UNIVERSITI TEKNOLOGI MARA

INVESTIGATION ON DIELECTRIC PROPERTIES OF SLUDGE WASTE FROM WATER TREATMENT USING MICROWAVE NON-DESTRUCTIVE TESTING (MNDT)

MUHAMMAD AL-HADI BIN ZABLE

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science
(Electrical Engineering)

College of Engineering

January 2024

ABSTRACT

The discharge of wastewater into waterways, accounting for approximately 80% of the total volume, highlights the significance of exploring opportunities for recovering valuable resources from the wastewater. The management of sludge waste, a by-product of the water treatment process, presents a critical challenge that necessitates the development of sustainable and efficient solutions. The increase of sludge waste that remains after the water treatment process will require additional cost of handling and eventually will limit the landfilling area to dispose the sludge. Thus, this research study focuses to investigate the potential reuse of sludge waste from water treatment plants as a potential carbonised materials or to be used as fertilizers for land treatment. The main objective is to investigate the correlation between sludge and frequencies used to ensure the capability of the measurement method in measuring the sludge waste. The measurement setup utilized Microwave Non-Destructive Testing (MNDT), employing a free-space system at X-band frequencies comprising a vector network analyser and a pair of horn antennas. The extracted S-parameters from the measurement were subjected to rigorous analysis using statistical tools of the Statistical Package for the Social Sciences (SPSS). Next, is to study the characteristic of raw and dry sludge S-parameters in response of the X-band frequencies used. Samples of sludge were collected from two distinct water treatment plants, and drying process was employed over a period of four weeks, where the samples were dried and monitored on a weekly basis to replicate the sludge waste management procedure typically implemented in these plants. This is to capture the variations in the composition of the samples, measurements were taken at three different states: raw, granules, and dust. Lastly, an evaluation of dielectric properties of the sludge using Nicholson-Ross-Weir (NRW) conversion method was conducted. The subsequent step involved studying the dielectric properties of the sludge waste, aiming to comprehensively characterize the material. Nicolson-Ross-Weir program was utilized using Matlab to calculate the permittivity of the sludge samples, which is well-suited for free-space measurement. The permittivity values were then compared with known materials possessing compatible permittivity to determine suitable applications for the sludge waste. From this research, it can be found that the MNDT – free space measurement technique is suitable for testing the sludge waste since all of the raw samples measured give high signal of correlation of S-parameters against the frequencies used. As for comparison of permittivity, two possible ways of sludge reuse were obtained from this study, namely as land application and as activated carbon materials where the dry sludge samples lies within the same permittivity range. It was also discovered that the raw sludge samples have a pH range that is good for agriculture, particularly for plant growth that demands an acidic environment. The findings and insights obtained from this research are expected to provide information on dielectric properties of sludge waste and also be a stepping stone towards identifying suitable usage of sludge waste reuse either as activated carbon materials or use in land application.

ACKNOWLEDGEMENT

Firstly, I wish to thank Allah for giving me the opportunity to embark on my Master Degree and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor Assoc. Prof. Ir. Dr. Zuhani Ismail Khan with all of the guidance and support along this journey.

My appreciation goes to the Microwave Research Institute (MRI) and school of electrical engineering who provided the facilities and assistance during laboratory measurement. Special thanks my co-supervisors, Ir. Dr. Nor Ayu Zalina Zakaria and Assoc. Prof. Ir. Dr. Nur Emileen Abdul Rashid and also big thanks to research officer, Encik Khairil Mohamad and to my other colleagues and friends for helping me with this project.

Finally, this thesis is dedicated to my loving parent and family for the love and determination to educate me. This piece of journey is dedicated to both of them and my other families for the unconditional love and support. Alhamdulillah.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Research Background

Wastewater remediation and sludge treatment have become one of a rising global environmental concern in the search for a green and sustainable future. The environment and public health should take this matter into consideration as the country progresses towards greater scale of national development heights. Several innovative treatment processes have been designed throughout the last few decades for treating wastewaters and sludge. In a view to find sustainable treatment processes, active research is being conducted globally and microwave technology is gradually making a modest but promising mark of its own in enhancing significant extents the ease, fastness, and efficiency of certain treatment processes involving wastewater and sludge management. Dielectric properties play a significant part in characterizing, monitoring, and optimizing different aspects of sludge waste treatment and management process using the application of dielectric measurements. Dielectric properties refer to the ability of a material to respond to an electric field and these properties are influenced by factors such as the composition, structure, and moisture content of the material. The dielectric properties of the material in the sludge is important to identify the material suitability and capability of the materials for any other usages. For instance, giving low permittivity for organic matter, sludge is suitable for agriculture purposes or even in construction where sludge is used as a microwave absorber in production of compressed brick [1], [2].

This study demonstrates the potential of the microwave non-destructive testing (MNDT) application to investigate the dielectric properties of the material in sludge waste. An in-depth study of dielectric properties of sludge which focusing on its permittivity to determine the sludge content in finding suitable sludge treatment. Permittivity is chosen as an indicator to compare with prospective uses for sludge waste reuse because of its sensitivity to moisture content, adaptability for non-destructive testing, and current information based on prior research for sludge waste reuse applications. The X-band frequency which ranges from 8 to 12 GHz is applied in a fundamental laboratory free space measurement system of MNDT due to its equipment