 (a) (b): Dendrogram showing different clusters of sampling sites located on the Sungai Terengganu, Terengganu based on sediment grain size

Based on the results obtained, the value of $R^2 = 0.061$ (wet season) and $R^2 = 0.10$ (dry season) showed weak regression relationship between TSS and TUR uneven distribution trends at downstream compared middle and upper stream at Sungai Terengganu. According to [18], the relationship between TSS and TUR is likely to show different trends in the effects of water bodies and anthropogenic factors as well as geomorphological factors surrounding the study area. The distribution of TSS and TUR has a direct relationship but the relationship between the two parameters is not as strong as the effects of different land use activities in the study area and natural factors such as uncertain climate change, especially the *El Nino* phenomenon during the quarter of 2016 [13,16] (Table 4). The opposite relationship occurs during wet seasons effected by El Nino phenomenon during January 2016. In addition, the regression value between river discharge (Q) and TSS for both seasons $R^2 = 0.060$ and $R^2 = 0.002$ respectively which are weak and insignificant relation (Table 5). The increasing the sedimentation problems in a river basin could lead the increasing of the turbidity parameter and the odors of water. The values of Q at the Terengganu River is the primary factor that affected the sediment mobility. The increasing rate of water flow triggers the suspended sediment production. The rainfall intensity frequency affected the level of discharge and producing level of TSS. From this study proved the sedimentation problems in the Terengganu River not only caused by the flow rate of water but the other factors land use activities such as sand mining, agriculture, farming, tourism around the Terengganu River Basin were also contributed to the increasing levels of sediment [19-23].

Table 4: Regression Analysis of Total Suspended Solid (TSS), Turbidity (TUR) and River Discharge (Q) In Wet Season, Sungai Terengganu, Terengganu

Variables	Turbidity (TUR) (NTU)	River Discharge (m^3/s)
Total Suspended Solid (TSS) (mg/L)	0.061	0.060

Table 5: Regression Analysis of Total Suspended Solid (TSS), Turbidity (TUR) and River Discharge (Q) In Dry Season, Sungai Terengganu, Terengganu

Variables	Turbidity (TUR) (NTU)	River Discharge (m^3/s)
Total Suspended Solid (TSS) (mg/L)	0.100	0.002

5. Conclusion

This study showed the TSS and the sedimentation problems of the 29 stations in the Sungai Terengganu were unstable level and detected the main causes of this problem happened. From observation, the sedimentation occurs in Terengganu River caused by the geomorphology and anthropogenic factors such as sand mining and bank erosion along the river basin. The authorities and communities need to act as the responsibility person to cover the environmental issues by the prevention and conservation steps. This research can be to enlighten the public about the importance of the environment, especially rivers and lakes which are the necessary water resources in the world. The law enforcement is expected to be carried out especially to sand-mining activists around Terengganu River Basin. Terengganu River is a major river in this state that is directly connected to Kenyir Lake in Hulu Terengganu. If without control of the strategic will be disrupt the river and lake ecosystem in the long term and it will give a negative impact on the environmental, society and economics.

Acknowledgement

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