

TOWARDS ZERO DISCHARGE of Palm Oil Mill Effluent

Editors
Norhaniza Yusof
Mohd Amir Asyraf Mohd Hamzah



UTM
UNIVERSITI TEKNOLOGI MALAYSIA

TOWARDS ZERO DISCHARGE

of Palm Oil Mill Effluent

Palm oil mill effluent (POME) is a highly polluting by-product generated from the processing of palm oil. It contains a significant amount of organic and inorganic matter, making it a major environmental concern due to its high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The untreated discharge of POME can lead to severe water pollution, soil contamination, and greenhouse gas emissions, posing risks to both the environment and human health. As Malaysia is among the 193 member states who adopting Sustainable Development Agenda, the treatment strategy of POME should not be to limit the contamination level but to adopt various innovating strategies to recapture, reuse and recycle the POME into various usable products, creating a circular economy from POME, ending up with zero discharge of POME and achieving clean water and sanitation (SDG6).

Current POME treatment methods, such as anaerobic digestion and aerobic processes, are necessary to reduce organic load but fail to achieve the aim of zero discharge. Advanced technologies like membrane filtration, advanced oxidation processes and hybrids of biological and physical/chemical treatment systems offer promising solutions. Membrane bioreactor technology is among the promising solutions offering compact setup, shorter hydraulic time and ease of operation. Microbial fuel cells (MFCs) harness microorganisms to generate electricity while treating POME, effectively lowering BOD and COD levels.

Waste-to-wealth initiatives are transforming POME into valuable products. Anaerobic digestion not only produces biogas but also nutrient-rich biofertilizer. POME can also be processed into animal feed, reducing reliance on conventional feedstocks. Additionally, POME can be used to produce adsorbents for water treatment, biopolymers for biodegradable plastics, industrial enzymes, bio-oil, and pyrolygneous acid through pyrolysis.

These advancements support sustainability and a circular economy by minimizing waste, reducing environmental impact, and creating economic opportunities. The use of renewable energy and valuable by-products from POME helps lower greenhouse gas emissions and decreases reliance on fossil fuels.

In conclusion, integrating advanced treatment technologies and waste-to-wealth approaches can achieve zero discharge in POME treatment, promoting environmental sustainability and resource recovery in the palm oil industry. Ongoing research and development are essential to enhance these solutions' efficiency and feasibility, contributing to a more sustainable and circular economy.



UTM
UNIVERSITI TEKNOLOGI MALAYSIA

Penerbit
UTM Press



**TOWARDS
ZERO**
DISCHARGE
of Palm Oil Mill Effluent

TOWARDS ZERO **DISCHARGE** of Palm Oil Mill Effluent

Editors
Norhaniza Yusof
Mohd Amir Asyraf Mohd Hamzah



www.penerbit.utm.my

2024

First Edition 2024

© NORHANIZA YUSOF & MOHD AMIR ASYRAF MOHD HAMZAH 2024

Hak cipta terpelihara. Tiada dibenarkan mengeluarkan mana-mana bahagian artikel, ilustrasi, dan isi kandungan buku ini dalam apa jua bentuk dan cara apa jua sama ada dengan cara elektronik, fotokopi, mekanikal, atau cara lain sebelum mendapat izin bertulis daripada Timbalan Naib Canselor (Penyelidikan & Inovasi), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor Darul Ta'zim, Malaysia. Perundingan tertakluk kepada perkiraan royalti atau honorarium.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical including photocopying, recording, or any information storage and retrieval system, without permission in writing from Deputy Vice-Chancellor (Research & Innovation), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor Darul Ta'zim, Malaysia. Negotiation is subject to royalty or honorarium estimation.

Editor: **NORHANIZA YUSOF & MOHD AMIR ASYRAF MOHD HAMZAH**

Editor Penyelaras/Acquisition Editor: **MAZLAN SAID**

Pereka Kulit /Cover Designer: **NORIZAN YAACOB**

Diatur huruf oleh /Typeset by:

NORHANIZA YUSOF & MOHD AMIR ASYRAF MOHD HAMZAH

Faculty of Chemical & Energy Engineering

UNIVERSITI TEKNOLOGI MALAYSIA

81310 UTM Johor Bahru

Johor Darul Ta'zim, MALAYSIA

Diterbitkan di Malaysia oleh/

Published in Malaysia by:

PENERBIT UTM PRESS

UNIVERSITI TEKNOLOGI MALAYSIA

81310 UTM Johor Bahru

Johor Darul Ta'zim, MALAYSIA

(PENERBIT UTM ahli MAJLIS

PENERBITAN ILMIAH MALAYSIA –

MAPIM dan MABOPA

dengan no. keahlian 9101)

Dicetak di Malaysia oleh/

Printed in Malaysia by:

JASAMAX ENTERPRISE

No.16, Jalan Kebudayaan 2,

Taman Universiti,

81310 Skudai Johor,

MALAYSIA



Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the

National Library of Malaysia

ISBN 978-983-52-2112-5

CONTENTS

<i>Contributors</i>	<i>vii</i>
<i>Preface</i>	<i>ix</i>
CHAPTER 1 PALM OIL MILL EFFLUENT	1
<i>Norhaniza Yusof and Mohd Amir Asyraf Mohd Hamzah</i>	
CHAPTER 2 POME: STATISTICS, CHARACTERISTICS, AND COMPOSITION	25
<i>Muzzammil Ngatiman and Mohd Amir Asyraf Mohd Hamzah</i>	
CHAPTER 3 AEROBIC AND ANAEROBIC BIODEGRADATION OF PALM OIL MILL EFFLUENT	39
<i>Jemilatu Omuwa Audu and Mohd Firdaus Abdul-Wahab</i>	
CHAPTER 4 PHYSICO-CHEMICAL TREATMENT FOR PALM OIL MILL EFFLUENT	53
<i>Mohamed Hizam Mohamed Noor and Norzita Ngadi</i>	

CHAPTER 5	ULTRAFILTRATION MEMBRANE FOR POME WASTEWATER TREATMENT	73
	<i>Teshini Hari Ram and Norhaniza Yusof</i>	
CHAPTER 6	MEMBRANE DISTILLATION FOR PALM OIL MILL EFFLUENT TREATMENT	95
	<i>Nadzirah Mohd Mokhtar and Nor Amirah Safiah Muhamad</i>	
CHAPTER 7	MICROBIAL FUEL CELL FOR POME TREATMENT	123
	<i>Nurafiqah Rosman and Muhammad Noorul Anam Mohd Norddin</i>	
CHAPTER 8	ADSORBENT FEEDSTOCK FROM PALM OIL MILL EFFLUENT SLUDGE	163
	<i>Azrul Nurfaiz Mohd Faizal and Muhammad Abbas Ahmad Zaini</i>	
CHAPTER 9	VALUABLES PRODUCTS AND ENERGY RESOURCE DERIVED FROM POME	181
	<i>Mohd Amir Asyraf Mohd Hamzah and Norhaniza Yusof</i>	
INDEX		205

CONTRIBUTORS

Azrul Nurfaiz Mohd Faizal *Faculty of Chemical and Energy Engineering,
Universiti Teknologi Malaysia, Johor Bahru*

Jemilatu Omuwa Audu *Faculty of Science, Universiti Teknologi Malaysia, Johor
Bahru*

Mohamed Hizam Mohamed Noor *Faculty of Chemical and Energy
Engineering, Universiti Teknologi Malaysia, Johor Bahru*

Mohd Amir Asyraf Mohd Hamzah *Faculty of Chemical and Energy
Engineering, Universiti Teknologi Malaysia, Johor Bahru*

Mohd Firdaus Abdul-Wahab *Faculty of Science, Universiti Teknologi
Malaysia, Johor Bahru*

Muhammad Abbas Ahmad Zaini *Faculty of Chemical and Energy
Engineering, Universiti Teknologi Malaysia, Johor Bahru*

Muhammad Noorul Anam Mohd Norddin *Faculty of Chemical and
Energy Engineering, Universiti Teknologi Malaysia, Johor Bahru*

Muzzammil Ngatiman *Engineering & Processing Research Division, Malaysian
Palm Oil Board, Kajang*

Nadzirah Mohd Mokhtar *Faculty of Civil Engineering Technology, Universiti
Malaysia Pahang Al-Sultan Abdullah, Gambang*

Nor Amirah Safiah Muhamad *Faculty of Civil Engineering Technology,
Universiti Malaysia Pahang Al-Sultan Abdullah, Gambang*

Norhaniza Yusof *Faculty of Chemical and Energy Engineering, Universiti Teknologi
Malaysia, Johor Bahru*

Norzita Ngadi *Faculty of Chemical and Energy Engineering, Universiti Teknologi
Malaysia, Johor Bahru*

Nurafiqah Rosman *Faculty of Chemical and Energy Engineering, Universiti
Teknologi Malaysia, Johor Bahru*

Teshini Hari Ram *Faculty of Chemical and Energy Engineering, Universiti
Teknologi Malaysia, Johor Bahru*

PREFACE

Welcome to *Towards Zero Discharge of Palm Oil Mill Effluent*, a book dedicated to tackling one of the most pressing environmental challenges of our time. Palm oil mill effluent (POME) is a highly polluting by-product of palm oil processing, rich in organic and inorganic matter, which leads to high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Left untreated, POME can severely degrade water and soil quality, harm the aquatic life, and contribute significantly to greenhouse gas emissions.

Traditional POME treatment methods, such as anaerobic digestion and aerobic processes, reduce the organic load but often fall short of achieving zero discharge. This book delves into advanced technologies i.e. membrane technologies that offer promising solutions. Membrane distillation (MD) employs hydrophobic membranes to separate water from contaminants, facilitating nearly complete water recovery and pollution reduction. MFCs, on the other hand, leverage microorganisms to generate electricity while treating POME, effectively lowering BOD and COD levels.

Furthermore, this book explores the transformative potential of waste-to-wealth initiatives. By harnessing anaerobic digestion, we not only produce biogas but also create nutrient-rich biofertiliser. POME can be processed into animal feed, reducing reliance on conventional feedstocks, and can be used to produce adsorbents for water treatment, biopolymers for biodegradable plastics, industrial enzymes, bio-oil, and pyroligneous acid through pyrolysis.

These advancements support sustainability and a circular economy by minimizing waste, reducing environmental impact, and creating economic opportunities. Utilising renewable energy and valuable by-

products from POME helps lower greenhouse gas emissions and reduces our dependence on fossil fuels.

In this book, you will find comprehensive insights into integrating advanced treatment technologies and waste-to-wealth approaches to achieve zero discharge in POME treatment. Whether you are a student, researcher, industry professional, or policymaker, this book offers invaluable knowledge and practical strategies to enhance environmental sustainability and resource recovery in the palm oil industry.

Join us on this journey towards a more sustainable, efficient, and responsible future in manufacturing. Let *Towards Zero Discharge of Palm Oil Mill Effluent* be your guide and companion as you work to shape a better world through innovative and sustainable practices.

Norhaniza Yusof

Mohd Amir Asyraf Mohd Hamzah

Universiti Teknologi Malaysia

2024