Estimating Turbidity and Total Suspended Solids to Measure Sediment Load in Kelantan River

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ABSTRACT
River-bed sedimentation occurs due to sequences of erosion, transport and depositional processes. The sediments input to the river can raise the flood levels and overload the river channel. The quantity of sediments transported by a river in a given section during time is composed of the suspended load and the bed load discharge. Nowadays, there are various invent to measure this load. One of that is study of variations in river water sample over time and then carries out filtration analysis to identify the total suspended solids (TSS) of the samples. The concentration of suspended solid (SS) is obtained by measuring the sediment quantity collected through the membrane filter. For TSS and Turbidity measurement, two sets of sampling were collected in before and after rain events corresponding with the month of February and March in the year 2013. The result shows the difference in the two sets of sampling and expressed the sediment input to the river for every rain event.

INTRODUCTION
The study area, Kota Bharu is located in Kelantan state lying at the east coast of Peninsular Malaysia with the latitudes 06°10’S and 05°55’S, and longitudes is 102°10’E and 102°20’E. The total land area of Kota Bharu is about 394 km² comprises of eleven different sub district.

Sediment Transport:
Surface flows is carrying along the sediment from upstream of the river which is in higher regions to downstream of the river which in the lower stream. Sediment transport can be defined as the quantity of sediments transported by waterway. The total amount of sediment transported every year around the world can be reached up to approximately 13,000 million metric tons which is equivalent to 86 million square kilometers [1]. The hydrological and erosive process not only depends on the watershed features but also on prior conditions together with the characteristics of rainfall event. For example, in semi-arid watershed in Southeastern Spain (Lanjaron), the runoff was highly variable with an average of 97.6 mm year⁻¹ and the sediment yields were ranging about 1.8 Mg ha⁻¹ year⁻¹ [2].

Sedimentation is a process of accumulation of sediment in the river resulting from the process of erosion at the land area. Sedimentation of river beds and deforestation of water catchments areas can exacerbate conditions leading to river valley floods. The process of sedimentation are mainly causes by factor such as erosion at the river banks. The erosion is controlled by two categories which is human activities and natural factors. Human activities that leads to soil erosion including poor landuse, construction, reclamation, and also urbanization. While the natural factors that effect soil erosion such as meteorology, topography, geology, composition of the Earth surface and vegetation cover.

Sedimentation in Kelantan Delta is ubiquitous, resulting in the growth of the existing island and the formation of more mudflats which subsequently form large islands. The silting of the lagoon has caused an enroachement of the land over the sea over a distance of 2.8 km between 1939 and 1966. Compared to the growth of other deltas in Asia, Kelantan Delta has a relatively faster average rate which estimated to be around 104.0 meter/year. It is due to the factor of climatIt is due to the factor of climatic differences, size and shape of the


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basin and the morphometry of the area which greatly influence the amount of material supplied through the process of transportation and deposition. [3].

**Description of Kelantan River:**
Kelantan River is the main river channel in Kota Bharu which occupies approximately 12,700km² or 85% of the state. Other major river is Pengkalan Datu River, Kemasin River and Semerak River. The platform of Kelantan River is floodplain. The bedrock cropping out in the Central Ranges and lying beneath the river basin comprises granites, metamorphic rocks, and minor tuff of Paleozoic identified as phyllite. The bedrock underlying the basin in the study area to the east of the Kelantan River mainly consists of granite but changing to phyllite towards the opposite west. Phyllite and other metamorphosed sediments are fine grained and mostly weathered to clay and silt. Some siliceous metamorphic rocks such as schist, and quartzite are hard rocks that give rise to sand and gravel detritus [4].

**MATERIAL AND METHOD**

**River water sampling:**
Eight site on the downstream of the Kelantan river were randomly chosen for the sampling based on few criteria including site accessibility which is along the upstream to downstream which is from Kemubu to Kuala Besar (L1 to L8). Two sets of sampling that is ‘before rain’ and ‘after rain’ was carried out at approximately the same location on 20 February 2013 and 19 March 2013.

**Laboratory Test:**
The river samples were taken to the laboratory for turbidity and total suspended solids (TSS) measurement. Turbidity is measured by using a turbidity meter which measures the amount of light that is scattered at 90° angle to the incident beam, and is usually stated in units of NTU (nephelometric turbidity units). While TSS was measured using filtration method according to the most common standard which is American Society for Testing & Material [5]. The porcelain with membrane cellulose filter was dried at 103°C to remove the water vapours. A well shaken 25ml of each river water sample was filtered through membrane cellulose filter with pore size of 0.22µm using vacuum filter pump. The filter paper was then dried in 103°C oven for 60 minutes and after that the sample was transferred to dessicator for another 60 minutes to avoid water vapours absorption from surrounding environment. The TSS reading was measured by the difference between the total mass of
dried porcelain crucible, membrane filter and its filtrate and the empty dry crucible with membrane filter over the volume of 25 ml river water sample [1].

**Statistical Analysis:**

The laboratory test data was statistically analyzed to generate location-wise concentration graphs. Statistical analyses were used in this study to identify the significance of correlation between Turbidity & Total Suspended Solids (TSS).

**RESULTS AND DISCUSSION**

The turbidity and TSS concentrations for two sets of sampling show different values. The average turbidity in ‘after rain’ samples differs by being 6 times higher than ‘before rain’ values. The average TSS concentrations in after rain samples are 1.5 times higher than TSS in before rain samples. Pattern in graph which is the highest location recorded the highest in TSS concentration also recorded the highest in turbidity. For example in location 8 (L8), the data recorded for TSS is 55.84 mg/L and turbidity is 736 NTU for sampling ‘after rain’ while in set of sampling ‘after rain’ shows TSS 34.64 mg/L while turbidity is 98 NTU.

**Table 1:** Data collected for Turbidity and TSS “before rain” and “after rain”.

<table>
<thead>
<tr>
<th>Sampling Location</th>
<th>Turbidity (NTU)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before rain</td>
<td>After rain</td>
</tr>
<tr>
<td>L1</td>
<td>89</td>
<td>374</td>
</tr>
<tr>
<td>L2</td>
<td>82</td>
<td>392</td>
</tr>
<tr>
<td>L3</td>
<td>90</td>
<td>553</td>
</tr>
<tr>
<td>L4</td>
<td>55</td>
<td>413</td>
</tr>
<tr>
<td>L5</td>
<td>75</td>
<td>519</td>
</tr>
<tr>
<td>L6</td>
<td>61</td>
<td>409</td>
</tr>
<tr>
<td>L7</td>
<td>79</td>
<td>415</td>
</tr>
<tr>
<td>L8</td>
<td>98</td>
<td>736</td>
</tr>
</tbody>
</table>

Fig. 2: Turbidity estimates in ‘before rain’ and ‘after rain’ samples.

A comparative distribution of Turbidity in two data sets can be inferred from Figure 1. The turbidity measures show similar trends except at the location L2 and L8.

Likewise, spatial distribution of TSS is presented in Figure 2. A comparative assessment between data set can be made. The TSS estimates show similar trend of occurrence with the exception at the location L2, L4 and L8.

The highest value of turbidity was recorded at location 8 (L8) for ‘before rain’ and ‘after rain’. L8 also shows highest value in TSS concentration where the value is 55.84 mg/L and turbidity is 736 NTU for sampling ‘after rain’ while in set of sampling ‘after rain’ shows TSS 34.64 mg/L while turbidity is 98 NTU. It located at the downstream of the river which is near to South China Sea. The possible reason is that maybe the sediment was accumulated there before flush into the sea.

While the lowest value of turbidity and TSS concentration was recorded at Location 4 (L4) where it only recorded 55 NTU for sampling ‘before rain’ and 413 NTU for sampling ‘after rain’. TSS concentration for L4 shows the value of 14.24 mg/L for sampling ‘before rain’ and 22.64 mg/L for sampling ‘after rain’. L4 sample were collected near Sultan Yahya Petra Bridge which is still on construction. The lowest value of turbidity and TSS concentration is maybe due to the construction process where the river sediment is taken out to insert the pile steel of the bridge. It will decrease the amount of sediment there.

The readings recorded for sample in location 2 (L2) also showing different trend in turbidity pattern where the value of turbidity before rain is decreasing from L1 and the value of the same location after rain is increasing from L1. It maybe because before rain event, the sediment particle is already settling down while after rain...
sample was taken a few days after rainfall event and the sediment particle is still on suspended on the surface and that why the value after rain is increasing.

![Fig. 3: TSS estimates in 'before rain' and 'after rain' samples.](image)

**Table 2:** Data calculation for obtaining TSS “before rain” and “after rain”.

<table>
<thead>
<tr>
<th>Sampling Location</th>
<th>Before rain</th>
<th>After rain</th>
<th>A - B</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>24.80</td>
<td>34.96</td>
<td>10.16</td>
<td>17.6</td>
</tr>
<tr>
<td>L2</td>
<td>21.60</td>
<td>41.20</td>
<td>19.6</td>
<td>31.21</td>
</tr>
<tr>
<td>L3</td>
<td>25.28</td>
<td>45.44</td>
<td>20.16</td>
<td>28.51</td>
</tr>
<tr>
<td>L4</td>
<td>14.24</td>
<td>22.64</td>
<td>8.4</td>
<td>22.76</td>
</tr>
<tr>
<td>L5</td>
<td>25.68</td>
<td>43.68</td>
<td>18.00</td>
<td>25.95</td>
</tr>
<tr>
<td>L6</td>
<td>18.40</td>
<td>21.04</td>
<td>2.64</td>
<td>6.69</td>
</tr>
<tr>
<td>L7</td>
<td>28.08</td>
<td>37.04</td>
<td>8.96</td>
<td>13.76</td>
</tr>
<tr>
<td>L8</td>
<td>34.64</td>
<td>55.84</td>
<td>21.2</td>
<td>23.43</td>
</tr>
</tbody>
</table>

*A = After rain
B = Before rain

The data in Table 2 shows difference in TSS concentration in two set of sampling. There are various amounts in difference between the two data set where the highest TSS in percentage is Location 7 with 31.21% of difference while Location 4 shows the lowest difference in TSS percentage with 6.69%.

**Statistical Analysis:**

The analysis of correlation was conducted for two sets of data which is ‘before rain’ and ‘after rain’. The correlation test was used to analyze the strength and direction of relationship between two variables. Correlation can be define as the number between -1.0 and +1.0 where the positive number indicates the prefect positive relationship between the two variables while the negative correlation indicates the perfect negative relationship between the variables. Zero correlation indicates that no linear relationship at all between the variables. The closer to +1.0 or -1.0, the stronger the relationship, whereas the closer to 0, the weaker the relationship is [6].

**Table 3:** Correlation between TSS (mg/L) and Turbidity (NTU) “before rain”.

<table>
<thead>
<tr>
<th>TSS</th>
<th>Turbidity</th>
<th>r value</th>
<th>&quot;Sig&quot;</th>
<th>r/v/s e r/ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>860</td>
<td>.006</td>
<td>.006</td>
<td>.006</td>
<td></td>
</tr>
</tbody>
</table>

Bivariate Correlation test was used.

![Fig. 4: Correlation between TSS (mg/L) and Turbidity (NTU) “before rain”.](image)
Table 3 shows the results for “before rain” sets of sampling. The value of “Sig” is less than 0.05 which means that the $H_0$ is rejected and $H_1$ accepted. It indicates that the correlation test shows that the correlation is statistically significant. The correlation test also shows positive relationship between turbidity and TSS concentration which means that Turbidity value increased with TSS concentration value.

The data plotted in Fig. 3 also shows a strong positive correlation between TSS concentration and turbidity “before rain” with correlation coefficient of $R^2$ of 0.9849.

Table 4: Correlation between TSS (mg/L) and Turbidity (NTU) “after rain”.

<table>
<thead>
<tr>
<th>TSS</th>
<th>Turbidity</th>
<th>r value</th>
<th>“Sig”</th>
<th>+ve/-ve r/ship</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>.764</td>
<td>.027</td>
<td>+ve</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed).

Table 4 shows the results for “after rain” sets of sampling. The value of “Sig” is less than 0.05 which means that the $H_0$ is rejected and $H_1$ accepted. It indicates that the correlation test shows that the correlation is statistically significant. The correlation test also shows positive relationship between turbidity and TSS concentration which means that Turbidity value increased with TSS concentration value.

The data plotted in Fig. 4 also shows a strong positive correlation between TSS concentration and turbidity “before rain” with correlation coefficient of $R^2$ of 0.9676.

Conclusion:

The river water sample for two sets of sampling which was ‘before rain’ and ‘after rain’ shows different value where the average turbidity in ‘after rain’ samples increase 6 times higher than ‘before rain’ samples. While TSS samples ‘after rain’ shows increasing by 1.5 times higher than TSS ‘before rain’. The correlation analysis conducted also shows strong positive relationship between Turbidity and TSS concentration for both sets of sampling.

Fig. 5: Correlation between TSS (mg/L) and Turbidity (NTU) “after rain”.

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