ELECTRICAL AND ELECTRONIC WASTE CHARACTERIZATION AND BIODEGRADATION OF OIL AND GREASE BY ISOLATED INDIGENOUS BACTERIA

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UNIVERSITI TEKNOLOGI MALAYSIA

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ABSTRACT

Oil and grease (O&G) are widely used in machine related processes and operations. It provides a fluid layer to separate moving surface of machines, minimizing heat and friction and hindering surface wear under extreme temperature and pressure. Hence electrical and electronic industry (E&E) has the possibility to generate O&G in their E&E effluent. However, the O&G content in E&E effluent became an issue due to factory located in catchment area. Thus it is strictly needed to meet permissible discharge limit of standard A. O&G contamination is hazardous to the aquatic environment as it contains toxic substances that are believed to be carcinogenic, mutational and exert toxic effects. Physical and chemical treatment system are inefficient and costly to remove low concentration of O&G (<10 ppm). Hence, the use of biological treatment to treat wastewater sample contaminated with O&G from E&E industry was investigated. The biodegradation experiment was carried out using *Aeromonas hydrophila* UTM2 which has been deposited in GenBank with accession number KF049214. The O&G sample screened using GC-MS revealed one of the phenolic compounds which is 2,6-di-tert-butylphenol as one of the components. Hence phenol degradation as representative of O&G derivatives was also carried out. Parameters such as effect of initial phenol concentration, contact time, initial pH, and effect of carbon and nitrogen supplementation on degradation of O&G at 200 rpm, 30^{o}C were studied in batch system. *Aeromonas hydrophila* UTM2 was chosen for biodegradation study as it showed the higher phenol degradation for phenol concentration of 10 mg/L, 50 mg/L and 100 mg/L. The highest degradation for phenol was 100% and 70.58% when the medium was separately supplemented with glucose (96 hours) and NH_4NO_3 (120 hours), respectively at initial concentration of 50 mg/L phenol. Complete degradation of O&G using real E&E wastewater was achieved at initial concentration of 5.19 mg/L after 4 hours at pH 7 when the medium was supplemented with tryptone and lactose separately. These optimization parameter for phenol and O&G were applied in real E&E wastewater subjected for phenol and O&G degradation. Complete degradation was achieved for phenol (0.198 mg/L) and O&G (4.88 mg/L) after 2 hours incubation in 1 g/L of tryptone and 1 g/L lactose supplementation at pH 7.0 at 200 rpm and 30^{o}C. Therefore, *Aeromonas hydrophila* UTM2 can be applied for degradation of low concentrations of O&G found in E&E wastewater.

ABSTRAK

Minyak dan gris (O&G) banyak digunakan dalam proses dan operasi yang melibatkan mesin. Ia menyediakan lapisan cecair untuk memisahkan permukaan mesin yang bergerak, meminimumkan haba dan geseran serta melindungi permukaan daripada suhu dan tekanan yang tinggi. Oleh ini, industri eletrik dan elektronik (E&E) mempunyai keberangkalian untuk menghasilkan O&G di dalam air sisa E&E. Walau bagaimanapun, kandungan O&G di dalam air sisa E&E menjadi isu berikutan dengan kedudukan kilang di dalam kawasan tadahan air, dengan ini ia harus menepati had perlepasan piawaian A. Pencemaran O&G berbahaya terhadap hidupan akuatik kerana mengandungi bahan toksik yang dipercayai karsinogenik, mutagenik dan menunjukkan kesan toksik. Rawatan sistem fizikal dan kimia tidak efektif dan mahal untuk merawat kepekatan O&G yang rendah (<10 ppm). Maka, penggunaan rawatan biologi untuk merawat air sisa sampel O&G daripada E&E telah dikaji. Eksperimen biodegradasi telah dijalankan dengan menggunakan *Aeromonas hydrophila* UTM2 yang telah didaftarkan di GenBank dengan nombor akses KF049214. Sampel O&G telah disaring menggunakan GC- MS, mendedahkan satu daripada sebatian fenol iaitu 2,6-di-tert-butilfenol sebagai salah satu daripada komponen. Dengan ini, degradasi fenol sebagai wakil terbitan O&G juga dijalankan. Parameter seperti kesan kepekatan awal bagi fenol, masa interaksi, pH dan kesan penambahan karbon dan nitrogen terhadap biodegradasi bagi O&G pada kelajuan 200 rpm, 30^{o}C telah dikaji di dalam sistem kelompok. *Aeromonas hydrophila* UTM2 telah dipilih bagi kajian biodegradasi kerana menunjukkan degradasi fenol paling tinggi bagi kepekatan fenol 10 mg/L, 50 mg/L dan 100 mg/L. Degradasi fenol paling tinggi iaitu 100% dan 70.58% apabila medium telah ditambahkan dengan glukosa (96 jam) dan NH_4NO_3 (120 jam) secara berasingan dengan nilai masing- masing pada kepekatan awal fenol 50 mg/L. Degradasi lengkap bagi O&G dengan menggunakan air sisa dari E&E telah diperolehi pada kepekatan awal 5.19 mg/L selepas 4 jam, pada pH 7 apabila medium ditambah dengan tripton dan laktosa secara berasingan. Parameter optimum bagi fenol dan O&G telah diaplikasi untuk air sisa E&E sebenar bagi degradasi fenol dan O&G. Degradasi lengkap telah diperolehi bagi fenol (0.198 mg/L), O&G (4.48 mg/L) selepas 2 jam pengeraman dalam 1 g/L tripton dan 1 g/L laktosa pada pH 7.0 dengan kelajuan 200 rpm, 30^{o}C. Oleh itu, *Aeromonas hydrophila* UTM2 boleh diaplikasi untuk degradasi O&G pada kepekatan yang rendah yang terdapat dalam sisa air E&E.

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LIST OF SYMBOLS/ABBREVIATIONS

A.hydrophila UTM2	*Aeromonas hydrophila* UTM2
E&E	Electrical and Electronic
O&G	Oil and Grease
mg/L	Milligram per litre
MT/year	Metric Tonne per year
COD	Chemical Oxygen Demand
BOD_5	Biological Oxygen Demand
TOC	Total Organic Carbon
T	Temperature
SS	Suspended Solids
NH_3-N	Ammoniacal Nitrogen
GC-MS	Gas Chromatography Mass Spectrometry
E_{24}	Emulsification Index
BATH	Bacterial Adherence to Hydrocarbon
MNCs	Multinational companies
USA	United State of America
EMS	Electronic Manufacturing Services
M&E	Mechanical & Electrical
ETP	Electronic Transformation Programme
NKEA	National Key Economic Area
GN1	Gross National Income
AV	Audio/Video
%	Percent
CMP	Chemical/ mechanical/ polishing
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
DO	Dissolved Oxygen
M	Molarity
DDW	Deionized Distilled Water
^oC	Degree Celsius
kPA	kilopascal
L	Liter
PAHs	Polyaromatic Hydrocarbons

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The electrical and electronic (E&E) industry today plays a vital role in the development of most nations as it has grown substantially over the past decades. United States, Japan and Korea are the top three E&E goods manufacturing country in the world. The world's E&E market size is $1038.8 billion in 2006 and increase 10.6% from the last year. In Malaysia, the E&E industry is the key driver of Malaysia's industrial development which contributes significantly to the country's manufacturing (26.94 %), exports (48.7 %) and employment (32.5 %). The E&E industry in Malaysia can be categorized into four sub-sectors; consumer electronics, electronic components, industrial electronics and electrical (Malaysian Investment Development Authority (MIDA), 2012). The electronic components which include semiconductor devices, passive components, printed circuits and other components such as media, disk, substrates and connectors are the most important sub-sector and accounts for 36 % of the total investments approved in the electronic sector in 2011 (Malaysian Investment Development Authority (MIDA), 2012).

Two main processes involved in hard-disk manufacturing are substrate fabrication and disk-fabrication where the production of substrate and disk involves the use of various types of machines such as texturing, cleaning, sputtering etc. (Higuchi and Mori, 2009). In order to maintain the performance of the machines, hydraulic oil, gear oil and grease are needed. Hence, the oil and grease (O&G) can stem as a source of contaminant in the electronic wastewater.

O&G contamination is hazardous to the aquatic environment as it contains toxic substances such as phenolic compounds, petroleum hydrocarbons, polyaromatic hydrocarbons (Alade *et al.*, 2011). These substances are believed to be carcinogenic, mutational and exert toxic effects such as reduced growth and reproduction, poor health (Zahed *et al.*, 2011) and cancer (Aluyor and Ori-Jesu, 2009) through bioaccumulation and biomagnification via food chains (Zahed *et al.*, 2010).

The issue of O&G contamination from E&E wastewater is not well addressed due to following factors; the treatment system mainly focuses on removal of heavy metal pollutants, most of the E&E factories have to follow standard B set by Department of Environment (DOE) which are more lenient due to the location of factories located at downstream from drinking water intake points and low concentration of O&G produced from the industry. However, the issue of O&G contamination arises when some E&E factory which is located at the catchment area produces some traces of O&G and needs treatment. The permissible limit for O&G set by Department of Environment (DOE) must not exceed 1 mg/L (Standard A) (Malaysia, 2009).

In 2010, the E&E industry generates the second highest amounts of waste which accounted to 274,582.79 MT/year. Meanwhile, the O&G waste can fall under either oil & hydrocarbon and phenol/spent adhesive/ spent resin categories, which are accounted to 106,939.39 MT/year (5.69 %) - 2010 increased to 133,260.91 MT/year (8.22 %) - 2011 and 17,620.58 MT/year (0.67 %) - 2010 decreased to 7,904.42 MT/year (0.49 %) - 2011, respectively (Department of Environment, Ministry of Natural Resources and Environment, 2010 ; Department of Environment, Ministry of Natural Resources and Environment, 2011).

As environmental regulation becomes stringent to control the quality of effluent discharge into the environment, there are many conventional methods that have been used to remove O&G from industrial wastewater. The method includes electrocoagulation (El-Nass *et al.*, 2009), adsorption (El-Nass *et al.*, 2010), electrochemical oxidation (Un *et al.*, 2008), corrugated plate separator, micro

filtration and activated sludge (Ahmadun *et al.*, 2009). However, these methods are ineffective due to high retention time, high energy requirement, very expensive to maintain and not environmental friendly. Employment of these methods is not economical when the initial O&G concentration in the wastewater is low (< 10 mg/L). Therefore, biological treatment system may provide an alternative way to treat traces of O&G as it is cheaper, environmental friendly and effective at low concentration of O&G.

1.2 Statement of Problem

The E&E industry generally generates wastewater containing large amounts of heavy metals and most of the treatment methods employed is focused on the removal of this contaminant. However, some E&E industry produce O&G as contaminants in their wastewater and necessitates treatment system to treat O&G. Existing conventional methods using chemical, physical and biological treatment are not efficient to remove trace O&G. Hence, the aim of this study was to evaluate the bioremediation method, using locally isolated bacteria from contaminated site which has promising efficiency to degrade traces of O&G.

1.3 Objective of the Study

The objectives of this research include:

- To characterize the E&E industry wastewater.
- To isolate and characterize bacteria from the E&E industry wastewater.
- To study the degradation of O&G using bacteria isolated from E&E wastewater.

1.4 Scope of the Study

The scope of this research will include characterization of E&E wastewater (chemical oxygen demand (COD), biological oxygen demand (BOD_5), pH, total organic carbon (TOC), temperature (T), suspended solids (SS), total dissolved solid (TDS), ammoniacal nitrogen (NH_3-N), phenol, oil and grease (O&G) content).

The bacteria degrading O&G from E&E wastewater will be isolated. The derivatives of O&G will be screened using GC-MS and the best O&G degrading bacteria will be chosen based on high growth rate monitored through growth profile study. The selected O&G degrading bacteria will be identified using 16S rRNA and will be characterized based on clump dissociation, emulsification index (E_{24}), and bacterial adherence to hydrocarbon (BATH).

Then, the selected bacteria will be used for degradation of O&G using synthetic and real wastewater. The parameters affecting the degradation of O&G such as effect of initial phenol concentration, effect of contact times, effect of pH, and effect of carbon and nitrogen supplementation will be optimized. Times factor for the performance of phenol, O&G degradation for some factors affecting degradation by the isolates will be evaluated. Finally, the optimized conditions achieved in O&G degradation will be used in real effluent using waste obtained from E&E industry.

1.5 Significance of Study

This research is expected to provide an alternative treatment system for E&E industry necessitates treating traces of O&G especially at low concentration (less than 10 mg/L). The treatment is biologically based which is expected to be cost effective, efficient and more environmental friendly.

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