Development of Alternative Fuel Briquettes from Poultry Processing Waste (Collecting, Storage and Handling)

by

Khairul Jafni B Abd Hamid

A Project Dissertation Submitted in Partial Fulfillment of
The Requirements for the
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(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Ir. Dr. Mohd Shiraz Aris)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

DECEMBER 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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KHAIRUL JAFNI B ABD HAMID

ABSTRACT

The use of poultry processing plant waste as biomass energy resource could reduce dependence on the conventional fuels like coal, oil and gas. However, if it is not managed properly, it could give adverse impact to society and environment as it contains pathogenic organism, an infectious agent that can cause disease. So, the major concern is to handle the poultry processing waste appropriately without the expense of safety and health.

This project is carried out to investigate and characterize the mechanical properties of biomass solid fuel briquette derived from sludge produced by Dinding Poultry Processing Plant (DPPP). The finding of this study will be made as reference to study the suitable procedure/system for collecting, storage and handling.

The sludge is converted into a compressed form through a simple briquetting process, by drying the sludge and pressing them into briquette form. The sludge is pressed under modest pressure of 5 – 7 MPa because at this range, the briquette could be pressed manually by using a hand press. Several important mechanical properties of the solid biomass briquette are identified namely, stability, durability, immerse test and crack analysis. Series of experiments are carried out and the results are compared with other source of biomass energy from agricultural and industrial waste. It turns out that DPPP briquette has shown relatively good result in durability (99.87%) and crack analysis with no cracks found during the experiments.

This project continues by incorporating hole to the briquette design. The experiments are repeated and the result has shown DPPP briquette without hole has relatively good result in each experiment.

From the results of the experiments and tests, it is found poultry processing waste is effective as a source of biomass renewable energy.

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CHAPTER 1
INTRODUCTION

Biomass a renewable energy source, biological material derived from living, or living organisms, such as wood, waste, and alcohol fuels. Available biomass conversion convert biomass waste into viable form of energy through the combustion of solid biomass fuel made from oil palm, rubber and brick waste. There are five (5) major agricultural sectors which have the potential of contributing towards the development of biomass energy in Malaysia; forestry (wood products), rubber cultivation, cocoa cultivation, sugar cane cultivation and oil palm cultivation. This report complements the development of fuel briquettes made from poultry processing waste where the focus is on addressing the collection, storage and handling issues.

1.1 Problem Statement

1.1.1 Collecting, Storage and Handling Issue

The use of poultry processing plant waste as biomass resource could give an adverse impact to the society and environment if it is not managed properly. This material is perishable and in some cases, containing pathogenic organism, an infectious agent, or more commonly germ, is a biological agent that cause disease [1]. Thus, one must put a great emphasize on managing the material from collecting, storage and handling so that it can be effective as a source of biomass renewable energy without harming the society and environment.

1.1.2 Disposal of Farming Waste as Potential Biomass Resources

Biomass is an alternative source of energy which has the potential of substituting conventional fuel. The poultry processing plant waste can be good biomass energy sources as it is produced in large amount; typical poultry processing plant can produce up to 1246 ton/day [2]. However, the current practice of the poultry processing industry is to dispose as solid waste. Based on the Environmental Qualification Act (EQA) 1974, as stipulated in the Environmental Quality (Scheduled Wastes) Regulations 2005 - P.U.(A) 294/2005, poultry processing plant waste can only be disposed at prescribed premises only. This has effect on the cost and operational implication on poultry processing industry. A well managed waste disposal facility can be beneficial to this industry.

1.1.3 Highly Dependence on Conventional Fuel

The world highly depends upon conventional fuels like coal, oil and gas. The majority of industries worldwide will continue to use gasoline and diesel for the foreseeable future since it can be obtained easily and has high conversion efficiency. The atmospheric concentration of carbon dioxide is increasing because the vital difference between biomass and conventional fuel is that biomass is carbon neutral. Combustion of conventional fuels generates sulphuric, carbonic, and nitric acids, which fall to Earth as acid rain, impacting natural areas, forests, freshwaters and soils, killing insect and aquatic life-forms as well as causing damage to buildings and having impacts on human health [3].

1.2 Objective / Workscope of the Project

This project is primarily to investigate and characterize the mechanical properties of biomass solid fuel briquette derived from the sludge produced by Dinding Poultry Processing Plant (DPPP). The finding of this project will be made as reference to study the suitable procedure/system for collecting, storage and handling.

1.3 Relevance of the Project

This project is an essential aspect of the development of solid fuel briquette from poultry processing plant waste. This can give a new perspective of biomass energy in Malaysia to employ poultry processing plant waste which has been growing remarkably align with the growth of poultry industry. In 1980, poultry production was about 115 million tonnes with per capita consumption of 10.22 kg [4]. However, in 2004, the poultry production had increased to 765 million tonnes or 568% with per capita consumption of 35 kg [4]. It is said that Malaysia has one of the highest per capita consumption rates in the world [4].

The finding from this project can determine the feasibility of poultry processing plant waste as biomass resource in the aspect of collecting, storage and handling.

1.4 Case Study

In this project, the Dinding Poultry Processing Plant (DPPP) is chosen as the case study. DPPP is the commercial poultry processing plant where it has the plant for chicken processing thus producing large amount of waste (sludge). This sludge has high potential to be used as biomass resource. DPPP has been producing about 5000 litre/day [4] sludge and this large amount of sludge will not be necessary for any other processes and simply disposed. Operated since 1990, it has been producing 45000 – 48000 processed chicken per day [5].

1.5 Dinding Poultry Wastewater Treatment Plant

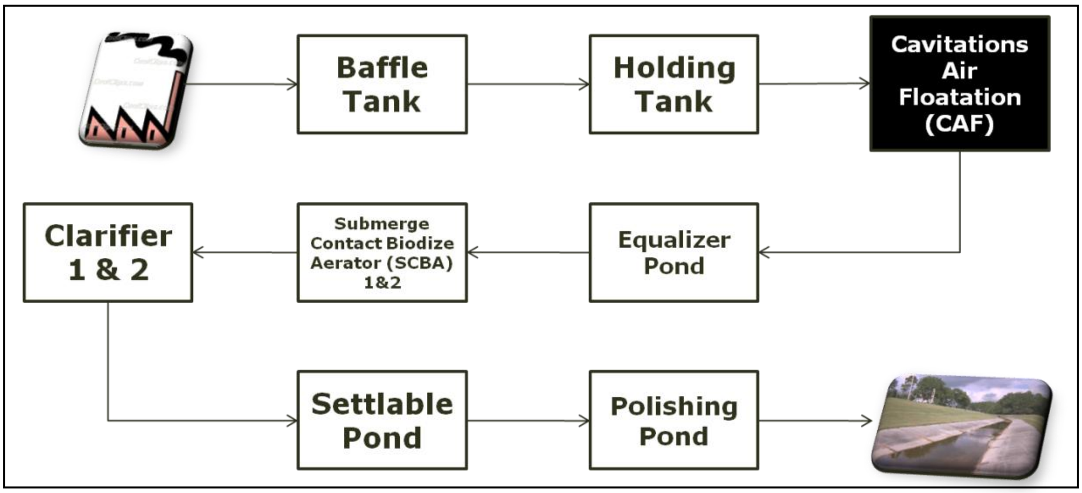

Figure 1.1: Process Flow of Wastewater Treatment Plant at DPPP [5].

From the overall DPPP, the main concern is the waste water treatment plant where the sample of sludge is obtained. In DPPP, the by-product of processing plant is treated before the waste water is discharged out of the plant. At the Baffle Tank, rotostrainer is used to segregate water and feather. The feather and remaining of the processed chicken will be collected in baskets and then moved out for disposal.

The water flows to a holding tank where it stores water for the next treatment at the Cavitations Air Floatation (CAF) equipment. At this stage, the sludge consists of chicken manure and residues which have been removed from the waste water are collected in a pool.

At this point, huge amount of sludge can be obtained for densification biomass to take place.

1.6 Biomass Densification – Impact on Handling and Storage

Biomass densification represents a set of procedure for the conversion of biomass into a solid fuel. Biomass densification is also known as briquetting, makes its mark to improve the handling characteristics of the materials for transportation and storage [6]. Biomass densification takes place after drying the sludge. Biomass densification requires compaction. The dried sludge will be compacted in a die mould with a suitable dimension and pressed under specific pressure to form the solid biomass briquette. Biomass material is pressed at modest pressure of 5 – 7 MPa because at this range of pressure, the briquette could be pressed manually by using a hand press [7].

Thus, the briquette now can be handled and stored easily. This procedure can help in expanding the use of biomass in energy production, since it reduces the cost of transportation, ease in storage and handling [6].
On the basis of compaction, the briquetting procedure can be divided into:

- High pressure compaction
- Medium pressure compaction with a heating device
- Low pressure compaction with a binder.

For all these compaction techniques, solid particles are the starting materials. The individual particles are still identifiable to some extent in the final product of solid biomass briquette. If fine materials which deform under high pressure are pressed, no binders are required since the strength of such compacts is caused by Van Der Waals' forces, valence forces, or interlocking [6]. Natural components of the material may be activated by the existing high pressure forces to become binders [6]. However, some of the materials require binders even under high pressure conditions [6].

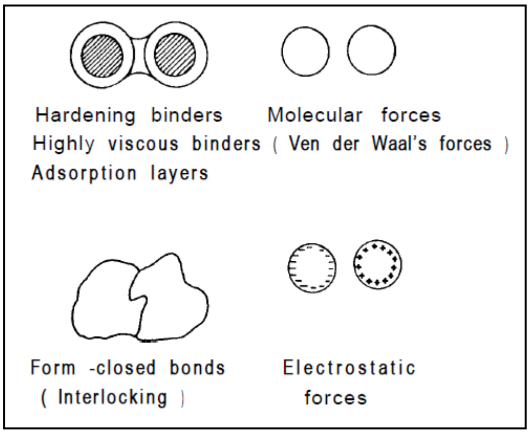

Figure1. 2: Binding Mechanism [6].

Under high pressure of 100 – 150 MPA or higher, the natural binding agent such as starch, protein, lignin, and pectin in the biomass materials are squeezed out of the particles bring about mechanical interlocking bonding [8] and increased adhesion between the particles, forming intermolecular bonds in the contact area [6]. In the case of biomass the binding mechanisms under high pressure can be divided into adhesion and cohesion forces, attractive forces between solid particles, and interlocking bonds.

CHAPTER 2
LITERATURE REVIEW

The main concern of this project is on the mechanical properties of the solid biomass briquette. It can determine the feasibility of the application of sludge as a source of biomass energy.

2.1 Experiments/Tests

Several important properties are considered in this paper solely related to the mechanical properties of the solid biomass briquette. The important properties for the fuel briquette are its durability, stability, toughness and its design. There are numerous experiments/test that have been identified applicable for this project.

2.1.1 Moisture Content

Generally, the strength and durability of briquette depends upon the moisture. Moisture generally refers to the presence of water, often in trace amounts. Water acts as both a binding agent and a lubricant. Water helps to develop van der Waals' by increasing area of contact between particles [8]. In fact, the surface effects of water are so pronounced that the success or failure of the compaction process solely depends upon the moisture content of the material [6]. Presence moisture between particles, especially in a wet agglomeration process, causes cohesive forces between particles [8].

2.1.2 Stability Test

This test is conducted primarily to determine how well a briquette could sustain its dimensions during storage. The expansion in diameter is measured weekly by using vernier calliper, at different positions of each briquette and the average is calculated. Generally, the sawdust, palm fibre and waste paper briquettes are relatively more stable. This happen could be because of the long fibre lengths of these fibrous materials, which in turn managed to maintain the structure dimension better [9]. Plus, the effectiveness of the inter-particle bonds created during densification process can be translated in strength and durability [8].

2.1.3 Water Resistant

The water resistance of the briquette was quantified by taking the time that a briquette required to fully disintegrate in water. The sawdust briquette could hardly disintegrate in water – the water merely wetted the briquette from the side and thus, the time recorded was the time the sawdust was fully wetted by water [9]. This property is important for considering the storage method or location of the briquettes.

2.1.4 Durability Test

Durability is defined as the ability to endure or sustain its dimension. For biomass solid fuel briquette, it reflects the ability for the briquette to sustain its dimension over period of time. It affords a means of indicating the ability of coal to withstand breakage when subjected to handling and during transportation. In this experiment, the percentage of the material still intact after few drops was noted. Four types of briquette – sawdust, waste paper, oil palm fibre and oil palm fronds briquettes had durability value more than 97% while oil palm shell briquette was the least durable briquette, with durability of only 85.28% [9].

2.1.5 Crack Analysis

The objective of this test is to study the impact resistance of the fuel briquette. In this experiment, a briquette is dropped from 1 m high and any crack in the radial direction was noted and measured. Waste paper briquette was the only briquette that showed very minor cracks, whereas sawdust, palm fibre, palm fronds and sugarcane waste briquette showed some longer cracks [9]. Different thing goes to rice husk by showing severe cracks and palm shell briquette had totally shattered into pieces [9].

Briquette Design

There two (2) designs of briquette which are considered in this project.

- Cylindrical shape
  Similar to Y.S Chin [9], 40mm in diameter. 10gram sample is used per sample yielding 7 - 8mm in height.
  This design is chosen based on the results obtained in Y.S Chin [9].

- Cylindrical shape with hole
  Resemble the first design but incorporating a hole of 8.5mm diameter at the centre.
  The reason of introducing a hole in the briquette is primarily to improve the combustion characteristic due to the greater surface exposed to the flame [10]. The results obtained in the second design are compared with the first design to investigate the effect of the hole in the briquette
  Since no suggestions or recommendations can be found, a 8.5mm diameter hole was chosen for this initial study.

2.2 The Application of Biomass Solid Fuel Briquette

There a few available power plant schemes which currently adopt the use of biomass fuels. They range from direct incineration to the use of indirect technique such as in the Indirectly Fired Gas Turbine (IFGT). The IFGT which utilizes biomass in its combustion chamber appears to be potential for the use of biomass fuels

2.2.1 Incineration

The other application for biomass solid fuel briquette is by means of incineration. Incineration is a waste treatment process involves the combustion of organic substances contained in waste materials. Incineration and other high temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas, and heat. The heat generated by incineration can be used to generate electric power.

The plant consisted of a number of features from, fluidized bed incinerator, heat recovery unit, electrostatic precipitator, wet scrubber and a stack or chimney. The reasons for using a fluidized bed incinerator are ones of economic achievement of a high degree of combustion efficiency and the avoidance of odour nuisances [12]. The use of an electrostatic precipitator is to clean the gases from the particulates and ash that they contain after incineration. The type of unit that is required for this particular instance is a high voltage, single stage, plate wire type. It does so because the particles themselves become highly charged after incineration.

2.2.2 Indirectly Fired Gas Turbine (IFGT)

The simple-cycle IFGT, is a modified gas turbine. The cycle is based on a gas turbine engine with compressor and expander, but with the combustion chamber replaced by a heat exchanger, transferring heat from the combustion products to the compressed air from the compressor. The combustion takes place externally to the gas turbine and uses the turbine exhaust as combustion air.

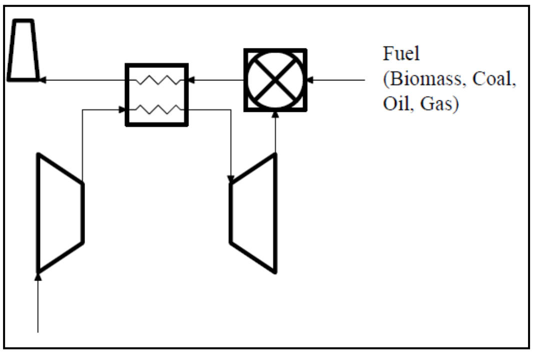

Figure 2.1: Simple-cycle IFGT [11].

The fuel is not limited to gaseous fuel, but can be solid and liquid as well. Thus, gives an opportunity for the utilization of biomass solid fuel briquette from poultry waste for the fuel. The main advantage of having IFGT is low optimal pressure ratio and maximum efficiency equal to the Carnot efficiency for an ideal process (in the limit when the pressure ratio approaches unity) [11].

2.2.3 The "Wet IFGT" – IFGT Combined with Fuel Drying

For DPPP case**,** sludge needs to be dried. For that purpose, it requires another modification on the existing IFGT. External heating mechanism might need to be installed for drying purpose only. However, utilization of the flue gas enthalpy for drying by using the "Wet IFGT" could be the solution to this matter [11]. On the other hand, it also improves the cycle efficiency.

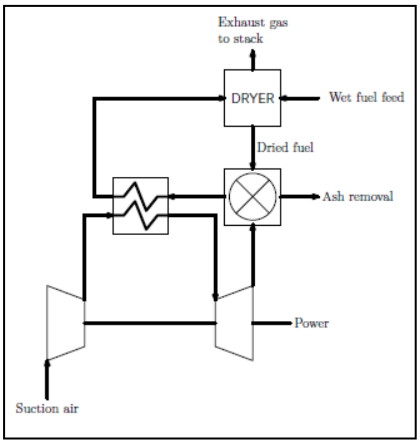

Figure 2.2: "Wet IFGT" [11].

The wet fuel enters the dryer, where it is dried by the flue gas leaving the heat exchanger. The water in the fuel evaporates and is carried with the turbine exhaust to the stack. The dried fuel is led to the combustion chamber.

CHAPTER 3
METHODOLOGY/PROJECT WORK

A series of experiments need to be carried out in order to determine the efficiency and capability of the DPPP sludge as the source of biomass energy. In the present work, a series of experiments were carried out to analyze the properties of DPPP sludge as compared to other existing type of biomass such as, rice husk, sawdust, waste paper, oil palm and oil palm shell. Most of the test procedures, calculations and the way the results are presented are based on Y.S Chin [9].

3.1 Drying

Drying process is carried out to eliminate the water content from the DPPP sludge. Briquetting the DPPP sludge require a dewatering process since energy recovery cannot be achieved from the raw sludge. Drying takes place under standard condition between 105 – 100 ˚C. In this work, an oven is used to ensure constant heat being supplied to dry the sludge.

3.2 Mould Fabrication

In order to obtain the sludge in the form of briquette, a mould of the desired diameter for the fuel briquette need to be manufactured. A mild steel rod is used to fabricate a mould of Ø40mm with variable height. The reason being is 10g of DPPP sludge is used for a single briquette and the height is not fixed, about 7 - 8mm. Precise measurement need to be maintained at every stage of the fabrication process especially at the finishing stage so that a very fine surface finish can be obtained. A very fine surface finish with small tolerance must be closely monitored between the plunger and it's mating parts to make sure the mould is fit for its intended purpose.

3.3 Briquetting Presses

The sludge is compressed manually up to 30bar. 10g of sample is used for a single press and can produce a briquette up to 7-8mm in height. DPPP sludge cannot sustain more than 30bar of pressing pressure due to the presence of moisture which makes the sludge slip through the mould.

3.4 Stability Test

In the stability test, the capability of the briquette to sustain its dimension over time is investigated. In this test, the diameter of the briquette is measured for three consecutive weeks [9]. The briquette is left in the lab at room temperature. All the briquettes are placed in the fume cupboard for the entire time to evacuate the bad smell through the systematic ventilation system. Five (5) samples of briquettes are used in this experiment and the change in diameter is recorded.

3.5 Immerse Test

In the immerse test, the water resistant capability of the briquette is investigated. The test is conducted by recording the time taken for the briquette to totally disintegrate in distilled water [9]. Since the briquette from the DPPP sludge could hardly disintegrate, different approaches need to be employed. Recording time in seconds for the briquette to totally disintegrate seems impractical for this sample. So, observation is recorded and pictures are taken after the specified interval time of 6-9 hours.

3.6 Durability Test

In the durability test, the capability for the briquette to sustain its dimension after four (4) drops is investigated. The percentage of material still intact after four drops is noted. . Five (5) samples of briquettes are used in this experiment and the test method and procedure is based on the ASTM D440 – 86 Standard Test Method of

Drop Shatter Test for Coal. From this test, it affords a means of indicating the ability of coal to withstand breakage when subjected to handling and transportation.

3.7 Crack Analysis

In this experiment, the briquette is dropped from a height of 1 m and any cracks in the radial direction were noted and measured [9].

CHAPTER 4
RESULT AND DISCUSSION

All were results were gathered and analyzed separately. These experiments have been done to both samples of DPPP Briquette without a hole (will be stated as "Sample A") and DPPP Briquette with a hole (will be stated as "Sample B") separately. All results for Sample A are compared with Y.S Chin [9] since they are equal in both size and design.

Figure 4.1: Sample A.

Figure 4.2: Sample B.

The results for Sample B are made available to study the effect of introducing a hole in the briquette. So, results from this sample are compared with the Sample A.

4.1 Moisture content

DPPP sludge has high moisture, about 60%. The strength and durability of the briquettes is affected by moisture content. In this experiment, the DPPP sludge is dried in the oven under standard temperature between 105 – 110 ˚C. After the drying process, dried DPPP sludge is kept in a closed container. From the experiment, it took about 2-3hours to dry just 10g of sample and this is not practical because the time taken for drying is too long. Increasing the temperature may sound the possible solution to this problem. However, thing turns out differently as increasing the temperature will only cause the sample to get burnt. The possible solution for this problem is to pre-dry before placing it in the oven.

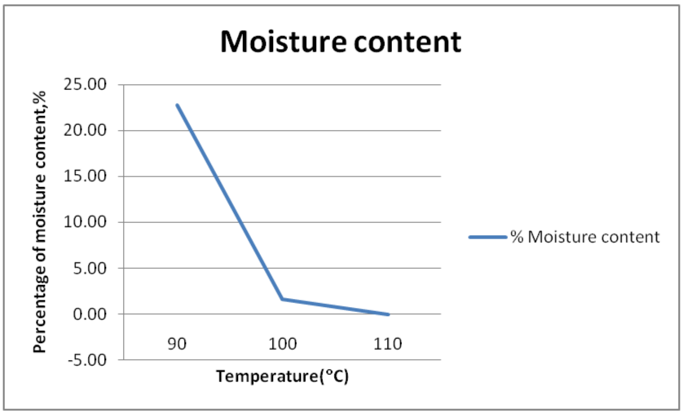

Figure 4.3: Moisture Content versus Temperature

4.2 Stability Test

From the stability test, it was found out that Sample A is relatively stable in retaining its dimensions compared to other agricultural waste such as rice husk, saw dust, waste paper, oil palm fiber and oil palm shell. The calculated variance for Sample A was 0.9983 which implies little dispersion in the data. Plus, from the graph, trend is linear where the expansion in diameter is proportional with time. (*see Appendix 3 at page 29*)

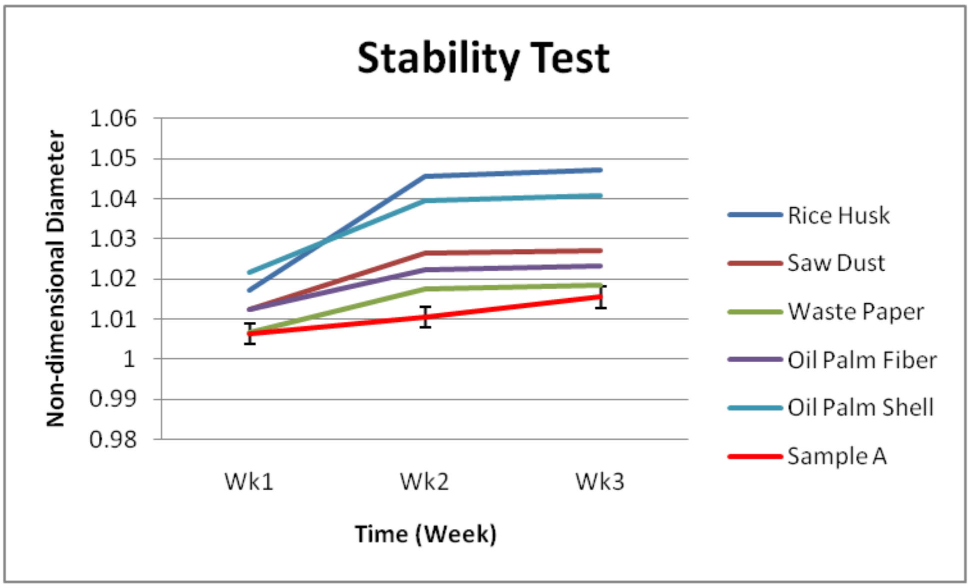

Figure 4.4: Non-dimensional Diameter versus Week.

The reason for being relatively more stable could be because of the presence of moisture as the natural binding agent and the fibrous structure, which help the Sample A to maintain the dimension better. Both moisture content and fibrous structure provide significant contribution for the Sample A to retain its dimension.

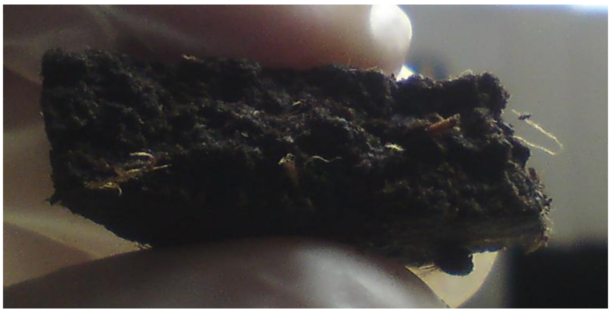

Figure 4.5: Cross section of DPPP briquette.

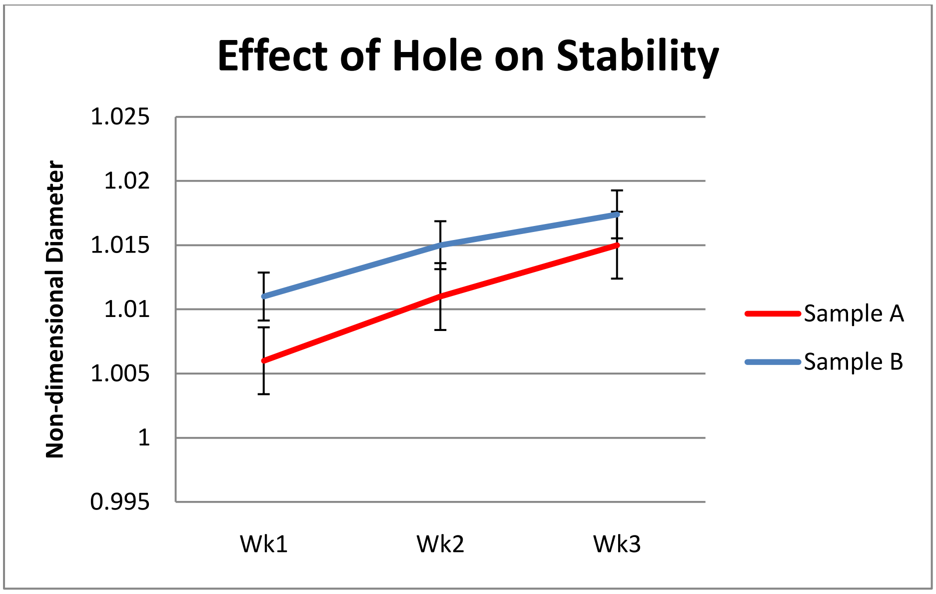

Figure 4.6: Effect of Hole on Stability

Sample B

From the graph, it indicates by incorporating the hole, it shows slight decrease in the capability of the briquette to sustain its dimension. The rate of expansion in diameter is greater for the Sample B (13.565mm/week) while Sample A (13.539mm/week). This could be happening due to the greater surface area exposed, thus greater possibility of humidity from environment to come in, loosen the bonding between particles, make the briquette easier to expand.

4.3 Immerse Test

For the immerse test, the water resistant of the briquette is evaluated by recording the time of the briquette to totally disintegrate in distilled water. This property is important for the reason that it would enable us to decide the storage method or location of the briquette.

Sample A

From the result, the briquette has shown tremendous water resistant property because it just go through moderate expansion in dimension and minor surface cracking with little loosen particle sank to the bottom. However, whole briquette was found to sink to the bottom after nearly 48 hours. This happen probably because after 48hours, the briquette is fully wetted.

Sample B

At the beginning of the experiments, observation is quite similar for both samples (*see Appendix 4 at page 32 and 33*) but at the end this sample found shattered and sank to the bottom. This happen probably because by incorporating hole to the briquette, greater surface exposed to the water thus, make water easily penetrate into the briquette, losing the bonding between particles. As the consequence, incorporating hole to the briquette reduces its water resistant characteristic.

Good water resistant characteristic reflects that briquette does not require any shielding from driving rain during transportation and storage [13]. Thus, Sample A is better in water resistant than Sample B.

4.4 Durability Test

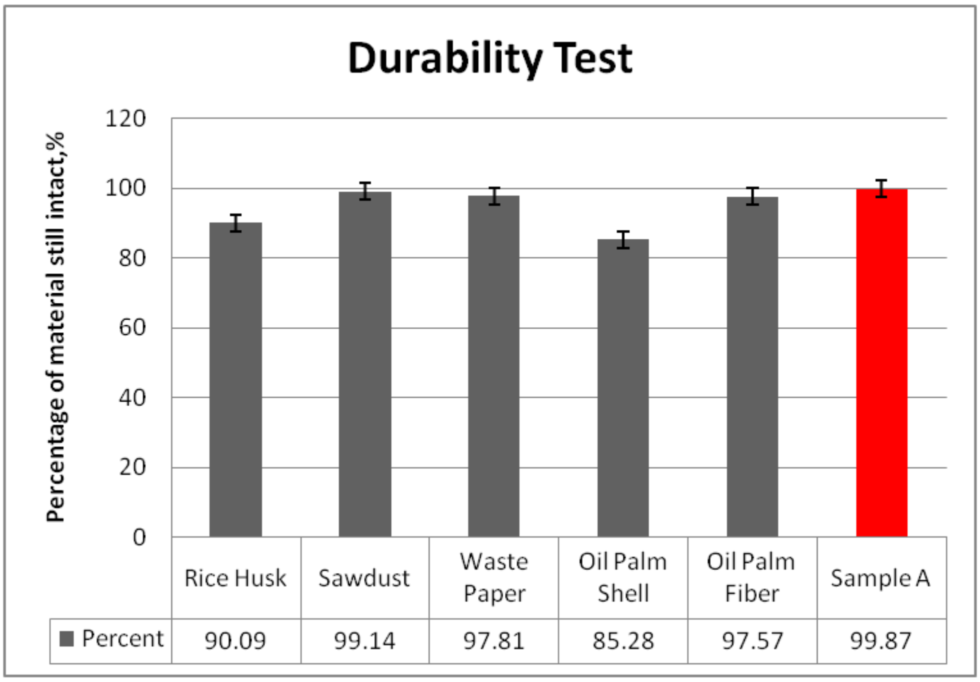

Figure 4.7: Durability Test.

From the graph, Sample A has shown a good indication in durability with the highest percentage of material still intact (99.87%) after few drops. Five (5) samples are used for this experiment and the standard deviation for weight loss of DPPP briquette is 0.01g.

Sample A

From the graph, it shows Sample A has the highest percentage of material still intact (99.87%). This happen because of the fibrous material tend to hold on the structure very well [9] and moisture as the binding agent to lock up the particle, forming cohesive force between particle [8] and thus make it relatively more durable compared with other samples from agricultural waste.(*see Appendix 5 at page 34*)

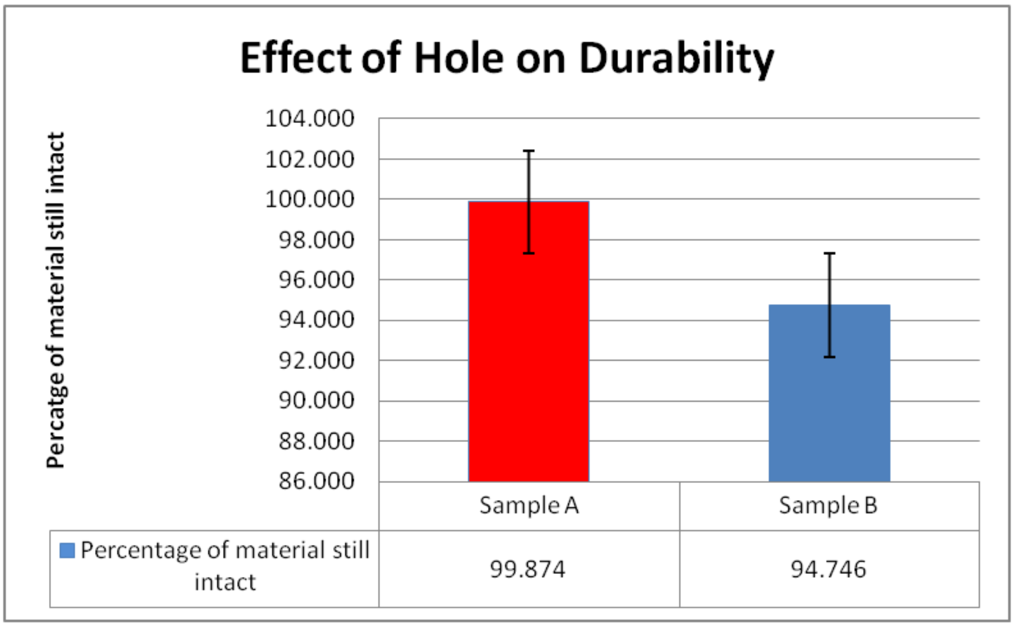

Figure 4.8: Effect of Hole on Durability.

Sample B

Five (5) samples are used for this experiment and standard deviation is 0.132g. From the graph, it is shown that Sample B has lower durability as compared to Sample A.

High durability reflects the capability of briquette to sustain its dimension when subjected to handling and storage. It is best suited for measuring the relative resistance to breakage when handled in thin layers such as during transportation and storage.

4.5 Crack Analysis

Five (5) samples are used for this experiment.

Sample A

From the observation, the briquette has shown tremendous result with no crack is found during the test (*see Appendix 6 at page 35*). . It reflects that the briquette does not require any special handling and easy to be stored in large number together for example in a box or container for transportation and storage.

Sample B

Unlike Sample A, Sample B has shown minor crack on the surface. Crack was found near the hole. Introducing hole to the briquette creating stress concentration where a location in an object, stress is concentrated. The reason for this might probably due to the presence of hole to the briquette has created stress concentration point. This stress concentration point weakens the briquette and makes them susceptible to crack and fail.

4.6 Safety Concern

The safety precautions and good hygiene need to be emphasized throughout the implementation of the project since the sludge is derived from the wastewater plant which can be harmful to human being. Sludge, by its nature, contains human pathogens: germs such as bacteria, viruses, and parasites. Some common pathogens in sludge include the bacteria E-coli and Salmonella, the virus Hepatitis A, and parasitic worms [14]. Pathogens can cause intestinal problems, other serious illnesses, and death [14]. However, the sources of contaminates in sludge are many, depending upon the specific water treatment facility and the community that it serves. Sources of contamination include industrial releases, small business discharges, hospital releases, household waste, leachate from landfills and superfund sites, including nuclear waste dumps, and municipal water and sewer systems as a whole.

In DPPP, the sludge is proven safe clinically. DPPP monitor the sludge by sending them for analysis based on MS ISO/IEC 17025 TESTING SAMM No. 147 and also acquired the certificate (*see Appendix 7 at page 36*). Nevertheless, an adequate Personal Protective Equipment (PPE) must be worn whenever dealing with the sludge to eliminate any possibility of any infections. Plus, the bad smell which is produced not just irritating the people close by but also create unpleasant odor to the environment.

CONCLUSION

Biomass densification improves the handling characteristics of the material for transportation and storage purpose. It can help in expanding the use of biomass in energy production, since the densification reduces the cost of transport, ease in storage and handling. DPPP briquette exhibits relatively good mechanical properties compared to other agricultural and industrial waste.

Incorporating a hole to the briquette does not improve its mechanical properties. It might be good for combustion characteristic but at the expense of mechanical strength.

In terms of safety, the sludge from DPPP is proven to be safe clinically. But, the use of adequate PPE is advisable to all personnel who are involved avoiding possibilities of any infections.

From all the test and experiments, it can be concluded that poultry processing waste can be a source of biomass energy.

Future works can be improved by eliminating the bad smell from the sludge which could offer significant contributions in the collection, storage and handling process.

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APPENDIX 1: Gantt Chart

	1	2	3	4	5	6		7	8	9	10	11	12	13
Project work continues														
Submission of Progress Report 1														
Experimental work														
Submission of Progress Report 2														
Seminar														
Varying the mould design and experimental work														
Poster Exhibition														
Submission of Dissertation Final Draft														
Oral Presentation								During Study week						
Submission of Dissertation (Hard Bound)								7 days after oral presentation						

APPENDIX 2: Pictures

	
Drying in lab: Place the back of the oven in the fume cupboard to ensure adequate ventilation	*Drying outside the lab: To resolve the smell issue in the lab*
	
Dying at 110˚C	*Solid Biomass Fuel Briquette*

APPENDIX 3: Stability Test

Table 1: Data (Stability Test)

Material	Sample	Week 0	Week 1				Week 2				Week 3			
			1	2	3	Average	1	2	3	Average	1	2	3	Average
Sample A	S1	40	40.23	40.32	40.25	40.26667	40.32	40.42	40.45	40.39667	40.65	40.78	40.57	40.66667
	S2	40	40.21	40.32	40.21	40.24667	40.43	40.39	40.42	40.41333	40.59	40.53	40.57	40.56333
	S3	40	40.29	40.25	40.25	40.26333	40.43	40.49	40.42	40.44667	40.65	40.59	40.58	40.60667
	S4	40	40.27	40.23	40.21	40.23667	40.41	40.44	40.39	40.41333	40.71	40.65	40.58	40.64667
	S5	40	40.21	40.26	40.29	40.25333	40.47	40.41	40.45	40.44333	40.63	40.62	40.57	40.60667
	Average for respective week					40.25333	Average for respective week			40.42267	Average for respective week			40.618
Sample B	S1	40	40.42	40.4	40.39	40.40333	40.62	40.59	40.58	40.59667	40.62	40.68	40.63	40.64333
	S2	40	40.58	40.61	40.6	40.59667	40.62	40.61	40.58	40.60333	40.68	40.73	40.69	40.7
	S3	40	40.38	40.4	40.42	40.4	40.59	40.63	40.61	40.61	40.72	40.7	40.68	40.7
	S4	40	40.39	40.42	40.41	40.40667	40.62	40.59	40.61	40.60667	40.69	40.73	40.72	40.71333
	S5	40	40.38	40.41	40.39	40.39333	40.65	40.64	40.62	40.63667	40.73	40.69	40.75	40.72333
	Average for respective week					40.44	Average for respective week			40.61067	Average for respective week			40.696

Calculation

Variance, $\sigma^2 = \frac{\Sigma(\chi - \mu)^2}{N}$

For DPPP Briquette = 0.9983

For DPPP Briquette with hole = 0.9643

Non-dimensional diameter = $\frac{Briquette's\ diameter\ for\ respective\ Week}{40}$

Rate of expansion in diameter = $\frac{Diameter\ of\ briquette}{Time\ (week)}$

For Sample A,

$= \frac{40.618}{3}$ = 13.539mm/week

For Sample B,

$= \frac{40.696}{3}$ = 13.565mm/week

Table 2: Non-Dimensional Diameter

Material	Wk1	Wk2	Wk3
Rice Husk	1.017333	1.045767	1.047233
Saw Dust	1.0125	1.026433	1.027033
Waste Paper	1.006733	1.017667	1.018433
Oil Palm Fiber	1.012467	1.0223	1.0232
Oil Palm Shell	1.021533	1.039467	1.0409
DPPP Briquette	1.006	1.011	1.015
DPPP briquette with Hole	1.011	1.015267	1.0174

Note the value of non-dimensional diameter for Rice Husk, Saw Dust, Waste Paper, Oil Palm Fiber, Oil Palm Shell are obtained from Y.S Chin [9].

<u>Experimental Accuracy</u>

1. The systematic uncertainties is calculated for the mean diameter (given that vernier calliper has accuracy of 0.01). For 1st row, it gives 0.01 x 40.242 = 0.40242

2. To find random uncertainty, the standard deviation of the diameter is required, and found to be 0.032496154. The random uncertainty is then calculated for 95% confidence according to Students t distribution with a sample size of 5. The result is a random uncertainty of 0.032496154 x 2.015 = 0.06547975.

3. Both the random and systematic uncertainties are combined using root square sum (RSS) calculation to give a total uncertainty in the diameter.

$$\sqrt{0.40242^2 + 0.06547975^2} = 0.407712$$

Table 3: Experimental Accuracy (Stability Test)

Sample	Week	S1	S2	S3	S4	S5	mean,σ	Systematic Uncertainties	Standard Deviation	Random Uncertainties	RSS
Sample A	Week 1	40.23	40.21	40.29	40.27	40.21	40.242	0.40242	0.03249615	0.06547975	0.407712
		40.32	40.32	40.25	40.23	40.26	40.276	0.40276	0.03720215	0.074962333	0.409677
		40.25	40.21	40.25	40.21	40.29	40.242	0.40242	0.02993326	0.060315517	0.406915
	Week 2	40.32	40.43	40.43	40.41	40.47	40.412	0.40412	0.04995998	0.100669368	0.41647
		40.42	40.39	40.49	40.44	40.41	40.43	0.4043	0.03405877	0.068628427	0.410083
		40.45	40.42	40.42	40.39	40.45	40.426	0.40426	0.02244994	0.045236638	0.406783
	Week 3	40.65	40.59	40.65	40.71	40.63	40.646	0.40646	0.03878144	0.078144599	0.413904
		40.78	40.53	40.59	40.65	40.62	40.634	0.40634	0.08309031	0.167426979	0.439482
		40.57	40.57	40.58	40.58	40.57	40.574	0.40574	0.00489898	0.009871444	0.40586
Sample B	Week 1	40.42	40.58	40.38	40.39	40.38	40.43	0.4043	0.07641989	0.153986084	0.432632
		40.4	40.61	40.4	40.42	40.41	40.448	0.40448	0.0813388	0.163897677	0.436425
		40.39	40.6	40.42	40.41	40.39	40.442	0.40442	0.07984986	0.160897466	0.435251
	Week 2	40.62	40.62	40.59	40.62	40.65	40.62	0.4062	0.01897367	0.038231937	0.407995
		40.59	40.61	40.63	40.59	40.64	40.612	0.40612	0.02039608	0.041098097	0.408194
		40.58	40.58	40.61	40.61	40.62	40.6	0.406	0.0167332	0.033717399	0.407398
	Week 3	40.62	40.68	40.72	40.69	40.73	40.688	0.40688	0.03867816	0.077936491	0.414277
		40.68	40.73	40.7	40.73	40.69	40.706	0.40706	0.02059126	0.041491389	0.409169
		40.63	40.69	40.68	40.72	40.75	40.694	0.40694	0.04029888	0.08120225	0.414963

APPENDIX 4: Immerse Test (Sample A)

Date/Time	Observation	Picture
Aug 27,10/ 0100	• Experiment begins • Briquette is floating at the surface	
0900	• Expansion in dimension was observed • Air bubble was found at the side of the briquette • Air bubble was found around the wall of container • Crack occur at a corner towards the center • Water turn to yellowish	
1500	• The yellowish color become more intense • Crack become more severe • A little loosen particles was found floating at the surface • Air bubble was found around the wall of container • Less air bubble was found at the side of the briquette	
2300	• Crack scatter over the briquette's surface • Lesser air bubble was found at the side of the briquette	
Aug 28,10 0700	• Numerous cracks scatter over briquette's surface • Loosen particles was found sank to the bottom • No air bubble found on both container and briquette	
2300	• Water become dim • Whole briquette sank to the bottom • Briquette did not fully disintegrate • Numerous cracks scatter over briquette's surface but did not break	

APPENDIX 4: Immerse Test (Sample B)

Date/Time	Observation	Picture
Oct 29,10/ 0100	• Experiment begins • Briquette is floating at the surface	
0900	• Crack found at sideway • Expansion in dimension was observed • Air bubble was found at the side of the briquette • Air bubble was found around the wall of container • Crack occur at a corner towards the center • Water turn to yellowish	
1500	• The yellowish color become more intense • Crack become more severe • A little loosen particles was found floating at the surface • Air bubble was found around the wall of container • Less air bubble was found at the side of the briquette	
2300	• Crack scatter over the briquette's surface • Lesser air bubble was found at the side of the briquette • Loosen particles found sank to the bottom	
Oct 30,10 0700	• Found shattered and sank to the bottom of the container	

APPENDIX 5: Durability Test

Material	Sample	initial weight (g)	Final weight (g)	Weight Loss (g)	% weight loss	%Remaining
Sample A	S1	10.029	10.026	0.003	0.030	99.970
	S2	10.001	9.996	0.005	0.050	99.950
	S3	9.854	9.826	0.028	0.284	99.716
	S4	9.729	9.725	0.004	0.041	99.959
	S5	9.406	9.385	0.021	0.223	99.777
Sample B	S1	9.525	9.207	0.318	3.339	96.661
	S2	9.069	8.509	0.56	6.175	93.825
	S3	8.894	8.206	0.688	7.736	92.264
	S4	9.465	9.089	0.376	3.973	96.027
	S5	9.547	9.065	0.482	5.049	94.951

APPENDIX 6: Crack Analysis

Table 4: Result (Crack Analysis)

Material	Sample	Crack Number	Length (mm)
DPPP Briquette	S1	No crack	0
	S2		
	S3		
	S4		
	S5		
DPPP Briquette with hole	S1	No crack	0
	S2	No crack	0
	S3	1	11
	S4	No crack	0
	S5	1	8


Sample A – No crack


Sample B – Crack found , 11mm in length

Appendix 7: Certificate of Analysis

13-NOV-2009 15:00 P.01

ALS TECHNICHEM (M) SDN BHD
(117964-P)
9, Jalan Astaka U8/84, Seksyen U8, Bukit Jelutong, 40150 Shah Alam, Selangor.
Tel: (603) 7845 8257 Fax: (603) 7845 8258 E-mail: info@alsmalaysia.com

ALS Technichem

CERTIFICATE OF ANALYSIS

STANDARDS MALAYSIA ACCREDITED LABORATORY
MS ISO/IEC 17025 TESTING
SAMM No. 147

DATE : 5 May 2009

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OUR REF. : ATHQ/25925EV/2009 (1)

COMPANY : Higard (M) Sdn. Bhd.,
No.83 & 84, Jalan Industry 4/2,
Kawasan Perindustrian Gopeng,
31600 Gopeng,
Perak.
Tel: 05 - 3575 448 Fax: 05 - 3572 400
(Attn.: Ms. Lo Win Yee)

RECEIVED 13 NOV 2009

DATE SAMPLE RECEIVED : 20 May 2009

SAMPLE MARKING : One sludge sample was received with the following references:

DPP CAF Sludge

DATE OF SAMPLING : 19 May 2009

Note : Results apply to sample(s) as submitted. This report supersedes any previous reports of the same reference number.

Sri Norazilina Bt Abd Shukor
BSc. (Hons), (Chem), AMIC
Chemist

Lee Yiu Lay
BSc. (Chem & Bio), MSc. (Chem), AMIC
Senior Chemist

BRANCH & COLLECTION CENTRE:
(JB): No.19, Jalan Kencana Mas 1/1,
Tebrau Business Park, Taman Daya,
81100 Johor Bahru, Johor.
Fax: (607) [illegible]

→ Attn: Mr. Tharmajan & Mr. Cheah (Plant Manager)
Pg: 2/2

Laboratory Testing & Industrial Consultancy 495927

Appendix 7: Certificate of Analysis (Con't)

-NOV-2009 15:00 P.02

DATE : 5 May 2009

OUR REF. : ATHQ/25925EV/2009 (1)

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ALS Technichem

Method References	Analysis Descriptions	Units	LOR	STD*	Lab I.D 25925 / Sample I.D DPP CAF Sludge
USEPA 3050B, 6010B	**Heavy Metals**				
USEPA 3050B, 6010B	Antimony	mg/kg	10	500	< 10
USEPA 3050B, 6010B	Arsenic	mg/kg	5	500	< 5
USEPA 3050B, 6010B	Barium	mg/kg	5	10000	18
USEPA 3050B, 6010B	Beryllium	mg/kg	1	75	< 1
USEPA 3050B, 6010B	Cadmium	mg/kg	1	100	< 1
USEPA 3050B, 6010B	Chromium	mg/kg	1	2500	20
USEPA 3060A, 7196A	Chromium (VI)	mg/kg	10	500	< 10
USEPA 3050B, 6010B	Cobalt	mg/kg	1	8000	1
USEPA 3050B, 6010B	Copper	mg/kg	1	2500	50
USEPA 3050B, 6010B	Lead	mg/kg	1	1000	3
USEPA 7471A	Mercury	mg/kg	1	20	< 1
USEPA 3050B, 6010B	Molybdenum	mg/kg	1	3500	2
USEPA 3050B, 6010B	Nickel	mg/kg	1	2000	8
USEPA 3050B, 6010B	Selenium	mg/kg	10	100	< 10
USEPA 3050B, 6010B	Silver	mg/kg	1	500	< 1
USEPA 3050B, 6010B	Thallium	mg/kg	1	700	4
USEPA 3050B, 6010B	Vanadium	mg/kg	1	2400	< 1
USEPA 3050B, 6010B	Zinc	mg/kg	1	5000	179
USEPA 3570, 8270C	**Semivolatile Organics**				
USEPA 3570, 8270C	Pentachlorophenol	mg/kg	1	17	< 1
USEPA 3570, 8270C	**Herbicides**				
USEPA 3570, 8270C	2,4-Diclorophenoxy acetic acid	mg/kg	1	100	< 1
USEPA 3570, 8270C	2,4,5-Trichlorophenoxypropionic acid (Silvex)	mg/kg	1	10	< 1
USEPA 5030B, 8260 B	**Volatile Organic**				
USEPA 5030B, 8260 B	Trichloroethylene	mg/kg	0.5	2040	< 0.5
USEPA 3570, 8270C	**Pesticides and PCBs**				
USEPA 3570, 8270C	Aldrin	mg/kg	0.5	1.4	< 0.5
USEPA 3570, 8270C	Chlordane	mg/kg	0.5	2.5	< 0.5
USEPA 3570, 8270C	DDT,DDE,DDD	mg/kg	0.5	1	< 0.5
USEPA 3570, 8270C	Dieldrin	mg/kg	0.5	8	< 0.5
USEPA 3570, 8270C	Endrin	mg/kg	0.1	0.2	< 0.1
USEPA 3570, 8270C	Heptachlor	mg/kg	0.5	4.7	< 0.5
USEPA 3570, 8270C	Kepone	mg/kg	0.5	21	< 0.5
USEPA 3570, 8270C	Lindane	mg/kg	0.5	4	< 0.5
USEPA 3570, 8270C	Methoxychlor	mg/kg	0.5	100	< 0.5
USEPA 3570, 8270C	Mirex	mg/kg	0.5	21	< 0.5
USEPA 3570, 8270C	PCBs	mg/kg	0.5	50	< 0.5
USEPA 3570, 8270C	Toxaphene	mg/kg	0.5	5	< 0.5

LOR: Level of Reporting ND - Not detected (< LOR)

USEPA : United States Environmental Protection Agency

* California Assesment Code Title 26 TTLC (Total Threshold Limit Concentration)