



بسم الله الرحمن الرحيم

∞∞∞∞

تم رفع هذه الرسالة بواسطة / سامية زكى يوسف

بقسم التوثيق الإلكتروني بمركز الشبكات وتكنولوجيا المعلومات دون أدنى

مسئولية عن محتوى هذه الرسالة.

ملاحظات: لا يوجد



MONITORING AND MANAGEMENT OF PLASTIC MARINE LITTER IN EGYPTIAN NORTHERN COASTAL AREAS USING NEW TECHNIQUES

Submitted By

Noha Samy Sayed Mahmoud

B.Sc. In Civil Engineering, Faculty of Engineering, Ain Shams University, 2003

Diploma in Environmental Sciences, Faculty of Graduate Studies and
Environmental Research, Ain Shams University, 2014

Master in Environmental Sciences, Faculty of Graduate Studies and
Environmental Research, Ain Shams University, 2018

A Thesis Submitted in Partial Fulfillment

Of

The Requirement for the Doctor of Philosophy Degree

In

Environmental Sciences

**Department of Environmental Engineering Sciences
Faculty of Graduate Studies and Environmental Research
Ain Shams University**

2022

APPROVAL SHEET
**MONITORING AND MANAGEMENT OF PLASTIC
MARINE LITTER IN EGYPTIAN NORTHERN COASTAL
AREAS USING NEW TECHNIQUES**

Submitted By

Noha Samy Sayed Mahmoud

B.Sc. In Civil Engineering, Faculty of Engineering, Ain Shams University, 2003

Diploma in Environmental Sciences, Faculty of Graduate Studies and

Environmental Research, Ain Shams University, 2014

Master in Environmental Sciences, Faculty of Graduate Studies and

Environmental Research, Ain Shams University, 2018

A Thesis Submitted in Partial Fulfillment

Of

The Requirement for the Doctor of Philosophy Degree

In

Environmental Sciences

Department of Environmental Engineering Sciences

This thesis was discussed and approved by:

Name

Signature

1-Prof. Dr. Iman Mahmoud Al-Azizy

Prof. of Water Researches

Vice President of 6th October University

2-Dr. Sameh Reyad Abdalla

Head of Central Department of Egyptian Environmental Affairs Agency

West Delta Region

3-Prof. Dr. Aly Nabih El Bahrawy

Prof. of Hydraulics

Faculty of Engineering

Ain Shams University

4-Dr. Noha Samir Donia

Prof of Environmental Hydraulics, Department of Environmental

Engineering Sciences

Dean Faculty of Graduate Studies and Environmental Research

Ain Shams University

2022

MONITORING AND MANAGEMENT OF PLASTIC MARINE LITTER IN EGYPTIAN NORTHERN COASTAL AREAS USING NEW TECHNIQUES

Submitted By

Noha Samy Sayed Mahmoud

B.Sc. In Civil Engineering, Faculty of Engineering, Ain Shams University, 2003

Diploma in Environmental Sciences, Faculty of Graduate Studies and
Environmental Research, Ain Shams University, 2014

Master in Environmental Sciences, Faculty of Graduate Studies and
Environmental Research, Ain Shams University, 2018

A Thesis Submitted in Partial Fulfillment
Of

The Requirement for the Doctor of Philosophy Degree
In

Environmental Sciences

Department of Environmental Engineering Sciences

Under The Supervision of:

1-Prof. Dr. Aly Nabih El Bahrawy

Prof. of Irrigation and Hydraulics
Faculty of Engineering
Ain Shams University

2-Dr. Noha Samir Donia

Prof of Environmental Hydraulics, Department of Environmental
Engineering Sciences
Vice Dean Faculty of Graduate Studies and Environmental
Research for Environment & Community
Ain Shams University

3-Dr. Hanan Ali Farag

Associate Research,
National Water Research Center
Ministry of Water Researches and Irrigation

2022

ACKNOWLEDGMENT

First of all, I would like to thank almighty Allah for his endless Grace and Blessing on me to fulfill this study.

I am greatly indebted to **Prof. Dr. Aly El-Bahrawy – Professor of Hydraulics – Faculty of Engineering – Ain Shams University** for his kind supervision, patience, help, valuable support, time, tolerance, and the facilities provided throughout the different stages of his work.

I am deeply grateful to **Prof. Dr. Noha Donia - Dean of the Faculty of Graduate Studies and Environmental Research**. She has been a tremendous mentor for me. I would like to thank her not only for his fruitful support but also for his continuous encouragement.

This work could not have been completed without the keen interest and the valuable support provided by **Dr. Hanan Farag - Associate Professor - National Water Research Center (NWRC)**.

Special thanks to **Dr. Mohamed Omar – Edgepro company** for his technical support on this study and for providing archived and common image processing software (ERDAS Imagine).

I wish to express my deepest appreciation to **Prof. Dr. Eman El-Azizy – Vice president of the 6th of October University**, for her generous and continuous professional assistance and continues support.

I would like to thank **Dr. Sameh Reyad – Head of The Central Department of EEAA - Alexandria Regional Branch** not only for facilitating the fieldwork procedures but also for his kind support and continuous motivation during this work.

Special thanks to my boss **Dr. Ayman Hamada – Head of The Central Department of Biodiversity – EEAA** for his daily encouragement and unconditional support.

I would offer my special thanks to my friends **Yasmin Abd Elrazik** and **Rania Salah** for their moral support and for enduring this long process with me.

Finally, there are no words that could express my sincere gratitude to my beloved family that believed in me and gave me all the support. I would like to dedicate this work to my family and especially my lovely daughter **Nour**.

ABSTRACT

Marine litter (ML) has recently become one of the most global prevalent pollution problems adversely affecting waterways. Litter makes its way into the water bodies as a result of disasters, accidents, mishandling, or oversight events. Minimizing the negative impacts of ML on marine ecosystems, biodiversity, human health, and the economy become a worldwide crucial need. However, an integrated system for monitoring and assessment of ML abundance in marine and coastal environments is still required to enhance existing policies and management practices.

This study aimed to examine an integrated science-based methodology for monitoring and assessment of macro-litter on the shoreline, and at the sea surface of El-Shatby beach, Alexandria Governorate as a pilot Egyptian Northern site. Quantitative measurements of ML were implemented using UNEP/MAP metadata through four years of beach-fieldwork surveys. ML quantities, materials, and main sources were identified to support the simulation of their possible fate and trajectory. Another monitoring technique was Optical spectral of Sentinel-2 (S2), and Planetscope (PS) images that were examined using a combination of different spectral bands with several indices, and verified by the pixel-value classification method of S2 images. Moreover, microwave remote sensing (SAR) was examined to add more information to the optical study. Exploring the vulnerability of coastal resources to ML using General National Oceanic and Atmospheric Administration Operational Oil Modeling Environment (GNOME) software was the additional target of this study. For simulating ML's possible trajectory hypothetical release of ML from El-Shatby beach was simulated using the GNOME model through three windage classes during wet and dry periods.

This study concluded that 72% of beach accumulated material was artificial polymers, and that variation in climatic conditions significantly influences trajectory and distribution patterns of ML under the forces of strong wind and rainfall. The most exposed sites to ML pollution were nearby public and private beaches, historical sites, Eastern and Western harbors, and Abu-Qir bay. Classification image was the most precise technique that reflects the real variety of different features, and the overall accuracy of plastics detection and identification using remote sensing techniques reached about 70-80%.

TABLE OF CONTENT

ACKNOWLEDGMENT	
ABSTRACT	I
TABLE OF CONTENT.....	II
LIST OF FIGURES	VII
LIST OF TABLES	VIII
LIST OF ABBREVIATIONS	IX
1. CHAPTER ONE	1
INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	1
1.2.1 Marine Biodiversity Threats.....	2
1.2.2 Damages Marine Ecosystem.....	2
1.2.3 Risks Human Health and Safety	2
1.2.4 Losses in Economy.....	3
1.3 Study Objectives	3
1.4 Work Plan	3
1.5 Study Approach	4
1.6 Thesis Structure.....	5
2. CHAPTER TWO	6
LITERATURE REVIEW	6
2.1 Definition of ML	6
2.2 Sources of ML	6
2.3 ML Materials	8
2.4 ML Fate	9
2.4.1 Fragmentation	10
2.4.2 Photooxidation.....	10
2.4.3 Biodegradation	10
2.5 Size and Shape of ML	11
2.6 Distribution of ML	12
2.6.1 Beaches.....	12
2.6.2 Floating ML	12

2.6.3 Seafloor	12
2.7 Impacts of ML.....	13
2.7.1 Entanglement/Entrapment	13
2.7.2 Ingestion.....	13
2.7.3 Habitat Destruction	13
2.7.4 Chemicals Transport to the Food Chain	14
2.7.5 Introduction of Invasive Species	14
2.7.6 Socio-Economic Impacts.....	14
2.8 ML Threats in the Mediterranean Sea.....	16
2.9 Remote Sensing (RS) Modeling.....	17
2.10 Trajectory Modeling	19
2.11 Concluding Remarks.....	21
3. CHAPTER THREE.....	22
STUDY AREA DESCRIPTION	22
3.1 Geographical Location	22
3.2 Administrative Division.....	23
3.3 Marine Habitats and Biodiversity	25
3.4 Main Economic Activities	26
3.4.1 Tourism and Recreation	26
3.4.2 Industrial Activities.....	27
3.4.3 Maritime Transport	27
3.4.4 Fishing and Aquaculture	28
3.4.5 Agriculture	29
3.4.6 Oil Refineries	29
3.5 Solid Waste in Alexandria Governorate.....	30
3.6 Laws and International Commitments.....	33
3.6.1 Main Regulating Laws.....	33
3.6.2 Main Regulating Conventions/ Strategies	34
3.7 Relevant Stakeholders	35
3.7.1 Primary Stakeholders (Category I)	36
3.7.2 Key Stakeholders (Category II)	36
3.7.3 Secondary Stakeholders (Category III)	36

3.7.4 Other Stakeholders.....	36
4. CHAPTER FOUR.....	37
4.1 Beach-Field Surveys	37
4.1.1 Type of Collected Data	37
4.1.2 Site Selection.....	38
4.1.3 Sampling Unit.....	38
4.1.4 Frequency and Timing of Surveys	39
4.1.5 Litter Size.....	39
4.1.6 Data Analysis	39
4.1.7 Specific Gravity of Polymers	42
4.2 Remote Sensing Technique	43
4.2.1 Remote Sensing Procedures.....	44
4.2.2 Sentinel-2 Satellite.....	45
4.2.4 Planetscope Dove Satellite.....	46
4.2.5 SAR Sensor	50
4.3 Trajectory Modeling.....	50
4.3.1 Setting GNOME Model.....	50
4.3.2 Location File Extraction	52
4.3.3 Litter Released Information.....	52
4.3.4 Minimum Regret.....	53
4.3.5 Movers Extraction	53
4.4 SWOT Analysis	54
4.5 DPSIR Framework	55
5 CHAPTER FIVE	56
5.1 Field Work Analysis	56
5.1.1 First-Year Field Survey.....	56
5.1.2 Second Year Field Survey	57
5.1.3 Third Year Field Survey	59
5.1.4 Fourth Year Field Survey	60
5.1.5 Fieldwork Results.....	62
5.1.6 Top Five Items.....	63
5.1.7 Smoking / Non-smoking items	64

5.1.8 Plastic Items Compared to Others	64
5.1.9 Fieldwork Discussion	65
5.2 Remote Sensing	66
5.2.1 Sentinel-2 Satellite.....	66
5.2.2 Planetscope Dove Satellite.....	68
5.2.3 Spectral Indices of Optical Images.....	69
5.2.4 SAR Sensor	72
5.2.5 Tidal Effects.....	76
5.2.6 Remote Sensing Discussions.....	77
5.3 GNOME Modeling Results	78
5.3.1 Model Inputs.....	78
5.3.2 Alexandria Map Extraction	80
5.3.3 Movers Extraction	80
5.3.4 Statistical Weather Data.....	81
5.3.5 GNOME Discussion	87
5.4 SWOT Analysis	88
5.5 DPSIR Analysis	89
CHAPTER SIX	92
6.1 Main Conclusion	92
6.1.1 Beach-Fieldwork.....	92
6.1.2 Remote Sensing.....	93
6.1.3 GNOME Model.....	93
6.2 Main Recommendations.....	94
SUMMARY	96
REFERENCES.....	98
مستخلص	١
الملخص العربى.....	٢

LIST OF FIGURES

Figure 1-1 Followed steps for obtaining the study objectives.....	4
Figure 2-1 Impact of ML on economic activities	15
Figure 2-2 Types of ML recorded in the Mediterranean Sea	16
Figure 3-1 Location of Mediterranean Sea.....	22
Figure 3-2 Satellite image for Alexandria Governorate	23
Figure 3-3 Administrative division of Alexandria Governorate	24
Figure 3-4 El-Shatby beach study area.....	25
Figure 3-5 Main harbors along with Alexandria Governorate	28
Figure 3-6 Sources of solid waste in Egypt (million tons)	30
Figure 3-7 Materials of solid waste in Egypt.....	31
Figure 3-8 Classification of solid waste materials in Alexandria.....	32
Figure 3-9 Final disposals of solid waste in Egypt.....	32
Figure 4-1 Satellite image of El-Shatby site	38
Figure 4-2 Sampling unit for monitoring litter on beaches	39
Figure 4-3 Sample of UNEP/MAP metadata template.....	41
Figure 4-4 Pictures of beach-field works.....	42
Figure 4-5 Specific gravity of artificial polymers	43
Figure 4-6 Analytic charting between ground objects.....	44
Figure 4-7 Applied procedures for RS monitoring.....	45
Figure 4-8 Verification image using Planetscope satellite	47
Figure 4-9 Diagnostic Mode selected in GNOME software	52
Figure 4-10 Location of Mediterranean region	52
Figure 4-11 Litter information window	53
Figure 4-12 Winds variable added in GNOME model.....	54
Figure 4-13 SWOT Analysis Framework.....	54
Figure 4-14 DPSIR framework chain	55
Figure 5-1 Main sources in first-year field surveys.....	56
Figure 5-2 Main materials in first-year field surveys	57
Figure 5-3 Main sources in second-year field surveys	58
Figure 5-4 Main materials in second field surveys.....	59
Figure 5-5 Main sources in third-year field survey	59
Figure 5-6 Main materials in third field surveys	60
Figure 5-7 Main sources in fourth-year field surveys	61
Figure 5-8 Main materials in fourth field surveys.....	62
Figure 5-9 Identification of beach debris a) materials, b) sources	62
Figure 5-10 Top five ML items	63
Figure 5-11 Smoking items compared with non-smoking items.....	64

Figure 5-12 Artificial polymers compared with other materials	64
Figure 5-13 Accumulation of ML at the study area	65
Figure 5-14 Spectral response of Sentinel-2 and PlanetScope	66
Figure 5-15 Sentinel-2 image of El-Shatby site	67
Figure 5-16 Visible bands (True Color) detected by Sentinel-2 satellite	67
Figure 5-17 Spectral zones (bands) to clarify types of ground features.	68
Figure 5-18 Verification image using Planetscope satellite	69
Figure 5-19 Examined indices of WRI, PI, AWEI.....	70
Figure 5-20 Examined indices of NDMI, NDVI, NDWI, SR, MNDVI	71
Figure 5-21 Sentinel-1 image (SAR Satellite) for the AOI.....	72
Figure 5-22 Sand and sea masks for the AOI.....	73
Figure 5-23 Backscattering information in dB values	74
Figure 5-24 Sentinel-1 VH channel, coastal sand classification	75
Figure 5-25 Comparison between photographic and SAR.....	75
Figure 5-26 Points (A, B) for tidal effect analysis	76
Figure 5-27 Series of temporal images	77
Figure 5-28 Modeling debris trajectory by three movers	79
Figure 5-29 Mediterranean Sea location map extracted from GOODS .	80
Figure 5-30 Current data using HYCOM extracted from GOODS.....	81
Figure 5-31 Average wind direction of Alexandria Governorate	82
Figure 5-32 Average rainfall (mm) in Alexandria Governorate	82
Figure 5-33 Scenarios of litter trajectory through different windage.....	84
Figure 5-34 Tracking of litter movements in wet periods	85
Figure 5-35 Tracking of debris movements in dry periods	86
Figure 5-36 Backward release of ML in dry periods, high windage.....	87
Figure 5-37 DPSIR framework chain	89

LIST OF TABLES

Table 2-1 Common categories of plastic wastes	9
Table 2-2 Size categories of plastic ML	11
Table 2-3 Morphological descriptors for marine plastic particles.....	11
Table 3-1 Approximate population of Alexandria Governorate	23
Table 3-2 Census population (2015) and its distribution in Alexandria	24
Table 3-3 Cultivated land in Alexandria Governorate	29
Table 3-4 Solid waste produced in Alexandria Governorate	31
Table 3-5 Number of laws regulating activities and waste disposals	33
Table 3-6 Number of regional and international conventions.....	34
Table 3-7 Stakeholders categorization (IUCN, 2014)	35
Table 4-1 Selected study areas along Alexandria coast	38
Table 4-2 Color coding for relevant activities.....	40
Table 4-3 Band metadata information of the S2 satellite	46
Table 4-4 Spectral indices using Sentinel-2 and Planetscope satellite	48
Table 5-1 Main sources of the first year of surveys	56
Table 5-2 ML materials in the first-year of surveys	57
Table 5-3 Main sources of the second year of surveys.....	58
Table 5-4 ML materials in the second year of surveys.....	58
Table 5-5 Main sources of the third year of surveys	59
Table 5-6 ML materials in the third year of surveys	60
Table 5-7 Main sources of the fourth year of surveys.....	61
Table 5-8 ML materials in the fourth year of surveys.....	61
Table 5-9 Top five items according to surveys	63
Table 5-10 Wavelength range of S2 and PS satellites spectral bands	66
Table 5-11 dB values of different objects.....	73
Table 5-12 Baseline parameter for GNOME simulation.....	79

LIST OF ABBREVIATIONS

Abandoned, lost, or otherwise discarded fishing gear	ALDFG
Area of Interest	AOI
Automated Water Extraction	AWEI
Dichlorodiphenyltrichloroethane	DDT
Driver/ Pressure/ State of Change/ Impact/ Response	DPSIR
Egyptian Environmental Affairs Agency	EEAA
Environmental Impact Assessments	EIA
European Space Agency	ESA
Extended Producer Responsibilities	EPR
Geographic Information Systems	GIS
General Authority for Fish Resources Development	GAFRD
General Authority of Remote Sensing	GARS
Global Programme of Action	GPA
Good Environmental Status	GES
Integrated coastal zone management	ICZM
Integrated monitoring and assessment programs	IMAP
Mediterranean Action Plan	MAP
Ministry of Agriculture and Land Reclamation	MALR
Ministry of Housing and New Communities	MHNC
Ministry of Water Resources and Irrigation	MWRI
Multispectral Instrument	MSI
Municipal Solid Waste	MSW
National Institute of Oceanography and Fisheries	NIOF
National Authority for Remote Sensing and Space Sciences	NARSS
NASA research Jet Propulsion Lab	JPL
Near Intra-Red	NIR
Normalize Difference Moisture	NDMI
Normalize Difference Water Index	NDWI
Normalize Difference Vegetation Index	NDVI
Non-Governmental Organizations	NGOs
Modified Normalized Difference Vegetation	MNDVI
Multispectral Instrument	MSI

LIST OF ABBREVIATIONS

Plastic Index	PI
Polychlorinated biphenyls	PCBs
Remote Sensing	RS
Reversed Normalized Difference Vegetation	RNDVI
Sea Level Rise	SLR
Shore Protection Authority	SPA
Strength – Weakness – Opportunities – Threats	SWOT
Simplified Ratio	SR
Ultraviolet	UV
United Nations Convention on Biological Diversity	UNCBD
United Nations Environmental Program	UNEP
Unmanned aerial vehicle	UAV
US Geology Survey Authority	USGS
Water Ratio	WRI