# OCCUPATIONAL HEALTH RISK ASSESSMENT AND HEALTH EFFECTS AMONG WORKERS IN BIOGAS PALM OIL PLANTS, SABAH

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# ABSTRACT

Biogas is produced by a processing residual waste from palm oil mill effluents (POME) as well as waste water treatment plants. By constructing biogas plant in a palm oil mill, this POME is treated and turned out to be the main source of water without contributing to water pollution. However, biogas plant workers will be exposed to various hazards. Hydrogen sulphide gas and bio-aerosol dust are available in biogas plant which can cause health risks to the workers. Therefore, the aim of this study is to determine occupational health risks in biogas palm oil plant and respiratory health effects to the workers. This cross-sectional study was carried out to 200 workers of palm oil mill in Sabah and their health effects were compared between exposed and unexposed of biogas environment. All the biogas plants were evaluated and measured on the level of occupational health risk assessment (OHRA) by using two stage assessment methods namely initial assessment and detail assessment. Respondents were requested to fill up a standardized questionnaire, a physical examination, oximetry measurements and spirometry tests. Then, all the data collected were analysed by using SPSS software version 22. The OHRA conducted at biogas plants showed that all hazards categories namely physical, chemical, biological, psychosocial and ergonomic were present at medium risk score. The means of FVC and FEV1 for exposed workers were 79.57% and 81.57%. The means of OHRA score by toxic gas and bio-aerosol dust were 11.89 (medium) and 5.68 (medium). Then, results of the Spearman's rho correlation showed that there is no significant correlation between respiratory health risk assessment by toxic gas and bio-aerosol dust with FVC, FEV1 and FEV1/FVC. Meanwhile by comparing the exposed group and the unexposed group, there is a significant differences between biogas plant environment exposure and lung function test (LFT) result using Pearson Chi-square ($p = 0.019$, $x^2 = 5.51$) with risk estimation in risk effect (OR = 1.96, 95% CI 1.12, 3.45). Regression analysis showed that duration of biogas plant operation was the most significant influence variable for respiratory health risk assessment scored by toxic gas and bio-aerosol dust. When the duration of biogas plant operation was longer, then the risk scores were also higher for both toxic and bio-aerosol risks. Thus, the working period of the respondents in biogas plant, is a significant influence variable for respiratory health effects. The biogas plant workers were two times at higher odds of being in abnormal lung function test compared to those workers in unexposed group. In addition, a worker who is active in sport or exercise is also a significant influence variable for respiratory health effect. Hence, the results of this assessment will be useful for manufacturers in planning and implementing optimal control measures to minimize the risks of respiratory diseases among the workers working at biogas plant environment.

Keywords: biogas plant workers, respiratory health effects, lung function test, occupational health risk assessment.

# *ABSTRAK*

## *PENILAIAN RISIKO KESIHATAN PEKERJAAN DAN KESAN KESIHATAN KEPADA PEKERJA DI LOJI BIOGAS KELAPA SAWIT, SABAH*

*Biogas terhasil daripada pemprosesan bahan sisa buangan dari air kumbahan kilang minyak sawit atau loji rawatan air sisa. Dengan pembinaan loji biogas di kilang minyak sawit ini maka air kumbahan kilang minyak sawit dapat dirawat dan dapat mengelakkan dari berlakunya pencemaran air sungai. Pelbagai jenis bahaya yang terdedah kepada pekerja yang bekerja di loji biogas. Gas hidrogen sulfida dan habuk bioaerosol yang terdapat di dalam loji biogas boleh menyebabkan kesan kesihatan kepada pekerja. Oleh itu, tujuan kajian ini adalah untuk menentukan tahap penilaian risiko kesihatan pekerjaan (OHRA) di loji biogas dan kesan kesihatan pernafasan kepada pekerja. Kajian keratan rentas ini melibatkan 200 pekerja di kilang sawit dan kesan kesihatan mereka dibandingkan di antara pekerja yang terdedah dan tidak terdedah dengan persekitaran biogas. Kesemua loji biogas telah dinilai dan diukur tahap risiko kesihatan pekerjaan melalui dua peringkat iaitu penilaian awalan dan penilaian lanjutan. Responden telah diminta untuk mengisikan borang soal selidik, pemeriksaan fizikal, pengukuran oximetri dan pengujian spirometri. Kemudian, semua data yang telah dikumpulkan dianalisis menggunakan perisian SPSS versi 22. OHRA yang dijalankan di loji biogas menunjukkan semua jenis bahaya iaitu fizikal, kimia, psikososial dan ergonomik berada pada skor kategori medium. Nilai min FVC dan FEV1 untuk pekerja yang terdedah dengan biogas adalah 79.57% dan 81.57%. Manakala nilai min bagi skor OHRA melalui gas toksik dan habuk bioaerosol adalah 11.89 (sederhana) dan 5.68 (sederhana). Kemudian dengan menggunakan korelasi Spearman telah menunjukkan bahawa tiada perbezaan yang singnifikans di antara penilaian risiko kesihatan pernafasan melalui gas toksik dan habuk bioaerosol dengan FVC, FEV1 dan FEV1/FVC. Sementara itu dengan membandingkan kedua-dua kumpulan yang terdedah dan kawalan didapati terdapat perhubungan yang signifikans di antara pendedahan persekitaran loji biogas dengan keputusan ujian fungsi peparu dengan menggunakan ujian Pearson Chi-square ($p = 0.019$, $x^2 = 5.51$) di mana anggaran risiko di dalam kesan risiko (OR = 1.96, 95% CI 1.12, 3.45). Analisis regresi pula menunjukkan tempoh operasi loji biogas adalah variabel yang paling kuat mempengaruhi skor penilaian risiko kesihatan pernafasan melalui gas toksik dan habuk bioaerosol. Bagi responden di dalam loji biogas pula, tempoh bekerja adalah variabel yang paling mempengaruhi kesan kesihatan pernafasan. Pekerja loji biogas adalah berkemungkinan yang lebih tinggi sebanyak dua kali mendapat keputusan abnormal pada ujian fungsi paru-paru berbanding dengan pekerja dalam kumpulan tidak terdedah. Di samping itu, pekerja yang aktif adalah variabel yang paling mempengaruhi kesan kesihatan pernafasan. Oleh itu, hasil penilaian ini dapat digunakan oleh pihak pengilang dalam merancang dan melaksanakan langkah-langkah kawalan yang optimum bagi mengurangkan pekerja daripada risiko mendapat penyakit pernafasan oleh pendedahan persekitaran loji biogas.*

*Kata kunci: loji biogas, kesan kesihatan pernafasan, ujian fungsi peparu, penilaian risiko kesihatan pekerjaan.*

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| | |
|---|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| DOE | Department of Environment |
| DOSH | Department of Occupational Safety and Health |
| DSM | Department of Standards Malaysia |
| *et al.* | and others |
| N | total number of sample |
| HIRARC | Hazard Identification, Risk Assessment and Risk Control |
| HRA | health risk assessment |
| IQR | interquartile range |
| MPOB | Malaysian Palm Oil Board |
| n | number of sample |
| OHRA | occupational health risk assessment |
| p | probability under the assumption of hypothesis |
| POME | palm oil mill effluent |
| PPE | personal protective equipment |
| ppm | parts per million |
| PTS | Petronas Technical Standard |
| r | correlation coefficient |
| $R^2$ | coefficient of determination |
| SD | standard deviation |
| SDS | safety data sheets |
| WHO | World Health Organization |
| $\alpha$ | significance level , the probability of making a Type I error |
| $\beta$ | probability of failing to reject the hypothesis tested when that hypothesis is false and a specific alternative hypothesis is true |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

The palm oil industry has developed hugely in the current years and represented the largest percentage of oil and fats production in the world. This is because oil palm has higher yearly oil yield per hectare contrasted with different oilseeds crops including soybean and the cost of palm oil is moderately lower as compared to other major alternative vegetable oils. With the higher worldwide request of palm oil, Malaysia has built up its palm oil industry to become one of the major palm oil exporters and producers in the world (Chin, Poh, Tey, Chan and Chin, 2013). As shown in Figure 1.1, from year 2004 until 2014, we can clearly see the oil palm plantation areas in Malaysia have grown enormously except in year 2011 which showed a little bit decreased.



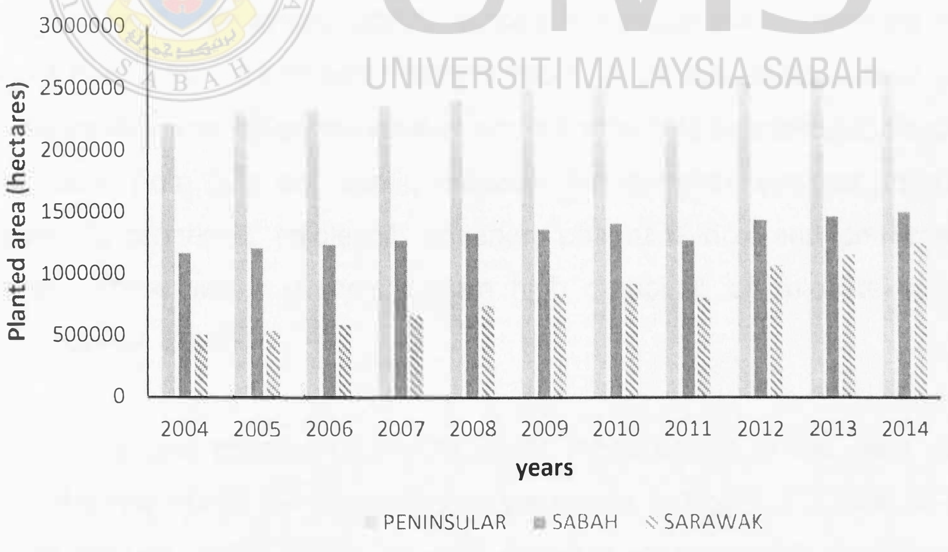


**Figure 1.1: Oil palm plantation areas in Malaysia**
Source : MPOB

Even though the fact that the development of palm oil industry has expanded the national economy, it likewise simultaneously created abundance of by products such as palm oil mill effluent (POME), empty fruit bunch (EFB), palm kernel shells (PKS) and mesocarp fibre in palm oil mills during the processing of palm oil from fresh fruit bunch (Chin *et al.*, 2013). POME is the liquid waste generated from the oil extraction process from FFB in palm oil mills.

The extraction of palm oil from the fruits involves a number of processing procedures namely sterilization, stripping, digestion, pressing, classification, purification and vacuum drying. In the extraction process, large quantities of water are required. It is calculated that around 1.5 $m^3$ of water is needed to process one tonne of fresh fruit bunch (FFB) and almost half of the water discharge ends up as POME (Zhang, Yan, Qiao, Chi, Niu, Mei, and Zhang, 2008)

The raw POME is a thick brownish, viscous and voluminous colloidal matters, containing 95% – 96% of water, 4% – 5% total solids including 2% – 4% suspended solids as well as 0.6% – 0.7% of oil and grease which discharged at a temperature of 80 °C – 90 °C (Ahmed, Yaakob, Akhtar and Sopian, 2015). POME being a waste with high organic carbon content has turned into a promising source for biogas production and to conceivably support up the sustainable power source sector. Some industrial effluents however are not amenable to anaerobic treatment, such as those from pulp and paper, molasses fermentation, seafood processing, potato-starch, tanneries, edible oil refineries, pharmaceutical and petrochemical production. These waste streams contain high groupings of sulphate and / or sulphide (Khanal, 2008).

For the best practice to handle waste management in the palm oil mill industry, the raw POME will be treated as per shown in Figure 1.2. First of POME has to go through centrifugal decanter to separate solid materials from liquids in slurry. These solid materials or palm oil mill sludge can be dried and used as a fertilizer as it contains high nutritional value (Rupani, Rajeev, Irahim and Esa, 2010). Meanwhile, the rest of POME liquids will go through a few treatment processes before they are discharged into watercourses to avoid a considerable cause of environmental problems. In anaerobic digestion, anaerobic bacteria degrades organic material to biogas in four stages i.e. hydrolysis, acidification, production of acetic acid and production of methane. A biogas plant can be portrayed as a building containing frameworks developed to produce biogas from plant biomass, animal excrements, disposal wastes, or even wastewater sediment. When all is said in done, a typical biogas plant consists of a biomass system, a heating system and a gas system (Barnert, Piesik and Śliwiński, 2014).

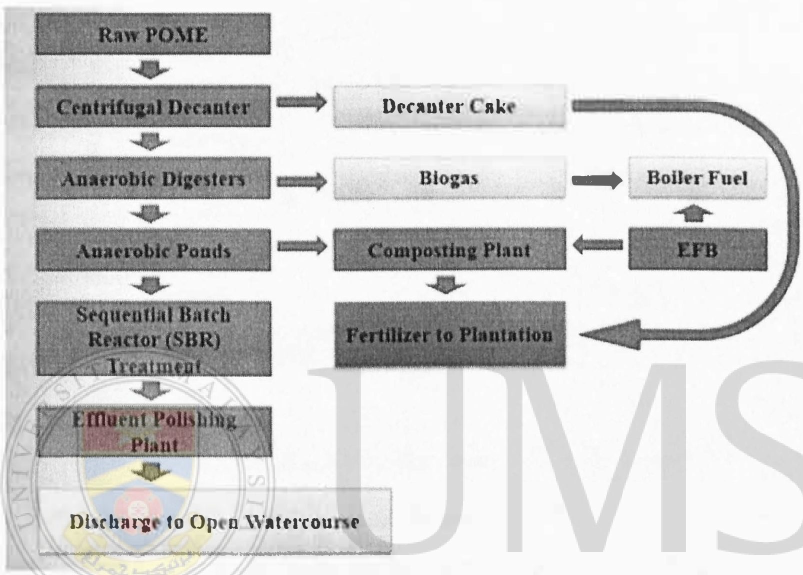


**Figure 1.2: Schematic process of waste management in a palm oil mill**

Biogas is a substance of obscure and variable composition and its composition changes from the composition of the organic mixture that is fed into the fermenters. It has combustible properties because of the presence of flammable gases, primarily methane. Furthermore, biogas has toxic properties, for instance when it contains a high level of hydrogen sulphide (Heezen, Gunnarsdóttir, Gooijer and Mahesh, 2013). In addition, biogas is a hydrocarbon gas produced from the breakdown of organic matters without oxygen. Depending on the source, biogas typically comprises the following compounds with varied percentages (Table 1.1).

The production of biogas is generally by one of two methods. The first method is called anaerobic digestion or in more specific it is produced by a biogas plant which is purposely designed, above ground tanks or in ponds to optimize the gas producing decay process from animal and other organic waste. On the other hand, there is a landfill which is biogas produced by allowing natural decay to occur within a landfill site where gas is produced and then captured.

**Table 1.1: Biogas Contents**

| Compound | % by volume |
|---|---|
| Methane | 55 - 70 |
| Carbon Dioxide | 30 - 45 |
| Hydrogen Sulphide | 0 – 0.5 |
| Ammonia | 0 – 0.05 |
| Water vapour | 1 – 5 |
| Nitrogen | 0 - 5 |
| Dust | > 5 µm |

Source: Dieter and Angelika (2008)



Biogas has different utilizations, however, as it is derived from biomass, it is a renewable energy source. There are numerous different advantages to be derived from the process of converting substrates in a biogas plant. The economic pressure on conventional agricultural products always continues to rise. Numerous agriculturists are required to give up their occupation, since their land is no longer brings adequate yield (Deublein and Steinhauser, 2008).

Genereally, biogas has been utilized as fuel for boilers to provide the heat needed to maintain the process temperatures in the anaerobic digesters. The most widely alternative use of biogas is as combustion in an engine generator and waste heat is recovered from the engine generator to heat the digesters. Before the biogas can be converted into electricity in engines at the place at which it is produced, the raw biogas must be cleaned in the first process in which the water vapour saturated biogas is desulfurized and dried by cooling. In developing countries, alternative possible avenue for digester gas is used as fuel for cooking and lighting (Harikishan, 2008).

In any case, the production of biogas is subsidized in many countries, giving the farmers an additional income. For the farmers, biogas production does not mean significant reorientation, since microorganisms for methanation require comparative care to that required for livestock in the stable. Since alongside the present tendency for farms to become large scale enterprises and with the widespread abandonment of agricultural areas, the cultural landscape is changing (Deublein and Steinhauser, 2008).

MPOB (2011) mentioned that Malaysia is to concentrate on 12 National Key Areas (NKEAs) to build the economy and accomplish a high-income status by 2020. These 12 NKEAs are the cores of the Economic Transformation Programme (ETP) and will get organized government underpins including funding, top talent and Prime Ministerial attention. Likewise, strategy changes, for example, the removal of barriers to competition and market liberalisation will be carried out if required. There will be committed consideration from the Prime Minister and fast-track mechanisms to determine question or bottlenecks in executing the NKEAs.

The impacts of harmful substances differ broadly, as the substances themselves. Be that as it may, all the different impacts and introduction times can be categorized as being either acute or chronic. Acute effects and exposures involve a sudden dose of a highly-concentrated substance. They are normally the aftereffect of a mischance that outcomes in quick medical issues extending from disturbance to death. Acute effects and exposures are not the results of an accumulation over time. Chronic effects and exposures involve limited continual exposure over time. Subsequently, the associated health issues grow gradually. When a toxic substance enters the body, it eventually affects one or more organs. One of the liver functions is to collect such substance, converts them into non-toxic, and sends them to the kidneys for elimination in the urine. However, when the dose is more than what the liver can handle, the toxics move on to other organs, producing a variety of different effects. Table 1.2 below lists some of the more widely system toxic substances and the organs that they endanger most.

Risk assessment is based on the principle that there is a level of risk in every activity performed and it is possible to make a quantitative assessment of this level of risk; risk being the product of severity of an accident either measured in Ringgit or lives lost and the frequency or likelihood of that accident happening. While risks may be reduced by good design, it is obvious that they cannot be eliminated. Therefore, an evaluation is made to determine whether the risk levels are acceptable in each location. Risks are generally categorized into two types, namely:

a) Risks that we voluntarily assume such as mountain climbing, surfing, parachuting, and smoking; and

b) Risks that are involuntarily assumed such as fire, being struck by lightning, major industrial accidents which affect persons outside of the Petrochemicals Plant boundaries; etc.

**Table 1.2: Selected toxic substances and the organs that they endanger most**

| Organs | Toxic Substance |
|---|---|
| Blood | Benzene, CO, Arsenic, Aniline, Toluene |
| Kidneys | Mercury, Chloroform |
| Heart | Aniline |
| Brain | Lead, Hg, Benzene, Mg, Acetaldehyde |
| Eyes | Cresol, Acrolein, Benzyl chloride, Butyl alcohol |
| Skin | Nickel, Phenol, Trichloroethylene |
| Lungs | Asbestos, Chromium, $H_2S$, Mica, $N_2O$ |
| Liver | Chloroform, Carbon tetrachloride, Toluene |

Source: Occupational Safety and Health book (Goetsch, 2005)

Learning from past accidents and raising the risk awareness in this emerging energy sector is crucial for a safe and sustainable exploitation of such a renewable resource. In this point of view, the present study focused on the collection and analysis of accidents in the biogas sector. The accident trends should have been analysed keeping in mind the safety of the biogas sector and to obtain some signals on the present risk figures (Casson Moreno, Papasidero, Emrys Scarponi, Guglielmi and Cozzani, 2015).

In general, the public willingly accepts a much higher level of voluntary risk as compared to involuntary risks. With voluntary risks, there is the perception of some benefits to the risk taker and the freedom of choice. With involuntary risks, there may be no perceived benefits and no freedom of choice to accept or not to accept the risk. The Department of Environment (DOE) in Malaysia has created risk acceptability criteria for involuntary risks that arise from chemical and petrochemical plants in Malaysia. The criteria stated that the risk of fatality from an industrial facility must not exceed 1 x $10^{-6}$ fatalities per person per year at nearby residential areas and 1 x $10^{-5}$ fatalities per person per year at nearby industrial areas.

## 1.2 The Research Problem

Malaysia's palm oil industry is one of the largest contributors to the national economy. In 2009, it accounted for RM53 billion in Gross National Income (GNI). This GNI is targeted to increase by RM125 billion to reach RM178 billion by the year 2020. As a major contributor to economic growth, the Palm Oil NKEA programme plans to execute eight core Entry Point Projects (EPPs) crossing the palm oil value chain. EPP5 has required to build biogas facilities at mills across Malaysia (MPOB, 2011). Therefore, an assessment must be done to investigate the risks and hazards for those working in the mills or in the biogas plants in Malaysia.



Due to higher demand on palm oil products, the oil palm plantation has extended immeasurably in Malaysia (particularly in Sabah and Sarawak) for as far back as 10 years from 3.88 million hectares in 2004 to 5.39 million hectares in 2014. It is evaluated that 57 million tonnes of POME were generated in 2011 (Chin *et al.*, 2013).

The statistic from MPBO sources shown that Sabah has the highest number of biogas plants in Malaysia (Loh, Nasrin, Mohamad Azri, Nurul Adela, Muzzammil, Daryl Jay and Kaltschmitt, 2017). Then from DOSH database shows that 21 palm oil mills in Sabah already have their own biogas plants. Based on survey and discussion on the development of palm oil in Sabah, it is stated that some other palm oil mills are planning to build and about 5 mills are in the midst of constructing their biogas plants. Therefore, Sabah is the state which places this assessment as the must do priority and as a result, it can be taken as our benchmark of occupational health issue to compare with other biogas plants in other states in Malaysia.

As referring to Table 1.3, it is stated that approximately 10 biogas plants in Sabah have already operated at least 5 years. Most employers in industrial sector including workers of the palm oil mills have never conduct health surveillance especially if chemical hazards are not in the schedule II, regulation 27 of Occupational Safety and Health (use and standards of exposure of chemicals hazardous to health) regulations 2000 (USECHH, 2000). Consequently, this research may perhaps give some benefits regarding occupational health issues to public especially to those palm oil manufacturers. Hence, they could have some awareness to prevent and protect their workers during operation in the biogas plant.



In the year 2005, there was an accident happened in Germany with four workers died due to a release of an extremely high concentrated $H_2S$ (Casson Moreno *et al.*, 2015). The estimated amount of $H_2S$ was about 10,000 ppm. Early in January 2010, there was a case in a biogas plant which caused death in Terengganu. Meanwhile in 2014, there was an incident in a biogas plant in Sabah but it only involved property damage. The most possible cause was of course from improper management of methane gas in safety manner.

Bioprocesses, for example, the production of biogas are frequently wrongly seen as safer and having a lower affect than conventional chemical processes. Be that as it may, the results of the accidents are actually early warnings concerning the major accident hazards in biogas industry. At that point it climbed the concern about the need of enhancing the safety culture and risk awareness in this area, also