

**FIELD AND LABORATORY STUDIES ON  
THE BIOACCUMULATION OF METALS IN  
BROWN SEAWEED (*PADINA* SPP.) FROM THE  
TERENGGANU COAST, PENINSULAR  
MALAYSIA**

**NABEELA ALI NASSER AL-AWLAQI**

**DOCTOR OF PHILOSOPHY  
UNIVERSITI MALAYSIA TERENGGANU**

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**NABEELA ALI NASSER AL-AWLAQI DOCTOR OF PHILOSOPHY 2019**



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**NABEELA ALI NASSER AL-AWLAQI**

**Thesis Submitted in Fulfilment of the Requirement for the Degree of  
Doctor of Philosophy in the Institute of Oceanography and Environment  
Universiti Malaysia Terengganu**

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**DEDICATION**

*I dedicate love, pens, papers, effort and life to both of you,  
I dedicate my beautiful words, the melodies of my soul and sensation,  
I dedicate, to who illuminates my way and my nights,  
who's praying for me,  
Dad and Mom.*

*To those who's fill my life with happiness, and my soul yearns for them,  
To those who nurture a love in my veins, and their mere mention makes  
my heart happy,  
Brothers and Sisters.*

*To who's my role model in scientific research,  
I dedicate, to my supervisor  
Emeritus Prof. Noor Azhar Mohamed Shazili*

*To all those I love, my country, my people, my lecturers, my friends, and  
All the knowledge-seekers,  
To those who are absent, but in soul and heart they are present,  
I dedicate this work with my love*

*Nabeela*

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfilment of the requirements for the degree of Doctor of Philosophy

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**Main Supervisor : Emeritus Prof. Noor Azhar Mohamed Shazili, PhD**

**Co-Supervisor : Nurulnadia Mohd Yusoff, PhD**

**School/Institute : Institute of Oceanography and Environment**

Heavy metal (Cu, Zn, Cd, and Pb) concentrations in seawater and brown seaweed *Padina* spp., and physico-chemical parameters were measured from three stations, representing control, low and moderately industrialised areas located along the coastline of Terengganu, peninsular Malaysia for one year (April 2014 to May 2015). In experimental set-up, *Padina* spp. was then exposed to a range of low metal concentrations at different seawater pH and salinity, and effects on growth, chlorophyll a and metal bioaccumulation determined over a period of 21 days. Strong correlation was observed between the concentrations of Cu and Pb in *Padina* spp. ( $r = 0.843$ ), and between Pb and Cd ( $r = 0.722$ ) in seawater samples. Metal concentrations in seawater were within the limits of the Malaysia Marine Water Quality Criteria and Standard (IMWQS), except Pb which may be considered slightly polluted. The strong Cd-Cu, and Cd-Pb correlation pairs in *Padina* spp. Tissue and seawater samples indicate that these metal pollutants were of the same source, possibly from industrial and sewage pollution. Bioaccumulation concentration of metals increased with time and experimental seawater metal concentrations. The pH at which bioaccumulation was highest concentration was metal-specific, i.e. Cd at pH 6, Cu at pH 8 and both Pb and Zn at pH 7. Growth rates were reduced ( $p < 0.05$ ) regardless of metal concentration

and pH levels. Compared with control growth rate at pH 8 , *Padina* growth rate decreased with increase of metal concentration, with lowest growth at pH 4 (for Cu, Pb, Zn) and pH 9 (for Cd). Chlorophyll content of *Padina* spp. significantly decreased after exposure to all metal concentrations, dependent on days of exposure and pH. Seaweeds has been generally identified as a good biomonitor for metal pollution, and this study further shows that *Padina* spp. respond sensitively, in terms of effects on growth, chlorophyll and pollutant bioaccumulation to slightly elevated concentrations of Cd, Cu, Pb and Zn when seawater pH and salinity is altered from natural nominal values.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

**KAJIAN LAPANGAN DAN MAKMAL MENGENAI BIOTUMPUKAN  
BAHAN LOGAM DI DALAM RUMPAI LAUT PERANG (*PADINA* SPP.)  
DARI PANTAI TERENGGANU**

**NABEELA ALI NASSER AL-AWLAQI**

**2019**

**Penyelia : Prof. Emeritus. Noor Azhar Mohamed Shazili, PhD**

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**Pusat Pengajian/Institut: Institut Oseanografi dan Sekitaran**

Kepekatan logam berat (Cu, Zn, Cd, dan Pb) dalam air laut dan rumpai laut *Padina* spp., dan parameter fiziko-kimia diukur dari tiga stesen, yang mewakili kawasan pengaruh perindustrian kawalan, rendah dan sederhana yang terletak di sepanjang pantai Terengganu, Semenanjung Malaysia selama satu tahun (April 2014 hingga Mei 2015). Dalam ujian eksperimen, *Padina* spp. kemudiannya didedahkan kepada pelbagai kepekatan rendah logam pada pH dan kemasinan air laut yang berbeza, dan kesan keatas pertumbuhan, klorofil a dan bioakumulasi logam ditentukan sepanjang tempoh 21 hari. Korelasi yang kuat diperhatikan antara kepekatan Cu dan Pb dalam tisu *Padina* spp. ( $r = 0.843$ ) dan kepekatan Pb dan Cd ( $r = 0.722$ ) dalam air laut. Kepekatan logam dalam air laut berada dalam lingkungan Kriteria dan Standard Kualiti Air Marin Malaysia (IMWQS), kecuali Pb yang mungkin dianggap sedikit tercemar. Hubungan kuat pasangan korelasi Cd-Cu dan Cd-Pb dalam *Padina* spp. dan sampel air laut menunjukkan bahawa bahan pencemar logam ini adalah dari sumber yang sama, mungkin dari pencemaran perindustrian dan kumbahan. Kepekatan bioakumulasi logam meningkat dengan kepekatan logam air laut dan tempoh masa ujikaji. pH dimana bioakumulasi tertinggi adalah khusus kepada logam, iaitu Cd pada pH 6, Cu pada pH 8 dan kedua-dua Pb dan Zn pada pH 7. Kadar pertumbuhan menurun

( $p < 0.05$ ) tanpa mengira kepekatan logam dan paras pH. Berbanding dengan kadar pertumbuhan kawalan pada pH 8, kadar pertumbuhan *Padina* spp. berkurangan dengan peningkatan kepekatan logam, dengan pertumbuhan paling rendah pada pH 4 (untuk Cu, Pb, Zn) dan pH 9 (untuk Cd). Kandungan klorofil *Padina* spp. berkurangan dengan ketara selepas terdedah kepada semua kepekatan logam, bergantung pada tempoh hari pendedahan dan pH. Rumpai laut telah dikenalpasti sebagai biomonitor yang baik untuk pencemaran logam, dan kajian ini selanjutnya menunjukkan bahawa *Padina* spp. bertindakbalas secara sensitif, dari segi kesan pertumbuhan, klorofil dan bioakumulasi pencemar kepada kepekatan Cd, Cu, Pb dan Zn yang meningkat sedikit tinggi ketika pH dan kemasinan air laut diubah dari nilai nominal semulajadi.