PHYSICO-CHEMICAL AND SEDIMENT CHARACTERISTICS OF THE BOTTOM SEDIMENT OF TERENGGANU RIVER, TERENGGANU, MALAYSIA

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A comprehensive study on the geochemistry and sediment characteristics of the sediment of Terengganu River was carried out in order to understand the effects of development and the pollution status of the river. The factors investigated were salinity, temperature, pH, sedimentology, organic carbon, metal concentrations and sedimentation rate. Sampling activities were conducted from May, 2002 to April, 2003 during the non-monsoon and monsoon season. Studies were carried out at 40 stations along the Terengganu River investigating physical parameters, sedimentology, heavy metals, and organic carbon (OC). Two core samples were collected in order to determine sedimentation rates.

The vertical profile of the physical parameters of salinity, temperature and pH were obtained by using the Hydrolab (Datasonde 3) apparatus. Generally, during non-monsoon seasons, the estuary was dominated by saline water ; and freshwater prevailed during the monsoon seasons. The temperature throughout the waters column

was quite uniforms even identical at times, while salinity was related to pH. Based on the salinity distribution and profile, the estuary can be classified as a partially mixed estuary.

Meanwhile, study of the impact of highest tide of decade (HTOD) phenomena on salinity, pH and temperature was carried out in the Terengganu River Estuarine System on October, 8, 2002. In general, salinity, pH and temperature did not differ significantly, although temperature showed a slight increase during the highest tide. Salinity averaged at 17.05 ppt and 22.09 ppt during the normal neap tide and highest tide of the decade respectively. Additionally, the temperature and pH profiles during both phenomena were all nearly uniform

The sediment mean size ranged from -0.67 Ø to 5.83 Ø and from -0.47 Ø to 4.37 Ø for the non-monsoon and monsoon season respectively. The mean diameter indicates that most of the sediment consists of medium to coarse sand. Sediment was dominantly poorly sorted during both non-monsoon season (1.46 ± 0.33 Ø) and monsoon season (1.30 ± 0.20 Ø). Sediment was classified as positively skewed for both seasons; this likely indicates deposition in environments dominated by stronger current actions, or the accumulation of coarser grains at these areas. Organic carbon content increased on the average, towards the downstream area in both seasons. The highest organic carbon content was observed in the estuarine region. The correlation of organic carbon and grain size indicated a significant relationship which was supported by the Pearson statistical analysis.

The metal concentration in the riverbed sediment was found to have anthropogenic contribution. The concentration of some metals studied was relatively high especially in the vicinity of town areas, shipyards, residential sand mining areas, and industrial areas. During the non-monsoon season, the ranges of metal concentration in the riverbed sediment were Al, 1.0 to 10.0 %; Cd, 0.03 to 0.48 μg/g dry weight; Co, 2.6 to 34.0 μg/g dry weight; Cr, 9.8 to 170.2 μg/g dry weight; Cu, 11.9 to 182.4 μg/g dry weight; Fe, 2.6 to 9.7 %; Li, 28.6 to 66.6 μg/g dry weight; Mn, 191.3 to 934.2 μg/g dry weight; Ni, 6.8 to 92.1 μg/g dry weight; Pb, 10.1 to 71.4 μg/g dry weight and Zn, 14.5 to 109.2 μg/g dry weight.

During the monsoon season, the concentration of Al in the riverbed sediment ranged from 2.2 to 8.9 %; Cd from 0.01 to 0.48 μg/g dry weight; Co from 8.1 to 28.3 μg/g dry weight; Cr from 22.1 to 153.7 μg/g dry weight; Cu from 8.3 to 148.9 μg/g dry weight; Fe from 2.9 to 8.7 %; Li from 22.5 to 53.6 μg/g dry weight; Mn from 122.8 to 930.5 μg/g dry weight; Ni from 12.1 to 80.1 μg/g dry weight; Pb from 13.8 to 61.2 μg/g dry weight; and Zn from 24.0 to 134.1 μg/g dry weight. Overall, most metal concentrations indicated a weak correlation to sediment grain size and to OC. Correlations may be due to complex geochemical reactions, not simply sedimentation process.

In order to determine the pollution status of the study area, the enrichment factor (EF), geoaccumulation (I_{geo}) and normalization methods were applied. According to the normalization method, stations 3, 10, 11, 12, 13, 14, 15, 17, 19, 20, 23 and 30 were influenced by anthropogenic sources. Meanwhile, the enrichment factor (EF) method of metal analysis showed that Pb, Cu and Fe can be categorized as moderate

enrichment from anthropogenic sources, while the rest of the metals studied can be categorized as deficient to minimally enrich from anthropogenic sources. Lastly, the geoaccumulation index indicated that all metals fell under practically uncontaminated classes (I_{geo}<0), and except for Pb which fell under uncontaminated to moderately contaminated classes (0<I_{geo}<1); Pb enrichment is possibly due to the input of local industries. Furthermore, the Terengganu River is also polluted by municipal, industrial and agriculture effluents and aquaculture and shipyard industries. Overall, however it was shown that the study area was practically uncontaminated and can be considered to be predominantly terigenous in origin.

To explore the sedimentation process in the river region, two sediment cores from the Terengganu River, Malaysia were studied by measuring the element thorium (Th). $^{230}Th_{excess}$ (non-supported ^{230}Th in sediments) and $^{230}Th_{excess}/^{232}Th$ methods were used to determine the sedimentation process where a sediment up to 300 000 years old can be dated by these method. Applying the $^{230}Th_{excess}$ and $^{230}Th_{excess}/^{232}Th$ methods, average sedimentation rates for both cores were found to be 0.011 ± 0.02 mm/yr and 0.013 ± 0.02 mm/yr.

In conclusion, even though the Terengganu area is rapidly developing, the activities at present are not widespread enough to effect significant pollution of the Terengganu River system.

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FIZIKO-KIMIA DAN KRITERIA SEDIMEN DI DALAM SEDIMEN DASAR SUNGAI TERENGGANU, TERENGGANU, MALAYSIA

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Kajian menyeluruh mengenai aspek geokimia dan kriteria sedimen telah dijalankan di Sungai Terengganu bagi mengetahui kesan pembangunan dan status pencemaran di dalam sistem sungai. Faktor-faktor yang dikaji adalah termasuk taburan saliniti, suhu, pH, sedimentologi, karbon organik, kepekatan logam dan kadar sedimentasi. Pensampelan telah dijalankan dari bulan Mei, 2002 sehingga bulan April, 2003 ketika musim bukan monsun dan monsun. Di dalam kajian ini, sebanyak 40 stesen kajian telah dijalankan di sepanjang Sungai Terengganu. Manakala, dua sampel teras telah di ambil bagi tujuan untuk mengenal pasti kadar sedimentasi di kawasan kajian.

Profil menegak bagi parameter fizikal saliniti, suhu, dan pH telah di peroleh dengan menggunakan peralatan Hydrolab (Datasonde 3). Secara keseluruhannya, persekitaran muara adalah didominasi oleh air masin ketika musim bukan monsun dan air tawar mendominasi persekitaran ini pada musim monsun. Taburan suhu bagi kolum air adalah pada amnya seragam atau tidak banyak menunjukkan perubahan terhadap masa, manakala saliniti mempunyai perkaitan dengan pH. Berdasarkan

kepada taburan dan juga profil kemasinan, muara di kawasan kajian ini boleh diklasifikasikan sebagai muara campuran kemasinan separa.

Sementara itu, kajian mengenai kesan fenomena air pasang paling tinggi bagi jangka masa sepuluh tahun (HTOD) terhadap saliniti, pH telah di jalankan di sistem muara Kuala Terengganu pada Oktober, 8, 2002. Secara keseluruhannya, taburan saliniti, suhu dan pH tidak menunjukkan perbezaan yang signifikan. Walau bagaimanapun, hanya taburan suhu menunjukkan sedikit peningkatan ketika HTOD ini berlaku. Purata bagi saliniti ketika air pasang normal dan HTOD adalah masing-masing mencatatkan bacaan 17.05 ppt dan 22.09 ppt. Selanjutnya, profil suhu dan pH menunjukkan taburan hampir sekata ketika kedua-dua fenomena ini berlaku.

Bagi min saiz sedimen pula, julat bagi musim bukan monsun dan musim monsun adalah masing-masing di antara -0.67 Ø hingga 5.83 Ø dan -0.47 Ø hingga 4.37 Ø. Nilai min saiz ini menunjukkan kebanyakan sedimen di kawasan kajian ini adalah terdiri daripada pasir kelas sederhana hingga pasir kelas kasar. Selain daripada itu, sedimen di kawasan kajian ini juga didominasi oleh sisihan yang agak teruk bagi kedua-dua musim bukan monsun (1.46 ± 0.33 Ø) dan musim monsun (1.30 ± 0.20 Ø). Selanjutnya, sedimen di kawasan kajian ini juga telah di kelaskan sebagai skew positif bagi kedua-dua musim dan ini adalah berkemungkinan berpunca daripada kriteria sedimen di persekitaran kajian didominasi oleh tindakan arus yang agak kuat atau di sebabkan oleh akumulasi butiran kasar di kawasan kajian ini. Daripada kajian ini, peratusan bagi kandungan karbon organik secara puratanya meningkat ke kawasan muara bagi kedua-dua musim. Kandungan karbon organik yang tertinggi telah dikenal pasti di persekitaran muara. Korelasi di antara peratusan karbon organik dan saiz

butiran menunjukkan korelasi yang signifikan yang mana ia telah dibuktikan dengan analisis statistik (Pearson).

Secara dasarnya, kepekatan logam di dalam sedimen dasar sungai adalah ke banyakkannya di pengaruhi oleh kehadiran sumber antropogenik. Kepekatan bagi sesetengah logam kajian secara relatifnya adalah tinggi terutama di kawasan yang berdekatan dengan pusat bandar, pembinaan kapal, lombong pasir dan kawasan perindustrian. Semasa musim bukan monsun, julat kepekatan logam bagi sedimen dasar sungai adalah Al; 1.0 hingga 10.0 %, Cd; 0.03 hingga 0.48 μg/g, berat kering, Co; 2.6 hingga 34.0 μg/g, berat kering, Cr; 9.8 hingga 170.2 μg/g, berat kering, Cu; 11.9 hingga 182.4 μg/g, berat kering, Fe; 2.6 hingga 9.7 %, Li; 28.6 hingga 66.6 μg/g, berat kering, Mn; 191.3 hingga 934.2 μg/g, berat kering, Ni; 6.8 hingga 92.1 μg/g, berat kering, 10.1 hingga 71.4 μg/g, berat kering dan Zn; 14.5 hingga 109.2 μg/g, berat kering.

Manakala, semasa musim monsun pula, kepekatan Al di dalam sedimen dasar sungai adalah dalam julat di antara 2.2 hingga 8.9 %; Cd di antara 0.01 hingga 0.48 μg/g, berat kering; Co di antara 8.1 hingga 28.3 μg/g, berat kering; Cr di antara 22.1 hingga 153.7 μg/g, berat kering; Cu di antara 8.3 hingga 148.9 μg/g, berat kering; Fe di antara 2.9 hingga 8.7 %; Li di antara 22.5 hingga 53.6 μg/g, berat kering; Mn di antara 122.8 hingga 930.5 μg/g, berat kering; Ni di antara12.1 hingga 80.1 μg/g, berat kering; Pb di antara 13.8 hingga 61.2 μg/g, berat kering; and Zn di antara 24.0 hingga 134.1 μg/g, berat kering. Keseluruhannya, ke banyakkan logam menunjukkan korelasi yang lemah ke atas saiz butiran sedimen dan juga peratusan karbon organik. Situasi

ini adalah berkemungkinan disebabkan oleh tindak balas sesetengah geokimia yang agak kompleks dan ia tidaklah semudah seperti proses sedimentasi.

Faktor pengkayaan (EF), indeks geoakumulasi (I_{geo}) dan juga kaedah penormalan telah dipraktikkan bagi mengenalpasti status pencemaran di kawasan kajian ini. Menurut daripada kaedah penormalan, St 3, 10, 11, 12, 13, 14, 15, 17, 19, 20, 23 dan 30 telah dipengaruhi oleh sumber antropogenik. Manakala, faktor pengkayaan (EF) bagi logam kajian telah menunjukkan Pb, Cu dan Fe boleh dikategorikan sebagai pengkayaan sederhana dari sumber antropogenik, dan yang selebihnya boleh dikategorikan sebagai pengkayaan yang minimum daripada sumber antropogenik. Akhir sekali, indeks geoakumulasi memperihalkan ke semua logam kajian adalah di dalam peringkat yang boleh dikatakan tidak begitu tercemar ($I_{geo}<0$) kecuali Pb telah dikenal pasti di dalam peringkat tidak tercemar hingga sederhana tercemar ($0<I_{geo}<1$). Ini adalah kesan daripada kemasukan sisa-sisa perindustrian ke persekitaran kajian. Tambahan pula, kesan daripada pertanian, industri, perkapalan dan akuakultur turut menyumbang kepada tahap pencemaran persekitaran kajian ini. Secara keseluruhannya, terbukti bahawa kawasan kajian boleh di katakan kurang tercemar dan boleh menganggap kawasan ini banyak dipengaruhi oleh trigenus.

Bagi mengetahui kadar sedimentasi di kawasan kajian, dua sample teras daripada Sungai Terengganu, Malaysia telah di kaji bagi mengukur kepekatan elemen thorium (Th). Kaedah $^{230}Th_{excess}$ (kepekatan ^{230}Th yang tidak dikenal pasti di dalam sedimen) dan $^{230}Th_{excess}/^{232}Th$ telah di gunakan bagi mengadaptasi proses sedimentasi di mana boleh yang berusia lebih dari 300, 000 tahun boleh dikenal pasti. Dengan mempraktikkan kaedah $^{230}Th_{excess}$ dan $^{230}Th_{excess}/^{232}Th$, purata bagi

kadar sedimentasi di kawasan kajian bagi Teras A dan B masing-masing mencatatkan bacaan 0.011 ± 0.02 mm/thn dan 0.013 ± 0.02 mm/thn.

Sebagai kesimpulannya, walau bagaimanapun kawasan Kuala Terengganu ini pesat membangun, aktiviti-aktiviti manusia yang hadir pada masa kini tidak banyak mempengaruhi tahap pencemaran di sistem Sungai Terengganu.