ASSESSMENT OF APPARENT OPTICAL PROPERTIES (AOP) OF TOTAL SUSPENDED SEDIMENTS (TSS) IN KUALA TERENGGANU COASTAL WATERS

NUR HAFIZA BINTI BAHLI

FACULTY OF MARITIME STUDIES AND MARINE SCIENCE
UNIVESITI MALAYSIA TERENGGANU

2007

1100054366

Perpustakaan Sultanah Nur Zahirah (UMT)
Universiti Malaysia Terengganu

PERPUSTAKAAN SULTANAH NUR ZAHIRAH
UMT

LP 38 FMSM 2 2007

1100054366

Assessment of apparent optical properties (AOP) of total suspended sediments (TSS) in Kuala Terengganu coastal waters / Nur Hafiza Ramli.

PERPUSTAKAAN SULTANAH NUR ZAHIRAH
UNIVERSITI MALAYSIA TERENGGANU (UMT)
21030 KUALA TERENGGANU

1100054366

Lihat sebelah

HAK MILIK
PERPUSTAKAAN SULTANAH NUR ZAHIRAH UMT

ASSESSMENT OF APPARENT OPTICAL PROPERTIES (AOP) OF TOTAL SUSPENDED SEDIMENTS (TSS) IN KUALA TERENGGANU COASTAL WATERS

By

Nur Hafiza Binti Ramli

Research Report submitted in partial fulfillment of
the requirement for the degree of
Bachelor of Science (Marine Science)

Department of Marine Science
Faculty of Maritime Studies and Marine Science
UNIVERSITI MALAYSIA TERENGGANU
2007

1100054366

This project report should be sited as follows:

Nur Hafiza. R. 2007. Assessment of Apparent Optical Properties of Total Suspended Sediments in Kuala Terengganu Coastal Waters. Undergraduate Thesis, Bachelor of Science (Marine Science). Faculty of Maritime Studies and Marine Science. University of Malaysia Terengganu. 80pp

No part of this project report may be reproduced by any mechanical, photographic, or electronic process, or in the form of phonographic recording, nor may it be stored in a retrieval system, transmitted, or otherwise copied for public or private use, without written permission from the author and the supervisor(s) of the project.

JABATAN SAINS MARIN
FAKULTI PENGAJIAN MARITIM DAN SAINS MARIN
UNIVERSITI MALAYSIA TERENGGANU

PENGAKUAN DAN PENGESAHAN
LAPORAN PROJEK PENYELIDIKAN I DAN II

Adalah ini diakui bahawa laporan penyelidikan bertajuk:

Assessment of Apparent Optical Properties of Total Suspended Sediments In Kuala Terengganu Waters.

Oleh **Nur Hafiza Binti Ramli** No. Matrik: **UK 9905**

telah diperiksa dan semua pembetulan yang disarankan telah dilakukan. Laporan ini dikemukakan kepada Jabatan Sains Marin sebagai memenuhi sebahagian daripada keperluan memperolehi ijazah.Sarjana Muda Sain Samudera Fakulti Pengajian Maritim dan Sains Marin, Universiti Malaysia Terengganu.

Disahkan oleh:

....
Penyelia utama

Nama: Mohd Suffian Bin Idris

Cop Rasmi:

MOHD SUFFIAN IDRIS
Pensyarah
Institut Oseanografi
Universiti Malaysia Terengganu (UMT)
21030 Kuala Terengganu, Terengganu

Tarikh: 24/5/07

....
Ketua Jabatan Sains Samudera

Nama:

DR. RAZAK ZAKARIYA
Ketua Jabatan Sains Marin
Fakulti Pengajian Maritim dan Sains Marin
Universiti Malaysia Terengganu
(UMT)

Cop Rasmi:

Tarikh: 6/6/07

DEDICATION:

THIS THESIS IS DEDICATED TO ALL PEOPLE WHO IS INTERESTED IN REMOTE SENSING STUDIES AND SPEACIALLY TO MY PARENTS, BROTHERS, SISTERS AND NOT TO FORGET TO MY DEAREST ONE WHO ALWAYS LENDING ME A HAND. THANK YOU FOR ALL OF YOUR SUPPORTS AND ENCOURAGEMENTS.

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

"In the name of Allah, Most Gracious and Most Merciful"

I am grateful to Almighty who has given the full blessings for me to finish this final project. My thanks go foremost to beloved mother, Madam Wan Rahimah, my father, Mr Ramli and my wonderful siblings who always supported me.

I would like to take this opportunity to thank to my best supervisor Mr Mohd Suffian b Idris for his guidance and in helping me to accomplish this project. I am grateful to him as he always gives many comments and suggestions that helped me a lot. In fact, I would like to thank him especially for his patience, caring and understanding personality.

Besides that, I would like to thank Mr Nasir and my colleagues who helped me during the sampling. Not to forget to my friends, my coursemates and those who helped directly and indirectly. Many of you people, thank you a lot!

TABLE OF CONTENTS

Acknowledgement *i*

Table of contents *ii*

List of Tables *v*

List of Figures *vii*

List of Appendices *x*

List of Abbreviations *xii*

Abstract *xiv*

Abstrak *xvi*

Chapter 1: **INTRODUCTION**

1.1 Background of study 1

1.1.1 Coastal waters 1

1.1.2 Classification of coastal waters 1

1.1.3 In-water optical properties 2

1.2 Importance of study 3

1.3 Objectives 4

Chapter 2: **LITERATURE REVIEW**

2.1 Remote sensing reflectance 6

2.2 Diffuse attenuation coefficient 7

2.3 Suspended solids 9

Chapter 3: **METHODOLOGY**

3.1 Description of study areas 10

3.2 In situ measurement 11

3.2.1 Water sample collection 11

3.2.2 Radiometric measurement 11

3.3 Water analysis 12

3.4 Data analysis 12

Chapter 4: **RESULT**

4.1 The observation of sky condition 14

4.2 Hydrographic measurement 16

4.3 Water clarity 18

4.4 TSS Concentration 20

4.5 Remote Sensing Reflectance 22

4.6 Diffuse attenuation coefficient 28

4.7 Relationship between AOP and TSS concentration 33

4.7.1 Reflectance versus TSS concentration 33

4.7.2 Diffuse attenuation coefficient 38

Chapter 5: **DISCUSSION** 44

Chapter 6: **CONCLUSION** 49

REFERENCES 51

APPENDICES 55

Perpustakaan Sultanah Nur Zahirah (UMT)
Universiti Malaysia Terengganu

LIST OF TABLES

TABLES			PAGE
Table 4.1	:	The observation of sky conditions, wind speeds measurement and the coordinate of each station	15
Table 4.2	:	Recorded data of hydrographic measurement	17
Table 4.3	:	Concentration of TSS, [TSS]	20
Table 4.4	:	The average of remote sensing reflectance of different in-water constituents for station 1 to station 4	23
Table 4.5	:	The average of remote sensing reflectance of different in-water constituents for station 5 to station 8	24
Table 4.6	:	The average of remote sensing reflectance of different in-water constituents for station 9 to station 12	25
Table 4.7	:	The average of remote sensing reflectance of different in-water constituents for station 13 to station 17	26
Table 4.8	:	The average of remote sensing reflectance of different in-water constituents for station 18 to station 22	27
Table 4.9	:	The average of the diffuse attenuation coefficient values of different in-water constituents for station 1 to station 4	29
Table 4.10	:	The average of the diffuse attenuation coefficient values of different in-water constituents for station 5 to station 8	30
Table 4.11	:	The average of the diffuse attenuation coefficient values of different in-water constituents for station 9 to station 12	30
Table 4.12	:	The average of the diffuse attenuation coefficient values of different in-water constituents for station 13 to station 18	31
Table 4.13	:	The average of the diffuse attenuation coefficient values of different in-water constituents for station 19 to station	32

Table 4.14 : The correlation values from the regression analysis between remote sensing reflectance and TSS concentrations 33

Table 4.15 : The correlation values from the regression analysis between the values of diffuse attenuation coefficient and TSS concentrations 38

LIST OF FIGURES

FIGURES			PAGE
Figure 2.1	:	Satlantic underwater sensor	8
Figure 3.1	:	The targeted areas of study	10
Figure 4.1	:	The values of diffuse attenuation coefficient of PAR in reverse meter for 22 stations	18
Figure 4.2	:	The values of ZEU in reverse meter for 22 stations	19
Figure 4.3	:	The graph of TSS concentration according to each station	20
Figure 4.4	:	Percentage of remote sensing reflectance versus wavelength	22
Figure 4.5	:	The curves represent the percentage of remote sensing reflectance versus wavelength between four stations (station 1- station 4)	23
Figure 4.6	:	The curves represent the percentage of remote sensing reflectance versus wavelength between four stations (station 5- station 8)	24
Figure 4.7	:	The curves represent the percentage of remote sensing reflectance versus wavelength between four stations (station 9- station 12)	25
Figure 4.8	:	The curves represent the percentage of remote sensing reflectance versus wavelength between four stations (station 13- station 17)	26
Figure 4.9	:	The curves represent the percentage of remote sensing reflectance versus wavelength between four stations (station 18- station 22)	27
Figure 4.10	:	Diffuse attenuation coefficient versus wavelength	28

Figure 4.11	:	The curves represent the diffuse attenuation coefficient values versus wavelength between four stations (station 1- station 4)	29
Figure 4.12	:	The curves represent the diffuse attenuation coefficient values versus wavelength between four stations (station 5- station 8)	29
Figure 4.13	:	The curves represent the diffuse attenuation coefficient values versus wavelength between four stations (station 9- station 12)	30
Figure 4.14	:	The curves represent the diffuse attenuation coefficient values versus wavelength between four stations (station 13 – station 18)	31
Figure 4.15	:	The curves represent the diffuse attenuation coefficient values versus wavelength between four stations (station 19 – station 22)	31
Figure 4.16	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 412nm	33
Figure 4.17	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 440nm	34
Figure 4.18	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 490nm	34
Figure 4.19	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 510nm	35
Figure 4.20	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 532nm	35
Figure 4.21	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 555nm	36
Figure 4.22	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 650nm	36
Figure 4.23	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 675nm	37
Figure 4.24	:	The percentage of remote sensing reflectance (R_{rs}) versus the concentration of TSS ([TSS]) for wavelength 715nm	37

Figure 4.25 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 412nm 38

Figure 4.26 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 440nm 39

Figure 4.27 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 490nm 39

Figure 4.28 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 510nm 40

Figure 4.29 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 532nm 40

Figure 4.30 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 555nm 41

Figure 4.31 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 650nm 41

Figure 4.32 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 676nm 42

Figure 4.33 : The values of diffuse attenuation coefficient (K_d) versus the concentration of TSS ([TSS]) for wavelength 715nm 42

LIST OF APPENDICES

APPENDICES	PAGE
Appendix 1: Table of TSS concentration and remote sensing reflectance (for 9 wavelengths) from station 1 to station 22	55
Appendix 2: Table of TSS concentration and diffuse attenuation coefficient (for 9 wavelengths) from station 1 to station 22	56
Appendix 3: The percentage of remote sensing reflectance for station 1 to station 4	57
Appendix 4: The percentage of remote sensing reflectance for station 5 to station 8	58
Appendix 5: The percentage of remote sensing reflectance for station 9 to station 12	59
Appendix 6: The percentage of remote sensing reflectance for station 13 to station 16	60
Appendix 7: The percentage of remote sensing reflectance for station 17 to station 20	61
Appendix 8: The percentage of remote sensing reflectance for station 21 to station 22	62
Appendix 9: The diffuse attenuation coefficient values for station 1 to station 4	63
Appendix 10: The diffuse attenuation coefficient values for station 5 to station 8	64
Appendix 11: The diffuse attenuation coefficient values for station 9 to station 12	65
Appendix 12: The diffuse attenuation coefficient values for station 13 to station 18	66

Appendix 13:
The diffuse attenuation coefficient values for station 19 to station 22 67

Appendix 14:
The data of remote sensing reflectance for every wavelength (350nm – 800nm)
from station 1 to station 22 68

Appendix 15:
The data of diffuse attenuation coefficient for every wavelength (350nm – 800nm)
from station 1 to station 22 73

Appendix 16:
The types of trends of Rrs percentage versus wavelength for several stations 78

LIST OF ABBREVIATIONS

SYMBOL	DEFINITION
AOP	Apperent Optical Properties
CDOM	Coloured Dissolved Organic Matter
$E_d(0^+, \lambda)$	Incident irradiance
$E_d(0^-, \lambda)$	Downwelling irradiance
IOP	Inherent Optical Properties
K_d	Diffuse attenuation coefficient
$L_u(0^+, \lambda)$	Upwelling radiance on surface
$L_u(0^-, \lambda)$	Upwelling radiance below surface
$L_w(\lambda)$	Water leaving reflectance
NTU	Nepholometric Turbidity Unit
PAR	Photosynthetic Active Radiance
R_{rs}	Remote sensing reflectance
R_{rs} (%)	Percentage Remote sensing reflectance
TSS	Total Suspended Sediment
[TSS]	Concentration of TSS
z	Depth (m)
ρ	Fresnel reflectance index of seawater (0.021)

η_w	Fresnel refractive index of seawater (1.345)
α	Fresnel reflection albedo of sun and sky (0.043)

ABSTRACT

The field of remote sensing can be used to determine the distribution of different types of constituents in seawater such as chlorophyll-a, Coloured Dissolved Organic Matter (CDOM) and Total Suspended Sediments (TSS). In this research, the measurements of Apparent Optical Properties (AOP) parameters such as R_{rs} and K_d have been conducted and their relationship with TSS were investigated. 22 stations along Kuala Terengganu coastal waters were chosen as the sites of study. The in-situ observations were carried out between 14th and 17th of September 2006. The in-situ data of radiometric measurements ($E_d(0^+)$ and $L_u(0^+)$) were processed using the Prosoft 7.78 software to derive AOP parameters (R_{rs} and K_d). For each station, water samples were collected to measure the concentration of TSS. The regression analyses were done between the concentration of TSS and AOP parameters in order to determine the relationship between them. The regression analysis revealed that the TSS can be best estimated at 675 nm wavelength of R_{rs} and 532 nm wavelength of K_d. Results obtained suggest that in-situ measurement of AOP parameters are potentially valuable to develop site-specific algorithms for estimating TSS concentration through remotely sensed optical data.

ABSTRAK

Bidang penderiaan jauh boleh digunakan untuk menentukan pelbagai konstituen yang terdapat dalam air laut seperti taburan klorofil-a, Bahan Organik Terlarut (CDOM) dan Jumlah Pepejal Terampai (TSS). Dalam kajian ini, pengukuran parameter Ciri-ciri Optik Nyata (AOP) seperti Pantulan Penderiaan Jauh (R_{rs}) dan Pekali Pelemahan Cahaya (K_d) telah dilakukan dan hubungan antara kedua-duanya dengan kepekatan TSS dikaji. 22 stesen di perairan Kuala Terengganu telah dipilih sebagai kawasan kajian ini. Pemerhatian 'in-situ' dijalankan antara 14 dan 17 September 2006. Data 'in-situ' pengukuran radiometrik ($E_d(0^+)$ dan $L_u(0^+)$) diproses menggunakan perisian Prosoft 7.78 untuk mendapatkan parameter AOP (R_{rs} and K_d). Sampel air bagi setiap stesen telah diambil untuk mengetahui kepekatan TSS yang terdapat di dalam air laut. Kemudiannya, analisis regresi dilakukan antara kepekatan kandungan TSS di dalam air dan data parameter AOP untuk mencari perhubungan antara kedua-duanya. Analisis regrasi menunjukkan TSS dapat ditentukan pada 675 nm panjang gelombang untuk R_{rs} dan 532 nm panjang gelombang untuk K_d. Keputusan yang diperolehi dapat menerangkan bahawa pengukuran 'in-situ' parameter AOP berpotensi untuk menghasilkan 'site-specific algorithms' dalam menentukan kepekatan TSS melalui data optik secara penderiaan jauh.