

**DISTRIBUTION AND FLUXES OF CHLOROPHYLL-*a* AND DISSOLVED
NITROGEN AND PHOSPHORUS FROM TERENGGANU RIVER
ESTUARY TO SOUTH CHINA SEA**

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MASTER OF SCIENCE

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**Thesis Submitted in Fulfillment of the Requirement for the
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This study is to determine the distribution, flux and relationship of dissolved nitrogen, dissolved phosphorus and chlorophyll-*a* (productivity), that are then used to develop the dissolved nitrogen, dissolved phosphorus and productivity (chlorophyll-*a*) fluxes model in the Terengganu River Estuary using the Land-ocean Interactions in the Coastal Zones (LOICZ) Biogeochemical Modelling Guidelines. Dissolved nitrogen and phosphorus and chlorophyll-*a* water samples were collected from 16 sampling stations in the rivers (Terengganu River and Nerus River), estuary and coastal water during the Northeast, Southwest and Inter-monsoon seasons as well as during low and high tides from January to November 2010.

Dissolved nitrogen and phosphorus concentrations were not much different from results of previous studies in the Terengganu River Estuary. Generally, dissolved nitrogen was higher than dissolved phosphorus. Spatially, nitrite-nitrogen (NO₂⁻-N), nitrate-nitrogen (NO₃⁻-N), ammonium-nitrogen (NH₄⁺-N) and total dissolved nitrogen (TDN) were high in the rivers, while dissolved organic nitrogen (DON) was

high in the coastal water. Dissolved phosphorus species which are orthophosphate-phosphorus ($\text{PO}_4^{-3}\text{-P}$), dissolved organic phosphorus (DOP) and total dissolved phosphorus (TDP) fluctuated from rivers towards coastal waters. Chlorophyll-*a* concentration (0.25 mg/m^3 to 67.19 mg/m^3) was high in rivers and diluted towards the coastal waters except during Northeast monsoon high tide (NE-HT) and Inter-monsoon high tide (IM-HT) which were high in the coastal waters and estuary respectively. Most of dissolved nitrogen species were high in the surface and middle water layers, while dissolved phosphorus species were high in the middle and bottom water layers. Seasonally, $\text{NO}_2^{-}\text{-N}$ and $\text{PO}_4^{-3}\text{-P}$ were high during the Southwest monsoon for both low and high tides. The $\text{NO}_3^{-}\text{-N}$, TDN, DOP and TDP were high during the Northeast monsoon (low tide) and Southwest monsoon (high tide). The $\text{NH}_4^{+}\text{-N}$, DON and chlorophyll-*a* were high during the Inter-monsoon for low tide. During high tide, $\text{NH}_4^{+}\text{-N}$ and chlorophyll-*a* were high during the Northeast monsoon, while DON was high during the Southwest monsoon. Chlorophyll-*a* concentration has a relationship ($p < 0.05$) with dissolved nitrogen and phosphorus concentrations except DON ($p > 0.05$).

Water residence time in the Terengganu River Estuary was less than a day (8 to 12 hours) with water and salts fluxes in a balance state. Thus, about 173.25 to 326.31 mol of dissolved inorganic nitrogen (DIN), -101.86 to 37.66 mol of DON, 146.18 to 224.45 mol of TDN, 1.45 to 5.10 mol of dissolved inorganic phosphorus (DIP), 3.54 to 16.01 mol of DOP, 4.98 to 19.31 mol of TDP and 15.13 to 355.87 tonne of productivity (chlorophyll-*a*) net fluxes were delivered from estuary into the coastal areas of Terengganu River Estuary annually. The estuary served as a source for dissolved nitrogen during all samplings. However, the estuary served as a sink for

dissolved phosphorus during Northeast monsoon low tide (NE-LT), Inter-monsoon low tide (IM-LT) and Southwest monsoon high tide (SW-HT), but as a source during the other samplings. The estuary was a source for productivity during all samplings except during IM-LT and SW-HT. During low tide, the DIN and dissolved phosphorus net fluxes were high during the Southwest monsoon, while DON was high during the Inter-monsoon. The TDN and productivity were high during the Northeast monsoon. During high tide, all dissolved nitrogen, dissolved phosphorus and productivity net fluxes were high during the Inter-monsoon except for DON which was high during the Northeast monsoon. Productivity net flux has a relationship ($p < 0.05$) with dissolved phosphorus and TDN net fluxes.

From the results obtained, the Terengganu River Estuary during the present study was phosphorus limited (TDN:TDP = 19:1). Based on comparison of nutrient values obtained with different Water Quality Standards, the nitrogen and phosphorus levels in the Terengganu River Estuary are still in good condition except for NH_4^+ -N which was slightly polluted. Thus, management measures should be put in place to prevent the nutrient levels from increasing further. In addition, further studies about the flux model using the LOICZ method should also be done frequently in the study area to monitor its ecological status.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk ijazah Master Sains.

TABURAN SERTA FLUKS KLOOROFIL-*a* DAN NITROGEN SERTA FOSFORUS TERLARUT DARI MUARA SUNGAI TERENGGANU KE LAUT CINA SELATAN

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Kajian ini dibuat untuk menentukan taburan, fluks dan hubungan antara nitrogen terlarut, fosforus terlarut serta klorofil-*a* (produktiviti), yang mana kemudiannya digunakan untuk membentuk model fluks nitrogen terlarut, fosforus terlarut serta produktiviti (klorofil-*a*) di Muara Sungai Terengganu dengan menggunakan Panduan Permodelan Biogeokimia bagi Perhubungan Daratan-lautan di Zon Pesisiran Pantai (LOICZ). Sampel-sampel air bagi nitrogen dan fosforus terlarut dan klorofil-*a* telah diambil dari 16 stesen persampelan di dalam sungai-sungai (Sungai Terengganu dan Sungai Nerus), muara dan pesisiran pantai pada musim Monsun Timur Laut, Monsun Barat Daya dan monsun perantaraan semasa air pasang dan air surut dari bulan Januari hingga November bagi tahun 2010.

Kepekatan-kepekatan nitrogen dan fosforus terlarut adalah tidak banyak berbeza dari keputusan kajian-kajian terdahulu di Muara Sungai Terengganu. Secara amnya, nitrogen terlarut adalah lebih tinggi daripada fosforus terlarut. Secara lapangan, nitrit-nitrogen (NO_2^- -N), nitrat-nitrogen (NO_3^- -N), ammonium-nitrogen (NH_4^+ -N)

dan jumlah nitrogen terlarut (TDN) adalah tinggi di dalam sungai-sungai, manakala nitrogen organik terlarut (DON) adalah tinggi di dalam pesisiran pantai. Spesies-spesies fosforus terlarut seperti ortofosfat-fosforus ($\text{PO}_4^{-3}\text{-P}$), fosforus organik terlarut (DOP) dan jumlah fosforus terlarut (TDP) adalah berubah-ubah dari sungai menghala ke pesisiran pantai. Kepekatan klorofil-*a* (0.25 mg/m^3 to 67.19 mg/m^3) adalah tinggi di sungai-sungai dan semakin terlarut menghala ke pesisiran pantai kecuali pada Monsun Timur Laut (NE-HT) dan monsun perantaraan (IM-HT) semasa air pasang yang mana masing-masing tinggi di pesisiran pantai dan muara. Kebanyakan spesies nitrogen terlarut adalah tinggi di dalam lapisan air permukaan dan pertengahan, manakala spesies fosforus terlarut adalah tinggi di dalam lapisan air pertengahan dan dasar. Secara bermusim, $\text{NO}_2^{-}\text{-N}$ dan $\text{PO}_4^{-3}\text{-P}$ adalah tinggi pada Monsun Barat Daya bagi kedua-dua air pasang dan air surut. $\text{NO}_3^{-}\text{-N}$, TDN, DOP dan TDP adalah tinggi pada Monsun Timur Laut (air surut) dan Monsun Barat Daya (air pasang). $\text{NH}_4^{+}\text{-N}$, DON dan klorofil-*a* adalah tinggi pada monsun perantaraan bagi air surut. Semasa air pasang, $\text{NH}_4^{+}\text{-N}$ dan klorofil-*a* adalah tinggi pada Monsun Timur Laut, manakala DON adalah tinggi pada Monsun Barat Daya. Kepekatan klorofil-*a* mempunyai hubungan ($p < 0.05$) dengan kepekatan-kepekatan nitrogen dan fosforus terlarut kecuali DON ($p > 0.05$).

Masa penggantian air di Muara Sungai Terengganu adalah kurang daripada sehari (8 hingga 12 jam) dengan fluks air dan kemasinan adalah dalam keadaan seimbang. Dengan itu, kira-kira 173.25 mol hingga 326.31 mol fluks bersih nitrogen inorganik terlarut (DIN), -101.86 mol hingga 37.66 mol fluks bersih DON, 146.18 mol hingga 224.45 mol fluks bersih TDN, 1.45 mol hingga 5.10 mol fluks bersih fosforus inorganik terlarut (DIP), 3.54 mol hingga 16.01 mol fluks bersih DOP, 4.98 mol

hingga 19.31 mol fluks bersih TDP dan 15.13 tan hingga 355.87 tan fluks bersih produktiviti (klorofil-*a*) telah dibebaskan dari muara ke dalam pesisiran pantai Muara Sungai Terengganu setiap tahun. Muara bertindak sebagai sumber (*source*) bagi nitrogen terlarut pada semua tempoh persampelan. Walau bagaimanapun, muara bertindak sebagai penenggelam (*sink*) bagi fosforus terlarut pada Monsun Timur Laut semasa air surut (NE-LT), monsun perantaraan semasa air surut (IM-LT) dan Monsun Barat Daya semasa air pasang (SW-HT), tapi bertindak sebagai sumber pada lain-lain persampelan. Muara bertindak sebagai sumber bagi produktiviti semasa semua persampelan kecuali pada IM-LT dan SW-HT. Semasa air surut, fluks bersih DIN dan fosforus terlarut adalah tinggi pada Monsun Barat Daya, manakala DON adalah tinggi pada monsun perantaraan. TDN dan produktiviti adalah tinggi pada Monsun Timur Laut. Semasa air pasang, semua fluks bersih nitrogen terlarut, fosforus terlarut dan produktiviti adalah tinggi pada monsun perantaraan kecuali DON yang tinggi pada Monsun Timur Laut. Fluks bersih produktiviti mempunyai hubungan ($p < 0.05$) dengan fluks bersih fosforus terlarut dan TDN.

Daripada keputusan yang diperolehi, Muara Sungai Terengganu dalam kajian terkini adalah terhad fosforus (TDN:TDP = 19:1). Berdasarkan perbandingan nilai-nilai nutrien yang diperolehi dengan Standard Kualiti Air yang berbeza, aras nitrogen dan fosforus di Muara Sungai Terengganu masih di dalam keadaan yang baik kecuali NH_4^+ -N yang mana sedikit tercemar. Jadi, ukuran pengurusan perlulah dibuat untuk mengelakkan aras nutrien dari terus meningkat. Selain itu, kajian-kajian akan datang berkenaan dengan model fluks yang menggunakan kaedah LOICZ perlulah dibuat dengan lebih kerap di kawasan kajian untuk memantau status ekologi.