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PREFACE

Environmental Engineering technology is an application of the environmental science to conserve the natural environment and resources, and to curb the negative impacts of human involvement. Sustainable development is the core of environmental technologies. Environmental technology is also known as envirotech. That is where this book comes in. The book confronts the reader with the applications in environmental engineering technology that widely used today. The main focus of this book is on the waste disposal management, air quality using houseplant, definition of Indoor Environmental Quality (IEQ) and Indoor Air Quality (IAQ), carbon dioxide removal in palm oil, wastewater matrix and characterisation, arsenic distribution in Johor, using concrete and windshield glass waste as filteration to remove phosporus, cultivate aerobic ganular sludge with soy sauce wastewater, modelling 2D hydrodynamic wave during spring tide at Tanjung Pelepas and geophysic technology in defining the environmental impact in coastal area. Each of these topics is vast thus we restrict our attention for each of these areas, for example air quality, wastewater, use of concrete to remove the phosporus and simulation of geophysic and hydrodinamics. The main contributors are from Department of Environmental Engineering Technology, Faculty Engineering Technology, UTHM. We thank all of our collaborators for their tremendous assistance in making this book possible.

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CONTENTS

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CHAPTER 1

A STUDY ON THE AWARENESS OF HOUSEHOLD WASTE SEPARATION IN PARIT RAJA, JOHOR: RESIDENTIAL AREA

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1.0 INTRODUCTION

Malaysia has set a target to become a developed nation by year 2020. This can be achieved in the Eleventh Malaysia Plan (2016 - 2020) that was introduced by the government which is the final step in order to provide a nation towards sustainable development in terms of politic, economy and social. In order to realize this vision, the government has defined six strategic thrusts to help Malaysia stay ahead of the challenges and opportunities of the fast-changing global and political landscape. Therefore, it demonstrates the commitment of Malaysia to renew and increase its commitment to the environment and the long-term sustainability [1]. As a result, some government agencies have been established such as Department of Environment (DOE) to achieve goals which is to the prevention, abatement, and control of pollution and to ensure that Malaysia's precious environment and natural are conserved and protected for present and future generations.

Solid waste management in Malaysia has recently approached a critical level, especially in terms of the amount and composition. Generation of waste increased each year by 3% due to many causes such as urban migration, affluence, and rapid development [2] and increased drastically where it was expected to increase from about 9.0 million tons in 2000 to about 10.9 million tons in 2010, and finally to about 15.6 million tons in 2020 [3]. In order to reduce this environmental problems at household level, the community itself should play a role by practicing of waste separation.

Nowadays, household waste separation is very important and waste separation is familiar in developed countries out there. However, in Malaysia waste separation is a new thing and take a long period to be practice and environmental awareness among the public generally is still not adequate [4]. The aim of this research is to investigate the awareness of household waste separation in residential areas.

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1.2 LITERATURE REVIEW

The environmental problem is a global concern and it has no boundary. One of the main cause that make environmental degradation is improper management in the disposal of wastes. Waste can also be generated as a result activities of household. Household waste considered as a type of municipal solid waste (MSW) and consists mainly of plastics, paper, glass, metals, organics, wood and others. These wastes must be predisposed accurately to assist keep environmental quality and human health, as well as to preserve natural resources [5].

1.3 CONCEPT OF HOUSEHOLD WASTE

Management of municipal solid waste (MSW) is a major challenge for developed countries, especially in the cities are growing rapidly and Malaysia is one of the most successfully country to go through transition. A good MSW management must cover waste generated from other sources like a commercial, industrial, institutional, and municipal services [3]. Table 1 shows the sources of solid waste and the location where wastes are generated.

Table 1: Sources of solid waste generation

Sources of Waste	Locations where wastes are generated
Residential/Household	Single and multifamily dwellings, terrace, semi-detached, bungalow, apartments, cluster house, etc.
Commercial	Stores, hotels, restaurants, markets, office buildings, motels, shops, private school, etc.
Institutional	Schools, hospitals, prisons, government centers, universities, etc.
Municipal	Street cleaning, landscaping, parks, beaches, recreational areas, water and wastewater treatment plants, open spaces, alley, roadside litter, etc.
Agricultural	Field and row crops, orchards, vineyards, dairies, farm, etc.
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings, broken pavement, etc.
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants, and refineries.

(Adapted from Eeda, Ali, & Siong, 2012)

Solid waste composition refers to the various elements that the waste contains. The composition of municipal solid waste is one of the factors to be considered before proposing any management option [6]. Composition of solid waste can be classified into organic and inorganic [7]. Table 1.2 describes the different types of waste and their

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sources. There are certain waste are inorganic but can be reused or recycled in fact it is believed that a larger portion of the waste can be recycled, a part of can be converted to compost, and only a smaller portion of it is real waste that has no use and has to be discarded [8].

Table 1.2: Physical Composition of Household Solid Waste

Physical Composition	Basic Classification	Example
Organic	Food Waste	Vegetables, meats
	Garden Waste	Yard (leaves, grass, brush) waste, wood
Inorganic	Plastic	Bottles, packaging, containers, bags, lids, cups
	Textile and Rubber	Clothes, leather products
	Paper and Box	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, telephone books, shredded paper, paper beverage cu
	Glass	Bottles, broken glassware, light bulbs, colored glass
	Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles

(World Bank, 2012)

One of the steps taken by the Malaysian government in solving environmental problems is waste minimization followed by 3R program, composting, incineration and landfill. Solid waste management planning strategies need to support the waste minimization. This is because waste minimization is best strategies for waste management to reduce amount of waste generated [9].

1.4 Method of Waste Minimization

Waste minimization can be defined as the preventing and reducing waste at source through the efficient use of raw materials, energy and water [10]. Waste minimization strategies aim to strengthen awareness and encourage environmentally conscious consumption patterns and consumer responsibility to reduce the overall levels of waste [11]. In waste minimization hierarchy, the first option is waste reduce which offers the best outcomes for the environment then followed by reuse, recycling, composting and disposal. Figure 1 shows the reduction is the most preferred option while the landfill is

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seen as the least favored option. The process involves six steps ranked which are i) 3R concepts (Reduce, Reuse, Recycle); ii) composting; iii) incineration; and iv) landfill.

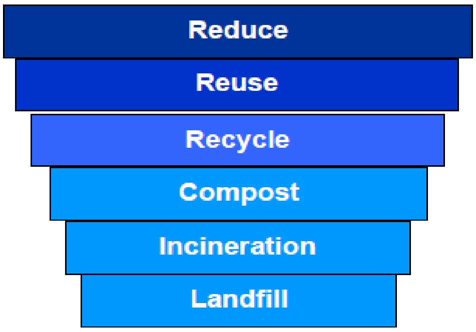

Figure 1: Waste Minimization Hierarchy (Eeda et al., 2012)

i. The concept of 3R's (Reduce, Reuse, Recycle)

Methods of reduce, reuse and recycling are the alternative options when managing the waste. Reduce simply means to make less waste [12]. Reducing waste is first in the hierarchy of solid waste management and is a difficult alternative compared to recycling. Especially, in the housing area, households must reduce the amount of municipal solid waste being produced [13].

Reuse can be defined as use the same item more than once, preferably many times, rather than throwing it out after one use [12]. Reuse is a process that many households already implement in their daily life without realizing it [14]. For example, paper bags obtained in the supermarket are often reused, old furniture can be given to others in need.

Next, recycling is refer to the process of separating out the waste materials that are useable for recycling so that they can be collected separately from the rest of the solid waste [13]. The waste is sorted and recyclables collected, the recyclables are used to create raw materials. These raw materials are then used in the production of new products [15].

ii. Composting

The decomposition of organic material is a natural, important process that returns valuable nutrients to the soil for plants to use [16]. Composting in Malaysia is not pursued as a solution to MSW disposal problems because the quality of product depends on the waste and hence waste separation is very important. Lack of suitable markets for compost and lack of economies of scale for quantities for the recyclable market is also a major problem. When composting is not suitable for component of waste, then landfill will still be required [17].

iii. Incineration

Incineration is the most common thermal treatment process. Incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities [18]. Process of incineration is carbon hydrogen and other elements in the waste are combined with oxygen in the combustion air which generates heat and also used to reduce waste materials to what was thought of as harmless ash [14].

However, in Malaysia, the use of incinerators has been discontinued recently due to the high cost of operation and poor technical expertise in maintaining the incinerators [19]. This method has become a challenge to find an incineration technology that is capable of incinerating wastes with high moisture content accompanied by a low calorific value and at the same time operates at a low cost in comparison to the relatively cheap landfilling method [20].

iv. Landfill

Landfilling is the most neglected area of SWM services [21]. Landfill can be defined as a waste disposal site used for the controlled deposit of solid waste onto or into land [22]. Landfill is by far the most commonly practiced waste disposal method in the majority of countries. The preferred method practiced for the disposal of MSW in Malaysia is through landfill and most of the sites are open dumping areas [4]. This is because, landfill is the simplest and cheapest way of disposing solid waste and it is also can deal with all kinds of materials in the solid waste stream [23].

1.5 Household Waste Separation

Residents have a legal responsibility to ensure that all of their rubbish and waste is disposed of properly. If they are not properly disposed it can cause diseases. The government provides the concession companies, operators or the respective local authorities to carry out the collection and disposal of municipal solid waste. The objective is to provide effective, and an integrated, well-planned, well-managed, efficient technologically advanced solid waste management system [24]. However, waste management sector were faced with numerous challenges, such as a land shortage for landfills and residents opposed to waste disposal facilities constructed near their homes. One way to overcome these problems is with recycling, and the important prerequisite for recycling is household waste separation at the source [25]. Source separation is one of the prerequisites for successful and economically feasible recycling activities [26].

Household waste separation involves separating waste into common material streams or categories for separate collection. This may be achieved using separate bin services or verge side collections, or through direct delivery of specific wastes to drop-off facilities [27]. In other countries, there are three or more bins in households for waste separation. In Malaysia, prefer 3 recycling bins for paper, plastic and glass [28]. Table 1.3 show the recycle bins at home in many countries.

Table 1.3: Recycling Bins at Household

Types of Bins	Country Name
2 Bins: Dry waste & wet waste	Belgium, Serbia, Norway, Brazil, Argentina, Russia, New Zealand, Indonesia, Egypt
3 Bins: Paper, plastic & glass	Philippines, Sri Lanka, Poland, Latvia, Moldova, Malaysia
4 Bins: Paper, plastic, glass, & organic	Bulgaria, Taiwan, Portugal, Spain
5 Bins: Paper, plastic, glass, organic & e-waste	Finland

(Adapted from Singh & Livina, 2015)

The way humans respond and co-operate on waste management issues is influenced by their education, therefore, the public's education is an essential element of the success of any waste management program. Normally, Malaysian still have very low awareness on the importance of involvement in waste separation. One's attitudes based on one's perception of a behavior as positive or negative, right or wrong, pleasant or unpleasant, or interesting or boring. Other than that, personal attitude had the strongest correlation with waste separation intention [25]. Attitudes and perceptions toward waste separation at source and rating of waste disposal issues in people's minds and in the scheme of official development plans have not been adequately considered which has thus led to the recent upsurge in waste disposal problems in developing countries [26].

1.6 Rules and Regulations

An Act to provide for and regulate the management of controlled solid waste and public cleansing for the purpose of maintaining proper sanitation and for matters incidental thereto [29]. In order to manage solid waste in Malaysia in an efficient way so can prevent from environmental degradation, the Solid Waste and Public Cleansing Management Act 2007 (Act 672) has been introduced. SWMPC Act 2007 aim to provide an act and regulate the management of solid waste and public cleansing in order to maintain proper sanitation in the country [30].

Currently, the enforcement of the Act 672 is under Solid Waste Management and Public Cleansing Corporation (SWMPCC) and this corporation has executive authority to take over the solid waste management from the local authorities. Hence, it has brought the confusion as well as overlapping power of enforcement between the corporation and local authorities [31]. This Corporation works under the Federal government and the function of the corporation includes every aspect that is deemed necessary to ensure the implementation and success of an effective and integrated solid waste management plan [32].

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1.7 Methodology

1.7.1 Research design adopted for the present studies

To meet those two objectives stated in the first chapter, the research design adopted for this study is by using the quantitative methods. The residents is recognizing as a representative of respondent, the simplicity and less time-consuming quantitative method may help them to answer the question. The quantitative method statistical analysis helps the researcher in providing a descriptive data that derive important facts from the research. This is because, data collection obtained through this method simplify comparisons between two or more variables. Hence, quantitative method suit for researcher limitation because due to lack of time and budget.

The instrument of the quantitative method for primary data collection was by using self-structured questionnaire. This method provides a quantitative method or data collection, attitudes, or opinions of a population by studying a sample of that population [33].

1.7.2 Questionnaire Construction

The survey questionnaire is designed based on the literature review in order to answer the objectives of this research. The questionnaire template consists of 16 questions and is divided into three parts, as follows: 1) demographic profile; 2) background of household waste; and 3) awareness on household waste separation. The first section of the questionnaire enquires details on the background of the respondents. Second section is concentrates on household waste produce by the respondent and the last part of the survey enquires on the awareness of the respondents about household waste separation.

1.7.3 Sampling design of the study

A sample is a finite part of a statistical population whose properties are studied to gain information about the whole study [34]. The sampling is the process or method involves taking a representative selection of the population and using the data collected as research information [35]. Samples were collected in certain areas in Parit Raja due to time and budget constraints. The questionnaire was distributed to the residential areas at Taman Universiti, Taman Melewar and Taman Maju Jaya. This research involved the quantitative method of data collection that took place in between September 2016 to October 2016. A total 150 respondents were selected randomly to representative sample of the target study. Table 1.4 shows the areas and the number of respondents in each area that were chosen for the study.

Table 1.4: Number of respondents in chosen area

Areas	Number of respondents
1. Taman Universiti	72
2. Taman Melewar	40
3. Taman Maju Jaya	38
Total	150 respondents

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1.7.4 Data Analysis

In this study, the data for quantitative self-structured questionnaire results will be analyzed using statistical analysis software namely Statistical Package for Social Sciences (SPSS, version 22.0) which are used for organizing, describing and analyzing data from questionnaire survey. In order to produce information on the frequencies, means and percentages, the data need to be analyzed through descriptive statistics. Descriptive analysis can be define as to the transformation of raw data into a form that will make them easy to understand and interpret also rearranging, ordering, and manipulating data to generate descriptive information in data analysis [36]. Other than that, it is suitable for measuring human perception, the objective of the study, the available time and financial resources [37].

Other than that, this study using test of cross tabulation. Crosstabs can be defined as form two-way and multiway table and measures of association for two-way table. A cross tabulation is a two or more dimensional table that records the frequency of respondents that have the specific characteristics described in the cells of the table. In addition, cross tabulation tables provide a wealth of information about the relationship between the variables [38].

1.8 Findings and Analysis

The data was collected by distributed the self-structured questionnaire at residential areas Parit Raja, Johor. The data analysis and discussion in this chapter were divided based 3 subtopics; i) demographic profile of the respondents; ii) background of household waste; and iii) awareness on household waste separation.

1.8.1 Demographic profile

Table 1.5: Summary demographic profile of respondent

Variable	Descriptions	Frequency	Percentage (%)
Housing Area	Taman Universiti	72	48
	Taman Melewar	40	26.7
	Taman Maju Jaya	38	25.3
Gender	Male	81	54
	Female	69	46
Age	20 years and below	30	20
	21 - 30 years	107	71.3
	31 - 40 years	6	4
	41 - 50 years	3	2
	51 years and above	4	2.7
Education Level	Secondary School	8	5.3
	College/Institution	11	7.3
	University	131	87.3

Results from Table 1.5 show that a total number of 150 respondents from residential areas which are 72 respondents were from Taman Universiti, 40 respondents were from Taman Melewar and another 38 respondents were from Taman Maju Jaya.

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Table 5 show that the total of 150 respondents indicates 54% (81 respondents) of the respondents that took part in this survey was male and 46% (69 respondents) of respondents were female.

In terms of age, Table 5 had shown that 20% (30 respondents) were between the ages of below 20 years old; 71.3% (107 respondents) were between the ages of 21-30 years old; 4% (6 respondents) were between in the ages of 31-40 years old; 2% (3 respondents) were between of the ages of 41-50 years old and 2.7% (4 respondents) were in the ages of above 51 years old.

From Table 5, it can be said that most of the respondents who took part in this survey is received their education until tertiary level with the percentages 87.3% (131 respondents) and 7.3% (11 respondents) and secondary school at 5.3% (5.3 respondents).

Table 1.6: Cross tabulation between respondent's education level and gender

Education Level	Gender			
	Male		Female	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Lower Education	4	4.9	4	5.8
Higher Education	77	95.1	65	94.2
Total	81	100	69	100

Table 1.6 above indicated that as a whole, majority of the respondents who took part in this survey were from tertiary level educational background (142 respondents, 94.7%). From this amount male were 95.1% (77 respondents) and female were 94.2% (65 respondents).

1.8.2 Background of Household Waste

i. Type of waste

Result analysis from graph in Figure 1.2 show that the most frequently type of waste produced from household in residential area was food waste with percentages 63.3% (95 respondents).

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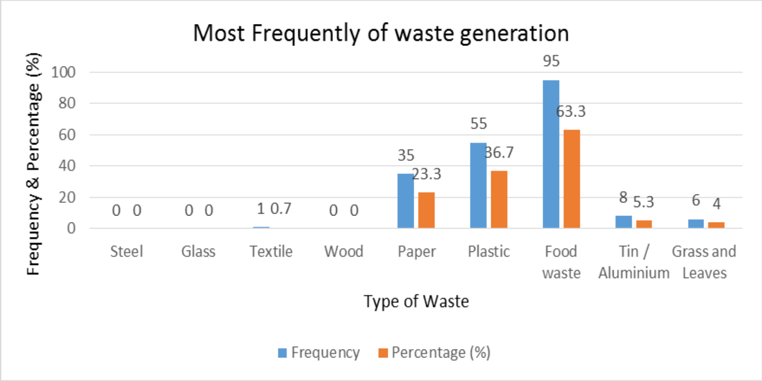

Figure 1.2: Frequency of waste generation

Table 1.7: Frequency of food waste

Description	Frequency	Percentage (%)
Rarely	8	5.3
Frequently	141	94
Total	149	99.3

Result from Table 1.7, shown that the frequency of food waste produced in household with percentages 94% (141 respondents).

Table 1.8: Cross tabulation between respondent's food waste and gender

Food waste	Gender			
	Male		Female	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Rarely	6	7.5	2	2.9
Frequently	74	92.5	67	97.1
Total	80	100	69	100

Table 1.8 above it can be summaries, male 92.5% (74 respondents) is produced more food waste than female 97.1% (67 respondents). Food waste become main contributor of waste composition since Malaysian people tend to produce more food waste rather than other waste [3].

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1.8.3 Awareness on Household Waste Separation

Table 1.9: Summary of awareness on household waste separation

Variable	Description	Frequency	Percentage (%)
Is the respondents aware about the program	Yes	72	48
	No	78	52
Is the respondents aware about the concept 3R's	Yes	135	90
	No	15	10
Is respondents separate their household waste	Yes	55	36.7
	No	95	63.3
Why respondents separate their waste	Because I see other people do it	2	1.3
	I know waste separation waste can save money	5	3.3
	I know waste separation can reduce environmental problems	30	20
	I have seen waste separation on the news (television, radio, newspapers)	4	2.7
	Avoid penalties	8	5.3
	Waste separation is easy to do it	6	4
Why respondents do not separate their waste	I do not know about household waste separation	12	8
	I do not see the differences do waste separation	9	6
	I do not think it is my responsibility	3	2
	I do not see the importance of the household waste separation	11	7.3
	I do not have time to do it	31	20.7
	Waste separation requires the use of a lot of bins and plastic	28	18.7

How far respondents aware about rules and regulation of waste management	Really do not know	7	4.7
	Do not know	34	22.7
	Slightly know	67	44.7
	Know	34	22.7
	Extreme know	8	5.3

Result from Table 1.9 above shown that the residents is not aware about the program of waste separation at sources with percentages 52% (78 respondents). Most of respondents were aware about the concept of 3R's with percentages 90% (135 respondents).

In terms of awareness, Table 1.9 above revealed that most of respondents were not separate their household waste with percentages 63.3% (95 respondents) and separate their household waste at 36.7% (55 respondents).

Table 1.9 shown that the majority of reason why residents separate their waste is they know waste separation can reduce environmental problems with percentages 20% (30 respondents) and most resident choose for why they do not separate their household waste is they do not have time to do it with percentages 20.7% (31 respondents).

From Table 1.9 it can be summaries majority of total respondents were slightly know (67 respondents, 44.7%) about rules and regulations of waste management.

1.9 Conclusions and Recommendation

People's awareness is the most important the initial waste separations at an individual level, from their workplace, public area, as well as households. In relation to the first objective which is to investigate the awareness level on household waste separation the residents staying in residential areas. Results achieved through quantitative method which distribute self-structured questionnaire at residential areas. Based on data analysis of survey it can conclude that majority of residents still lack of awareness.

In relation to the second objective which is to determine residents involvement in household waste separation within residential area. Result achieved through the same with quantitative method. Based on data analysis of survey it can be conclude that most of residents do not participate in household waste separation. A few of residents still take a part on this program. Residents that separate their waste aware about the aim of waste separation. This is because waste separation can minimize the environmental problems. However, for those who do not separate their waste they give a reason they do not have time to do it. The level of household participation in waste separation is alarmingly low in the study area. This low participation in waste separation can lead to the low level of awareness of environmental issues.

In conclusion, this study was successfully conducted and achieved the objective of this research. The recommendation for further studies is waste separation has been

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carried out in the whole city, but the participation of the citizen should be improved. More guidance, propaganda and regulations need to be developed and set up.

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CHAPTER 2

HOUSEPLANT ABILITY IN REDUCING FORMALDEHYDE AND TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCs) IN INDOOR AIR OF NEW UTHM PAGOH CAMPUS BUILDING

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2.1 INTRODUCTION

People often think that air pollution is only about smog from car emission and open burning. This actually called outdoor air pollution. It is more dangerous when it comes to indoor air pollution which may occurs when certain air pollutants contaminate the air of indoor areas. Indoor pollution such as chemical pollutants, dust particles and microbiological pollutant emissions from people or building materials in the form of either gases or tiny particles into the air are the primary cause of indoor air quality problems in buildings. Formaldehyde is one of common chemical particles that leading to indoor air pollution that can be recognised from their pungent odor. Previous studies had stated that formaldehyde can be found in paints, sealants, and wood floors. Other than formaldehyde, volatile organic compounds (VOCs) which may consist of benzene, toluene, xylene, styrene, and limonene, also have been recorded as reason that lead to problem related to indoor air pollution. Awareness about how dangerous indoor air pollution had lead to many studies to investigate the type of contaminants that occupied indoor air environment of buildings and their probably factors.

The purpose of this study is to find the potential way to help in reducing formaldehyde concentration in indoor environment by using two selected identical rooms, by placing a houseplant namely Boston Fern for a same determinate period. By referring to Industry Code of Practice on Indoor Air Quality 2010 (ICOP IAQ 2010), Indoor Air Quality (IAQ) parameters monitored to determine any change of readings with the absence and presence of the houseplants. This study also included the measuring awareness among building occupants toward formaldehyde emissions by assessing the impact on their health, comfort and productivity (relating to SBS), by using questionnaire method. The questionnaire distributed to building occupants which only limited to occupants that own enclosed-room as work station.

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INDOOR AIR QUALITY (IAQ)

IAQ is a term that used to refer to the air quality within and around buildings and structures,especially as it relates to the health and comfort of building occupants. This evaluation has relation with health and comfort of buildings occupants which physically and mentally will affect their work productivity [1]. It is necessary to evaluate the parameter of indoor air assessment of building in order to approach total performance of the building [2]. Generally, environmental parameters that define the IAQ such as temperature, relative humidity, thermal comfort, and rate of ventilation are usually depend significantly with the building design and operation [3]. In Malaysia, the acceptable range for indoor air parameter and the allowable limits for indoor air contaminants (as shown in Table 2.1 and Table 2.2, respectively) are stated in the Industry Code of Practice on Indoor Air Quality 2010 [4], provided by Department of Occupational and Health (DOSH) as a guidelines and also to protect the health of workers and other occupants of abuilding. This practice is applicable in only non-industrial workplaces.

Table 2.1: Acceptable Range for Indoor Air Parameter.

Parameter	**Acceptable Range**
Air temperature	23-26°C
Relative humidity	40-70%
Air movement	0.15-0.50 m/s

(Source: DOSH, 2010)

Table 2.2: The Maximum Limits of Indoor Air Contaminants.

Indoor air contaminants (8 hour time weighted average air-bone concentration)	**Acceptable limits**	
	ppm	***mg/m^{3}**
<u>Ventilation performance indicator</u>		
(a) Carbon dioxide, CO_2	C1000	
<u>Chemical contaminants</u>		
(a) Carbon monoxide, CO	10	
(b) Formaldehyde, HCHO	0.1	
(c) Ozone	0.05	
(d) Respirable particulates		0.15
(e) Total volatile organic compounds (TVOC)	3	

* Concentration at 25°C, 1 atmospheric pressure
C is maximum ceiling limit that shall not be exceeded at any time.
(Source: DOSH, 2010)

FORMALDEHYDE AND TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCs)

Formaldehyde which also knows as *formalin* was first reported in 1859 by the Russian chemist, Aleksandr Butlerov and conclusively identified in 1869 by August Wilhelm Von Hofmann [6]. Formaldehyde (CHCO) with molar mass of 30.03 g.mol^{-1}

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has a density and melting and boil point os 0.8153 gcm^{-3} and -92°C and -21°C, respectively [9].

Formaldehyde is actually one of division of TVOCs but not detected by the gas chromatographic methods commonly applied to TVOCs monitoring or analysis, hence formaldehyde is often considered separately [8]. As already known, formaldehyde concentrations in new buildings are claimed as several times higher than that in older buildings [17] and widely produced by emission from a wide range of sources, including wood based products, glue, paints, furniture, clothes and cleaning agents [11]. In addition, veneering and preparation with acid-curing lacquer may cause long term emissions of formaldehyde. Formaldehyde emission from wooden construction panels has been regulated since the early 1980s [12].

It also had been said that office equipments such as photocopiers and laser printers had potential to emit formaldehyde during their operation [7]. Experiments on office equipments that operated using LCD or lasers had concluded that these office equipments release high level of contaminants. This is because ink toner that used in are contains methyl alcohol [13]. Printers and photocopiers also are sources of volatile organic compounds (VOCs), which derive from the toner that undergoes heating during the printing process [14].

TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCS)

The US EPA defines VOCs as substances with vapor pressure greater than 0.1mmHg, while the Australian National Pollutant Inventory said TVOCs as any chemical with carbon chains with a vapor pressure greater than 2mmHg at 25°C [4]. The term ‘total’ used because combination of all VOCs materials in one monitoring. VOCs actually consist of 300 types of compounds which have boiling point ranging from a lower limit of 50-100˚C to an upper limit of 240-260˚C [5]. Indoor TVOCs concentrations are generally higher than outdoor concentrations may be much higher than typical ambient levels in newly constructed building, and also those building which in renovation work or decoration process [17].

SICK BUILDING SYNDROME (SBS) ISSUES

Sick Building Syndrome (SBS) is a term that used to describe a situation where the building occupants experience medical conditions acute health effects for no apparent reason that seem to be linked directly to the time spent in the building, and may disappear when they away from the building [1]. Numerous studies suggest that most of people exposed to poor quality indoor air are higher than who are exposed to outdoor air contamination. This perception is compatible with that the fact that many people pass most of their times indoor as people spend 80–90% of their time within enclosed living spaces [16]. Previous estimated that that over 30% of office workers have suffered from SBS [9][17]. In general, tiredness; dry, irritated or itchy eyes and headache are among top-three symptoms complained by occupants in the study where the outcome report strongly depends on the occupants activities, their antibodies, period spending in the building, building operation and maintenance, and the timing when the occupants have been asked, as the mood of the occupants also can affect answer and their reaction [10].

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HEALTH EFFECTS BY FORMALDEHYDE EXPOSURE

Formaldehyde was positively correlated with increased SBS symptoms prevalence [18]. For instance, health effects due to acute exposure to formaldehyde is shown in Table 2.5 while long time exposure to formaldehyde will result in more serious health effect as shown in Table 2.6.

Table 2.6: Health Effects Due to Short-time Exposure Towards Formaldehyde.

Health effect	Description
i. Irritation	Affect the mucus membrane, which leading to dermatitis, tearing eyes, sneezing, and coughing. In the study that had conducted, subjects that exposed to formaldehyde in the range of 0.25-3.0ppm experienced eye, nose, and throat irritation.
ii. Acute poisoning	Acute formaldehyde poisoning is from inhaling its fumes or from swallowing its liquid phase. A study of 17 employees in a pharmaceutical company who continuously inhaled formaldehyde vapors showed symptoms of irritated eyes, sneezing, coughing, chest congestion, fever, loss of appetite, and vomiting.
iii. Skin allergies	Human skin sensitive and can caused allergies when have contact with products with formaldehyde contains. An observation at a mushroom farm where formaldehyde was sprayed to make the mushroom whiter, 75% of the employees who exposed about 0.49-3ppm of the sprayed formaldehyde experience dermatitis on their arms.

(Source: Kulle, 1993; Hao *et al.*, 1998; Scheman *et al.*, 1998; Wu & Wu, 2001)

Table 2.7: Health Effects Due to Long-term Exposure Towards Formaldehyde.

Health effect	Description
i. Neurotoxicity	Neurotoxicity is where the normal activities of the nervous system altered by toxic substances called neurotoxins such as formaldehyde, which can damage the nervous tissue. The symptoms include headaches, dizziness, and memory loss
ii. Cellular change	Formaldehyde at concentration above 2ppm cause cell failure in the nasal lining where failed to repair cellular damage in nasal lining.
iii. Carcinogenesis	Carcinogenesis means initiation of cancer formation. Discussion about formaldehyde as a possible carcinogen started in 1980 when the carcinogenicity of formaldehyde in rats after long-term inhalation exposure.

(Source: Kim *et al.*, 2011; Hester *et al.*, 2003; Salthammer, 2015)

ABILITIES OF HOUSEPLANT IN REMOVING POLLUTANT IN INDOOR AIR OF BUILDING

In 1980, NASA’s scientists discovered that houseplants could purify and revitalize air [20]. Introducing houseplants into building indoor environment is seen as alternative cost –effective solution to deal with polluted indoor environment problem and also have a major role for improving the air quality. Moreover, houseplants also

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provide beauty sight and appear to have calming, spiritual effect on most people [21][22]. It also have been indicated that houseplants can act as bio-filtration. It is a bioreactor process where a contaminated air or water passed through a region with high biological activity where the contaminants are neutralized by biological processes [23]. Roughly, Figure 2.2 shows the concept of air purification of houseplants that used by many previous study. The plants absorb pollutants from the air into their leave through microscopic opening called stomata. The absorbed pollutants are then pulled by leaf transpiration convection currents to the root zone. The root microbes then will bio-grade the pollutants [22].

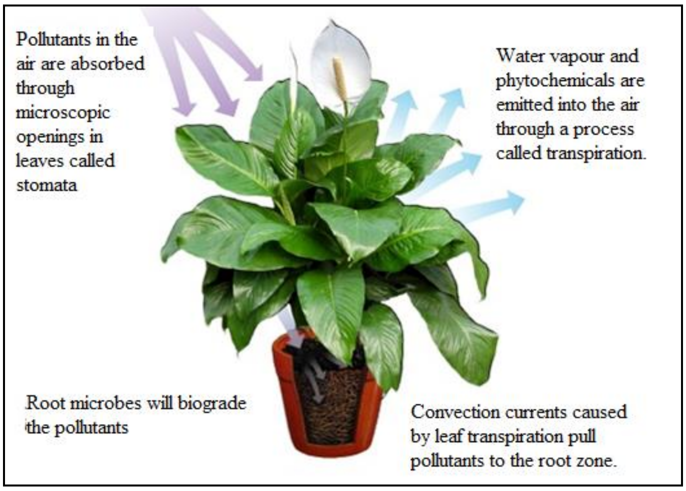

Figure 2.1: Air purification process of houseplants.

HOUSEPLANTS THAT REDUCING FORMALDEHYDE CONCENTRATION IN INDOOR

Fifty houseplants have been tested by Propulsion Controlled Aircraft Computer (PCAC) and Wolverton Environmental Service by using $1m^3$ test chambers. Since formaldehyde is the most commonly chemical toxin in indoor environment, the ability to remove this substance from air was used as the standards for rating those houseplants. This test had been stated by Wolverton (1996) in his book titled “How to Grow Fresh Air”. Figure 2.2 shows bar chart of the rate of formaldehyde removed by houseplants in µg/hr. The research had concluded that houseplants Boston Fern is the best in removing formaldehyde with rate of ±20µg/hr [18].

On the other previous study which using 310 liter chamber that induced with 250 ml solution that contain 37% formaldehyde test for 33 types of houseplants, which also has similar result where Boston Fern remove the highest formaldehyde contaminants with rate of 1863µg/hr [24].In the other study which experiment on the efficiency of volatile formaldehyde removal, was assessed in 86 species of plants representing five general classes, which is family of ferns, woody foliage plants, herbaceous foliage plants, Korean native plants, and herbs [25]. This study had support statement that family ferns had the highest formaldehyde removal efficiency.

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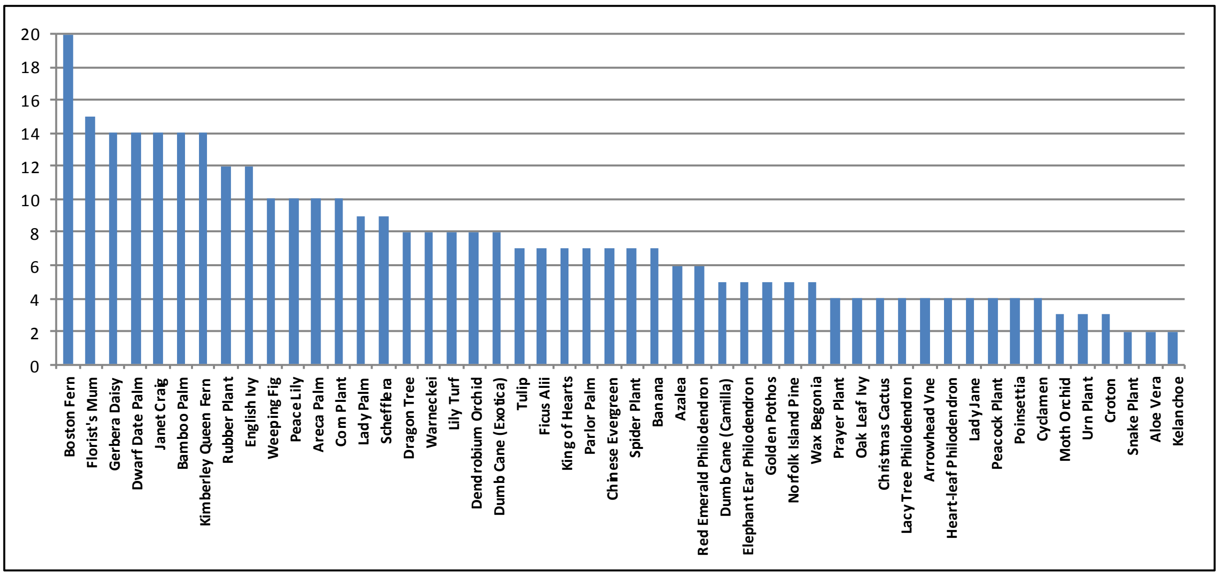

Figure 2.2: Chart of rate of formaldehyde removed by houseplants(μg/hr)
(Source: Wolverton, 1996)

2.2 METHODOLOGY

Houseplant namely Boston Fern *(Nephrolepis exaltata)* has selected for this study. The four selected plants were having slightly similar in size and height with two moths aged. Next, all pots of the plants also had approximately same number of leaves (28-34 leaves) to ensure their total area leaves was approximately 1120-1360 cm^2 per plant.

Figure 2.3: Boston Fern

The main areas of interest for this study are two identical lecturer rooms which have same designation; same floor area and ceiling height. Both rooms namely as Room 1and Room 2, have same ventilation system used (MVAC), receive same rate of ventilation (0m/s), did not use any additional air filtration device and receive same amount of daily sunlight. Figure 2.4(a), Figure 2.4(b), Figure 2.4(c) and Figure 2.4(d) show the floor plan and the full view of both rooms.

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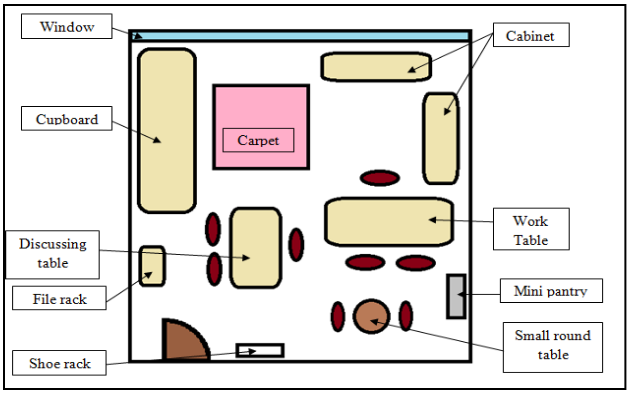

Figure 2.4(a): Floor Plan of Room 1

Figure 2.4(b): View of Room

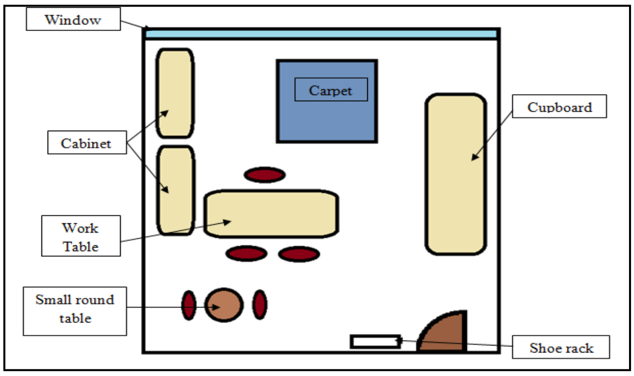

Figure 2.4(c): Floor Plan of Room 2

Figure 2.4(d): View of Room

PARAMETER ASSESSMENTS

Parameters that include in this assessment are divided into two types namely physical parameters which are temperature and relative humidity and chemical parameter for formaldehyde and TVOCs. In this studey, physical parameters were measured by 4 in 1 Air Velocity Meter while for chemical parameters Formaldehyde Multimode Monitor and T-502 Graywolf Toxic Gas Probe (TVOCs Direct Sense) were used.

Each room was monitored for five consecutive days with the absence and another five days with the presence of the houseplants. Time interval for all monitoring was 30minutes, and average are recorded every two hours during eight hours of working time, which are every 9.00am, 11.00am, 1.00pm, 3.00pm and 5.00pm. The daily average readings also calculated.

2.3 RESULTS AND DISCUSSION

Formaldehyde

Formaldehyde concentrations in the new buildings are often several times higher than that in older buildings. Thus the ability of houseplants to remove formaldehyde is used as standard for rating a houseplant in many previous researches. Both rooms have all furniture that made up from compressed wood, carpets and also laser printer which all these items are releasing formaldehyde.

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Figure 2.5(a) and Figure 2.5(b) indicated the concentrations of formaldehyde versus time for Room 1 and Room 2. Both of them showed similar pattern where the readings of formaldehyde were higher during morning, gradually decreased during afternoon and become slightly unchanged during evening. This observation may due to Mechanical Ventilation and Air Conditioning (MVAC) system in where the system will only operating during the working hours, which make the formaldehyde that released from certain items suspended in the rooms.

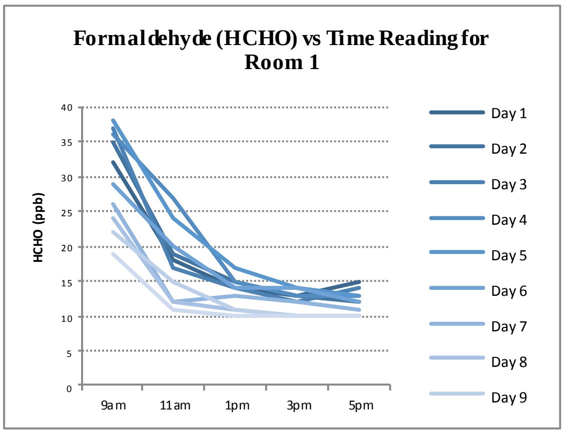

Figure 2.5(a)

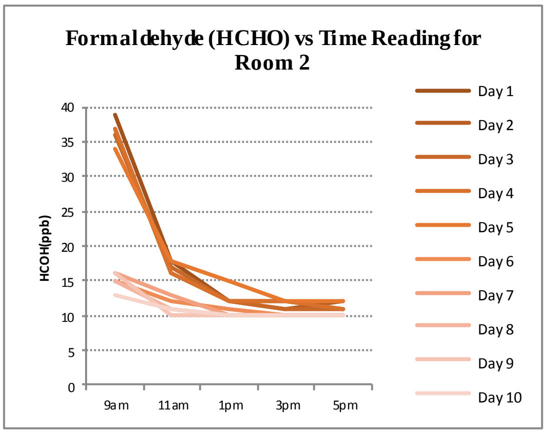

Figure 2.5(b)

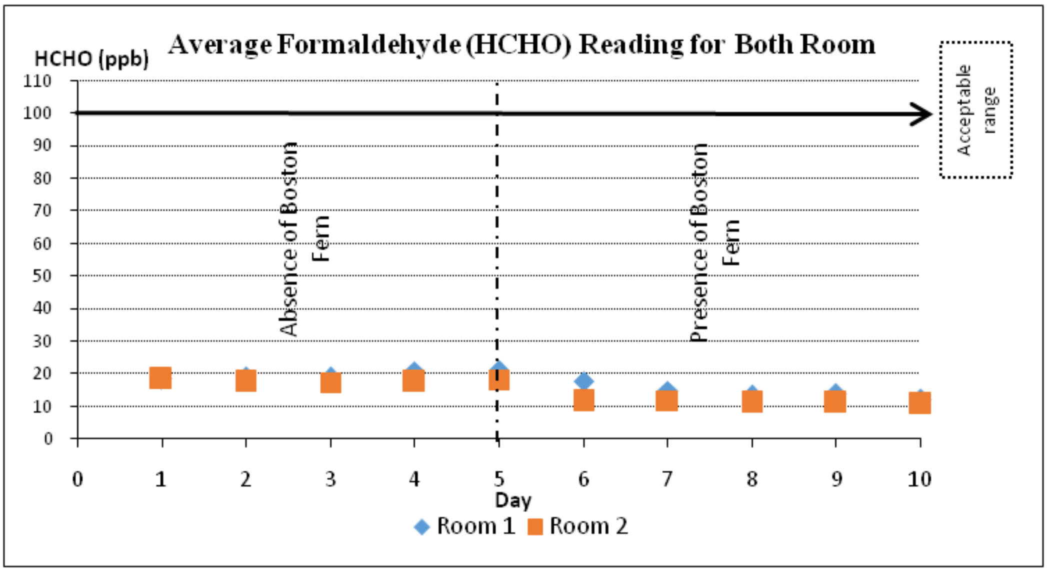

Figure 2.6: Average concentrations of Formaldehyde in both rooms

Average readings of formaldehyde concentration in both rooms as shown in Figure 2.6, was way far lower than acceptable range indicated by DOSH 2010, which is 0.1 ppm. However for Room 1, the readings was still slightly higher than Room 2 even after placement of Boston Fern, this may due to activities by the occupants. The observation showed that the frequent used of laser printer due to the occupant in Room 1 activity gave the significant impact of formaldehyde concentration in Room 1 compared to Room 2. In addition, the activity of video display unit usage for meeting purpose in Room 1 was also observed as the other contributor of formaldehyde and TVOC concentrations as well. Besides, the occupant was also used correction fluid and marker

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pen in the room. This eventually effects the concentration of formaldehyde concentration readings.

Most important, the readings of formaldehyde for both rooms were drastically decreased during the first day of placements of Boston Fern and continue decrease readily until the end of monitoring. This shows the statement in line with Wolverton (2010) which said that Boston Fern is good in reducing formaldehyde. However, the formaldehyde concentration actually will decrease from time to time as claimed by Salthammer *et al.* (2010) because items that release formaldehyde such as compressed wood furniture in the room and carpets will release the contaminants lesser day by day.

TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCS)

TVOCs had recently become priority of environmental interest among others indoor pollutants. TVOCs is material that easy to volatiles with room temperature, and example materials of TVOCs like benzene, toluene, xylene, styrene, and limonene (Mahathir *et al.*, 2014). TVOCs origins are building product emissions, human activities, and infiltration of outdoor air. In other word, TVOCs are result from components byproducts which produce toxic effects when it at high concentration (Allen *et al.*, 2016).

According to Figure 2.7(a) and Figure 2.7(b), each room had high initial readings of TVOCs in the morning which was in range of 0.25-0.4ppm and decreased over time throughout the day. This may caused by MVAC system in room was not operating before working hours which make the TVOCs in indoor air suspended. After the air conditioner activated a while, the air in the room then circulating as MVAC system also will be activated and make the TVOCs readings decreased on the evening which usually in range of 0.1-0.3ppm in Room 1 and 0.1-0.25ppm in Room 2.

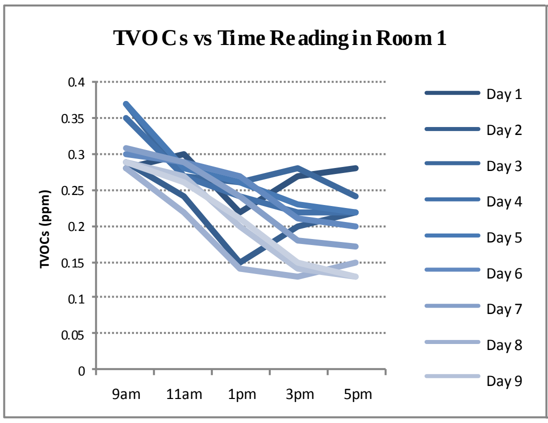

Figure 2.7(a): TVOC in Room 1

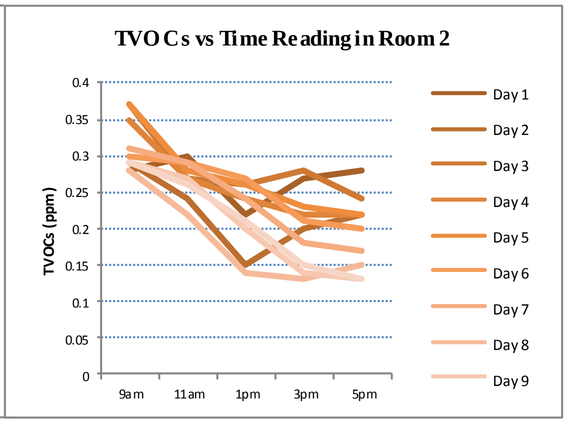

Figure 2.7(b): TVOC in Room 2

In addition, the line graph shows in Figure 4.4, the TVOCs readings in Room 1 were fluctuated but TVOCs readings in Room 2 were almost in consistent pattern. This may because occupant of Room 1 carried out many activities in the room and spend more times in the room compared to occupant of Room 2 which conduct fewer activities and spend less time in the rooms. Occupant of Room 1 spend about 6-8 hours in the rooms whereas occupant Room 1 spend only about 0-2 hours in the rooms every day with the air conditioning system switched on.

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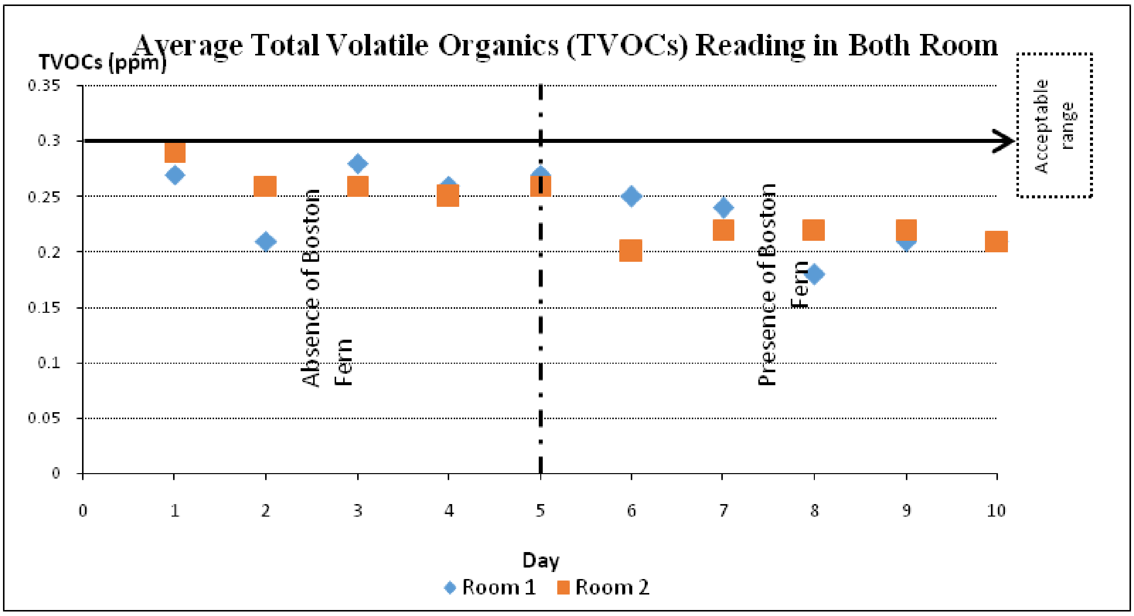

Figure 2.8: Average concentrations of TVOC in both rooms

According to Figure 2.8, average TVOCs readings for every consecutive monitoring day in both room were unstable but still under acceptable range that stated by DOSH which is under 0.3 ppm. However, the pattern showed slightly decreased values of TVOCs after presence of Boston Fern in both rooms which were in range of 0.15-0.25ppm compared to readings prior to the presence of Boston Fern which was in the range of 0.2-0.3ppm. There were a huge difference of readings in Day 5 and Day 6 showed by readings in Room 2.

RELATIVE HUMIDITY

Figure 2.9 shows that both rooms have high relative humidity readings, either with absence or presence of Boston Fern. This may due to problem of Motor Vehicle Air Conditioning (MVAC) system. The air in the rooms does not well circulated, causing the exceeded humid were still suspended in the room air.

However, relative humidity readings in Room 2 shows a obvious different range of readings where the readings for Day 1 until Day 5 (absence of Boston Fern) were between 60-70% while readings for Day 6 until Day 10 (presence of Boston Fern) were slightly higher, between 70-80%. Besides, the average readings of relative humidity readings as shown in Figure 4.6 also admitted that the relative humidity of both room show increasing pattern during presence of Boston Fern.

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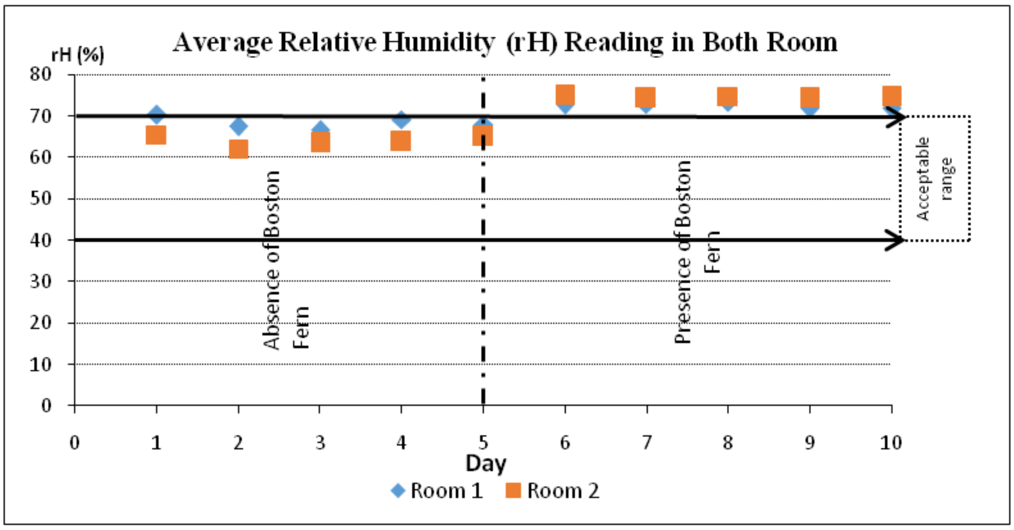

Figure 2.9: Average Relative Humadity in Room 1 and Room 2

Relative humidity readings in Room 2 were lower than Room 2 during first 5 days without Boston Fern. This may due to the activity of occupant where occupant in Room 1 using water heater electric equipment almost every day which release water vapour during its operation whereas occupant in Room 2 does not use any. Boston Fern show some effect after placed into both rooms which increased the relative humidity readings. However, the pattern is switched where the relative humidity of Room 2 were higher and show obvious difference pattern than Room 1. This may due to occupant in Room 1 and other people which related with occupant in Room 1 often open-closed the entrance, which can cause humidity escaped from the room. Whereas in Room 2, the houseplant continuous to provide additional humid to the Room 2 without any disturbance.

Unfortunately, the readings during presence of Boston Fern are slightly exceeded the acceptable range by DOSH that stated in their Industry Code of Practice on Indoor Air Quality 2010 where the acceptable range by DOSH is 40-70%, a condition that actually not good especially for enclosed room work station. Human are sensitive to high humidity because the human body uses evaporative cooling, enabled by respiration, as primary mechanism to rid itself of waste heat. Respiration process is more slowly under high humid condition. This is because humans perceive a low rate heat transfer from body to be equivalent with surrounding temperature, where human body experiences greater distress from excessive heat waste that cannot be release due to high humidity of surrounding air (Wolkoff *et al.*, 2010).

In addition, high relative humidity in rooms can promote the growth of bacteria and fungus. However, this condition is actually not really encourage for occupants that have asthma or other mucosal irritation where exceed humid will increase the effect. This is because increasing of relative humidity can promote more particle composition and will enhance microorganism's growth in indoor air environment (Wolkoff *et al.*, 1997). But, some occupants not really affected by high humid condition. The results obtained prove that the presence of houseplants in rooms can help increase the room's humidity. In other words, houseplants can act as natural humidifier, as said by Wolverton (2010), as plants undergo natural process which are respiration and photosynthesis that release water vapour through its stomata.

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2.4 CONCLUSION

Percentage change value is measured of increase or decrease percentage which represent the degree of change over time. From this study, it can be observed that the presence of formaldehyde can reduced the folmaldehyde concentration up to 26% and 36.6 % for Room 1 and Room 2, respectively. While, the reduction of TVOCs were recorded to be 15.5% and 18.9% for Room 1 and Room 2, respectively. However, the present of this plant was also caused the increment in humadity around 2.8% to 6.1% for both Rooms. As a conclusion, the presence of Bostern Fern in lecture room in Pagoh Education Hub Administration Building can help in formaldehyde and TVOCs reduction in order to maintain a clean air for good surrounding work area for staffs. The presence also contribute to the indoor aesthetic for calm and relax feelings.

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CHAPTER 3

CARBON DIOXIDE REMOVAL IN LIQUID AND GAS USING BIOGRANULES CONTAINING PHOTOSYNTHETIC PIGMENT IN PALM OIL MILL EFFLUENT TREATMENT

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3.1 INTRODUCTION

Malaysia contributes 39 % of world palm oil production and 44 % of world exports [1]. According to [2], the total export of oil palm products in 2013 had increased by 4.3 % or 1.10 million tonnes to 25.66 million tonnes compared with 24.56 million tonnes in 2012. Throughout the years, the crude palm oil (CPO) production has increased from only 1.3 million tonnes in 1975, to 4.1 million tonnes in 1985 and 7.8 million tonnes in 1995 to 17.56 million tonnes in 2009 [3]. Among all biomass by-products from the palm oil industry which include the palm kernel shell (PKS) and empty fruit bunch (EFB), only the palm oil mill effluent (POME) is not commercially re-used.

The palm oil production has resulted in a massive waste generation, as it was estimated that nearly 60 million tonnes of POME was generated from a total of 421 palm oil mills in Malaysia [4]. There are approximately 0.2 million tonnes of methane (CH_4), or 4 million tonnes of CO_2 equivalent, being emitted from the entire palm oil industry in Malaysia per year [5]. In addition, [6] had claimed that the average greenhouse gases (GHG) emissions produced from processing one tonne CPO was 1100 kg CO_2e. Also, each tonne of POME was expected to generate approximately 28.13 m^3 of biogas.

The conventional ponding system has been a less preferable method to reduce the biological and chemical constituents of POME. Despite its being relatively simple and reliable, it produces large amounts of sludge and takes up large land area. The ponding system, especially the anaerobic process produces harmful and odorous gases such as sulphur dioxide (SO_2), CH_4 and carbon dioxide (CO_2) [7, 8].

According to [9], about 28.82 m^3 of biogas produced from one tonne POME consisted of 18.72 m^3 CH_4 and 10.08 m^3 CO_2. Hence, the abundance of these gases in the air may lead to global warming, climate change and danger to public health. Besides, the facultative ponding system also produces scum and tends to generate CO_2 as a by-product of biological reactions. Presently, there were some alternative treatments proposed to be used for primary treatment of POME such as membrane filtration and evaporation to overcome previous limitations [10, 11, 12]. Nevertheless, similar problems still occur, such as the formation of scum, sludge floating problems, and high energy consumption.

By combining the cultivation of photosynthetic microorganisms with biofixation of CO_2, the cost of culture media for an industrial scale can be minimized while the carbon emission can be neutralized [13,14]. Nevertheless, the separation of photosynthetic bacteria after wastewater treatment became an issue for practical applications because of their poor solid-liquid separation [15,16].

Generally, granulation technology offers some advantages for industrial process as the cells are entrapped into suitable gel matrices which most of their viability and physiological activity are retained [17,18]. This study provides a potential alternative for conventional activated sludge treatment as the technology offers reduction of CO_2 emission from POME, as well simultaneously removing organic and nutrient, for a better solid-liquid separation in wastewater. In other words, the benefits claim the promotion of clean and efficient energy production technology especially for small footprint wastewater treatment process.

In this chapter, biogranules containing photosynthetic pigments used were developed by [19] in a sequencing batch reactor (SBR) using high strength agricultural wastewater such as POME. The next section will explain the experimental setup of the batch reactor and also discuss the capability of developed biogranules containing photosynthetic pigments for removal of CO_2 in liquid and gas phases. The experiments results were then analyzed using the statistical analysis such as Minitab 17.

3.2 REMOVAL OF CARBON DIOXIDE IN GAS AND LIQUID

The wastewater used was the treated POME taken from the final pond (aerobic or algae pond) of a local palm oil mill ponding system located at *Bukit Besar, Kulai* in *Johor* due to its low organic content compared to raw POME generated directly from the factory.

In principal, in the ponding treatment system, the raw POME is channelled through several ponds consisting of anaerobic, facultative and aerobic pond as shown in Figure 3.1. These steps are important to allow biological conversion of diverse types organic compounds into smaller readily degradable molecules depending on the activities of indigenous microorganisms. In terms of biodegradability, [19] had stated that the BOD/COD value of the POME used in this study was closer to 0.2 which makes it biodegradable [20] because some of readily biodegradable organic molecules were removed during previous treatment.

Initially, the collected sample was screened using a 2.35 mm sieve to remove any debris and large particles. Next, the sample was stored in the cool room at temperature about 4 ^oC. Additionally, the POME was autoclaved to reduce the oil and grease that could affect aerobic granulation process [21] and also limit the rate of photosynthesis due to low light penetration [22].

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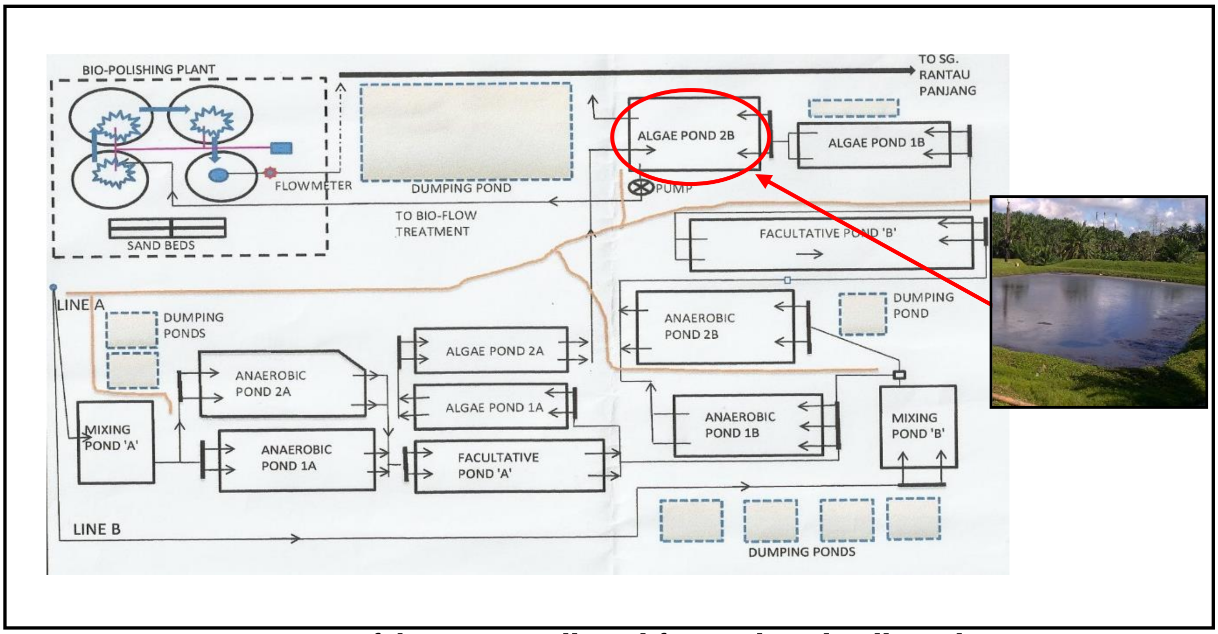

Figure 3.1: Locations of the POME collected from palm oil mill ponding treatment system

The CO_2 is readily soluble in water as it presents in water in the form of a dissolved gas. Normally, the surface waters possess less than 10 ppm of free CO_2, while some ground waters may easily exceed that concentration. Furthermore, the CO_2 solubility is 200 times more than O_2 for temperatures of 0-30 ^oC.

In this study, 50 mL bottles were employed where a dosage of 100 % CO_2 gas (initial concetration ≈ 400 ppm) was dispersed upon bubbling slowly through the 20 mL POME to measure the CO_2 in gas and liquid form as shown in Figure 3.2. It was operated under the duration of light/dark cycles of 12:12 hours, by controlling the lighting system to provide substantially constant illumination. The bottles were properly sealed with parafilm to avoid any leakage of CO_2 as well as other gases coming from outside the bottles.

A portable CO_2 meter (Extech EA80) was applied to detect the CO_2 gas taken-up from the headspace of the bottles while a titrimetric method HACH CO_2 Test Kit (Model CA-23) for CO_2 in the liquid phase. This experiment was monitored for a few days (approximately seven days) till the CO_2 measurements become steady. In addition, the FESEM-EDX (Carls Zeiss Supra 35 VPSEM) was used to analysed the morphological changes and composition of the biogranules during the experiment.

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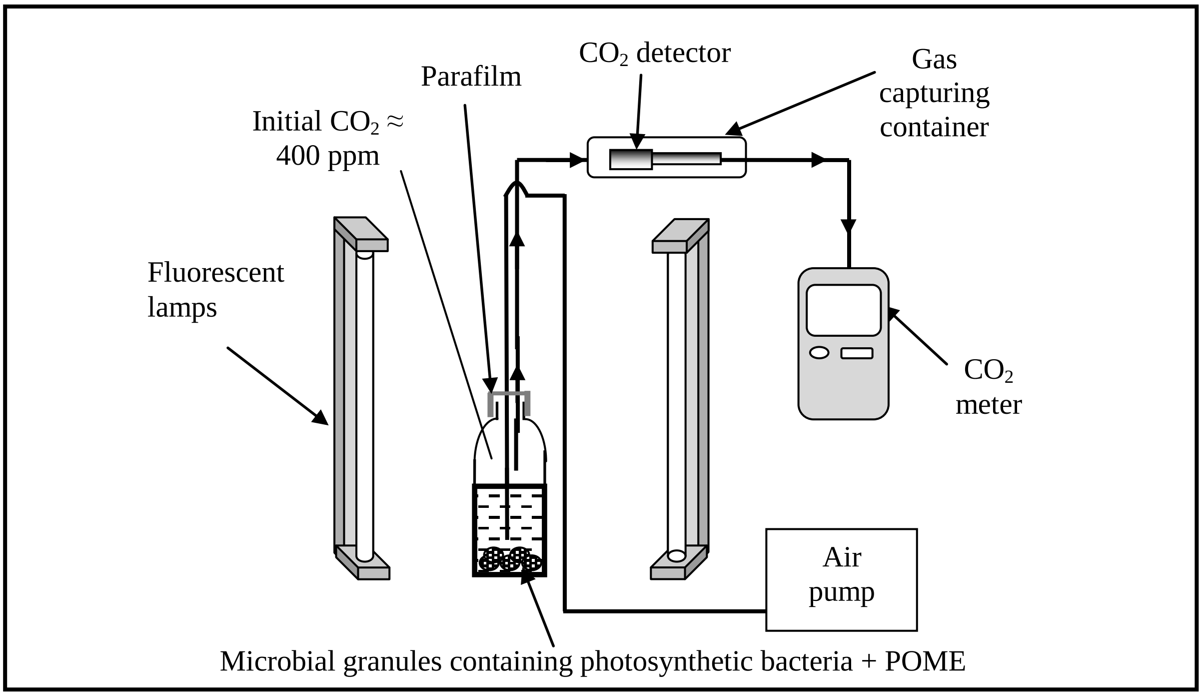

Figure 3.2: Schematic overview of CO_2 removal test

3.3 RESULTS AND DISCUSSIONS

The graph plotted in Figure 3.3 compares the percentage of CO_2 removal in gas with the CO_2 concentration in liquid for seven days. At the beginning, the removal of CO_2 gas increased to approximately 22 % and then slightly reduced to 19 % over the next three days. In contrast, during that period, the CO_2 concentration in liquid experiences an upward trend starting the period at about 55 mg/L.

The CO_2 level in liquid continued to rise gradually finishing at nearly 50 % (90 mg/L); the removal efficiency of CO_2 gas improved from 19 to 27 % at the same time. Nevertheless, the average CO_2 removal in gas was inconsistent which the plotted data went up and lastly falls below than 20 %. Interestingly, the CO_2 concentration in liquid tends to grow slowly throughout the experiment.

To sum up the results, it was believed that the CO_2 removed from the air increases proportionally with the percentage of CO_2 removed in liquid. Additionally, the overall decrement of CO_2 gas in the atmosphere was caused by either the absorption of CO_2 into the liquid at atmospheric pressure or the biological fixation of CO_2 by photosynthetic microorganisms [23].

When examined using FESEM as shown in Figure 3.4, an interesting formation of hexagonal crystals (expected to be calcite) about 7.0 µm in length was observed. This finding was also found by [24]. Such phenomenon suggested it is related to dissolved inorganic carbon (DIC) mechanism as it could served as a supplementary way to sequester carbon [25]. With the increase availability of carbon source as a result of high DIC concentration will influence several key enzymes in carbon metabolism such as carbonic anyhydrase and Rubisco. A higher carboxylating activity will result increment in photosynthesis [26].

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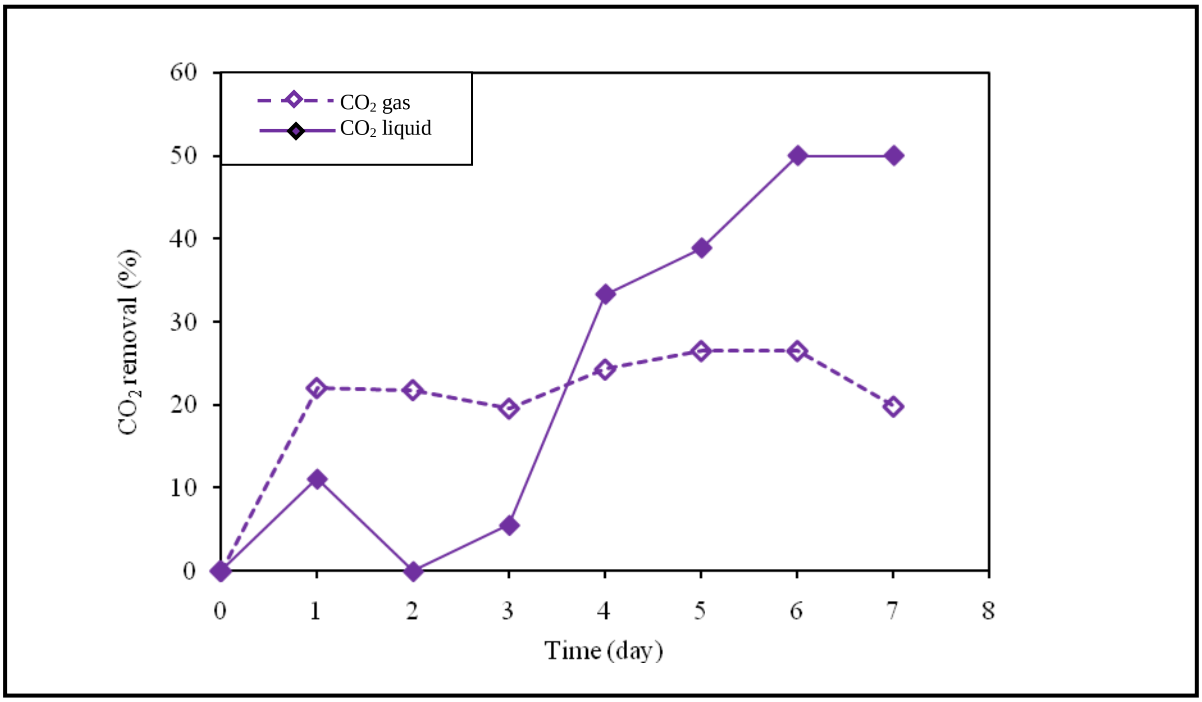

Figure 3.3: Data plotted between the CO_2 removal in gas and liquid for seven days of treatment.

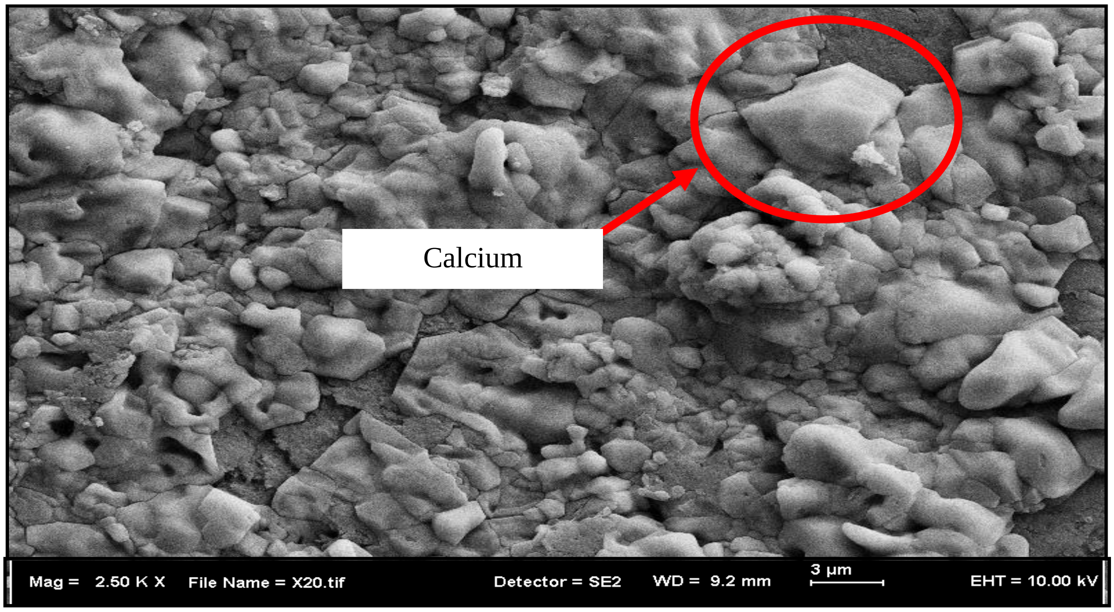

Figure 3.4: FESEM micrograph showing calcium carbonate crystalline structure formed (circled) on the surface of biogranule (magnification = 2,500X).

Regression analysis was done to investigate the connection between the CO_2 concentration in liquid (dCO_2) and gas (gCO_2) as well as the number of treatment days. Thus, the equation obtained was $dCO_2 = 0.154\ gCO_2 + 5.99\ t$ which the CO_2 in liquid acted as the dependent variable. Moreover, the analysis of variance (ANOVA) analysis had predicted these parameters fitted well with each other as the p-values lower than the

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significance level of 0.05 as summarized in Table 3.1.

The standard error (S) was also small indicating the average distance of observed values fall closer to the regression line as shown in Table 3.2. This outcome had further proven stronger relationship existed between the CO_2 concentration in liquid, gas and time.

Table 3.1: ANOVA for fit of simultaneous CO_2 removal in liquid and gas with time

Sources of variation	Sum of squares	Degree of freedom	Mean square	F value	P
Regression	35272	2	17636	387.06	0.000
Error	228	5	46		
Total	35500	7			

Table 3.2: Estimated regression coefficients for CO_2 removal in liquid and gas with time

Term	Coefficient	Standard error	T	P
gCO_2	0.15376	0.01204	12.78	0.000
t	5.9908	0.9556	6.27	0.002

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CHAPTER 4

DISTRIBUTION OF ARSENIC IN THE STRAITS OF JOHOR DUE TO LOCAL DEVELOPMET

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4.1 INTRODUCTION

Johor Straits is located at the southernmost tip of Peninsular Malaysia, sitting between two powerful regional hubs of Johor and Singapore, is the only passageway by land between the two as well as a strategic geographic position on the world's busiest shipping routes both eastbound and westbound [1]. Figure 4.1 illustrates various development projects in the western part of the area such as the Port of Tanjung Pelepas, Tanjung Bin Power Plant, Port City, and a petrochemical and marine industry area. The Port of Tanjung Pelepas alone covers 9.13 km² of landside and 4 km of shoreline. The state government has set aside approximately 13.5 km² of land for the development of Tanjung Bin Power Plant which is begin commercial operations by 2016, three component power plant projects, maritime center, and a bunker terminal [2]. As such, the area will be one of the most important maritime hubs in Malaysia.

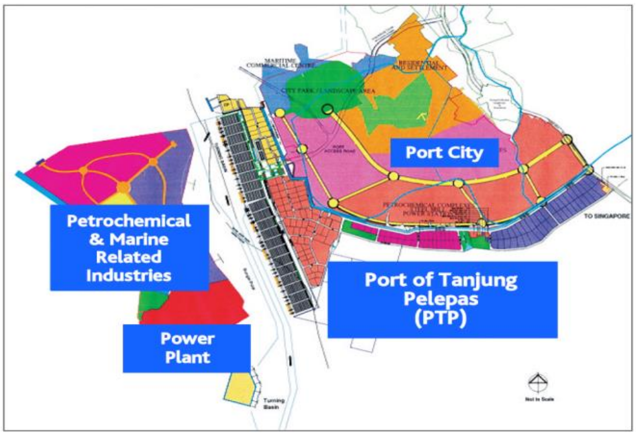

Figure 4.1 The development plan for the western part of Johor straits [2].

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It is common knowledge that land use cause pollution to the estuarine ecosystem by releasing undesired contaminants into waterways; such is agreed by researchers around the world [3,4]. The development and traffic at the Johor Straits, as well as the marine traffic at the Straits of Malacca and Singapore can cause harm to Pulai River Estuary especially the mangrove and seagrass bed [5]. The seagrass bed is located at the estuary and functions as a nursery and shelter for various vulnerable creatures such as sea cucumbers, star fishes, and seahorses [6]. Seagrass beds represent one of the most important ecological components in the coastal ecosystem; seagrass leaves act as phytoremediators and cleanse seawater by absorbing dissolved metals [7]. Seagrass roots play a role in shoreline protection by reducing coastal erosion from raging storms. The estimation value for conservation of seagrass ecosystem is US$ 34,000 per hectare per year [8]. The seagrass bed at Pulai estuary is approximately around of 3.15 km². The public and environmentalists alike have raised their concerns about the severity of heavy metal pollution caused by the development of petrochemical and maritime industries along Pulai River and Straits of Johor. Arsenic (As) have to cause of various deleterious effects in fish and to the aquatic ecosystem [9]. Hence, this study was conducted to evaluate the distribution of these metals in water in order to establish the route taken by the metals from land to the estuarine ecosystem.

4.2 MATERIALS AND METHOD

Pulai estuary receives water from upstream rivers, Malacca Straits and Singapore Straits. Samples were collected on March 2012. Water samples from the rivers were collected from 17 different locations (Figure 4.2). Sample collection from R11, R12, R13, R14, R15, R16 and R17 were by speedboat, while the rest were done by land. Figure 4.3 shows pictures taken while collecting the samples from R1, and R5.

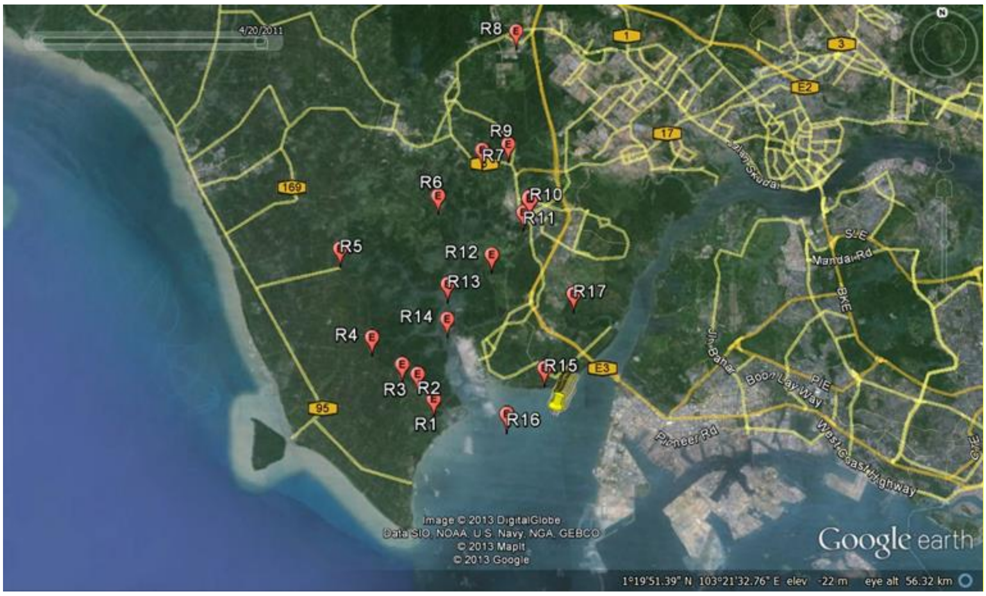

Figure 4.2 River sampling sites: R1-R17 in Red points.

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Figure 4.3 Pictures of sampling locations a) on-going road construction (R1), b) on-going road construction at Paradin River (R5).

Water samples were collected at multiple locations both within and surrounding the seagrass bed in order to determine the distribution of the designated metals within the seagrass bed as a whole and around it. The distance from the mouth of Pulai River to the seagrass bed is approximately 4.8 km. The water samples were collected and kept in high density polyethylene bottles. ArcGIS 9 of ArcMap version 9.3 was used to determine metal distribution via Kriging data interpolation method.

4.3 RESULT AND DISCUSSION

Figure 4.4 shows the flow distribution of As, all the way to the seagrass bed of Pulai estuary. It is suggested that the metals originate upstream, flow into Pulai River and subsequently into Pulai Estuary where the seagrass bed is located. The pollutants are may due to nearby development, land use, and oil spills from ship. Undesired metal contaminates were trapped on the seagrass bed due to high metals concentration in seagrass bed area compared to metals concentration at the upstream river. The seagrass bed's ability to trap metal contaminats is evident that it is functioning well.

As pollution occurs more harshly near the estuary especially at the eastern side of Pulai River. The highest ranges are 3.51µg/L-3.82µg/L .The level of As was above Class E (mangroves, estuarine and river-mouth water) for the standards and criteria for seawater quality as determined by the Department of Environment of Malaysia. The permitted levels for As under Class E are below 2.9µg/L. The eastern side of Pulai River, also known as mouth of Pulai River is where the Port of Tanjung Pelepas is located. As of this writing, the expansion of the port is still on-going. Moreover, development projects nearby such as the Tanjung Bin Power Plant also contributes to metal contamination. Indeed, the [10] claims that 80% of marine pollutants come from land-based activities either through deliberate dumping or run-off from activities such as agriculture, sewage and disposal, and oil spilled down drains and rivers.

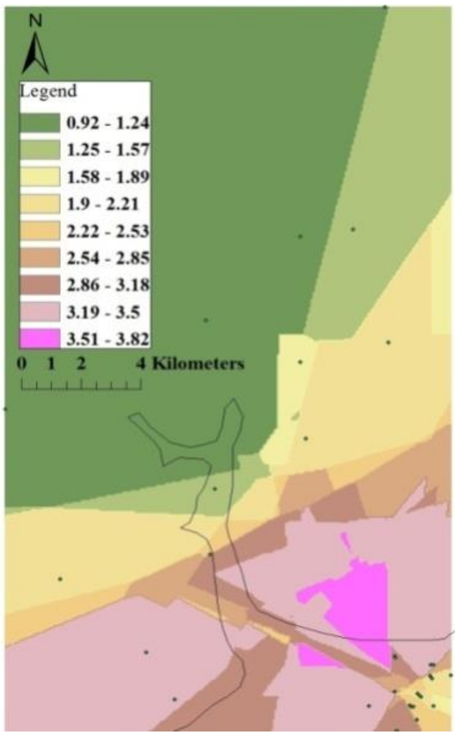

Figure 4.4 Kriging data interpolation of As distribution.

The seagrass bed cleanses seawater by absorbing dissolved metals and is a bioindicator that reflects the overall health of the aquatic ecosystem [11,12]. Aside from that, the seagrass bed acts as a buffer zone to protect against shoreline erosion [13].

4.4 CONCLUSION

Economic activity such as construction and maritime hubs contribute to the release of dissolved metals into rivers and damage the estuarine ecosystem. Nowadays, in the 21st century we are faced with the challenge of balancing construction for the nation's economic needs with the duty of protecting the environment. Keen monitoring of road constructions, development, and shipping transits should be practiced at all times, with contingency plans devised for unpredicted circumstances. A combination of such efforts will reduce the likelihood of metal contaminants entering the estuarine ecosystem. Such is to ensure the survival of both the estuarine ecosystem and vulnerable marine species habitat which are valuable for generations to come.

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CHAPTER 5

UNDERSTANDING THE WASTEWATER MATRIX AND CHARACTERISATION

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5.1 INTRODUCTION

Adsorption is a complex process, as it involves the interaction of various parameters. Moreover, the complexity and variability of the wastewater matrix also has a direct impact on the process performance [1]. However, in a real-world wastewater treatment plant (WWTP), the water matrix will be far more complex. The composition of wastewater is typically a complex water matrix, often containing a variety of organic and inorganic compounds. In addition, wastewater varies in composition both temporally and spatially (within a WWTP and between different wastewater streams). The variation in wastewater composition may contribute to the inaccuracies and decreased predictive capabilities of models for the optimisation of remediation of copper from the wastewater matrix. Therefore, the main objective for this chapter is to study and determine not only the concentrations of heavy metals and their variations in wastewater samples, but also the physicochemical properties of the wastewater as characterised by Water Quality Practices.

This chapter is divided into four sections. The first section is focused essentially on the correct laboratory practice required, prior to ICP-MS instrumental analysis, to ensure robust analytical data. The second section provides the results of the analysis of heavy metal concentrations and their variability in the influent and effluent samples. The Water Quality Practices, including the physicochemical parameters, are described in third section. The final section describes benchmark experiments that basically inform the effects of wastewater matrix characteristics (wastewater composition and its variability) on the adsorbent's capability to remediate Cu(II) from this matrix.

5.2 RESULTS AND DISCUSSIONS

Sources of contamination of ICP-MS instrumental analysis

The analysis of metals with low detection limits involving concentrations of parts per billion or parts per trillion is a difficult and complicated process, requiring extra care during sample preparation [2]. Table 5.1 shows the limit of detection (LoD) and limit of

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quantification (LoQ) for each element, determined by ICP-MS (Thermo-Fisher iCAP-Q) equipped with CCTED (collision cell technology with energy discrimination). LoD and LoQ for ICP-MS were determined in a similar way as the employed for these limits by atomic absorption spectrometry (AAS) where LoD is defined as three times the standard deviation of the calibration blank.

Table 5.1: Detection capabilities of ICP-MS for wastewater analysis

Element	Unit	LoD	LoQ
Al	µg/L	0.036	0.121
Ca	mg/L	0.011	0.036
Cd	µg/L	0.002	0.008
Cu	µg/L	0.001	0.003
Fe	µg/L	0.153	0.509
K	mg/L	0.003	0.012
Mg	mg/L	0.001	0.004
Mn	µg/L	0.002	0.008
Na	mg/L	0.001	0.003
Ni	µg/L	0.017	0.056
Pb	µg/L	0.002	0.005
Zn	µg/L	0.058	0.193

In order to ensure an accurate determination of low concentration metals, it is necessary to minimise errors by avoiding any sources of contamination during all stages of experimental procedure, from sample transport to sample preparation and analysis. The potential sources of contamination are listed below:

- Sampling equipment
- Storage containers
- Preservation reagents
- Laboratory environment
- Instrumentation

In order to evaluate the efficiency of the washing procedure and the impurity levels in Milli-Q ultrapure water (18.2 MΩ-cm resistivity) and any chemical reagents used, several control experiments were conducted, the samples being analysed by ICP-MS. Since Milli-Q water has been used as a reagent blank, the purity of the Milli-Q water is important, in order to avoid contamination during sample preparation and analysis. The impurity levels in Milli-Q water were evaluated and the results show that Milli-Q water acidified by HNO_3 (2% by volume) has similar purity to commercial high-purity water. However, the concentration of Zn was detected at a higher level compared to other elements in Milli-Q ultrapure water. This may be attributed to contamination from the paper towels used during the sample preparation. Besides Zn, paper towels generally contain trace levels of transition metals such as Pb, Cr and Co [3]. Moreover, powder gloves should be avoided during the sample preparation as powder in these gloves contain high concentration of Zn. Therefore, powder-free or non-latex gloves are recommended when handling the equipment, samples, blank and standard solutions.

Moreover, the quality and selection of acids are important when dealing with analysis at low detection limits (ng/g and pg/g) [4]. The main purpose of acidification is

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to avoid any metals being adsorbed onto the container walls. Therefore, HNO_3 was used for sample preparation and acid washing, as other acids such as H_2SO_4 and H_3PO_4 are not suitable for analytical analysis by ICP-MS. This is because these acids do not completely decompose in the plasma and can adhere to the interface components and ion lenses causing signal instability [4]. Also, insoluble metal sulphates or phosphate may form (depending on the acid used) and thus change the dissolved relevant metal ion concentration. Furthermore, these acids have low purity levels compared to HNO_3 and HCl, causing further contamination of the samples [5].

According to Rodushkin *et al*., (2010), sample containers and glassware are potential sources of contamination that require appropriate acid washing with dilute nitric acid prior to use. The acid-washed laboratory glassware showed a significant decrease in the contaminations and concentrations of selected elements. Also, minimising the number of laboratory items used during the experimental process, and keeping those washed items filled with acid, helps to reduce contamination.

The results show that acid-washed polypropylene sample tubes show lower levels of contamination compared to acid-washed glassware. These results are in agreement with the work of Rodushkin *et al*., (2010) who suggested that disposable tubes made of polystyrene or polypropylene are much more suitable for ICP-MS sample preparation. Moreover, glass sample containers should be avoided, as trace levels of some metals in water commonly adsorb onto the glass wall, thus releasing measureable concentrations of metals when acidic solutions are added. Moreover, a study assessing metal contaminations leaching from a series of plastic recycling bottles during various treatments has been reported [6]. The results revealed that heating and microwaving significantly enhance antimony leaching from polyethylene terephthalate (PET) bottles. Therefore, polypropylene and other plastic materials are more suitable for sample storage. Similar sampling procedures were observed in other studies, where the collected wastewater samples were stored in polypropylene containers prior to metal analysis [7].

The influence of storage time

The influence of storage time on heavy metal concentration is important, as ICP-MS analysis can take several days (up to two days) due to instrument accessibility. The stability of wastewater effluent was tested at different time intervals, prior to analysis by ICP-MS. Monitoring the influence of storage time on the effluent was necessary, as it allowed for the observation of any changes in wastewater quality during storage, normally between 0 and 120 hours [8]. However, the impact of wastewater storage time on water quality parameters is not necessary, as the adsorption process to remediate Cu(II) from the wastewater matrix is performed using fresh effluent wastewater.

As shown in Table 5.2, the effluent samples do not show any significant changes in heavy metal concentration during storage at 4 °C for 72 or 120 hours. This demonstrates that storage under these conditions does not affect the stability of heavy metals. Besides proper storage, suitable sample containers, and acidification to a pH below 2.0, have been used in this study, to minimise the precipitation and adsorption of heavy metals on container walls.

Table 5.2: Comparison of selected heavy metal concentrations after 0, 72 and 120 hours storage of effluent samples

Heavy metals (µg/L)	Storage time (hours)		
	0	72	120
Al	3.83 ± 0.11	3.83 ± 0.01	3.56 ± 0.03
Cd	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
Cu	3.65 ± 0.05	3.58 ± 0.07	3.59 ± 0.04
Fe	40.74 ± 0.73	41.05 ± 0.02	40.58 ± 0.78
Ni	3.46 ± 0.06	3.46 ± 0.05	3.47 ± 0.02
Pb	0.26± 0.01	0.26 ± 0.01	0.26 ± 0.02

Values represent mean of three replicates ± standard deviation

Physicochemical data analysis of water samples

Wastewater characterisation by various water quality parameters (e.g. pH and conductivity) is required in order to meet legislation requirements. Influent and effluent wastewater samples were collected from Severn Trent Water Stoke Bardolph wastewater treatment plant (WWTP), for a period of three months (January to March 2016). Samples were characterised for pH, total dissolved (TDS) and total suspended solids (TSS), conductivity, and chemical oxygen demand (COD) in the laboratory, while dissolved oxygen (DO) and temperature were analysed at the sampling points. The analytical methods used for the water quality analysis were in accordance with “Standard Methods for the Examination of Water and Wastewater” in order to meet legislation requirements. The results of the physicochemical parameters for influent and effluent water samples are shown in Table 6.3. These data represent a total of 10 wastewater samples for both influent and effluent at different sampling periods, with hydraulic retention time (HRT) of 17 hours. The effect of HRT on pollutant removal performance is important due to its impact on the reduction of organic matter and nutrients [9].

Dissolved oxygen (DO) is a measure of the content of molecular oxygen present in water. The concentration of dissolved oxygen is a necessary control factor in wastewater, as it favours the organisms desired during the aerobic process. Low dissolved oxygen will decrease the activity of aerobic organisms and may cause sludge bulking, while an increase in dissolved oxygen may cause flocculation, with unsettled particles remaining in the wastewater. The work by Chapman (1997) reported that the minimum DO value for supporting aquatic life is 4 – 5 mg/L; concentration below this value may adversely affect aquatic biological life, while concentrations below 2 mg/L may lead to death for most aquatic life [10]. The DO level for effluent samples (4.9 – 5.8 mg/L) were within the range for sustaining aquatic life, while the DO level for influent samples (1.2 – 5.3 mg/L) were found to be below the standard.

Observations of temperature of wastewater are important as the rate of biological activity and solubility of oxygen depends on the temperature [11]. The realistic range for temperature in the wastewater treatment environment varies from 6–25°C [12]. Therefore, the temperature obtained for both influent and effluent were within the expected temperature range.

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Besides temperature, pH, a measure of the concentration of hydrogen ions in a solution, is an important parameter in the operation of biological treatment units. An increase in pH is due not only to industrial or other non-domestic discharges, but also to the denitrification process [13]. As shown in Table 5.3, the pH of the samples were within the permissible limit for wastewater, ranging from 6.0 to 9.0 . Moreover, all pH values were also within the range set by the WHO for wastewater, ranging from 7.0 to 7.4 [14].

The TSS values of the influent and effluent were found to be in the range of 38.9 – 177.4 and 3.9–14.2 mg/L, respectively. According to literature, the wastewater can be classified as follows: TSS < 100 mg/L as weak, 100 < TSS < 220 mg/L as medium, and TSS > 220 mg/L as strong wastewater [15]. Therefore, TSS levels in influent and effluent samples classified them as medium and weak wastewater, respectively. Moreover, the permissible standard for TSS (for discharge) is 35 mg/L [16]. Therefore, the effluent is safe to be discharged into the river, while the high TSS level in the influent, due to the suspended particles from the waste, may affect aquatic life. However, the mean values (0.5 g/L) obtained for TDS in both sampling points were within the permissible limits stipulated by the WHO for wastewater [14].

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Table 5.3: Characteristics of influent and effluent wastewate

Parameters	Unit	Discharge limit	Influent		Effluent	
			Range	Mean	Range	Mean
DO	mg/L O_2	5 – 9[a]	1.2 – 5.3	3.8	4.9 – 5.8	5.4
Temperature	°C	6 – 25[a]	7.6 – 11.9	10.4	10.3 – 16.2	12.1
pH		6 – 9[d]	7.0 – 7.8	7.6	6.9 –7.4	7.0
COD	mg/L	125[a]	61.3 – 285	120	13.1 – 26.2	21.3
TSS	mg/L	< 35[d]	38.9 – 177.4	89.8	3.9 – 14.2	6.4
TDS	g/L	0.3 -0.9[c]	0.3 – 0.9	0.5	0.3 – 0.4	0.4
Conductivity	mS/cm	0.05 – 1.5[a]	0.7 – 2.0	1.0	0.6 – 0.9	0.8
Sodium	mg/L	40 – 70[c]	54.8 – 81.7	80.9	62.6 – 89.9	74.4
Magnesium	mg/L	4 – 10[b]	32.07 – 40.27	30.9	22.2 – 30.7	27.1
Potassium	mg/L	7 – 15[b]	12.5 – 21.0	19.7	14.4 – 28.2	18.4
Calcium	mg/L	6 – 16[b]	85.0 – 113.7	85.8	61.9 – 81.9	74.8

[a][17], [b][18], [c][14], [d][16]

DO=dissolved oxygen; COD=chemical oxygen demand; TSS= total suspended solid; TDS=total dissolved solid

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Conductivity measurements indicate the level of dissolved inorganic material present. The biological nitrogen removal in wastewater treatment is the main cause of the significant reduction in the conductivity of wastewater [19]. However, the increase in the conductivity measurement of the influent indicates an unusual discharge, probably from an industrial source. Moreover, the measurements obtained were in agreement with other studies reported in the literature [20]. The conductivity of wastewater generally ranges from 0.05 – 1.50 mS/cm, while some industrial wastewater is reported to have higher conductivity measurements, up to 10.0 mS/cm [13].

Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is one of the standard parameters, and provides information on the level of organic contamination of wastewater. The procedure for the determination of COD using the cuvette test. The COD of influent published in literature was reported to be in the range of 200 to 600 mg/L [13]. Although the results for influent were within this range, the COD concentrations of the influent during the sampling periods were highly variable. However, it was observed that the measurements of effluent samples consistently produced lower COD v alues than for influent samples.

COD levels of the effluent were stable for all sampling periods, at lower than 40 mg/L. This suggests that the high level of organic pollution due to anthropogenic activity may have resulted in high values of COD in the influent. These results were in agreement with the work of Gardner, Comber [21] who measured the characteristics of final effluent from wastewater treatment plants around the UK. To summarise, variations in water quality parameters were observed in both influent and effluent wastewater samples. Table 5.4 summarises these water quality parameters for both influent and effluent wastewater samples.

Table 5.4: Data for water quality parameters for influent and effluent wastewater samples during February-March 2016

Parameters	Influent (average ± SD)	Effluent (average ± SD)
Temperature (°C)	10.4 ± 0.9	12.1 ± 1.4
Dissolved oxygen (DO) (mg/L)	3.8 ± 4.2	5.3 ± 4.6
pH	7.6 ± 0.2	7.0 ± 0.1
Conductivity (mS/cm)	1.0 ± 0.3	0.8 ± 0.1
Chemical oxygen demand (COD) (mg/L)	120.4 ± 51.6	21.3 ± 4.1
Total suspended solid (TSS) (mg/L)	89.8 ± 37.3	6.4 ± 2.8
Total dissolved solid (TDS) (g/L)	0.5 ± 0.1	0.4 ± 0.1
*SD=standard deviation		

Heavy metal concentration and its variation in influent and effluent wastewater samples

The concentrations of heavy metals such as copper (Cu), cadmium (Cd), chromium (Cr), iron (Fe), and lead (Pb) were determined using ICP-MS analysis of influent and effluent samples taken from 10 different sampling periods at the Severn Trent Water Stoke Bardolph WWTP. The concentration of heavy metals in influent and effluent ranged from 0.01 – 439.05 µg/L and 0.006 – 99.82 µg/L, respectively. These

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observations are consistent with the trend observed in other studies [22]. The highest concentration of Cu content in influent wastewater sample was found to be 12.34 μg/L. However, this concentration is within the range for wastewater discharge contained in the Water Framework Directive (2000/60/EC). From the results obtained for copper concentration in influent and effluent wastewater samples, the selected range for initial Cu(II) concentration (10 – 60 mg/L) in the clean water matrix is not environmentally relevant. However, the range chosen is closer to the copper concentration observed in some industrial wastewater.

Benchmarking the wastewater matrix from the pollutant and adsorbent perspective

New wastewater quality parameter (benchmark study) has been developed to quantify the impact of wastewater composition on the efficiency of Cu(II) removal by oxidised CNW adsorbents. The issue with previous studies is the assumption that the actual wastewater composition is the same for each experiment, or has no influence on the removal capability of that process. No work to date has performed benchmark experiments on each fresh wastewater sample to challenge that assumption.

Moreover, the impacts of the variability and composition of the wastewater matrix on the adsorbent's capability to remediate Cu(II) have not yet been reported by other studies. Thus, throughout these benchmark experiments, the complexity and variability of the wastewater to the treatment was controlled. Benchmark experiments for each effluent wastewater sample were carried out under similar conditions and the percentage of Cu(II) removal by oxidised CNW adsorbents are reported in Table 6.5.

Table 5.5: Data over time of Cu(II) removal as evaluated by benchmark studies (Initial concentration of wastewater effluent spiked with Cu(II)=4.0 mg/L, sorbent dosage=1.0 g/L, pH=6.0)

Sampling date	Benchmark experiment for Cu(II) removal (%)
18/1/16	80.11
20/1/16	68.22
25/1/16	81.82
10/2/16	74.41
15/2/16	77.39
22/2/16	78.76
9/3/16	74.15
16/3/16	81.27
23/3/16	80.11
30/3/16	77.27

For these benchmark experiments, a sorbent dosage of 1 g/L was selected in order to study the impacts of the variability and compositions of the wastewater matrix on the adsorbent capability. If higher sorbent dosage was selected, the results for each wastewater sample will gave 100% Cu(II) removal, since effluent contained less contamination than influent wastewater. As the main aim of this benchmark experiment is to study the effect of wastewater matrix on the efficiency of Cu(II) removal by

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oxidised CNW adsorbents, it is important that the independent variable (benchmark experiment) varies for ANN modelling, in order to detect the variation of wastewater and the influence of this variable on the removal capability.

The results reported in Table 6.5 show that the percentage Cu(II) removal by oxidised CNW adsorbents varies for each wastewater sample on different sampling dates. Results over six weeks give an average 77.35 ± 4.15%. Although the difference was low (around 4%), it is significant, and is likely to influence the efficiency and capability of oxidised CNW adsorbents. Moreover, the results obtained only support and covered only three months of sampling trips and focused on the effluent from only one treatment plant. According to the United State EPA, the complexity of the wastewater matrix depends on the number and volume of wastewater streams generated. The amount and type of contamination found in wastewater will depend on the different industrial activities realised in the area, the degree of urban development, and the type of treatment facilities found around it .

The composition of wastewater in WWTPs depends on several factors, such as compound physico-chemical properties, the climate conditions (temperature and sunlight intensity), the type of treatment process employed, and the operational conditions of the treatment process (temperature of operation and hydraulic retention time). Thus, variations in water quality parameters were observed in both influent and effluent wastewater samples, as shown in Table 6.4. For example, in the case of COD in influent and effluent, the COD concentrations of the influent during the sampling periods were highly variable. This indicated that the influent contained higher levels of organic pollutants than did the effluent wastewater, which may have influenced the capability of the adsorption process. Removal of Cu(II) from wastewater by an adsorption process is dependent on the organic compound’s biodegradability, its volatility, and its ability to be adsorbed onto adsorbents. Therefore, the composition of wastewater can vary significantly from plant to plant, between different wastewater streams, and within a plant at different times.

This demonstrates that the complexity of wastewater, in terms of its composition and variability, affect the capability of the adsorbent to remediate Cu(II) from the wastewater matrix. Moreover, the complexity and variation of wastewater composition may also affect the accuracy and efficiency of mathematical modelling in predicting the capability of this adsorbent to remediate spiked copper from the wastewater effluent.

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CHAPTER 6

WINDSHIELD GLASS WASTE AS SUSTAINABLE MATERIAL IN CONCRETE

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6.1 INTRODUCTION

Nowadays, the high demand of concrete has made it become one of the substantial material in construction. The characteristic of the concrete meet the required criteria that ensure it suitability for most construction process. However, it was estimated that the consumption of concrete is now at an annual rate of about 5 billion tons of natural aggregate, sand and gravel that has become one of the largest amount of raw material utilizes [1]. Quarrying activity has severely damage the natural mountain landscape and green vegetation of the environment. Concrete is the most broadly used construction material [2], while aggregate makes 70% of its volume and consumes 8–12 million tons of natural aggregate annually [3,4]. Aggregate resources has become scarce since many countries have no limit on mining of aggregates [5].

Along with this situation, other resources alternatives for aggregate, such as sea sand aggregate, waste concrete recycled aggregate, tailings production of aggregate and artificial aggregates are studied [6]. Toward the effort to minimizing growing environmental impact, researchers have been searching for efficient and innovative solutions that can conserve non-renewable resources, in construction field [7].

Therefore, research on the reused materials such as windshield glass can be an alternative material to meet the increasing demand of concrete making and the growing problem of resource scarcity. This not only preserve the natural resource, but also promote sustainability of the environment. Natural aggregates can be easily replaced by

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recycled concrete aggregates generated from construction and demolition waste that lead toward savings of natural resources. Ecological aspects of the usage of recycled material waste can save the natural aggregate and space of landfills. Economical aspect is shown by the lower price of recycling and separation process in comparison with the higher price of aggregate exploitation that is more energy-intensive.

6.2 GLASS

Glass is a 100% recyclable material with high performances and unique aesthetic properties that make it suitable for various purposes. Glass is widely used through manufactured products such as sheet glass, bottles, glassware, and windshield glass. Unfortunately, the majority of glass waste is not being recycled and end up in the dump site. Therefore, this has led to problems such as waste of natural resources and environmental pollution [8]. Glass waste is a major component of the solid waste stream in many countries. It can be found in many forms, including container glass and flat glass (laminated glass). Although a small proportion of the post-consumer glass has been recycled and reused, about 74% of the glass waste generated is dump in the landfill [9].

Due to the limited landfill space available and stringent environmental regulations, many research on glass waste are conducted to develop efficient, economic and environmental sound alternatives [8]. Advantages of utilizing glass waste is the low production and the high strength material of concrete. Glass waste can be used in the construction field for concrete production. The use of glass waste in concrete is economic as it will decrease the production cost of concrete [10].

Recently, the use of recycled glass as aggregate in concrete has attracted wide research interest. It is known that concrete containing glass aggregate has lower water absorption and drying shrinkage. However, the use of glass in concrete may result in expansion due to alkali-silica reaction. According to Topcu et al. [10], the higher content of silica in clear glass can cause alkali-silica reaction expansion in concrete. In addition, finely milled glass waste can be considered a pozzolanic addition that acts as a filler, reduce porosity, permeability and yields denser mortars than the original materials, thus increasing the durability.

6.3 THE USE OF CONCRETE FOR SUSTAINABILITY

Concrete can be categorized into three types which is lightweight concrete, normal concrete and heavy concrete. Each types of concrete have different densities in which lightweight concrete has a density of 1800-2000 kg /m^3, while normal concrete has a density between 2240-2400 kg /m^3 and heavy concrete has a density greater than 2600 kg/m^3. Concrete is very suitable for the use in construction work as it will harden when mix with water. These properties are very important in building construction. In addition, concrete will not rust, heat-resistant, durable, non-flammable and have high compressive strenght [11]. Concrete is considered as an excellent and globally available construction material that can be cast from sustainable material. Concrete components typically are cast with the recycled or reused material. In addition, production of concrete can save the landfills and minimize cement use by replace with waste materials.

Concrete has a long service life because of the reinforced of concrete durability ensures the structural capability for many years. It can withstand natural disaster including earthquake and floods. This resistance helps to minimize the need for replacement or

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repair. To enhance the energy efficiency, the inherent thermal mass of reinforced concrete can absorbs heat during the day and releases it at night thus reducing heat, ventilation and air condition cost. The cast-in-place concrete reinforcement offers a monolithic approach to design. Few or no joins or connections needs to be maintain which minimize the need of extensive maintenance compared to other construction material. Therefore, this will provide long term durability of a concrete.

6.4 METHODOLOGY

The methodology involves the preparation of raw material based on DOE method and the testing of sample. The laboratory work and test include sieve analysis, slump, compressive, and tensile strength test. The aggregates were process by sieve analysis to divide sample of coarse and fine aggregates into fraction of same particle size. The total value of windshield glass as coarse aggregate used in concrete mixture is vary at 0, 10, and 30%. A total of 36 units of 100 mm^3 cubes and 6 units of 100 mm diameter of cylinder were prepared for compressive and tensile strength test. Figure 6.1 shows the flow chart of the methodology.

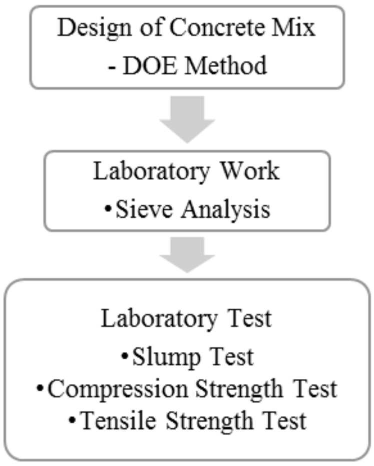

Figure 6.1 Flow Chart of Methodology

6.5 RESULT AND DISCUSSIONS

Table 3.2 shows the value of slump test with respect to the windshield glass waste used. The slump increases from 75 mm to 120 mm with the increasing percentage of windshield glass from 0 to 30%. This show that the increased of windshield glass in the concrete mix result in poor cohesion and bonding in the cement paste.

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Table 6.2 Slump test value

Windshield glass waste (%)	Slump test (mm)
0	75
10	85
30	120

Figure 6.3 shows the concrete sample of windshield glass at 10% and 30% at age 7 and 28 days. The concrete compressive strength is increased from 15 to 25 Mpa at 7 days with increased windshield glass content from 0 to 30%. However, at 28 days, the compressive strength was maximum at 10% windshield glass content with compressive strength of 34.4 MPa. This may be due to the optimum content of the windshield glass in the concrete that produced strong bond in the concrete mix.

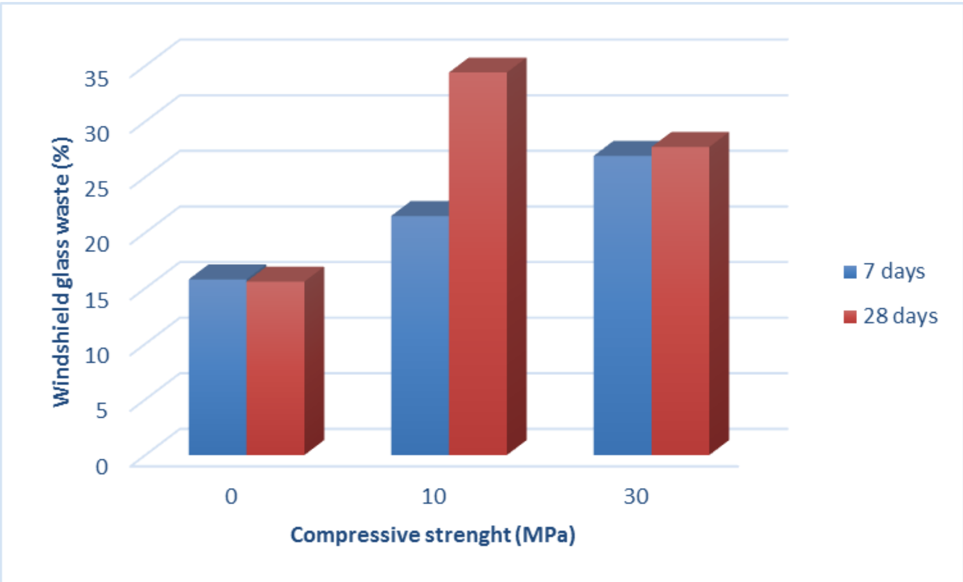

Figure 6.3 Compressive strength of windshield glass waste at 7 and 28 days

Figure 6.4 shows that the content of 10% windshield glass as replacing course aggregates had the highest tensile strength at 7 and 28 days which is 2.69 Mpa and 3.06 Mpa, respectively while the 30% windshield glass had the lowest tensile strenght of 2.23 Mpa at 7 days. This shows that the optimum windshield glass content in concrete for maximum tensile strength is at 10%.

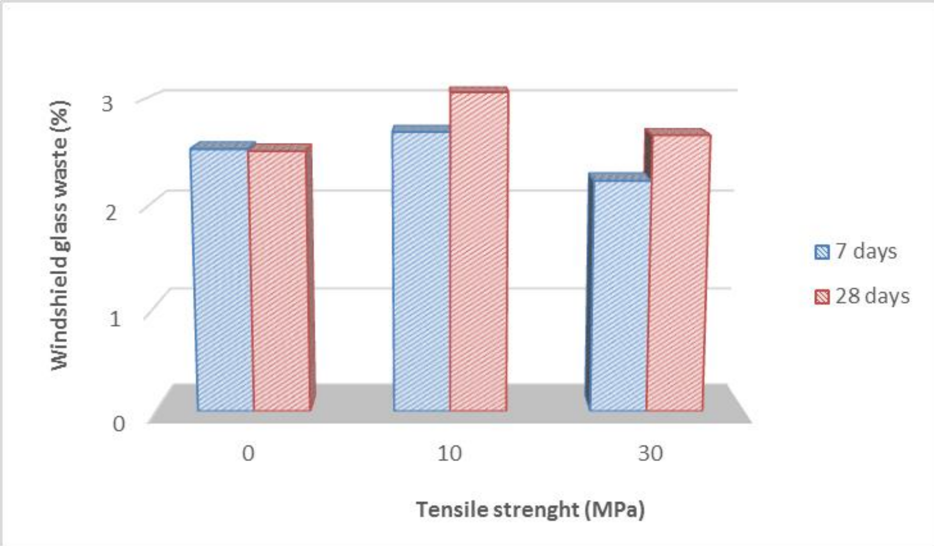

Figure 6.4 Tensile strength of windshield glass waste at 7 and 28 days

6.6 CONCLUSION

Windshield glass has the potential to be a substitute for coarse aggregate in concrete with higher compressive and tensile strength achieved at the 10% of the windshield glass content in the concrete. However, higher percentage (30%) is not suitable to be uses as substitute because the bond between glass and concrete maybe is weaken. Therefore, it can be conclude that 10% is the optimum percentage of windshield glass use in concrete. The use of windshield glass in concrete mixing can lead to a better change in the construction as it is more environmental friendly.

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CHAPTER 7

CULTIVATE AEROBIC GRANULAR SLUDGE WITH SOY SAUCE WASTEWATER

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7.1 INTRODUCTION

Anaerobic Granular sludge was first found in anaerobic upflow sludge blanket (UASB) reactors to treat industrial wastewaters at the end of the 1970s [1] while the phenomenon of aerobic granular sludge was initiated by [2] with using domestic wastewater operated under sequential batch reactor (SBR) system. Aerobic granular sludge technology widely applied in treating nutrient and organic wastewater to meet the water quality-based standards while anaerobic granular sludge treatment capable in save the energy consumption and potentially in degrading activated sludge and treat wastewater effectively [3]. Since both technologies promising an efficient treatment of wastewater, combination of the two systems could anticipate a better wastewater treatment from this time forth. Recently, researcher focused on integration of aerobic treatment with anaerobic treatment in one SBR system for municipal and industrial wastewater treatment. The integrated anaerobic aerobic granulation systems have proved the efficiency in removing COD and have the ability to treat high OLR wastewater [4, 5]. Besides, the integrated anaerobic aerobic granulation is a straightforward system where is no return sludge compared to the conventional system resulted less sludge handling at the end of the process. The anaerobic aerobic granulation system favors less equipment since the using of clarifiers and other equipment is eliminated and yet less cost required compared to conventional system which demand large surface area. Considering small surface area required due to the compact bioreactor of aerobic anaerobic granulation system, the footprint produce from the system is minimal and controllable.

Revolutions on the development of aerobic-anaerobic granulation are varied in types of wastewater such as industrial pharmaceutical [6], livestock [7, 8], palm oil mill effluent (POME) [9], dairy [10, 11, 12], petrochemical [13], landfill leachates [14] and soybean processing [15] wastewater are fed in a SBR system to treat

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the wastewater. SBR technology has been success in removing nitrogen and phosphorus. Soy sauce is a dark brown liquid produce by the soybean fermentation process as food seasoning. Effluents from soy sauce wastewater are high in COD, Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) therefore brown in color. Even though the soy sauce wastewater is completely treated in biodegradation treatment as used in most industrials, certain amount of color is remaining in the effluent [16]. In this study, the anaerobic-aerobic granules were cultivated in an SBR fed with soy sauce processing wastewater, which is an industrial wastewater that rich in proteins and starch. The development of granular sludge and the effectiveness of anaerobic aerobic system in treating soy sauce wastewater are focused in this paper.

7.2 REACTOR SETUP AND OPERATION

A column-type anaerobic-aerobic sludge reactor with internal diameter of 6.5cm and 100cm of height and a working volume 3.0 L were used. The influent was fed into the reactor from the bottom of the column while the decanting of the effluent took place via a 50 cm outlet port located from the bottom of the reactor, resulting 1.5L of mixed liquor left in the reactor yielding 50% of volumetric exchange rate.

Air was introduced through fine air bubble stone by an air pump at the bottom of the reactor at 1.5 cm/s of superficial air velocity. The reactor was monitored to be in room temperature (25°C ± 3ºC). The reactor was operated at a cycle time of 6h, in sequential mode: 5 min of feeding, 230 of reaction, 5min of settling, and 5 min of withdrawal. During anaerobic phase, the wastewater in the reactor was allowed to circulate to ensure homogenous distribution of substrate and biomass. Figure 7.1 illustrated the schematic diagram of the setup reactor.

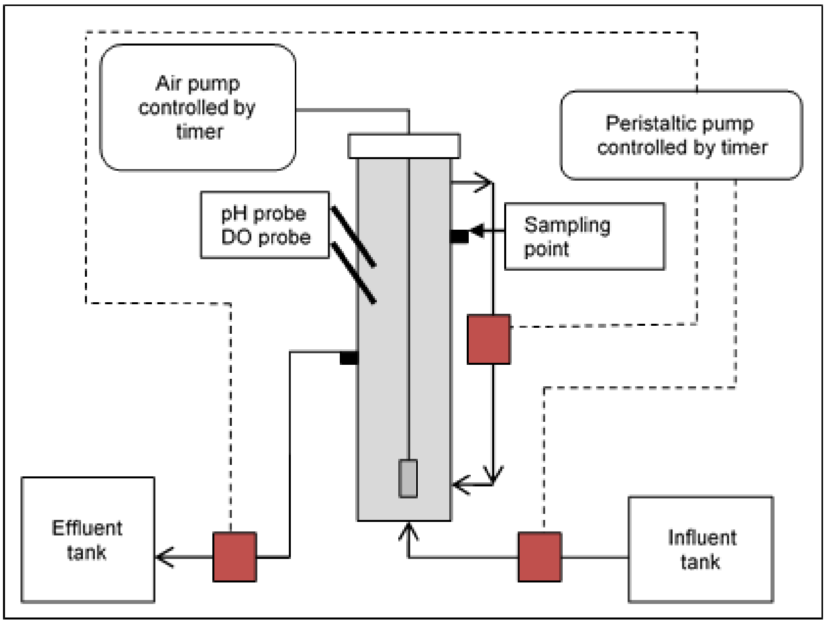

Figure 7.1 schematic diagram of setup reactor.

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7.3 WASTEWATER COMPOSITION

Raw wastewater was collected from an industrial sauce plant once a week and was kept at temperature of 4 °C [17] to prevent the wastewater from undergoing biodegradation due to microbial activity [18]. The characteristics of the sauce wastewater were analyzed and summarized in Table 7.1, in comparison with sauce wastewater as described in the literature [16]. The influent pH value was observed within the range of 5.5 ±1.6. The reactor was inoculated by 1.5 L of activated sludge form municipal wastewater treatment plant, resulting an initial MLSS in the reactor is 5000mg/L.

Table 7.1 Characteristics of soy sauce wastewater used throughout this experiment.

Parameter	[16]	This study
pH	5.0	5.0-6.0
COD, mg/L	3200	7000-10000
Color, times	8000-10000	6500-8000
BOD_5, mg/L	1900	2000-3000
SS, mg/L	900	750-1000
NH_3-N, mg/L	85	100-200

7.4 ANALYTICAL METHODS

Wastewater in the reactor and the effluent samples were periodically analyzed for suspended solids (SS), volatile suspended solids (VSS), mixed liquor suspended solid (MLSS), mixed liquor volatile suspended solid (MLVSS),NH4-N, color and COD using Standard Methods for the Examination of Water and Wastewater (APHA, 2005). The pH and dissolve oxygen (DO) was measured by using a pH/DO meter (Orion 3-Star Benchtop pH/DO Meter). The granule morphology of sludge was observed by a scanning electronic microscope (FESEM-Zeiss Supra 35 VPFESEM). The granules developed in the reactor's column were analyzed for their physical characteristics which include structural and morphological of granule, settling velocity, sludge volume index (SVI) and granular strength.

The morphological and structural observations of the granules were carried out by using a stereo microscope equipped with digital image processing and analyzer (PAXITv6, ARC PAX-CAM). The settling velocity was determined by averaging the time taken for an individual granule to settle at a certain height in a glass column filled with tap water. The SVI assessment was carried out according to the procedure described by [19].

7.5 STRUCTURAL AND MORPHOLOGICAL OF GRANULES

The seeding sludge of the reactor is the typical activated sludge with brown color with fluffy, irregular shape and loosely clumps. Figure 7.2a shows seed sludge during the initial inoculation stage, most of the flocculent sludge was washed out in the effluent result only the good settled sludge remains. After two weeks inoculation, small granular sludge with diameter 0.1-0.3mm was observed although the irregular sludge was still dominant in the reactor as shown in Figure 7.2b. At this stage, the develop granules

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were easily crush into pieces when high shear force applied. Afterwards, the quantities of average diameter of 0.3mm keep increasing. At this stage, the tiny yellow granules as shown in Figure 7.2c were in irregular shape, where the spherical granules were about to developed. At day 50 where the reactor reached steady state, mean diameter of granules were about 1mm with spherical smooth surface and cleared defined boundary as shown in Figure 7.2d.

[9] achieved 2.0-5.0mm diameter of matured granules after nine weeks operation feed with palm oil mill effluent (POME) which larger than [15] that cultivated soybean-processing wastewater about eight weeks operation and obtained 1.22 ± 0.85 mm diameter of stable granules. A faster developed matured granules had been reported by [20] which is only three weeks operation that fed using synthetic wastewater (glucose and acetate) and achieve 2.0-7.0 mm diameter of granules. The seed sludge, aeration rate, granules size and substrate composition is proved influenced the microbial of granules developed [21].

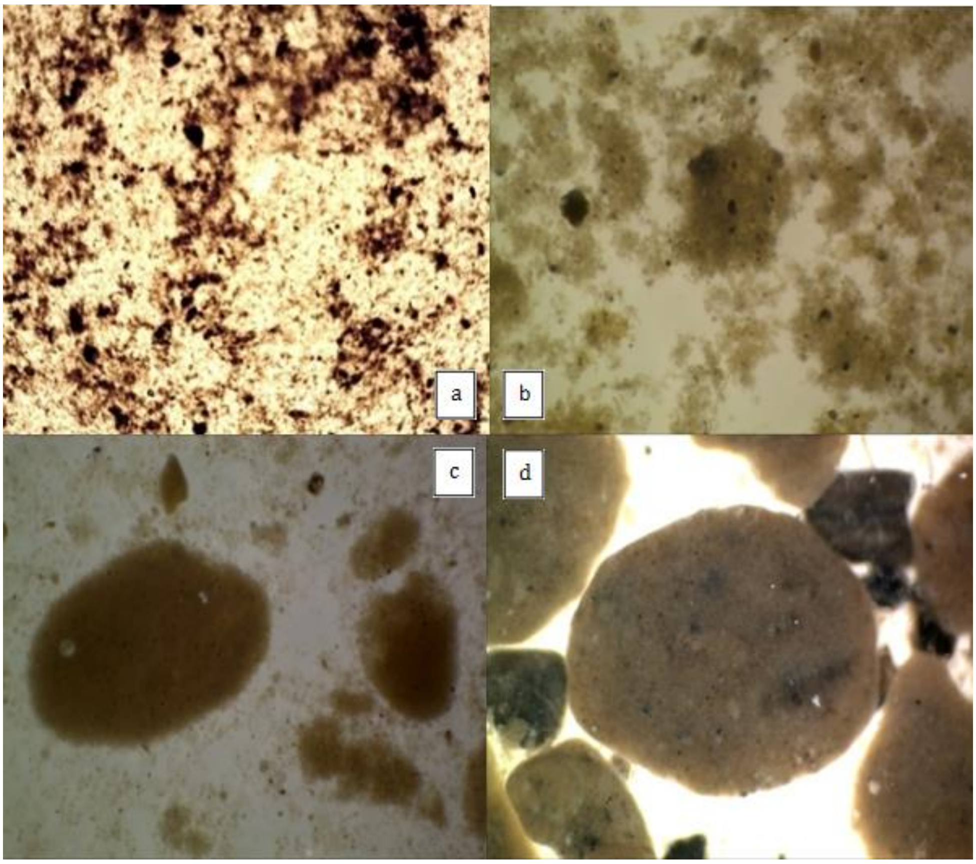

Figure 7.2 Morphology of granular sludge. (a) Seed sludge during initial inoculation from activated sludge. (b) Loose clump of granular sludge after two weeks inoculation. (c) Granular sludge at day 50. (d) Matured granular sludge.

7.6 SLUDGE SETTLING AND BIOMASS PROFILE

The settling characteristic of sludge in certain time is described the sludge volume index (SVI) besides the properties of sludge bed composition and morphology of sludge. The SVI of seed sludge at the initial stage is about 100mL/g where was show the poor

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settling ability. During the start up, the reactor experience almost complete washout due to the low settle ability of the seed sludge and short time of settle phase (i.e. 5 min). The remaining sludge initiated the micro colonies consortium in the reactor [9].

The initial SVI of seed sludge before inoculation process was 210.5 mL/g. The SVI of the inoculated granules gradually decreased after 20 days due to the granules formation. At the end of the experiment, the settling velocity was improved as shown by the low SVI value (32 mL/g) and the stable granules. The granules achieved 32-40 m/h of average settling velocity which is in agreement with [20] which in rage of 30-35 m/h. Granules began to form after 17 days of operation and mature granules were observed after approximately 8 weeks. The change of biomass concentration and SVI values throughout the experiment is shown in Figure 7.3. Additionally, the settling properties are reflected in the biomass content in the reactor (MLSS, VSS), which is inversely related to the efficiency of the settling.

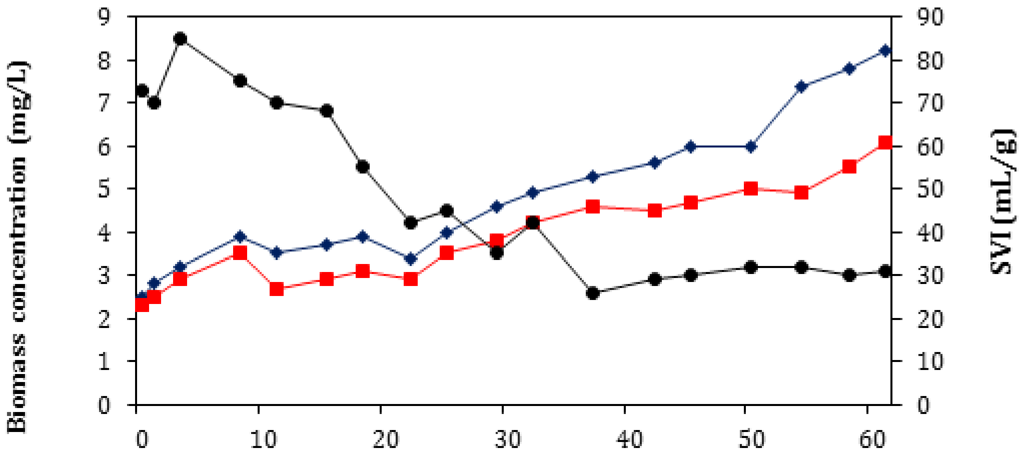

Figure 7.3 The concentration of biomass during granulation process (◆) MLSS, (■) MLVSS and (●) SVI.

The biomass concentration was keep increasing since day 1 until the end of the operation eventhough during initial operation, most of biomass was drain off when the effluent being discharged. The day 1 biomass concentration was about 2.5g/L and the day 60 the biomass concentration was 8.2g/L. Due to the foaming conditions associate with soy sauce wastewater, the MLSS value decreasing during the first and second week operation. In the initial stage of operation, flocculent with good settling ability remained in the reactor while most of floc-like sludge was washed-out into the effluent. The MLSS began to improve on day-17 when small granules started to appear in the reactor.

When the flocculant sludge developed into granular sludge during week four, the MLSS value increased and reached 8.2± 0.5 g/L. During theoperation until the end, the MLVSS have same trend with MLSS which the initial value was 2.3g/L and at the end operation, the value was 6.1g/L.

7.7 REACTOR PERFORMANCE AND REMOVAL EFFICIENCIES

Figure 7.4 and Figure 7.5 represent the removal performance profiles of COD and ammonia during the process of granulation respectively. At the first week of operation,

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the removal percentage of COD and ammonia was 69% and 65% respectively. During that stage, the effluent was not achieving good quality. After 22 days operation, removal percentage of COD was stable although flocculent sludge was dominating in the reactor. As the granular sludge slowly developed, the removal efficiency was improving continuously up to 90% for COD and 93% for ammonia. The result of removal percentage in this operation as in agreement by [11] in dairy wastewater which achieve 90% COD removal and 80% of ammonia removal using granulation technology.

The improving of removal percentage efficiency shown the existence of high biological activities in the reactor [22]. The results of this study prove that seed sludge developed in soy sauce wastewater is capable in treating high concentration of COD and ammonia continuously. During the initial stage, the percentage ammonia remova was irregular due to the developing and growth of flocculent sludge to granular sludge.

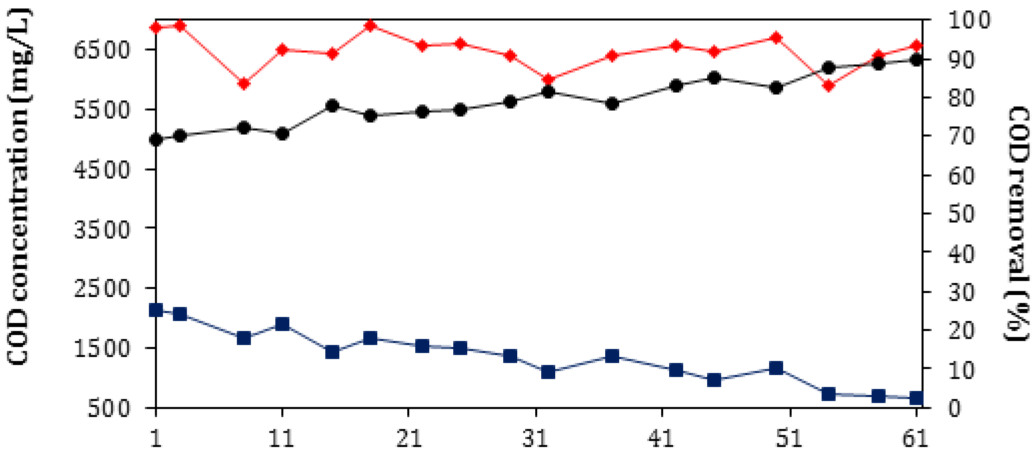

Figure 7.4 The COD concentration (◆) COD influent, (■) COD effluent and (●) COD removal.

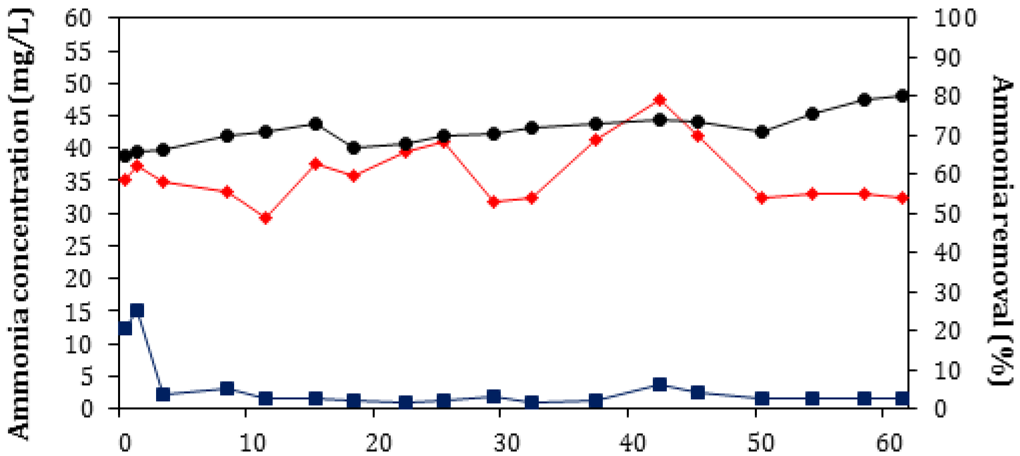

Figure 7.5 The Ammonia concentration (◆) Ammonia influent, (■) Ammonia effluent and (●) Ammonia removal.

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7.8 CONCLUSION

Stable microbial granular sludge sucessfully cultivated in a single SBR system with the soy sauce wastewater as feeding. Soy sauce wastewater is potentially treated using granular sludge system. The microscopic examinations showed that the matured granules depict a clear spherical-shaped outline boundary. Following granulation, good accumulation of biomass in the reactor and good settling characteristics were observed. When tested for COD and ammonia removal, the granules showed 90% and 93% maximum removal, respectively indicating the feasibility of a single SBR system for the treatment of soy sauce wastewater.

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CHAPTER 8

THE VERTICAL AERATED RECYCLED CONCRETE AGGREGATE FILTER (VARCAF) FOR REMOVAL OF PHOSPHORUS

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8.1 INTRODUCTION

Eutrophication of fresh water bodies is one of the main problems facing aquatic ecosystems. In developing countries, approximately 75% of domestic wastewater is released to the environment without treatment (Rozari *et al*. 2016). Ayaz *et al*. (2012) reported that eutrophication in receiving water bodies may occur when phosphorus concentrations of nitrogen (N) was 6 mg/L. Therefore, proper treatment to remove phosphorus from domestic wastewater to achieve the admissible level for natural systems is needed.

Phosphorus (P) is an essential nutrient element for aquatic plants growth in natural water system. However, excessive P loads to water bodies from industrial, agricultural, household wastes may cause the overgrowth of aquatic plants or algae, greatly accelerating the depletion of dissolved oxygen (DO) in waters, even leading to serious eutrophication.

The management of the collected debris and waste causes real problems at the environmental level. Apart from that, Recycled Concrete Aggregates (RCA) have choose as part of our commitment to helping the environment and being sustainable. Recycling of concrete is important because it helps to promote sustainable development in the protection of natural resources, and reduces the disposal of demolition waste from old concrete. Crushed waste concrete was used in this study to evaluate its performance as an effective filter for phosphate reduction. Hence, in this study the RCA has been choose to be the materials for filters the removal of phosphorus.

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8.2 EXPERIMENTAL

8.2.1 MATERIALS

The RCA was taken on thrown waste cubes produced from the Material Laboratory in University Tun Hussein Onn Malaysia. Initially, the thrown waste cubes outside laboratory were selected. Then the waste cubes were crushed by using the crushing machines in order to produce the aggregates. Next the all aggregates are being sieves into 5 mm to 30 mm by using sieve analysis process. The crushed samples was collected and sieve through a 5 to 30 micrometer test sieve using a shaker, Endecott Lambard Rd. London, model Sw193BR. The chemical microanalysis obtained from Energy-dispersive X-ray spectroscopy (EDX) test.

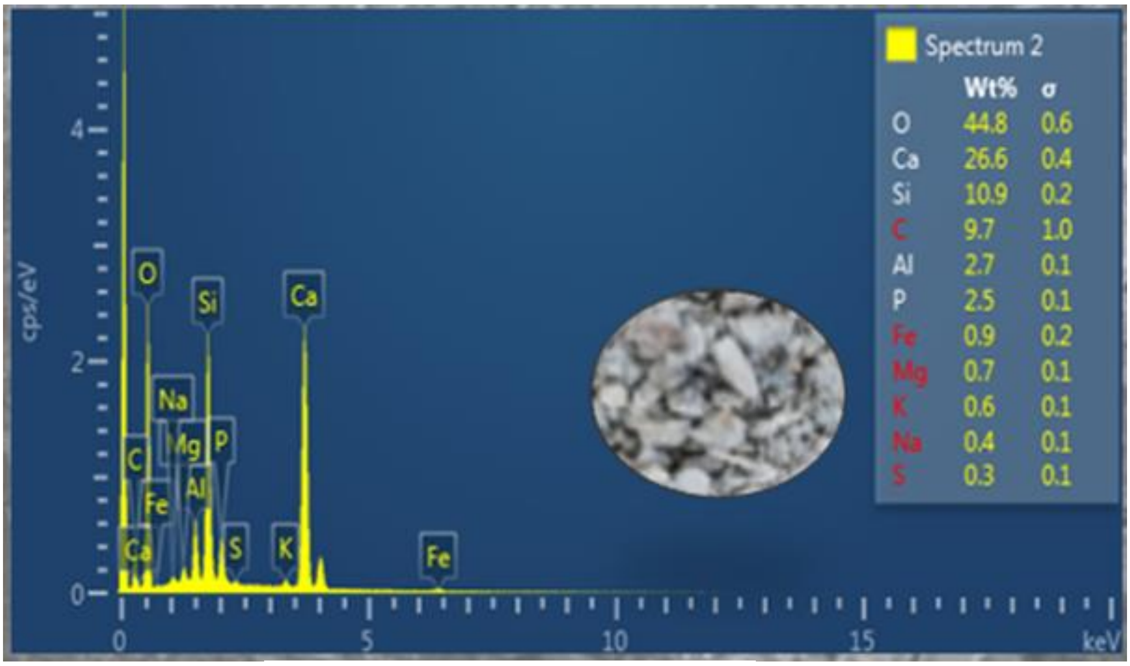

Figure 8.1 : Energy-dispersive X-ray spectroscopy (EDX) test for RCA

8.2.2 COLUMN STUDY

Lab-scale vertical column filters study was developed to investigate the difference between to size of RCA on the phosphorus removal efficiency using RCA as the adsorbent. Six column filters with the inner diameter of 150 mm, 6 mm thickness and total height 420 mm made from Perspex materials were set up with six different of concentration synthetic wastewater which is 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, 50 mg/L which was prepared by dissolving KH_2PO_4 (Potassium Dihydrogen Phosphate) into distilled water. Synthetic wastewater was flowed via gravity from the influent tank located at the higher level and connected to the influent point of each column filter. The aeration was controlled to ensure tiny and uniform bubbles of air spread throughout the

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column filters. The sampling was done weekly for influent and effluent to test for phosphorus removal.

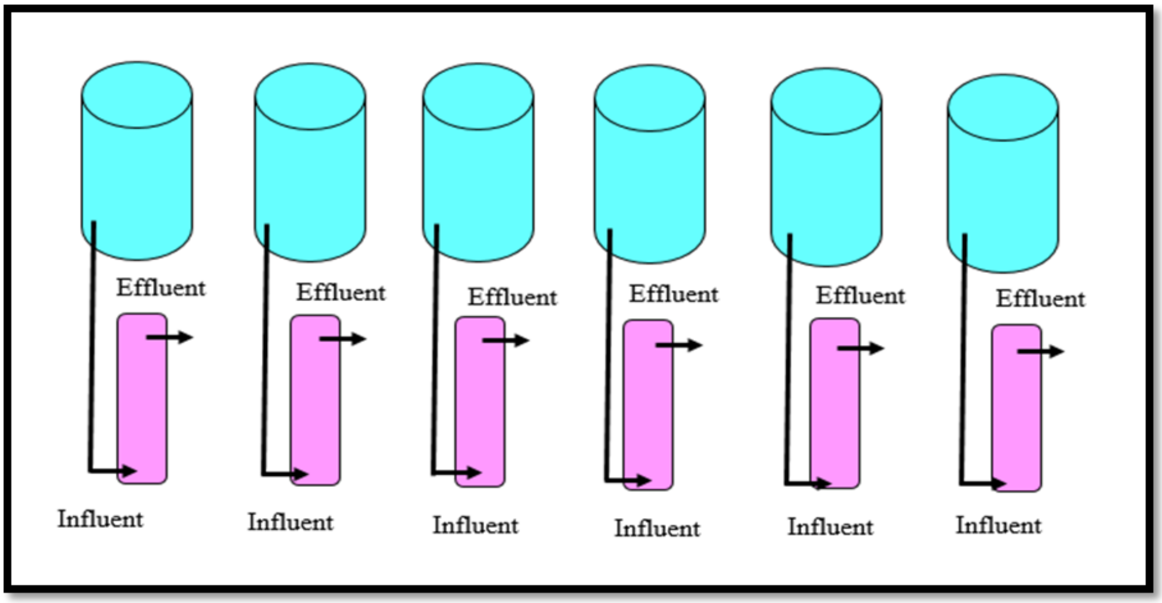

Figure 8.2 : Schematic diagram of lab-scale varcaf

8.2.3 ANALYSIS METHODS

The concentration of Phosphorus was measured by the ammonium molybdate spectrometric method using WESTCO Discrete Analyzer, model Smartchem 200, France. The efficiency of removal of phosphorus was observed by determining the removal percentage of the phosphorus using the following equation:

$$\textit{Removal percentage } (\%) : \frac{\text{influent} - \text{effluent}}{\text{influent}} \times 100$$

in which the initial phosphorus concentration (influent) in mg/L and the final phosphorus concentration (effluent) in mg/L.

8.3 RESULTS AND DISCUSSIONS

Figure 8.3 shows graph of percentage of Phosphorus removal with different size of RCA vs different concentration of synthetic wastewater for RCA size 5 mm to 10 mm and 25 mm to 30 mm with six different concentration of synthetic wastewater which is 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, 50 mg/L and distilled water. The highest percentage of P removal is 99.54% which is in concentration 10mg/L for RCA size 5 mm to 10 mm while the lowest percentage of P removal is 66.25% which is in concentration 50 mg/L for RCA size 25 mm to 30 mm.

Generally it can be seen that the percentage of P removal decreasing as concentration of synthetic wastewater increasing. From the graph for different size of RCA which is 5mm to 10mm and 25mm to 30mm, it is obvious shown that RCA which smallest size and lower concentration have the highest percentage of P removal. This

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results, shows the similarities finding with Akratos and Tsihrintzis (2007) found greater removal efficiency of P removal for fine gravel is 89%, followed by medium gravel with cattail 67% and cobbles (57%). Percentage of P removal efficiency was predominantly affected by media size. This is because the smallest size of media, the greater surface available for Calcium Oxide dissolution (Chazarenz *et al.*, 2017). Secondly is the Calcium (Ca) content in RCA. In EDX test it clearly shows to us in in previous sub-chapter that RCA contain 26.60% of Ca. Ca is one of the element for enhanced phosphorus adsorption. The porous surface structure of RCA also influenced the ability RCA for removing the P (Xiou *et al*., 2016). The larger the porosity, the larger the specific surface area where the adsorption of mechanism can take place.

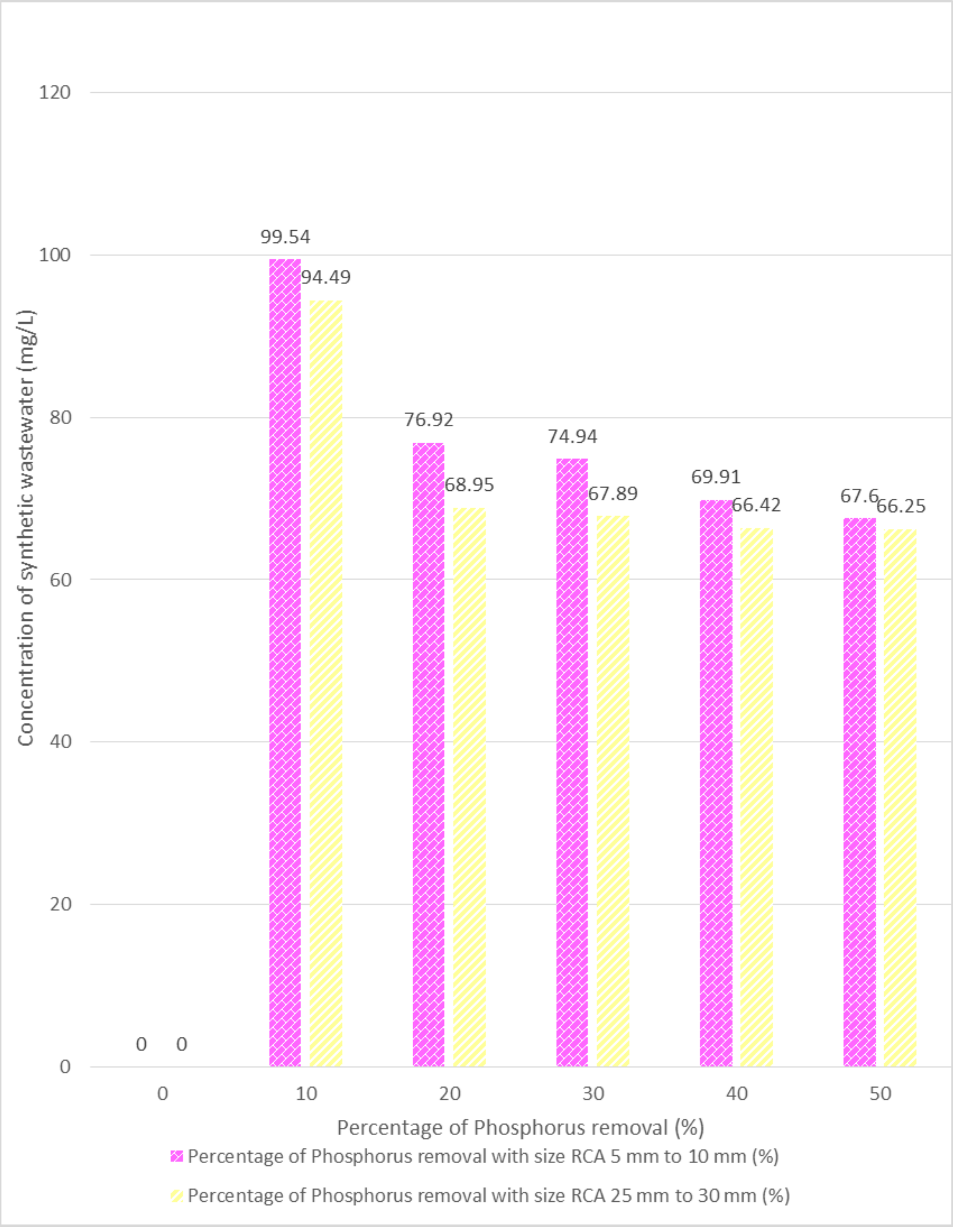

Figure 8.3: Percentage of phosphorus removal with different size of RCA

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CONCLUSION

This study showed the higher percentage of removal of Phosphorus at lower concentration synthetic wastewater which is 10mg/L is 99.54% which is RCA size 5 mm to 10 mm and it was proved that RCA is one of the absorbent that is good efficiency for removal of phosphorus.

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CHAPTER 9

CHARACTERISTICS OF HYDRODYNAMICS WAVE AT PORT OF TANJUNG PELEPAS DURING SPRING TIDE BY USING TELEMAC-2D

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9.1 INTRODUCTION

The Port of Tanjung Pelepas (PTP) located in the most southern tip in the State of Johor. It is one of the largest and busiest container port in Malaysia. The development of PTP has transformed the region in to a great development area [1]. A study has been done in Tanjung Piai Johor, a location near the PTP. The study shows that the causes of erosion at Tanjung Piai were coastal development such as land reclamation and port dredging. Heavy shipping activities also had generating waves that disturbed the growth of the existing mangroves [2]. Since the number of ships that went through PTP are keep on increasing, this will possibility affect the surrounding area as in Tanjung Piai.

This research is intended to generate the hydrodynamic simulations using computational fluid dynamics software that is TELEMAC 2D and to study the characteristics of wave hydrodynamics at the Port of Tanjung Pelepas, Johor Malaysia. Hydrodynamic model is comprehensive and detailed approach to represent the dynamics of coastal water. Numerical calculation models can be used to simulate the flow of water levels, sediment transport and salinity [3]. Hydrodynamic model may actually be a physical model built to scale. However, almost all of hydrodynamic models used today are based on a numerical model. Studies of the characteristic of hydrodynamics in coastal areas in PTP is important and any development should be planned and well designed to make sure an appropriate structure to be developed in the area.

9.2 RESEARCH METHOD

To conducting this study with systematic way and achieving the objectives stated, a proper planning on work flow is needed. In this study, three main parts of work are

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planned that are data collection, creating simulation model (meshing) by intergrating bathymetry data with the software Blue Kenue and analysis the collected data by using the Telemac 2D. The hydrographic parameters used in this study are collected from National Hydrography Center of Malaysia.

Telemac 2D

Telemac-2D is a computer software that calculates the free surface flow in natural water bodies. It solves the equations of Saint-Venant two dimensions, better known as shallow water equations (SWE) using the finite element method on unstructured triangular elements [4]. Telemac is a software system designed to assess the environmental processes on the surface of transient flow. Therefore, it can be used in marine and coastal domain, estuaries, rivers and lakes. Hydrodynamic model can also be produced in three dimensions using Telemac-3D software.Windows screen on Telemac 2D are using Fortran code that users need to enter specific codes to start work. Hydrodynamic model produced is easy to be converted from 2D to 3D calculations, 3D grid has the same structure as the 2D in the horizontal plane. 2D and 3D models are largely similar in scale with the most notable difference in the local area around coastal structures both gave the same pattern of change in velocity [5]

Blue Kenue

Blue Kenue is computer software that is used to display the movement and hydraulic characteristics. Blue Kenue also functions as a data processing, analysis and visualization tool for hydraulic model [6]. In the production of hydrodynamic model, Blue Kenue has been used for meshing works, integrating geospatial data with model input and results data. Visualization by Blue Kenue is able to display diamensi 1 d, 2D, 3D, polar and spherical views that can be recorded as digital film or saved as images for inclusion in reports or presentations.

9.3 DATA COLLECTION

Data collection consists of collecting data is needed for meshing and also analysis by Telemac 2D. For meshing work, bathymetry data, map of the study area and Universal Transverse Mercator (UTM) coordinates for the study area has been used for the model simulation preparation. Bathymetry data is used for determination of the water depth of the study area. While, map of the study area and Universal Transverse Mercator (UTM) coordinates are used for creating the simulation surface model. Besides that, analysis works by Telemac 2D will also need the Global Tidal Solution (tpxo) data for sea current properties, moon phase period for neap tide and spring tide determination and also wind speed together with wind direction to support the model that used in the analysis section.

Creating Simulation Model (Meshing)

Model is created to support the analysed data to be shown in a graphical state and to help researcher to easily view the properties of the sea area at a certain condition. This work was done by using Blue Kenue software which firstly will traced the study area with a map and coordinated by using Universal Transverse Mercator (UTM) coordinates system to get the proper scaled area. Blue Kenue was developed by the Canadian Hydraulics

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Centre (National Research Council), it is a tool to prepare, analyse and visualize the model [2]. Proper meshes were created resulting triangular shaped mesh all over the simulation area. By using the bathymetry data, the depth of water is interpolated with the mesh created. Next, boundary conditions were determined to differentiate between the upstream and the downstream area. A completed mesh area (Figure 9.1) then has been exported into a selafin file that will be used for Telemac 2D software to analyse the wave hydrodynamic characteristic.

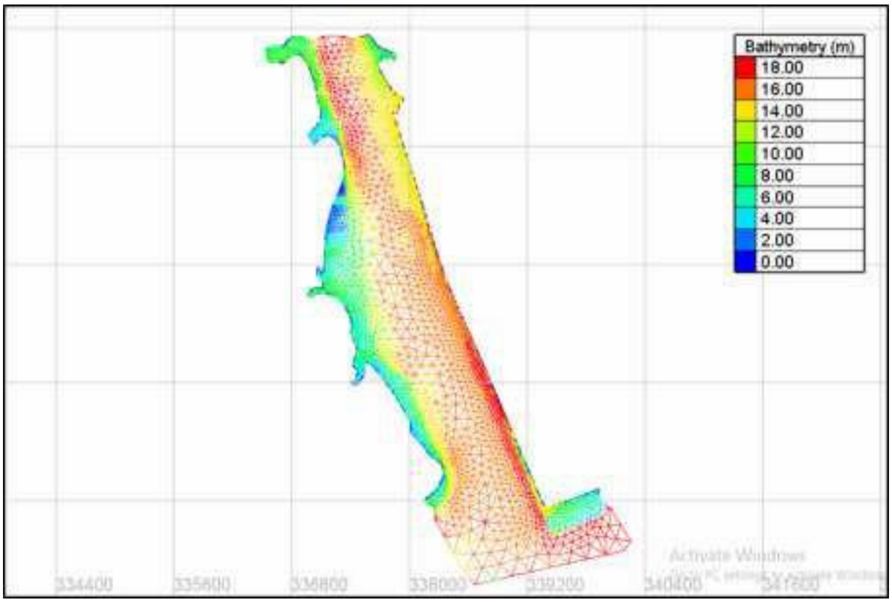

Figure 9.1: Final Results of meshing works

Analysis using Telemac 2D

After the meshing work part, analysis was done using Telemac 2D software. Information about the period of data, wind speed and wind velocity are as in the Table 9.1. Since a data collection would be very expensive, analysis were done using available data achieved from National Hydrography Center of Malaysia. The data was taken during spring tide (1 January 2012, 16 January 2012 and 31 January 2012) and in the state of flood tide. This preliminary study will have some understanding of the hydrodynamic forcing that characterise the Port of Tanjung Pelepas area. Besides selafin file, Global Tidal Solution (tpxo) file was also attached to the model before the analysis starts. The model prepared was saved in cas. format. The final analysis has create a new selafin file that can be used to produce wave hydrodynamic simulation to see the changes in the velocity of sea currents and changes in sea level height during the tide occurrence.

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Table 9.1: Wind properties (Sources: National Hydrography Center of Malaysia)

Date	Velocity (m/s)	Wind degree
Spring tide		
9 January 2012	4.03	0°
23 January 2012	4.47	22.5°
8 February 2012	2.68	337.5°

9.4 RESULTS AND DISCUSSIONS

From the result of the study two critical areas shows significant changes upon the happening of spring tide. The first area is the Tanjung Bin (Area 1), a natural mangrove areas and the second area (Area 2) is near the port of Tanjung Pelepas as shown in Figure 9.2. Figure shows the areas experiencing critical ocean current changes. Both areas has been analysed to study the speed of flow and elevation of water. Analysis is done by comparing the patterns of changes at the three days time of flood tide.

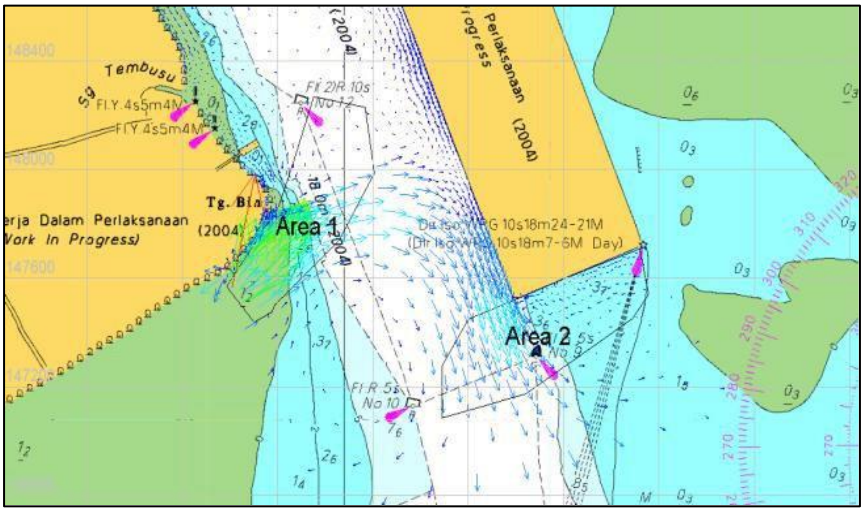
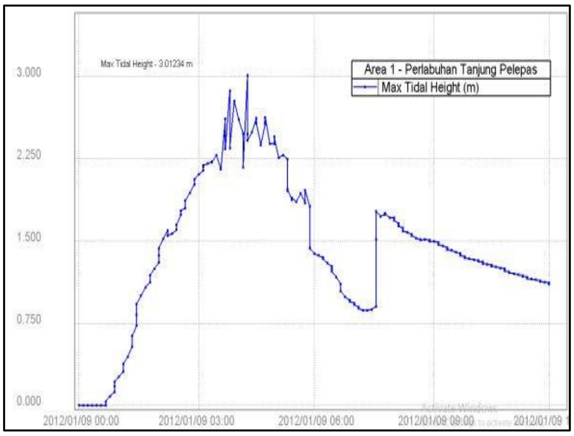
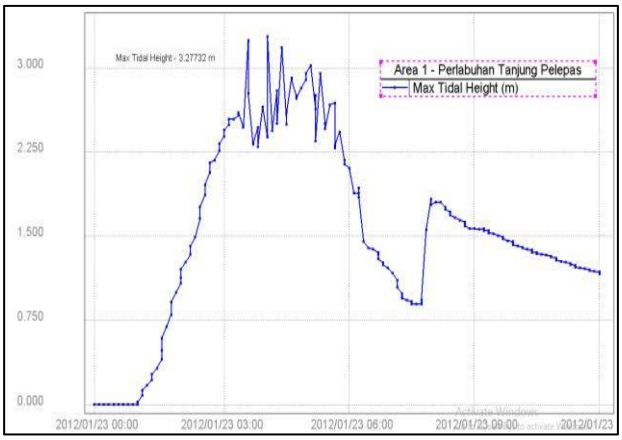


Figure 9.2 : Area of critical section

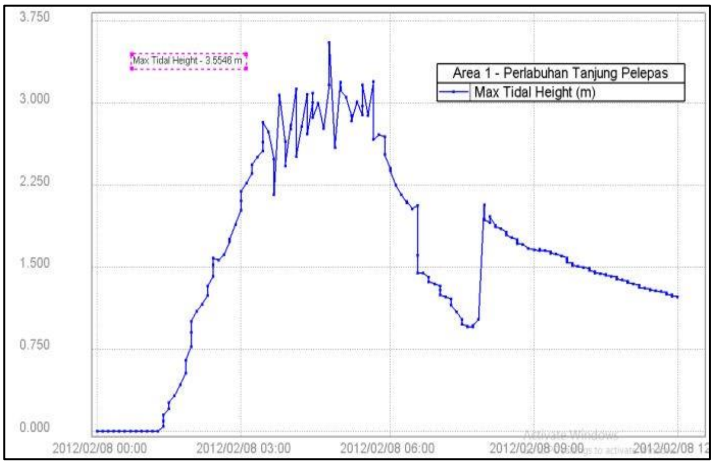
Tidal Height at Area 1

Figure 9.3 a)-c) below shows the result of simulation model analysis of tidal height for 12 hours in area 1 in the Tanjung Bin from 12:00 am until 12:00 pm on 9 January, 23 January and 8 February 2012





a) 9 January 2012 (b) 23 January 2012



c) 8 February 2012

Figure 9.3: Result of tidal height at Area 1

Results of tidal height on 9 January 2012 shows the highest reading of 3.01 m at 4:30 in the morning. On 23 January on the other hand the tidal height reading was 3.27 m at 4:30 in the morning. On 8 February tidal height reading of 3.55 m at 4:30 in the morning. Pattern of changes in tidal heights in the Area 1 show the sea level began to rise from 2:00 am and reach the highest readings at 4:30 am at the time of flood tide. Tidal height would decrease dramatically at 5 a.m. as a result of the occurrence of ebb tide. At 8 am the tidal height is increase to 2 m and declining slowly to 12 pm. Average height of tidal height in these three days during the time of flood tide is 3.28 m at 4:30 in the morning.

Tidal Height at Area 2

Figure 9.4 a)-c) below shows the results of simulation model analysis of tidal heights for 12 hours in Area 2 from 12:00 am until 12:00 pm on 9 January, 23 January and 8 February 2012.

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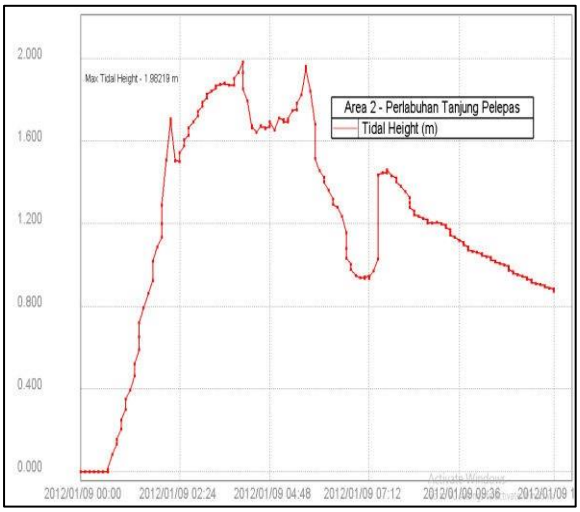
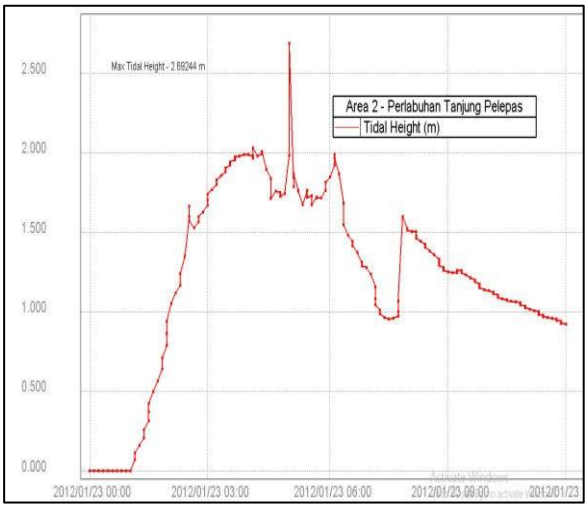
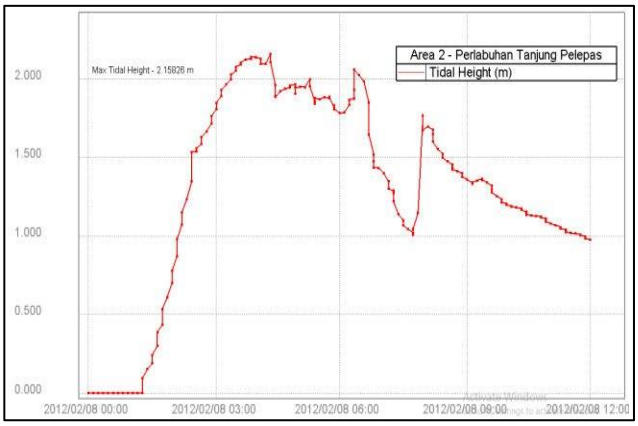


a) 9 January 2012



(b) 23 January 2012



c) 8 February 2012

Figure 9.4: Results of tidal heights at Area 2

For Area 2, the results of tidal heights on 9 January 2012 shows the highest reading of 1.98 m at 4:30 in the morning. On 23 January on the tidal height reading is 2.69 m at 4:30 in the morning. On 8 February tidal height reading is 2.15 m at 4:30 in the morning. Changes of tidal heights in the area started rising from 1:30 a.m. and reached the highest reading at 4:30 am at the time of flood tide. Height of tidal has been decreased dramatically at 5 a.m. as a results of the ebb tide. At 8 a.m there were very few increasing of tidal height up to 1.5 m and it is declining slowly. Average height of these three days during the flood tide is 2.27 m at 4:30 in the morning.

Sea Current at Area 1

Figure 9.5 a)-c) shows the results of the analysis of model simulating the velocity or current for 12 hours in Area 1 in the Tanjung Bin from 12:00 am until 12:00 pm on 9 January, 23 January and 8 February 2012. Reading of velocity on 9 January 2012 shows the highest sea currents velocity of 14.0071 m/s at 4:00 am. On 23 January the highest velocity readings is 14.15 m/s at 4:00 am and on 8 February the highest reading of velocity is 14.76 m/s at 4:00 am. Changes of sea currents velocity in Area 1 is increased

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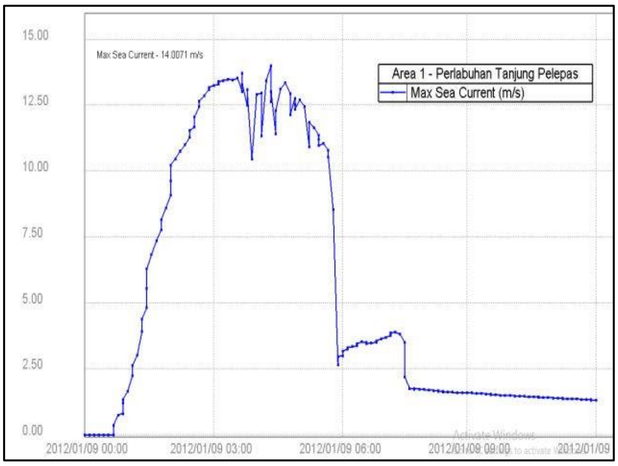
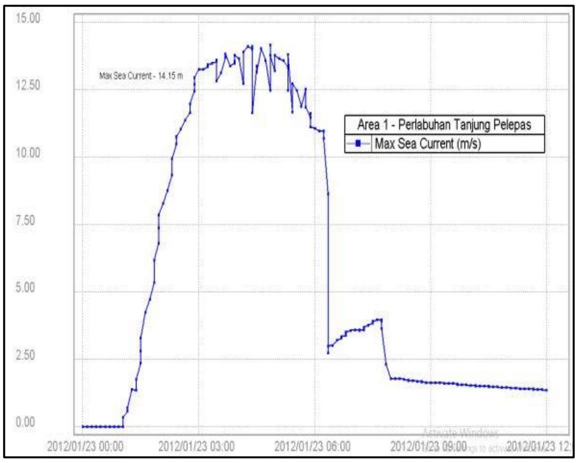
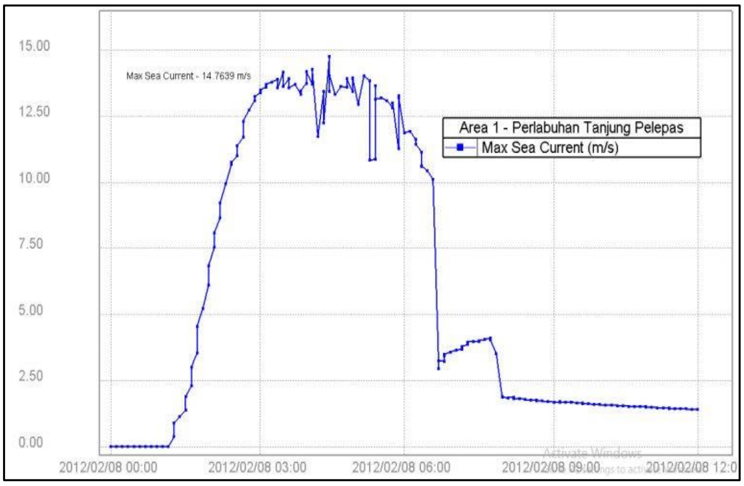
from 2:00 am and reached the highest readings at 4:00 am at the time of flood tide. The velocity of the sea current began to decrease dramatically at 5 a.m. as a results of the occurrence of ebb tide. An average of velocity in these three days at the time of flood tide is14.31 m/s.



a) 9 January 2012



(b) 23 January 2012



c) 8 February 2012

Figure 9.5 : Result of sea currrent at Area 1

Sea Current at Area 2

As can be seen from figure 9.6 a)-c), the reading of velocity on 9 January 2012 shows the highest sea currents velocity of 8.28 m/s at 4:00 am. On 23 January the highest velocity reading was 8.20 m/s at 4:00 am and on 8 February the highest velocity reading is 8.75 m/s at 4:00 am. Changes in sea currents velocity in Area 2 is increased from 1:00 am and has reached the highest readings at 4:00 am at the time of flood tide. Sea current velocity then decreased drastically at 4 a.m. and continued to decrease slowly to 12 pm as a result of the occurrence of ebb tide. An average of velocity in this three days at the time of flood tide is 8.41 m/s.

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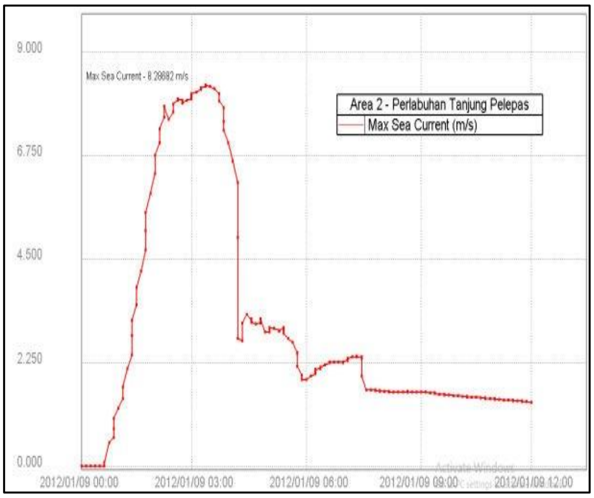
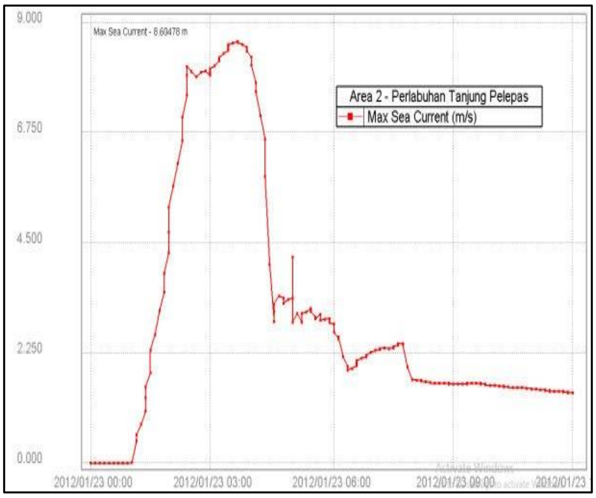
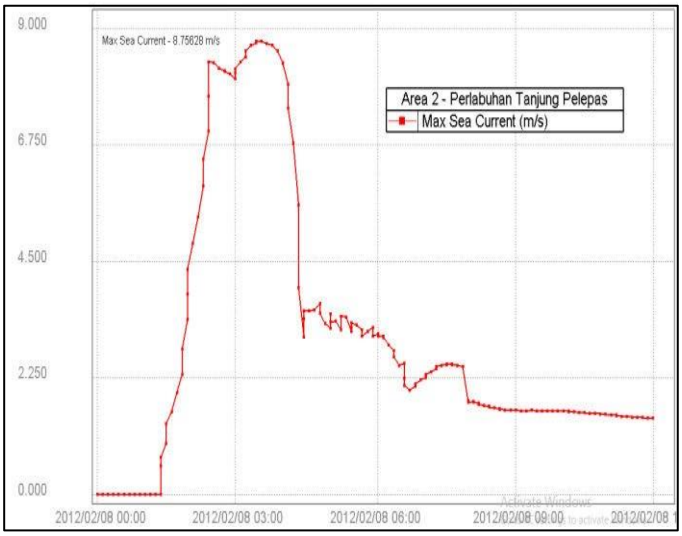


a) 9 January 2012



(b) 23 January 2012



c) 8 February 2012

Figure 9.6 : Results of sea current at Area 2

The direction of the currents for the three days of spring tide shows almost the same pattern of direction. In the Area 1 it shows the sea current moves into Pulai River via Tanjung Bin and partly towards Tanjung Pelepas. In the Area 2 the sea currents heading into Pulai River but conflicted with the mainstream from the Area 1 which headed to the area of Tanjung Pelepas causing currents could not get through the Pulai River from the Area 2. Figure 9.7 shows simulation for the sea current direction for both areas.

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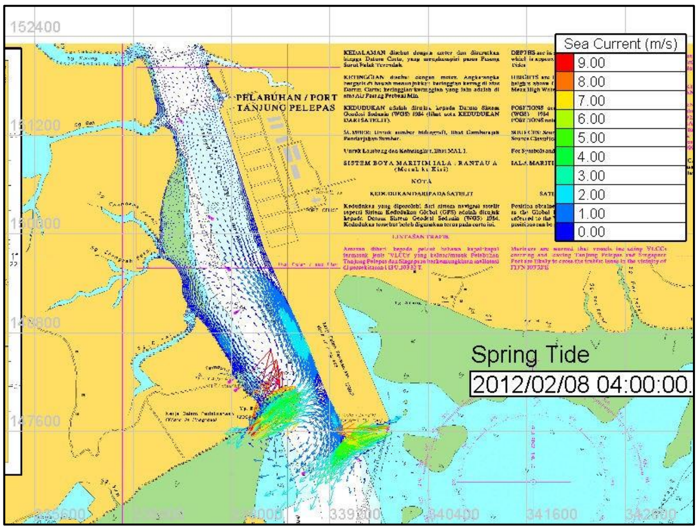

Figure 9.7 : Current pattern during spring tide

9.5 CONCLUSIONS

Hydrodynamic simulation models can be created based on hydrographical parameters such as wind waves, tidal currents and tidal height by using the software Telemac2D. The results of all this simulation model has shown the features of hydrodynamics at the Port of Tanjung Pelepas by showing the movement of the currents and the tidal heights in the study area at the condition of spring tide and in a state of flood tide. The following are the conclusions that has been made.

1. Construction of hydrodynamics simulation models using Telemac2D software in Port of Tanjung Pelepas can be produced and shows the hydrodynamic characteristics.
2. The average of highest velocity of the sea currents around the Port of Tanjung Pelepas is 8.41 m/s while 14.31 m/s at Tanjung Bin during the spring tide.
3. The highest tidal height at the time of spring tide is 2.27 m at 4:00 am in the state of flood tide around the Port of Tanjung Pelepas.
4. Bathymetry and terrain factor varying influence the characteristics of hydrodynamics in coastal area as comparison made in Area 1 and Area 2.

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We would like to thank the National Hydrography Center of Malaysia for providing the valuable data for conducting the study.

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CHAPTER 10

APPLICATION OF GEOPHYSIC TECHNOLOGY IN DEFINING THE ENVIRONMENTAL IMPACT AT COASTAL AREA

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10.1 INTRODUCTION

Knowledge on groundwater requirement for domestic water supply and agricultural activity is important to ensure a holistic management approach of groundwater aquifer. This scenario is more complex at costal area due to saltwater contamination that restricted groundwater usage for water supply and agricultural activity. Degree of salinity in groundwater aquifer should be suitable for both requirements in order to ensure sustainability for both important socioeconomic activities at coastal. Problem of saltwater contamination always related with seawater intrusion phenomena due to proximity contact with sea. In Malaysia, the coastal zone of Malaysia with a long coastline (4,800 km) and huge area (4.43 million ha), has a special socio-economic and environmental significance, which supporting 70% of Malaysia’s population. In addition, the Malaysian coastal zone is also the centre of economic activities encompassing urbanization, agriculture, fisheries, aquaculture, oil and gas exploitation, transportations and communication, and recreations (Syed Alwi, 1992). Among the coastal regions in Malaysia, the west coast of Peninsular Malaysia is the most developed socio-economically, with 57% of its coastline is utilized for agricultural activities and 21% for housing, transportation, and recreational facilities (Abdullah and Loi, 1992).

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Coastal area in Peninsular Malaysia has been identified as having the largest prospect for groundwater supply (Suratman and Awang, 1998). Groundwater supply can be extracted from alluvial, limestone, meta-sedimentary, and igneous aquifers. Comparing to the other categories of aquifer, alluvial aquifer is highly productive by generating an average of 30 m3/hr to 50 m^3/hr groundwater yield (Suratman and Awang, 1998). The water quality is suitable for domestic purposes, with some localities having brackish and saline water. Alluvial aquifer is vulnerable to seawater intrusion due to its close proximity to the sea (Suratman and Awang, 1998). Seawater intrusion can cause deterioration in the groundwater quality by changing the groundwater salinity. Among the coastal areas in Peninsular Malaysia that has been identified as having the most impact by seawater intrusion to the socioeconomic activities is Langat Basin which situated at the most advance and well development area in Malaysia (JICA and DMGM, 2002).

The coastal plains of Malaysia in certain places are unsuitable for plant growth due to salinity problem (Mohd Hashim, 2003). Several factors of salinity occurred in the coastal area of Malaysia where the most significant factor is seawater intrusion to low elevation coastal landform. Other factors that also influenced salinity problems are tidal inundation, groundwater seepage and over-drainage of adjacent area. Various studies showed agriculture activities such as oil palm, rice and turf grass had been affected by salinity problem in the coastal area in Malaysia (Roa, 1982, Kimi, 1991 and Uddin et al., 2012). The agriculture activity most affected by salinity problem in coastal area of Malaysia is oil palm (Mohd Hashim, 2003). Coastal plains with relatively fertile alluvial soils are found on the west coast of Peninsular Malaysia. Alluvial soils are also present in some parts of the east coast. Based on the topography factor, areas with greater than 20° slopes are unsuitable for oil palm plantations. Hence, only 42% of the 33 million ha of land in Malaysia is suitable for agricultural activity for oil palm (Abd. Ghani et al., 2004), and most of these locations are in coastal areas.

However, previous studies focused on salinity problem in order to define the suitability of agriculture towards soil salinity. There was limited study on the effect of seawater intrusion into groundwater aquifer that relates to groundwater supply and agriculture activities at the coastal area. Furthermore, groundwater for water supply and agriculture used in coastal areas can be affected by sea level rise in the 21st century due to climatic change (IPCC, 2001). Climatic change is expected to worsen the existing environmental problems along the coastal areas. Future sea-level rise near coastal aquifers may lead to a change in the present hydrogeological boundary. Saline groundwater is thicker than before and more shifts to the landward coastal areas in the future (IPCC 2007; Vaeret et al., 2009). The relationship between sea-level rise and seawater intrusion can be estimated according to the Ghyben–Herzberg relationship (sharp-interface model). This relationship states that the depth of the interface below the mean sea level is equal to 40 times the height of the potentiometric surface above the mean sea level. Therefore, a 1-m increase in sea level may cause a 40-m reduction in freshwater thickness (Fetter 2002; Hiscock 2005; Abd-Elhamid 2010).

The problem might become very serious when the effects of sea-level rise were to combine with the huge amount of water requirements for water supply and agriculture. This phenomenon requires practical hydrogeological investigation methods to assess the present status of seawater intrusion to groundwater system, especially in the coastal area which extensively involved with demand of water supply and agricultural activities. Three types of methods have commonly been used for seawater intrusion

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investigations: geochemical methods, geophysical methods and integrated method (Bear and Cheng 2010). The best geophysical method to assign, particularly in seawater intrusion investigations, is geo-electrical method (Loke 2010). Electrical resistivity method is unique as it detects increased aquifer conductivity via increased pore-water conductivity (Abdul Nassir et al. 2000). A number of studies have used the geo-electrical method to study seawater intrusion into groundwater aquifers in coastal areas. Issar and Levanon (1974) used the geo-electrical method and boreholes data to examine the extent of aquifer and salinities in alluvial aquifers (with depths more than 180 m) beneath the coastal plains of Arava valley in southern Israel. Ginzburg and Levanon (1976) used the geo-electrical method and boreholes data to determine a boundary of fresh-saline water aquifer along coastal area in Israel. Edet and Okereke (2001) used the geoelectrical method and geochemical data to examine the extent of seawater intrusion in shallow aquifers (with depths less than 300 m) beneath the coastal plains of Southeastern Nigeria. Benkabbour et al. (2004) used the geo-electrical method to characterise seawater intrusion in the Plioquaternary consolidated coastal aquifer of the Mamora Plains in Morocco.Di Sipio et al. (2006) used the geoelectrical method and geochemical data to obtain a better salinity profile of the groundwater system in Venice estuaries. Awni (2006) used the two-dimensional (2D) geoelectrical method to detect sub-surface freshwater and saline water in the alluvial shoreline of the Dead Sea in Jordan. Sherif et al. (2006) integrated the geo-electrical and the hydro-geochemical methods to delineate seawater intrusion in Wadi Ham, UAE. In Lagos, Nigeria, Adepelumi et al. (2009) used the vertical electrical sounding survey to delineate seawater intrusion into the Lekki Peninsula freshwater aquifer.

Baharuddin et al. (2009) used the geo-electrical method to study the effect of seawater intrusion and shoreline physical changes in the coastal area of Selangor, Malaysia. Hodlur et al. (2010) used the geo-electrical method and geochemical method to identify the resolution of the freshwater and saline water aquifers in a coastal terrain of Mahanadi Basin in India. Sikandar et al. (2010) used integrated a geo-electrical resistivity survey and geochemistry measurements to investigate groundwater conditions in Pakistan. Zouhri et al. (2010) combined the geo-electrical method and hydro-geochemical method to determine the groundwater salinity at Rharb Basin in Western Morocco. Sathish et al. (2011) combined the geo-electrical and the geochemical methods to assess the zone of mixing between seawater and groundwater in the coastal aquifer in South Chennai, in Tamil Nadu, India. Ebraheem et al. (2012) conducted a 2D earth resistivity imaging survey in the Wadi Al Bih area in the Northern UAE to determine the potential of the quaternary aquifer and its groundwater quality. Khalil et al. (2012) used the geo-electrical method and time domain electromagnetic method to access seawater intrusion into the groundwater system in the northwestern coast of Egypt. Maiti et al. (2013) used neural network inversion using the geo-electrical methods to assess suitable groundwater exploration at coastal area in Maharashtra, India. These studies demonstrate that the geo-electrical method combined with other methods is effective for depicting saline-water boundaries and studying the effects seawater intrusion. The advantages of each of the methods supplement the limitation of the other methods. The most apparent advantage of the combination technique is the reduction in study cost and time without jeopardising the integrity of the data obtained (Maillet et al. 2005; Sathish et al. 2011).

In the present study, the combined the geo-electrical and the geochemical methods were implemented, but emphasis was on the present seawater intrusion status, water supply and oil palm cultivation at Carey Island, located in the Langat Basin on the west coast of Peninsular Malaysia. The technique was aided by information related to

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the elevation, land cover and oil palm plant physiography. The elevation and land cover discussed in the current work involves the physical changes in the coastal area that can influence seawater intrusion distribution at coastal islands.

10.2 MATERIALS AND METHODS

Hydrogeology area

Eight monitoring wells (Figure 10.1) were installed in the unconfined aquifer: four (MW6, MW11, MW12, MW13) in the northwest in the mangrove preserved area and four (MW5, MW7, MW10, and MW14) in the southeast in the heavily eroded area without mangrove. Additionally six other wells (MW1, MW2, MW3, MW4, MW8, and MW9) were installed in the semi-confined aquifer in the southwest of the semi-confined aquifer. The wells reached various depths (40, 50, and 80 m), respectively, with open screens installed in the 34–36, 47–49, and 67–69 m depths for groundwater quality sampling. Soil samples collected from the each of the well boreholes by rotary-washing were visually examined and laboratory analysed. Soil classification followed the BS 1377 (1990): fine sand (0.063–0.1 mm); medium sand (0.1–0.4 mm); and coarse sand (1–2 mm). Tests on the soil physical properties included particle-size distribution, Atterberg limit, moisture content, specific gravity, and linear shrinkage. Surface elevations were conducted to obtain topography information of the study area. The precision of total station equipment, model GPT-3100N Series Top Con were used for data acquisition of elevation for the fourteen (14) monitoring wells and also along a route surveys. The reference datum is benchmarked to station BM No. 3082 obtained from DSMM. The elevation of benchmarked station is 3.0458 m from mean sea level (m.msl). Land-use mapping is useful for assessing the past and present land-use activities change in Carey Island. The past land-use map was obtained from topography map in the year 1974 published by The Department of Survey and Mapping Malaysia (DSMM). Scale of the topography map ratio is 1:63360 which covered the whole of Carey Island. As for the present land-use map, it is obtained from a modified land-use map with ground mapping in the year 2010. The topography map (1974) and modified land-use map with ground mapping (2010) are combined through a digitized process by using AutoCAD software version 2009. The superimposed maps are used to interpret the land-use activities change from the year 1974 to 2010. The 30 years of land-use activities change are estimated in unit m^2.

Subsurface Resistivity and Geochemistry Survey

Earth resistivity (ER) was measured following the traverse set up (Figure 10.1) using a resistivity meter (ABEM Terrameter SAS4000 with electrode selector ES10-64). Spread in two phases, the first phase data were collected in August 2009, November 2009, and February 2010; and the second phase data in December 2010. The former data were used to establish a TDS-ER relationship in the vertical profile of the study area; whereas the latter data were used to map out the subsurface resistivity in the horizontal profile.

Groundwater monitoring was done once or twice a week, starting August 2009 until March 2011. Groundwater samples were collected from the monitoring wells by using a bailer. Four groundwater quality parameters (conductivity, salinity, TDS, and temperature) were measured using a water quality checker (YSI EC300) pre-calibrated against a standard potassium chloride solution (conductivity 1.411 mS/cm) in

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accordance with the APHA (2005) procedures. Hydrogeochemical parameters measured were major cations and anions. Collected groundwater samples were divided, kept in two containers. For cation analysis, the groundwater samples were filtered by Whatman 42 filter paper and preserved with 2% nitric acid (HNO3). For anion analysis, the groundwater samples were filtered and then preserved at a maintained 4◦C. The anion analysis was done within 48 h of collection time. Cations analyzed were sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), and iron (Fe), on the Perkin Elmer Inductive Coupled Plasma Optical Emission Spectrometer (ICP-OES) model Optima 3300RL. Anions analyzed were chloride (Cl−), sulfate (SO42−), nitrate (NO3−), and bromide (Br−), on Dionex Ion Chromatography model ICS2000. The analyses were done to standard methods (APHA 2005), a five-point calibration quantifying the analyses with correlation co-efficient of the calibration curve between 0.995 and 0.999. Fetter (2002) proposed the classification of groundwater salinity can be classified into three types namely; fresh, brackish and saline by using TDS values. Freshwater are classified with TDS values < 1000 mg/L, brackish water are classified as TDS values ranging from 1000 mg/L to 10000 mg/L and TDS values > 10000 mg/L are classified as saline groundwater. According to Interim National Water Quality Standards for Malaysia (Department of Environment Malaysia, 2010), TDS values of < 1000 mg/L required no treatment for water supply.

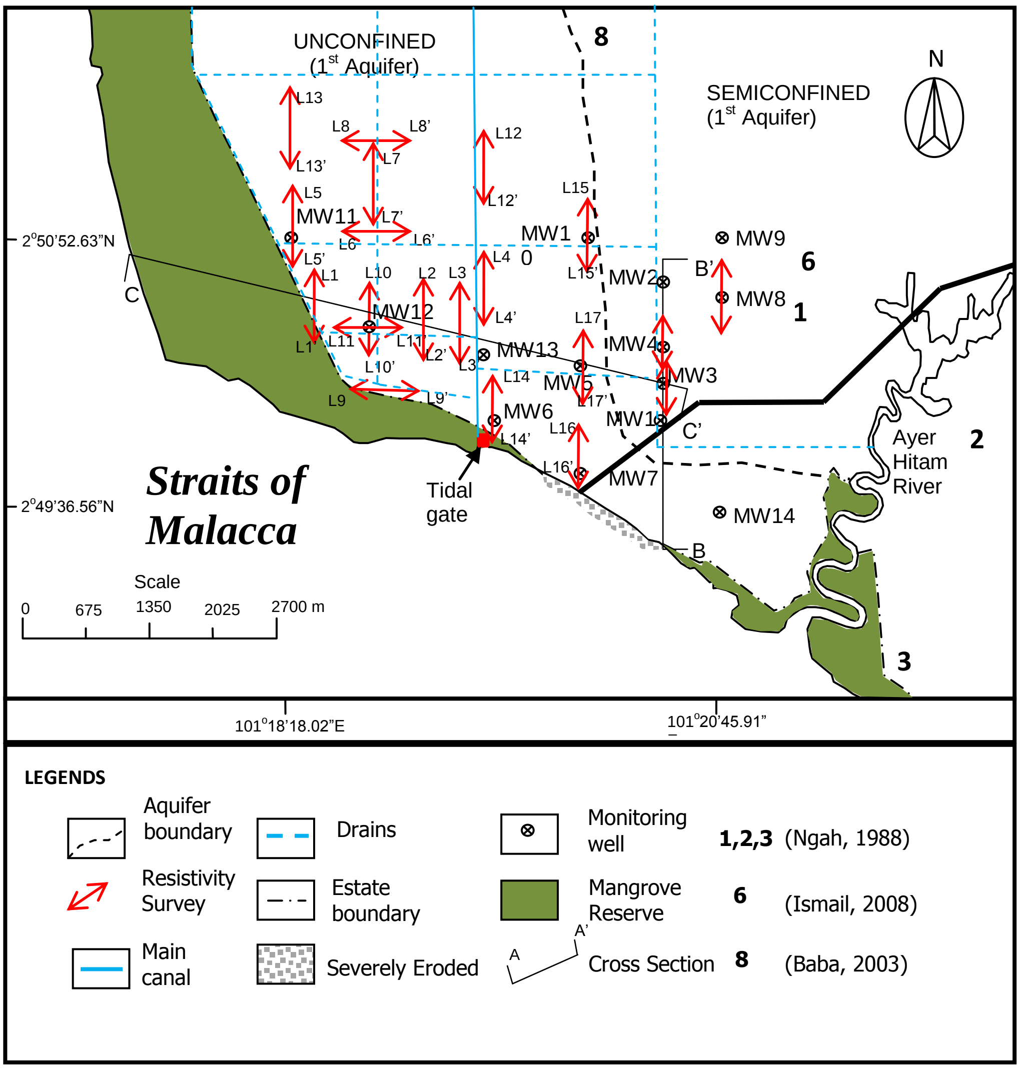

Figure 10.1: Locations of monitoring wells, resistivity survey lines, drainages system and boundary between unconfined and semi-confined aquifers

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In the first phase, a number of eight resistivity lines L18-L18', L19-L19', L17-L17', L5-L5', L4-L4', L3-L3', L2-L2', and L12-L12' were set up, each crossing respectively MW3, MW4, MW5, MW6, MW7, MW10, MW11, and MW12. No resistivity lines were set up crossing other wells (MW1, MW2, MW8, MW9, MW13 and MW14). In the second phase, a number of nineteen resistivity lines, L1 through L19, were set up, and the lines crossing the wells were as indicated above for the first phase and those not crossing other wells are as shown in Figure 10.3.

All the nineteen resistivity lines were each laid into the ground surface almost perpendicular to the shoreline (Figure 10.3): sixteen lines in the N-S direction; and three in the W-E direction of the study area. Each resistivity line (cable) was 400m long, divided into four sections each 100m long (designated as 1st, 2nd, 3rd, and 4th cables). Using an initial electrode spacing of 5m intervals (for the middle 2nd and 3rd cables) and 10m intervals (for the end 1st and 4th cables) a number of ten electrodes were pegged each on the end 1st and 4th cables; and twenty electrodes each on the middle 2nd and 3rd cables, making a total of sixty one (61) electrodes for each 400m survey cable. The spacing flexibility afforded by the Wenner array could thus propagate increasingly denser resistivity in the vertical resistivity image profile near the subsurface (Hamzah et al. 2006).

In the analysis, the measured resistivity data, which were merely apparent, were subjected to inversion that resulted in a model of subsurface resistivity which approximated the true subsurface resistivity distribution as described by Loke and Barker (1996). The inversion was made possible using software RES2DINV as previously described by (Dahlin and Loke (1998) and Loke et al. (2003). Using the same technique, Loke (2013) later in the study of an alluvial setting, obtained high resistivity (10 - 100 Ω m) in the freshwater, in distinct contrast to the seawater with very low resistivity (<0.2 Ω m) due to high salt content. This same method was thus adopted in the study analysis involving also alluvial soils.

In using the inversion technique, each entire profile block was divided into a number of rectangular model cells based on the spread of the measured data (Loke and Barker 1996). The data inversion was executed using the smoothness-constrained least square method (deGroot-Hedlin and Constable 1990; Sasaki 1992) where the block's resistivity values (model parameters) were adjusted iteratively to obtain a true distribution of resistivity (model response). The model parameters and response were linked via a finite-difference method as described by Dey and Morrison (1979). Thus the differences between the calculated and measured data in an initial model were minimised using the root-mean-squared (RMS) method; and the iteration was continued to an RMS error limit of less than 5% (Awni 2006), which was considered acceptable. However, the model with the lowest RMS error is not always the most appropriate as it can induce unrealistic variations in the resistivity model (Loke 2010b).

10.3 RESULTS OF RESISTIVITY AND CONDUCTIVITY

Resistivity and conductivity distributions was spatially analysed by interpolation using the Kriging technique available in Surfer 8. The true (inverted 2D) vertical profiles were converted into true (inverted 3D) horizontal profiles, shown in Figures 10.2 and

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10.3 for selected depths. Although the 3D images have apparently limited resolution due the limited number of profiles examined in comparison to the survey area (100 km^2), the method has produced sufficiently better resistivity and conductivity distributions of the different water types and oil palm tolerance toward salinity respectively.

The three colour codes are used to describe resistivity distribution for water types: blue for freshwater (>10 ohm.m); green for brackish water (3-10 ohm.m); and red for saline water (<3 ohm.m). The following discussion is only confined for demonstrative purpose for the 2.5-5.0m depth [Figure 10.2a) and b)] of the unconfined aquifer. In this water zone freshwater (horizontal) coverage is about 3km^2, half that for brackish-saline water (about 7.0km^2). The dominancy of water brackishness/salinity was due to seepage from the irrigation canals (profile L6-L6'near MW6, profile L7-L7' and profile L8-L8' shown in Figure 10.1). The freshwater contamination in the shallow aquifer was believed to be caused by seawater infiltrating from the irrigation canals. In the same depths (2.5-5.0m) the saline water occurred mostly in the southwest (in the reserved mangrove) due to tide moving from the mangrove to the bunds separating it from the oil palm cultivation. In the past the bunds in the mangrove have been frequently damaged, causing the saline water to overflow into the oil palm plantation, thus contributing to the groundwater salinity in the southwest area. An important finding in the study is the indication of freshwater availability in the midwest-study area as deep as 21.8 m into the aquifer beneath the mangrove as shown in Figure 10.3i). For depths exceeding 7.8m the saline water occurrence was mainly due to seawater intrusion.

In the east close to profiles L1-L1', L2-L2' and L3-L3', no freshwater appeared at depths exceeding 7.80m [Figure 10.2c)] due to the saline-brackish water dominancy resulting from seawater intrusion that seemed more dominant than on the western side. In contrast there was freshwater in the west close to the mid-study area (profiles L2-L2' and L3-L3') in the 21.8 m depth [Figure 10.3 i)] underlying the brackish-saline water. This observation has correlation with TDS in the monitoring wells on the eastern side in the 36m depth, having concentrations twice (20,000 mg/L) as high as on the western side (10,000 mg/L). Freshwater in the 30m-40m zone was less thick compared to the 10m-20m zone, concentrating in the mid-aquifer over 10 - 30% of the mapped area. The freshwater lens in these depths seemed to be isolated from the surrounding saline water especially in the east, west and south directions, indicating saline water dominancy in every direction. Conductivity distributions for the suitability of oil palm towards salinity are represented by using different colour codes. The colour codes used are blue for suitable (> 0.4 S/m), green for moderately suitable (0.4 S/m < C < 0.2 S/m), and red for not suitable (< 0.2 S/m).

The 3-D conductivity slice images at the depths of 2.5 m and 5.0 m [Figures 10.2 d)-f) and 3 j)-l)] showed that more than 80% of the area with conductivity values of 0.2 S/m is suitable for oil palm plantation. These results contradict with water type's distribution that showed almost 50% is suitable for water supply at the same depth [Figures 10.2a)-b)]. The image also showed that some areas are moderately suitable and not suitable for plantation, especially along the main agricultural canal drainages (mid-study area) and areas near the coast with un-bund mangroves (west area). On the east side area with severe coastal erosion, the area still exhibits suitable condition for oil palm cultivation. The severe erosion in the area was mitigated by the construction of man-made bund and well-developed roads that prevented the penetration of saline water into the plantation ground surface. Contradict to the west coastal mangrove side, saline water intrusion occurs during high tide when seawater floods the area. Mangrove plants

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that grow close to this coastal area are more tolerant towards salinity due to saline water intrusion. Behind the mangrove reserved area, man-made bunds were constructed to prevent saline water intrusion into the plantation area.

As for the severely eroded area on the east side, the moderate conductivity condition (0.2–0.4 S/m) appeared at a depth of 7.8 m. This results showed a different condition in the same depths of water type resistivity distribution [Figure 10.2 c)] where all east side is coverage by brackish and saline water (not suitable for water supply). On the west side, a similar depth was still suitable for oil palm cultivation [Figure 10.2 f)]. The conductivity value for the severely eroded area which is not suitable for oil palm plantation was at 14.10 m depth [Figure 10.3 k)]. In the west side, where mangrove forests still existed, the conductivity value suitable for plantation was at 21.80m depth [Figure 10.3 l)].

10.4 DISCUSSIONS AND CONCLUSION

The 3-D resistivity and conductivity slice image revealed different groundwater suitable salinity distribution and depth for water supply and oil palm in Carey Island. The factor different results of groundwater salinity for two different socioeconomic activities are due to water levels standard toward salinity for both are different. Water level standard for water supply can be deduced as TDS < 1000 mg/l meanwhile for oil palm requirement the TDS <5300 mg/l.

Other factors that determine the tolerance of water supply and oil palm for groundwater salinity are different elevation height and land cover between the west and east area as well as groundwater salinity distribution finding. The east area has a low surface elevation and no mangroves covered the coastal area. Compared with the west area, surface characteristics in the east area naturally provide a more conducive environment for seawater intrusion into the groundwater system. The middle area between east and west has a high topography, which prevents the migration of salinity from the east to the west. The middle area also showed the dominance of brackish water as a result of the seepage of saline water from the main canal that is located in this area. As discussed by Scheineder and Kruse (2006), the variations in the hydrogeology conditions, such as terrain effects, vegetation pattern and sea level rise, are among the factors that can contribute to groundwater salinity. In this study, the terrain effect and land cover were considered significant to seawater intrusion due to high variations (1.3-2.3m) in the elevation and land cover of the study area. These might have a major influence on the wider saline-brackish water distribution in the south-east where the semi-confined aquifer was located where showed low elevation and no mangrove covered compared to the west area.

According to the Ghyben-Herzberg assumption, a 0.5 m increase in the sea level will reduce the thickness of freshwater storage by 20 m. The predicted sea level rise in the 21st century will increase seawater intrusion in the area. Based on the predicted slope from 2001 to 2010 by a sea level rise prediction study, which used the B1, A1B, and A2 scenarios from the Special Report on Emissions Scenarios, the mean sea level rise rate at Port Klang is 0.387 m. Based on the Ghyben-Herzberg assumption and local scenario sea-level rise prediction, the east area will become unsuitable for water supply and oil palm plantation much sooner than the west area, which still has a mangrove forest.

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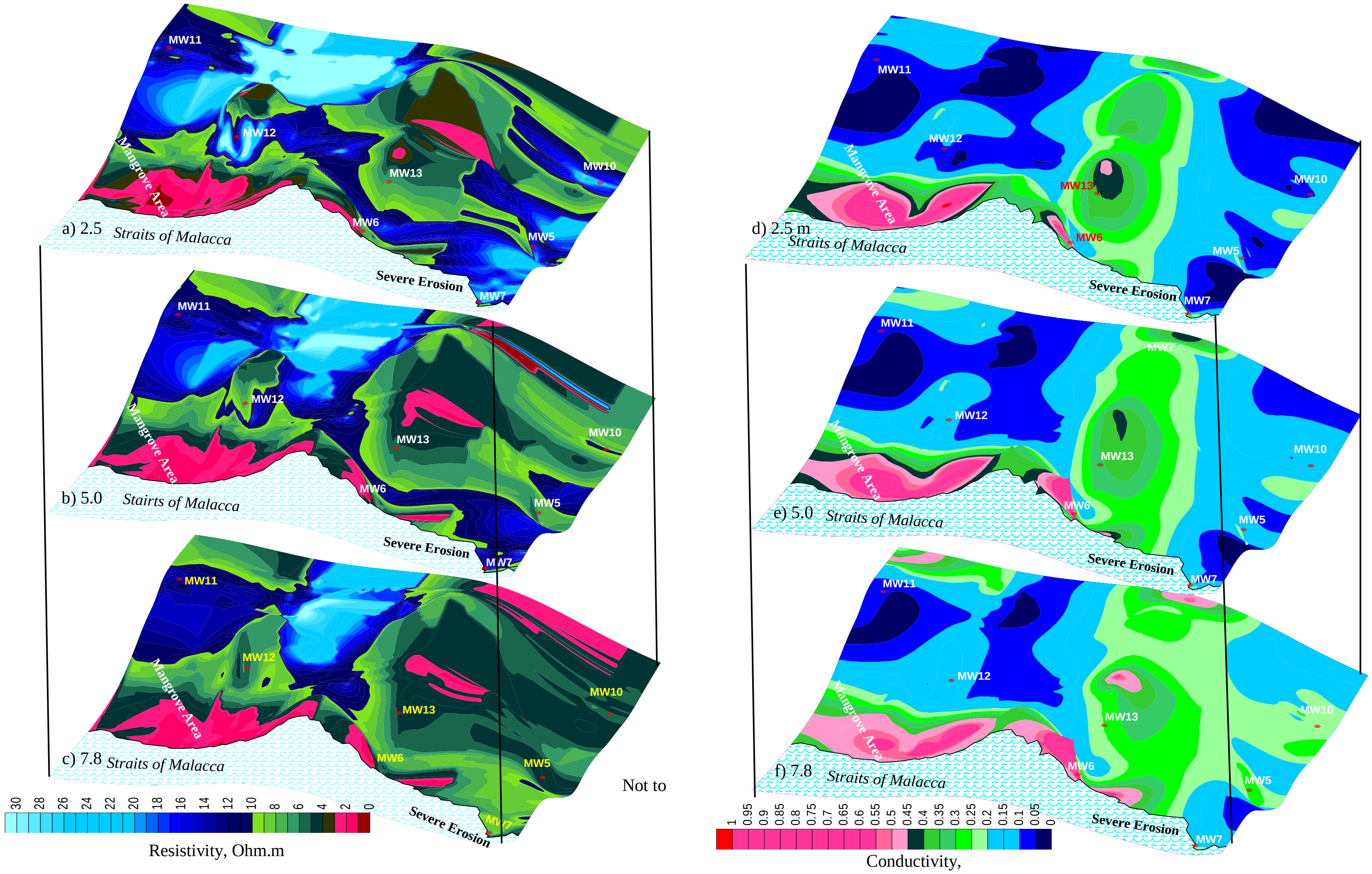

Figure 10.2: Resistivity and conductivity distribution relative to elevation from 2.5 to 7.8 m depths

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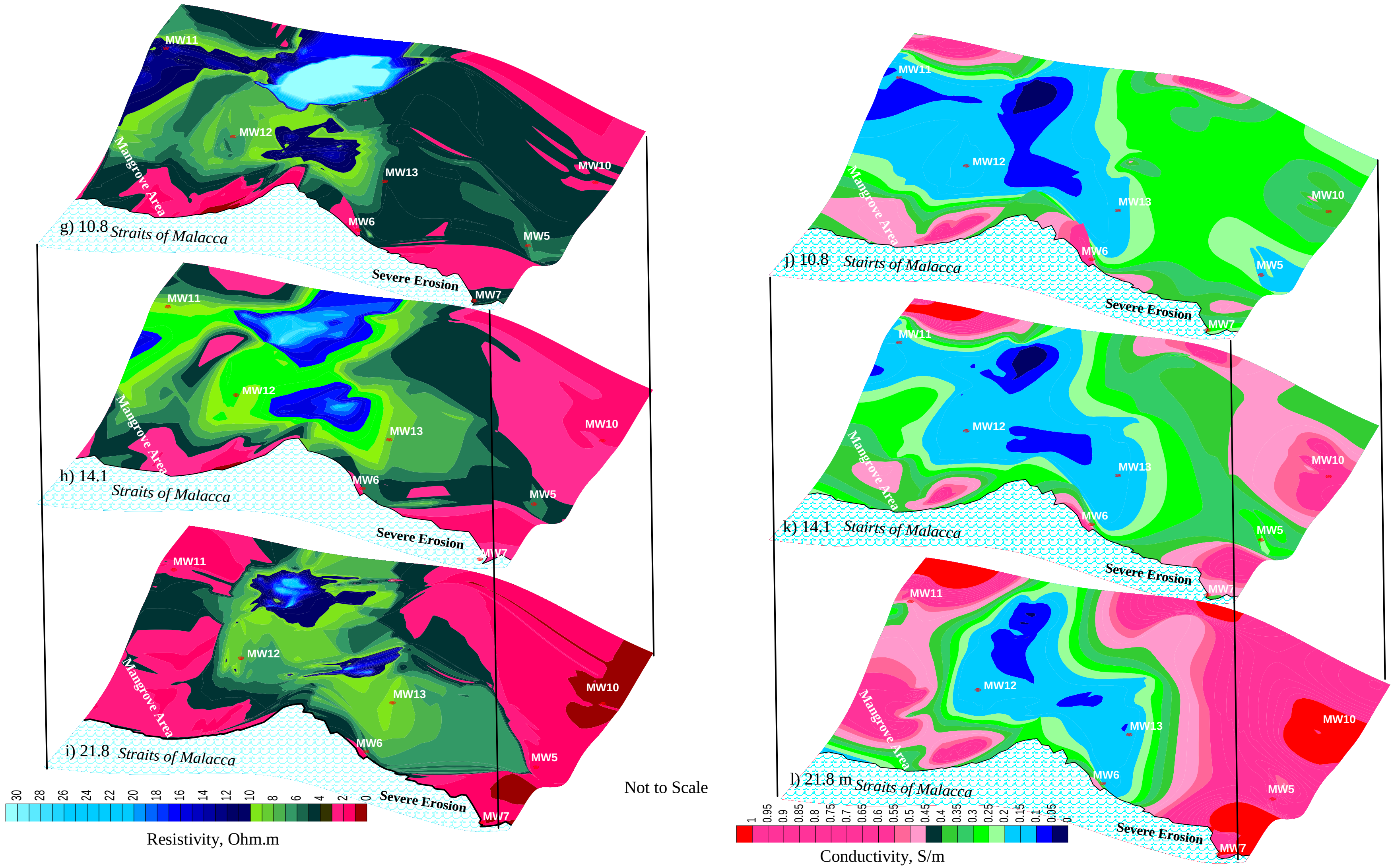

Figure 10.3: Resistivity and conductivity distribution relative to elevation from 10.8 to 21.8 m depths

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CHAPTER 11

INDOOR ENVIRONMENTAL QUALITY (IEQ) AND INDOOR AIR QUALITY (IAQ)

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11.1 INTRODUCTION

Good indoor air quality (IAQ) is required for the healthy indoor environment quality (IEQ); whereas poor IAQ can cause a variety of diseases to the building occupants. Normally, the health problems related to poor IAQ include respiratory problems, eye irritation, allergic reactions, sinusitis, and others. In addition, the ventilation and air conditioning system in enclosed work space also contribute to poor IAQ if not maintained properly. Thus, the ventilation and air conditioning (VAC) system are obviously related to IAQ problems. Additionally, the living organisms in building such as fungi, bacteria, and virus that are inhaled by occupants can cause allergies, respiratory disorders, infectious diseases, and hypersensitivity diseases. Also, organic chemical compounds that are released from the maintenance, building products in sufficient quantities, VOC can cause irritation of the nose, eyes, and throat, headache, dizziness, visual disorder, and memory impairment.

The IAQ in building can be undermined by microbial contaminants (like fungal and bacteria), chemicals (such as carbon monoxide, formaldehyde), and allergens that accounted health effects to the building's occupants [1]. In Malaysia, the Department of Human Resources had launched the Industry Code of Practice on IAQ (ICOP-IAQ) 2010 proposed to identify the significant parameters distributed to the indoor air contamination. Therefore, this chapter elaborated the details of indoor air quality as overview that included in this

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book series. The detail of indoor environment quality (IEQ) and indoor air quality (IAQ) also provided in this chapter.

11.2 INDOOR ENVIRONMENTAL QUALITY (IEQ) AND INDOOR AIR QUALITY (IAQ)

Indoor environmental quality (IEQ) is referred to the quality of environment condition in a building which provides human health and wellbeing effect. The exposure to the contaminants can cause the symptoms and poor health condition especially in non-industrial buildings (enclosed work space) to the building's occupants. There are various contaminants (gases and particles) come from offices such as machines, cleaning products, construction activities, furnishing, water-damaged building materials, microbial growth (fungal and bacterial), insects and outdoor pollutants. Moreover, factors such as indoor temperature, relative humidity, and ventilation in the building also have been identified influencing to the indoor environment condition [2].

Meanwhile, indoor air quality (IAQ) is defined as the quality of indoor air in the buildings and structures that influence to the building's occupants' health. According to ICOP-IAQ by DOSH, the meaning of IAQ refers to the quality of air contains including the air in the room and the air removed by the mechanical system. This was supported by World Health Organization [3] in which IAQ is referring to the human health as follow;

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".

The indoor air quality (IAQ) in any building can be undermined by microbial contaminants (like fungal and microscopic organisms), chemicals, (for example, carbon monoxide, formaldehyde), and allergens that can make wellbeing impacts to the building's occupants [4,5]. Other than that, indoor air quality likewise influenced to bioaerosols, characterized as airborne particles comprising of driving living beings, for example, microscopic organisms, infection, fungi, or issuing from non-living beings as toxins, by-results of microbial development, or sections of wiped out microorganisms [6].

11.3 INDOOR ENVIRONMENT QUALITY (IEQ)

The effect of poor IEQ is not only on physical health of the building occupants, but also on their physiological health [7]. Basically, IEQ can be determined by many factors such as lighting, air quality and damp conditions. Dampness, cleanliness and ventilation characteristics are associated with building related symptoms [8]. Therefore, many health

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related problem was occurred due to this poor environment. The thermal comfort, indoor air quality, noise level and illumination level are the four aspects to examine the IEQ [9]. Air quality and freshness, the presence of light, thermal comfort and quality of acoustic are the important factors of IEQ in healing environments, which affect occupant satisfaction [10,11].

Variety of contaminants whether from machines inside the buildings, dust cleaners, renovation works, water damaged building materials, carpets and furnishings,cigarette smoke, perfumes, microbial growth, insects and outdoor pollutants are the common contaminants faced by the building occupants [12]. How individuals respond to indoor environment can also predicted through the indoor temperature, relative humidity and the ventilation levels of a building. Energy consumption of buildings depends significantly on the criteria used for the indoor environment (temperature, ventilation and lighting) [11]. Building related symptoms could be resolved by understanding the sources of indoor environmental contaminants and by controlling them. There are 6 categories of IEQ which shown in Figure 11.1 and Table 11.1 tabulated the definition of Indoor Environmental Quality (IEQ) according to EN 15251.

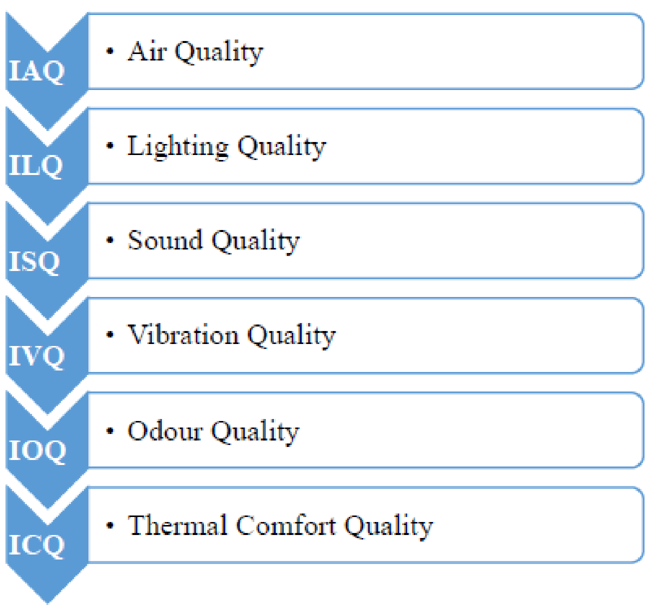

Figure 11.1: Categories of Indoor Environmental Quality [13].

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Table 11.1 Definition of Indoor Environmental Quality (IEQ) According to EN 15251.

Category	Explanation
I	High level of expectation is recommended for space occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons.
II	Normal level of expectation and should be used for new buildings and renovations.
III	An acceptable, moderate level of expectation and may be used for existing buildings.
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year.

11.4 INDOOR AIR QUALITY (IAQ)

It is defined as the air quality within and around buildings, because it is concerning the health with comfort of building occupants. The degradation of indoor air quality induced by microorganisms (molds, bacteria, fungi) is of growing concern to international health organization [14, 15]. Indoor air quality is a major determinant of personal exposure to pollutants in today's world. Much time is being spent in numerous different indoor environments by people [11]. Other researcher reported that people spend their lifetimes up to 80% in workplace or homes [16]. Problems caused by microbial, especially fungal growth do exist in some new buildings [12, 17, 18]. IAQ is a part of indoor environmental quality (IEQ) [19]. Collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces and computer modeling of air flow inside buildings are some of the way involved in determining the IAQ.

11.5 ELEMENTS OF IAQ PROBLEMS

In any home, there are many types of indoor air pollution that can occur. Some of the reasons for the pollution to happen are gas, coal and tobacco products which are common in the kitchen. Other than that, damp carpets, wood furniture's, heating and cooling systems and pesticides are also sources of pollution that affect the IAQ of a space. The unsuitable fitting materials, adhesive and furniture selection are also contributing to the sources of poor IAQ. Mainly, the importance factor is how much of pollutant is releases and the danger level that the pollutant has. Age factor of the source and its maintenance are also important in its determination. Elements which involved in development of indoor air quality problems are clearly shown in Table 11.2.

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Table 11.2 Elements of Indoor Air Quality problems (EPA, 1991)

Elements	Description
Source	There is a source of contamination or discomfort indoors, outdoors or within the mechanical systems of the building.
Heating, Ventilation, and Air Conditioning (HVAC)	The HVAC system is not able to control the existing air contaminants and ensure thermal comfort (temperature and humidity conditions that are comfortable for most occupants.
Pathways	One or more pollutants pathways connect the pollutant source to the occupants and a driving force exists to move pollutants along the pathway(s).
Occupants	Building occupants are present.

11.6 SUMMARY

Indoor air quality is very important because it is one of the main discomfort causing factors in a closed space. Removing this discomfort factor causes most people to feel better. Indoor environment also affects health, productivity and comfort of the occupants. Some pollutants cause diseases which have no symptoms immediately but will emerged later. Meanwhile some examples of the diseases are cancer and respiratory problems. All elements that contributed to the issues in indoor air quality problems are discussed that should address as necessary tool for best practice of health and safety implementation.

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