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Determination of Total Organic Carbon Concentration in Surficial Sediments of Sungai Juru and Sungai Tengah, Penang, Malaysia

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Abstract: According to Malaysia Environment Report 2013, Sungai Juru was categorized as a polluted river based on water quality analysis. Urban surficial sediments of Sungai Juru and Sungai Tengah in Penang were collected for determination of the concentration of Total Organic Carbon (TOC) and type of sediment. From the finding of sediment texture (%), most of sampling stations in both rivers were categorized as silt. On one hand, the correlation relationship of TOC and mean size sediment of Sungai Juru and Sungai Tengah was accounted for$r$=0.28 and r=0.61 respectively. This was probably showing that both rivers have different controlling factors that affect the TOC content in surficial sediment. The highest of TOC concentration in Sungai Juru was 4.64% at station J1 which located at upper catchment of rivers. The concentration was then level off at river mouth (1.34%-1.83%). Anthropogenic waste might play the dominant role in TOC enrichment at Sungai Juru. Compare with Sungai Tengah, strong positive correlation between TOC and mean size sedimentwas demonstrated, it indicates that mean grain size was possibly the important controlling factor had influences the TOC level in surficial sediment.

Key words: Total Organic Carbon · Mean Size Sediment · Surficial Sediments · Sungai Juru · Sungai Tengah

INTRODUCTION

Determination of total organic carbon (TOC) in surficial sediment has been carried out widely by researchers as chemical sediment quality measurements [1]. This is because TOC is playing important roles in controlling concentration of other components [2]. It have been reported that distribution of inorganic and organic chemical compounds on sediment includingmercury and polycyclic aromatic hydrocarbons (PAHs) respectively was influenced by content of TOC [3, 4]. Apart from the sources of TOC are contributed from living organisms via natural process, the major anthropogenic sources of TOC in aquatic environment are come from chemical wastes effluent and fertilizer [5].

Surficial sediment was used as medium for analysis of TOC content in present research study as it interacts with bottom of water column and undergoes different ways of sorption process. In addition, sediments have been described as storage, reservoir and sink of chemical compounds [6, 7]. It accumulates all the substances that have been settle down on the bottom of water column, including particulate organic carbon (POC) and sediment particles which are attached with OC substance [8]. Moreover, contaminated of surficial sediment might pose health risks and toxic to living organisms at higher trophic level because surficial sediment is a habitat for most of benthos in aquatic environment [9]. Some of benthic organismsfor instances blood cockle (*Anadaragranosa)* is theone of the favourite seafood and also important income for local fisheries at Sungai Juru [10]. Furthermore, according to Malaysia Environmental Report 2013 [11], the water quality of Sungai Juru was categorised as polluted. Apart from that, up to date, analysis of sediment in Sungai Tengah has not yet been reported.

In the light of these reasons, the research of determination concentration of TOC in surficial sediment at Sungai Juru (Sg. Juru) and Sungai Tengah (Sg. Tengah) became a necessity as the finding of present studycan be

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used as baseline in the assessment. In addition, thepresent study also reveals the relationship between TOC (%) and mean size sediment (□).

MATERIALS AND METHOD

Figure 1 and 2 shows the sampling locations of Sungai Juru and Sungai Tengahrespectively inthe present research study. It located at SeberangPerai (Province Wellesley) in Penang.The present research study was carried out in July 2015 with totals 52 sampling stations which were deployed. There were27 and 25 of sampling stations were deployed atSgJuruand Sg Tengah respectively with about 300m interval in order not to miss any hotspot that might have extreme level of TOC in surficial sediments.

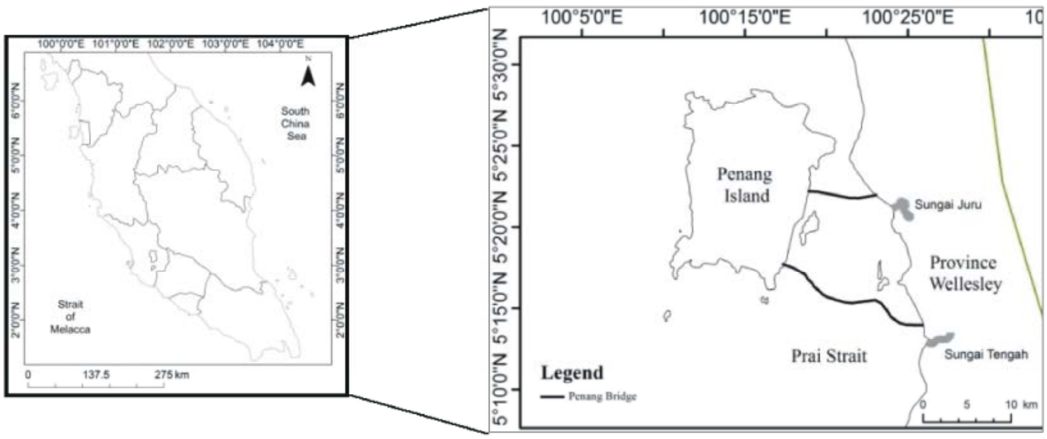

Fig. 1: Sampling locations were conducted at the mainland of Penang which located at Northeast of Peninsular Malaysia.

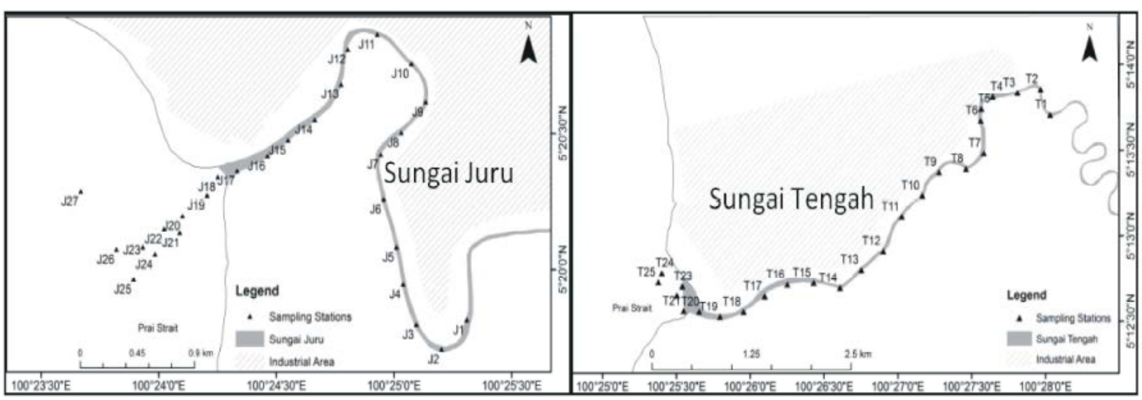

Fig. 2: Total 52 sampling locations were carrying out along the Sungai Juru (on the left) and Sungai Tengah (one the right).

All reusable apparatus were cleaned with phosphate-free detergent solution. Then, the apparatus including plastic spoon and polythene bags were soaked in 10% of nitric acid overnight and rinse with distilled water for sampling preparation activity. PONAR grab was used for collecting about 10.0 cm surficial sediments [12]. Precaution was taken to make sure the grab is firmly closed to ensure maximum preservation of the fine sediments samples in order to maintain the accuracy in the reading for the sediment grain size fractions. Actual coordinates of sampling stations was recorded by using Global Positioning System (GPS).

Sediments samples were then transferred into 2 plastic bags without air and kept at low temperature in an ice-box during sampling to minimize the chemical and biological reaction [13].

The sediment samples were then proceeded to TOC and grain size sediment analysis.

Total Organic Analysis (TOC): For TOC analysis preparation, sample ceramic boats were cleaned with scraper and soaked with 2 to 3 M of Hydrochloric acid (HCL) for 10 minutes. The samples ceramic boats were then rinsed with distilled water and transferred to furnace.

The purpose of heating ceramic boats under 900°C for 2 hours is to remove the carbon residue that attached on its surface. For the next step, a total 0.025g of dried sediments samples were weighed and transferred into two samples boats for Total Carbon (TC) and Inorganic Carbon (IC) analysis by using TOC Analyzer -SSM-5000A (Shimadzu). For TCanalysis, sediment samples went through combustion catalytic oxidation under 900°C [14]. Values of IC were obtained after the sediment samples wasacidified using phosphoric acid and heated under 200°C [14].

Grain Size Sediment Analysis: wo different methods were used forparticle size analysis which are dry sieve method and laser diffraction method for fine and coarse fraction analysis. For dry sieving method, about 200g of dried sediments were shaken by using Sieves and Shaker with 14 different mesh size sieves for 10 minutes with 5 minute interval [15]. The sieves were arranged consecutively downward from larger mesh size to fine sizes as follows: 4000µm, 2800µm, 2000µm, 1400µm, 1000µm, 710µm, 500µm, 355µm, 250µm, 180µm, 125 µm, 90µm, 63µm and < 63µm. The reading of weight of sediments thatretained on in each sieve was recorded. The weight percentage readings were proceeded to calculate the statistical data of mean grain size.

For laser diffraction method, about 1.5g of sediment samples was diluted with distilled water in a 100 mL beaker. Volume 20% of Calgon (Sodium hexametaphosphate) solution was added into the sediments samples to disperse bonded particle sediments and it has been widely accepted to sedimentologists [16 & 17]. The grain size of fine sediments was then analysed by using Laser Diffraction CILAS 1180PSA and the unit for reading is in volume percentage.

Data Analysis: Value of TOC (%) was calculated by subtracting the content of IC from the total content of TC in surficial sample (TOC= TC-IC) [14].

For grain size sediment analysis, the unit of diameter size of each fraction was converted into phi (□) reported by Krumbein (1934) and it was convenient in data comparison. The reading of weight and volume percentage from coarse fraction analysis and fine fraction analysis respectively were then employed to logarithmical moment method to calculate the mean size sediments [18]. Mean value can be computed by a moment method, as shown below:

$$\text{phi}\ (\varnothing) = -\log_2 d \qquad (1)$$

where, d = size of diameter in each fraction (mm)

$$\text{Mean}\ (x\,\varnothing) = \frac{\sum fm}{n} \qquad (2)$$

where, f = percentage weigh of each grade of particle size (%)

m = midpoint of each class boundaries in phi (*Ø*)
n = total number of sample in 100 when f=%

Correlation coefficient was applied to elucidate the relationship between the concentration of TOC and sediment grain size.

RESULTS AND DISCUSSION

The distribution concentration of the TOC in surficial sediments at Sg.Juru and Sg. Tengah were as shown in Figure 3 and 4 respectively. The results of determination of TOC content was expressed as percentage of dry sediments. Overall, the mean level of TOC was accounted for 2.06% and 1.62% in Sg. Juru and Sg. Tengah respectively.

The trend of TOC (%) in surficial sediments shows fluctuation at the upper catchment of Sg.Juru. The highest enrichment of TOC was found at J1, 4.64% and it slumped to 1.65% at J2. The concentration of TOC was then raisedto the third highest concentration of TOC which accounted for 3.54% at J5, followed by a sharp drop at J7, 0.21%. The trend was thenfollowed by an upswing as itsurgedtoward the second highest of TOC which accounted for 4.38% at J9. Except J15, thepattern of distribution of TOCexhibiteda decreasinggradually from J9 to J13, 2.80% to 2.01% respectively. The changing trend was thenremained stable within 1.34%-1.83% from J14 to J27 in down reaches of the rivers. At J15, it showed significant enrichment in TOC which accounted for 3.20%. Mangrove was observed along the river. Debris was grabbed several times during the sampling activities at upper catchment of the river at station J2, J4, J5 and J13. Additionally, fishing boat parking was found at J3, J6, J9 and J15.

As shown in Figure 4, the changing trend of TOC enrichment in surficial sediments along Sg. Tengah was consistent. The highest level of TOC (%) at Sg. Tengah is almost half of the highest TOC content at Sg. Juru. The highest content of TOC at Sg. Tengahwas observed at T8, 2.37%.The trend was then elevatedmoderately from T13, 1.27% till T16, 2.06%. Toward the river mouth, the trend wasfollowed by a consistent decrease till to T20, 1.43%. The lowest concentration of TOC was located at the river mouth, T25 which accounted for 0.53%. Debris was observed at the surface water of T3-T6 and fishing boat parking can be found at between of T13 and T14. Bridge was observed nearby T12 and mangrove was found along the river.

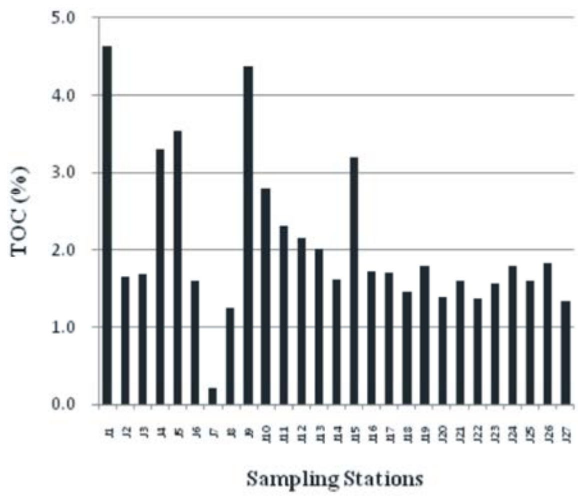

Fig. 3: Concentration of TOC (%) in surficial sediment at Sungai Juru, Penang.

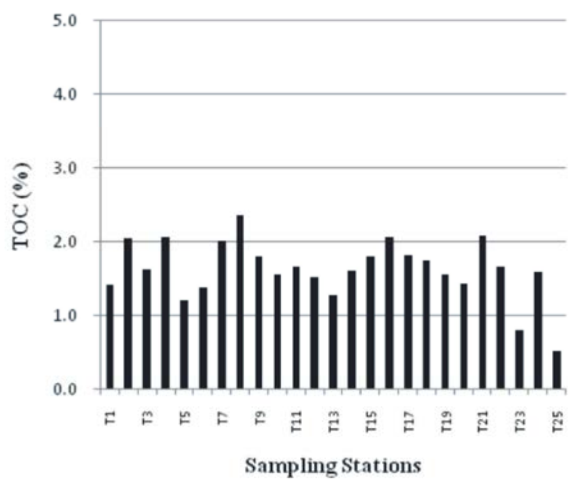

Fig. 4: Concentration of TOC (%) in surficial sediment at Sungai Tengah, Penang.

Except J7, J9, T21, T23 and T25, the other stations have above 80% of sediment texture were containing silt and clay (<63 µm) as is shown in Figure 5 and 6 at Sg. Juru and Sg. Tengah respectively. The high portion of sand located atJ7 and J9 were accounted for 99.8% and 32.2% respectively. On one hand, as shown in Figure 6, estuary at Sg Tengah tended to have higher percentageof sand texture which was accounted for 22.8, 30.99 and 81.54% at T21, T23 and T25 respectively. In general, the mean of silt in sediment texture was 82.46% and 82.97% for Sg. Juru and Sg. Tengah respectively.Sediment texture analysis showed that more than 90% of total sampling stations were predominated by silt and clay-grain sediment. Out of 52 sampling stations, 47 sampling locations had fine-grain (<63µm) content higher than 80%.

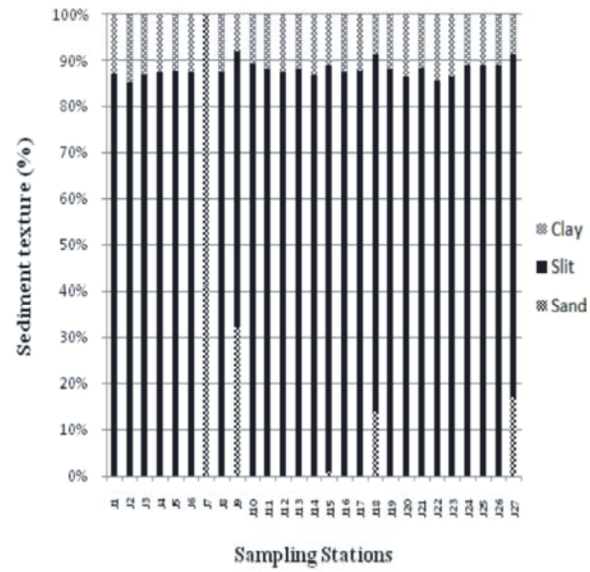

Fig. 5: Sediments texture (%) in surficial sediments of Sungai Juru, Penang.

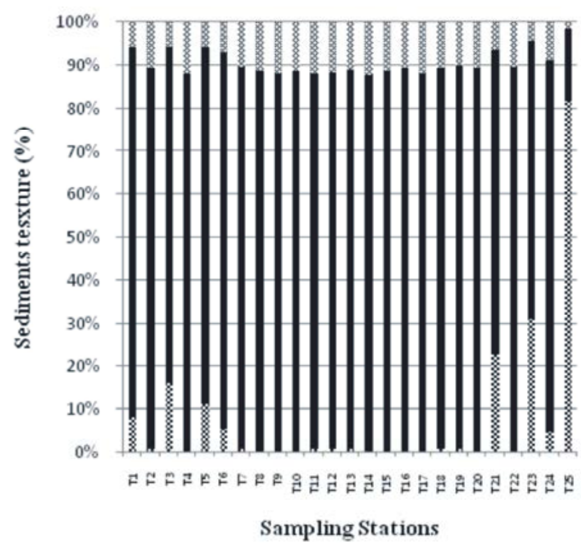

Fig. 6: Sediments texture (%) in surficial sediments of Sungai Tengah, Penang.

Correlation relationship of TOC and mean size sediment of Sg. Juru and Sg. Tengah was accounted for r=0.28 and r=0.61 respectively. Figure 7 showed an outlier point and it indicates that low mean size of sediments have low concentration in TOC (%)in surficial sediments.

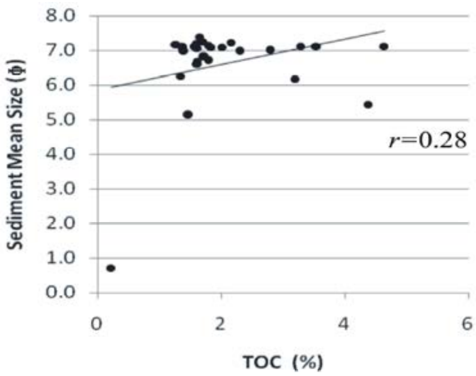

Fig. 7: Correlation between TOC (%) and mean sediments size (□) in surficial sediments of Sungai Juru, Penang.

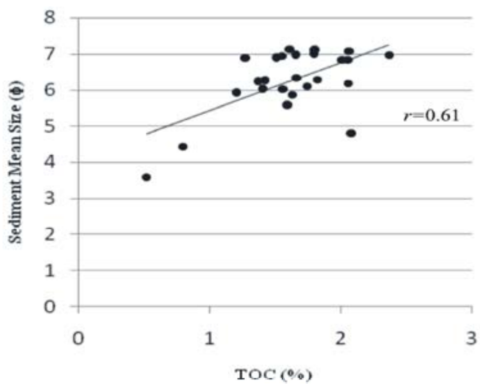

Fig. 8: Correlation between TOC (%) and mean sediments size (□) in surficial sediments of Sungai Tengah, Penang.

The concentration of TOC in surficial sediments at. Juru with average 2.06% (range 0.21% - 4.64%) is higher than Sg. Tengah with average 1.62% (range 0.53% – 2.37%). Both are comparable to Klang river, Malaysia (0.19% - 4.5%) and Han River Estuary, Korea (0.11% - 3.49%) [19,20].Most of the area ofSgJuru and Sg. Tengah are surrounded with mangrove and the enrichment of organic mattersin sediments maycome from decomposition of plant and animal as well as living and dead microorganismvia bacterial action [2]. In addition, the significant high content of TOC was found nearby boat parking and area that has plenty of debris observed probably due to the waste discharged fromthe boat activities and urban area. It is supported by theresearch study of Naji and Ahmad [19], as the highest of TOC in sediment in Klang River was also obtained at the local fishing activities and the medium enrichment of TOC was from industrial and urban area.Apart from that, the high enrichment of TOC also can be observed at the upper catchment at Han River Estuary, Koreaand suggested that it indicates there are high organic matters loaded from industrial and urban area [20].

The highest concentration of TOC was found at the first sampling points, J1 as shown in Figure 3. According to the research study done by Zali *et al*. [21], reported that high concentration of metal As and low dissolve oxygen (DO) in river water quality were found surrounding at J1. Owing to metal As was utilized for wood preservation, therefore, the high possible sources of TOC enrichment may be contributed from timber and wood industry [21]. Apart from that, the enrichment of TOC (%) in sediments at J1 was 2 fold higher than theSg. Tengah. The continuous deposit of organic matterswas probably the combination of terrestrial, dead organisms, urban runoff and untreated waste discharged from the tributaries which surrounded with resident and industrial area at the upper catchment of Sg. Juru[2,21].Additionally, the pollution load of TOC might be theanthropogenic waste that discharged from Prai industrial area. This is because inorganic contaminants in surficial sediment at estuary of Sg.Juru have been examined and pointed out the sources was mostly come from various industrial activities for instances paper and metal manufacturer as well as chemical or fertilizers factory [22, 23].

Grain size sediment is playing important roles as fine sediments providing larger surface area to volume ratio, thus it has high capacity to adsorb TOC [13,19]. In Figure 6 was exhibited a decreasing gradually for silt and clay sediment texture at the river mouth of Sg. Tengah. It shared the similar pattern of distribution for TOC as shown in Figure 4. It is suggesting that declining of TOC level maybe due to have higher hydrodynamic condition at estuary [13]. As a consequence, sediments being suspended in water column to have less time to sink and re-deposition at the bottom [13].

Apart from that, according to the research of Idris and Ahmad [24], the trend of enrichment of organic matter (%) in surficial sediments at Sg.Juruwas shown increasing from the sampling area around J2 to J21 with 5 stations interval points. The finding was partiallyin agreement with present study, the pattern of TOC distribution exhibited anincreasing from J2 to J5 and from J7 to J9 as shown in Figure 3. However, a decreasewas observed from J9 to J13 and followed by a level off from J14 to J21 in river mouth.From this point, fine sediments may not be the major controlling factor for the concentration of TOC at river mouth. The decreasing trend of TOC may imply a tidal intrusion which plays dominant roles in prevention the pollutant load in sediments from outflowing seaward [25]. Toriman *et al*. [25] have reported that tidal influence can extended upstream more than 13km from estuary and make an assumption that Sg. Juru may not be the potential channel in transportation of contaminants to coastal area.

Blood cockle and green mussel are living in sediments and it has a high risk to uptake of the inorganic pollutants from sediments [10, 24]. The concentration of heavy metals (Pb, Zn, Cd and Cu) in blood cockle (*Anadaragranosa*) and green mussel (*Pernavirdis*) werereported to have high value in Hazard Quotient and it may possibly causeadverse impacts on aquatic organisms [10]. The TOC in surficial sediments could become carrier of inorganic pollutants. The previous studies have showed positive correlation between heavy metals and TOC in surficial sediments [13,19,24]. Organic matter including humic materials have act as scavenger which increase the magnitude of adsorption and complex influence on re-deposition of inorganic pollutants [13,26]. Therefore, the amount of TOC in surficial sediment may regulate the content of inorganic pollutants and eventually affects the metal bioavailability in living organisms [13,27].

However, no significant correlation were found between TOC and mean size sediment at Sg. Juru, r=0.28 as shown in Figure 7. This might indicate there is a minor influence of grain size on the TOC. The concentration of TOC probably affected by other controlling factors and contributed with different anthropogenic or natural sources [7]. This finding was correlated with the results of previous research studies done by Idris and Ahmad [24], which reported that some of stations havinglarger grain size of sediments were enriched with organic matters. This phenomenon can be observed from the surficial sediments at J9 which has high portion of sand texture together with the second highest content of TOC.

On the other hand, Figure 8 demonstratessignificant strong relationship (r=0.61) of TOC toward to fine sediments size at Sg. Tengah. This similar phenomenon can be found at Pearl River Estuary, China [28]. This suggests that TOC content was influenced by grain size to a certain extent [26]. The finesediments probablywas the dominant factor in controlling the enrichment of TOC in surficial sediments at Sg. Tengah [26,28]. This is because fine sediments had provided larger specific surface area and binding sites which allows TOC absorption [13].

In conclusion, grain size sediment might not be the dominant controlling factor that influences the content of TOC in surficial sediment at Sg.Juru. On the other hand, grain size sediment in Sg. Tengah has shown positive correlation with concentration of TOC in surficial sediments.

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