Investigating the Effect of Different Salinity Levels of Water in Waterflooding on Drag Reducing Agent Extracted from Natural Waste Materials

by

Harith Faezsal Bin Zakaria

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Dissertation submitted in partial fulfillment of the requirement for the

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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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(PETROLEUM)

Approved by,

…………………………………

(SITI SARAH SALEHUDIN)

Universiti Teknologi PETRONAS

TRONOH, PERAK

September 2014

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.

HARITH FAEZSAL BIN ZAKARIA

ABSTRACT

The use of drag reducing agent (DRA) as an additive in oil and gas industry has become famous and widely used nowadays. The usage of DRA is not limited in pipeline only, it has been also used in waterflooding or water injection system. However, information on the usage and reliability of natural polymers as DRA in water injection system are still limited. In this paper, polymer was extracted from natural waste materials (coconut residue) for the purpose of producing the DRA. Other than that, the effectiveness of the DRA was tested in different properties of water since the parameters of water used in waterflooding may vary one from another. In this study, the focus parameter will be the water salinity and a test was done to determine the effectiveness of the DRA in different levels of salinity. To accomplish these objectives, an amount of coconut residue was processed for the extraction of carboxymethylcellulose (CMC). Then, it was used as DRA and tested by using fluid friction apparatus in different levels of salinity with 0 ppt (tap water), 10 ppt, 20 ppt, 30 ppt, 40 ppt and 50 ppt concentration. The concentration of DRA used is 400 ppm for each sample. From the test, it was found that the DRA extracted from natural waste materials (coconut residue) can reduce drag. Nonetheless, as the salinity of water increase, the percentage of drag reduction decrease. Or in other word, drag increase percentage is increased. Therefore it is concluded that, the CMC extracted from natural waste materials (coconut residue) can act as DRA to reduce drag in water injection system. However, by increasing the salinity of the water used, the capability of DRA to reduce drag will decrease. This research will make the abundance of natural waste material to turn into a resource to be utilised as DRA and hence can transform the waste to profit in terms of operation cost. This research also will contribute to the study of flow assurance as well as can determine whether the different salinity of water will affect the effectiveness of DRA.

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CHAPTER 1: INTRODUCTION

1.1. Background Study

The development of advance technology in oil and gas industry is growing very swift. But then, some of the problems in the industry still cannot be overcome by this new technology. One of the problems is the pressure loss that occurs in pipeline. Basically, this problem will lead to the other problem like in water injection system. It is a method to increase and maintain the reservoir pressure once the pressure is depleted. However, because of the pressure loss that occurs in pipeline, the injected water from the injection well cannot be delivered effectively to sweep the oil from the reservoir to the production well. In this case, the deliverability of the water to the reservoir is crucial so that the process of the waterflooding goes well and the oil recovery can be optimized.

This pressure loss in pipeline matter continues to be one of the major energy consuming in the industry as the water that flow inside the pipeline is in turbulent flow regime. This kind of flow will produce a force which known as drag inside the pipeline. This force will result in the pressure drop along the pipeline thus reduce the flow capacity. It is a main concern for almost all the petroleum companies since it will cause the expenditure of transporting the water to increase especially the operating cost.

Negative consequences of pipeline pressure loss can be reduced in several methods such as modify the size of pipeline diameter or install more pumping stations along the system, to name a few. These methods definitely have been proven to be a success to reduce the pressure drop inside the pipeline thus the flow rate can be maintained. However, although the transportation of the fluid can be done without having the pressure loss inside the pipeline, the presence of drag in turbulent flow still cannot be overcome by applying these methods. Other than that, these methods also cost a lot of money and takes time to be implemented.

In order to tackle this problem, H.A. Abdulbari et al. (2013) described a lot of techniques were suggested by many researchers for various applications. One of them is by using baffles with different heights in turbulent flow region to suppress the turbulent swirls. As in submarine applications, skin friction can be reduced by using layers of bubble. On the other hand, H.R. Karami and D. Mowla (2012) proposed that the best alternative to handle the pipeline pressure loss problem is by using additives called drag reducing agents (DRA).

H.R. Karami and D. Mowla (2012) defined DRA basically is a chemical which when added into the fluid, the friction of fluid will decrease and the flow capacity will increase without disrupt the pipeline conditions. Since the famous successful usage of DRA in Trans-Alaska Pipeline late in 1970s, extreme improvement in DRA has been made in terms of its efficiency and dependability (Prasetyo, 2003). In this study, the effectiveness of DRA will be tested by varying the selected variables in order to know their outcome.

C. Kang and W.P. Jepson (1999) mentioned in their report, there are a few factors known that the performance of DRA depend on such as oil viscosity, composition of oil, pipe diameter, DRA concentrations, fluid velocity, pipeline inclination and pipeline roughness. Besides, H.A. Al-Anazi et al. (2006) suggested, the factors like molecular weight of polymer, solubility, cloud point, flow turbulence, degradation and injection location are some factors that affect the performance of DRA.

1.2. Problem Statement

Drag force inside the pipeline that produces due to turbulent flow cause the pressure to drop. This pressure drop will reduce the flow rate of the fluid and make the flow capacity of the pipeline to reduce. In water flooding system, this occurrence will cause problem since the optimization of the hydrocarbon production from reservoir depends on the flow efficiency and the flow capacity of the pipeline. According to H. Oskarsson et al. (2005), there are some cases, the water injected from the injection well does not reach the reservoir completely and the hydrocarbon from the reservoir cannot be displaced and produced efficiently.

One of the techniques that can be used to overcome this issue is by installing the booster pump which will increase the flow capacity of the pipeline. Thus, the injected water can be flowed at the desired flow rate. Nonetheless, this method will cost a lot of money and time to implement. Other alternative is by adding DRA to the system. By using the DRA, the pressure loss inside the pipeline can be reduced. However, the water that flow in the pipeline may possess various properties which will react differently with the DRA. Therefore, the effectiveness of the DRA used in water that contains different parameters may vary one from another.

On the other hand, many studies had been made for the development of DRA and some of them are still on-going. At the moment, the DRA from synthetic polymers is widely used because it gives many advantages. Nevertheless, this type of polymers can cause harm to the environment if use excessively as it contains chemical. Other than that, compared to the DRA from natural polymers, the synthetic polymers is way more expensive. This is why the research of DRA from natural polymers becomes more popular nowadays. So, in this report, the study of the DRA from natural polymers also will be discussed.

1.3. Objectives

i. To extract carboxymethylcellulose (CMC) from natural waste materials (coconut residue) to be used as DRA

ii. To study the performance of DRA from natural waste materials (coconut residue) in different levels of salinity

1.4. Scope of Study

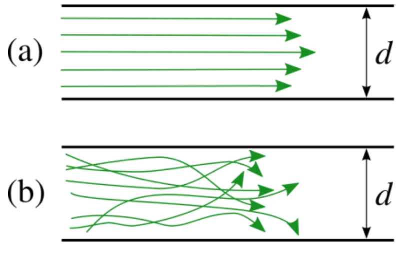
Based on the objectives, the scope of study in this experiment extends to the study of the natural waste materials as DRA in water injection well. The extraction of CMC from the natural waste materials is done to prepare the DRA. In this project, the natural waste materials that are used in order to obtain the CMC are coconut residue. Other than that, the scope of study is focus on testing the efficiency of DRA in different levels of salinity. The range of salinity levels to be used is from 0 ppt (distilled water) to 50 ppt. The CMC extracted from the coconut residue is added to each sample of solution that contains different salinity and tested by using fluid friction apparatus. In this case, it is tested in turbulent flow regime as the DRA will effectively react in this type of flow regime only. From the test, pressure drop, drag increase percentage and flow decrease percentage are recorded and analysed. From these results, the efficiency of the DRA can be determined.

CHAPTER 2: LITERATURE REVIEW

2.1. Drag

In fluid dynamics scope, drag is a force that oppose to the relative motion of an object. Drag force acts opposite to the oncoming flow velocity. This kind of force is different with other resistive force because it dependent on velocity (Coffey, 2010). From the perspective of petroleum industry, this force is such a problem mostly in transporting the production fluid through a pipeline. The fluid that flow in pipeline which in contact with the pipe wall will adheres to the surface as a consequence of the viscous effect. Due to this effect, drag force is produced in the pipeline. This force causes the pressure along the pipeline to reduce and also slow down the movement of the adjacent layer fluid. The longer the pipeline, the higher the pressure reduced and affects the flow rate (Hamouda, 2003).

Drag is more likely to happen in turbulent flow compared to laminar flow. R. K. Rodrigues et al. (2013) explained in his technical report regarding these two types of main flow regime for general understanding. For laminar flow, it happens when the speed of the fluid flow is slow. This condition can be seen as in Figure 2.1(a) where the fluid is flow in alike and equivalent wave. When the pace of the flow increases continuously, the transition of the flow from laminar flow to turbulent flow occur. This is due to the viscous force of the fluid is overcame by inertial force. This will lead to the formation of structures and frequency called vortices to happen in the pipeline as in Figure 2.1(b).



d = diameter

Figure 2.1: Laminar and turbulent flow

2.2. Turbulent Flow

I. Prasetyo (2003) explained, in turbulent flow regimes, there are three different zones or layers which consist of laminar sub layer, turbulent core zone and buffer zone. In laminar sub layer zone which is the nearest zone to the pipe wall, the fluid is in a typical laminar flow regime and trails the pipeline flow. There are no cross flows in this zone. The largest section which comprises the most of the fluid is in the center of the pipe. It is called the turbulent core zone. This is where the random motion of turbulent flow occurs. It is the largest region and most of the fluid comprise in this zone. Between the laminar sub layer and turbulent core zone there is a buffer zone. This zone is crucial as it is where the turbulence start to form before it goes to the turbulent core zone.

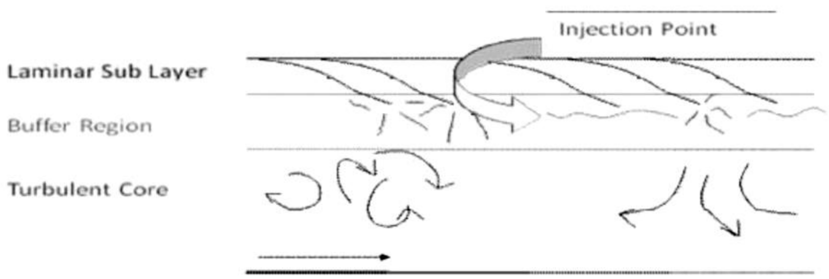


Figure 2.2: Layers in turbulent flow regimes

On how the turbulence is created, he stated that a portion of the laminar sub layer, called a “streak” seldom will move to the buffer region. After entering into this region, the streak starts to vortex and oscillate. As the streak approaches the turbulent core, its motion becomes quicker. Then, the streak becomes unstable and breaks up as it throws fluid into the core of the flow which is known as “turbulent burst”. This burst produce the turbulence and end up in wasting energy in various paths that will cause drag and loss of pressure.

Values of Reynolds number (Re) can be used in order to define the transition between the laminar and turbulent flow regimes in pipe. The Reynolds number for pipe can be determined by using below equation. Generally, the values of Re below 2300 indicates the laminar flow regime and the values above 4000 indicates the turbulent flow regime. In the interval between 2300 and 4000, laminar and turbulent flows are possible and are called "transition" flows.

$$Re = \frac{\rho v d}{\mu}$$

Where ρ = fluid density (kg/m^3)

v = velocity (m/s)

d = diameter (m)

μ = fluid viscosity (kg/m.s)

2.3. Drag Reduction

In oil and gas industry, large pressure loss due to the drag effect in pipeline has been a major concern. Pressure loss in pipeline will not only lower the flow rate but also will affect the pipe capacity as well as increase the additional capital and operating cost. In order to prevent this problem, a lot of researches has been done and studies to find the alternative to reduce the pressure loss in pipeline has been made.

N. Blatch (1906) discovered that there will be a significant pressure drop in flowing fluid when adding some substances into it. This statement was further justified by Toms through his experiment in 1948. Toms stated that the addition of small concentrations of high molecular weight polymer solvent can reduce frictional pressure drop in turbulent flows and maintain the flow energy as well as increase the pipeline capacities. He used a solution of polymethyl methacrylate in monochlorobenzene under particular flow conditions and the outcome was so encouraging. The effect of that solution cause the resistance in the flow become lesser than in the pure solvent. His study has contributed a good understanding for all regarding drag reduction and become a key factor for extensive research on all kinds of additives.

To calculate drag reduction in percentage (%DR), following equation generally used:

$$DR(\%) = \frac{|\Delta P_f - \Delta P_{fDRA}|}{\Delta P_f} \times 100$$

Where ΔP_f = friction pressure drop without presence of drag reducing agent (DRA) in flowing liquid

ΔP_{fDRA} = friction pressure drop with the presence of drag reducing agent (DRA) in flowing liquid

Other than that, flow rate and the velocity of the flow are also the vital parameter to be considered. These two parameters can be calculated by using following equation:

$$\text{Flow rate, Q (gallon per minutes)} = \frac{Volume}{Time}$$

$$\text{Velocity} = \frac{Flow\ Rate}{Area}$$

Where Time = time taken for the pump to flow water to fill up the tank (minute)

Velocity = average velocity of the flow (m/s)

Area = cross-sectional area of the pipe (m^2)

To calculate the percentage of increase in flow this equation can be used:

$$\%FI = [(\frac{100}{100-\%DR})^{0.556} - 1] \times 100\%$$

2.4. Drag Reducing Agent

DRA are chemical agents used to assist in reducing the pressure drop when added to the fluid flow in pipeline. When DRA is added, it helps to reduce the frictional pressure drop caused by the turbulent flow in the pipeline by reducing the frictional drag between the fluid and the wall of the pipe. By reducing the frictional drag, the loss of pressure during transportation of the fluid in the pipeline is reduced (Lester, 1985). F. Vejahati (2014) also agreed that by using DRA, the flow capacity can be increased as well as reduce the operating cost. In some instances, there is no pressure drop even when the pump stations are shut down. In fact, the usage of DRA gives a lot of advantages and benefits to the petroleum industry as it offers considerable economic return and a higher effectiveness in transportation.

Other than that, the flow pattern of the fluid also can be changed by using DRA. The addition of DRA will change the stratified flow into slug flow hence reduce the corrosion rate. For slug flow, the slug frequency will decrease by adding DRA and the corrosion rate can be reduced by almost 50% (Kang et al., 1998). In this case, H.A. Al-Anazi et al. (2006) also reported the same thing in his report. After doing the corrosion test, he said that DRA decreased the corrosivity of seawater by 50%.

In the industry, DRA that comes from polymers is the most effective and widely used. This type can be classified into two categories which are synthetic polymers and natural polymers. Synthetic polymers come from the derivation of petroleum oil while the natural polymers are extracted from the natural source. Compared to natural polymers, synthetic polymers give more advantages but then the natural polymers are more preferred. This is because, synthetic polymers biodegrade very slowly which will cause the effect to the environment. Synthetic polymers are also more expensive than natural polymers. On the other hand, natural polymers are biodegradable and easy to obtain (Singh and Jaafar, 2013).

2.5. Carboxymethylcellulose (CMC)

According to H. J. Choi et al. (2000), the most widely polymer that use as DRA nowadays consist of CMC, Polyethylene Oxide (PEO), Polyacrylamide (PAM) and Guar Gum (GGM). These natural polymers have been studied in many research due to its abundance availability as well as cheaper compared to the synthetic polymers. Besides, these polymers contain high molecular weight which is good characteristic of drag reducers as stated by N. J. Kim (2009). He mentioned, as the molecular weight of the polymer and Reynolds number increase, the effect to the drag reduction will also increase.

In this study, CMC is chosen since it can be extracted from waste of plants or waste of fruits which are easy to get. Bono et al. (2009) described that CMC is a linear and water soluble polysaccharide derived from cellulose. Moreover, the traits of purified cellulose are white in colour, tasteless, odourless and it is a free-flowing powder (Keller, 1986). In this project, coconut residue is used as the resource of CMC. Coconut residue is a product of grated coconut after the extraction of coconut milk.

The coconut residue is selected as it has high cellulose content which is an essential quality to become a good DRA. A recent study also showed that coconut residue comprises approximately 70% of cellulose for total dietary fiber (S. P. Ng et al., 2010).

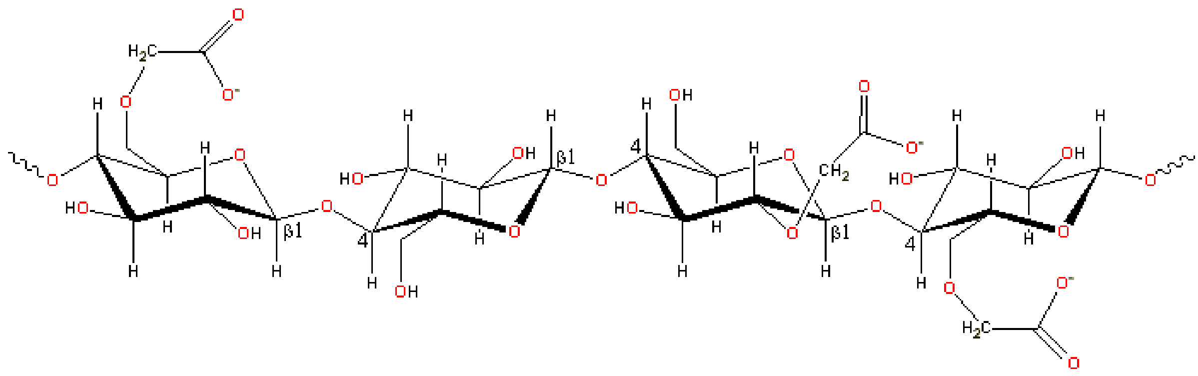


Figure 2.3: Structure of carboxymethylcellulose

2.6. Polymer Degradation

The most notable difficulties that may be faced regarding the study of drag reduction by polymer additives are the degradation of the polymer. Den Toonder et al. (1995) indicated the competence of the polymer to reduce drag is limited by chemical degradation and mechanical degradation. When an alteration in polymer structure occurs due to the chemical reaction, it is known as chemical degradation. Generally, it is due to the existence of metals in the solvent. Besides, the presence of oxygen and a high level of salinity or calcium in the solvent also the reason for chemical degradation to happen (Choi et al., 1992). On the other hand, mechanical degradation happens because of the mechanical energy acting on the polymer in the solution. Due to the presence of mechanical stress, the polymer tends to break and cause its molecular weight to reduce as well as its drag-reducing ability (Den Toonder et al., 1995).

2.7. Waterflooding System

Water flooding is classified as one of the recovery method to lower the producing bottomhole pressure on the formation to obtain a higher production rate from the well. Over the life of an oil reservoir, the reservoir pressure will gradually fall and thus reduce the production rate. Water flooding is considered as secondary recovery which generally refers to simple water flooding or gas injection to optimize oil production by artificially maintaining reservoir pressure.

According to Wright (2008), this method is by far the most common, efficient and practical method. By injecting water, potential oil recovery is increased to nearly 40-50% of the oil originally in place. In 1971, F.R. Craig mentioned it is recognized that first water flood happened unintentionally. It was back then in 1865 where water is injected by mistake in Pithole City, Pennsylvania. In 1880, it was known that water from shallow sands will flow by itself into a wellbore through oil sands. It is found that this movement of water is very useful in helping to boost the oil recovery. Since that time, water flooding has become the dominant technique employed in worldwide oil recovery operations.

Until now, most of oil fields that experience the depletion in pressure will apply this method. The fields will produce by using water injection which will sweep the oil towards the production wells and avoid the pressure to reduce as well as maintaining the productivity at the production well at the same time (J. Rochon et al., 1996). H. Oskarsson et al. (2005) wrote in an article entitled "Surfactants as Flow Improver in Water Injection" that in order to lay down an additional water pipe to injection site for the purpose of water flooding in offshore operation, great cost is needed and is not economic. Hence, by the usage of flow improvers, this approach will become more cost effective and efficient as a method to increase the flow rate once the pressure of the reservoir deplete.

CHAPTER 3: METHODOLOGY

3.1. Research Methodology

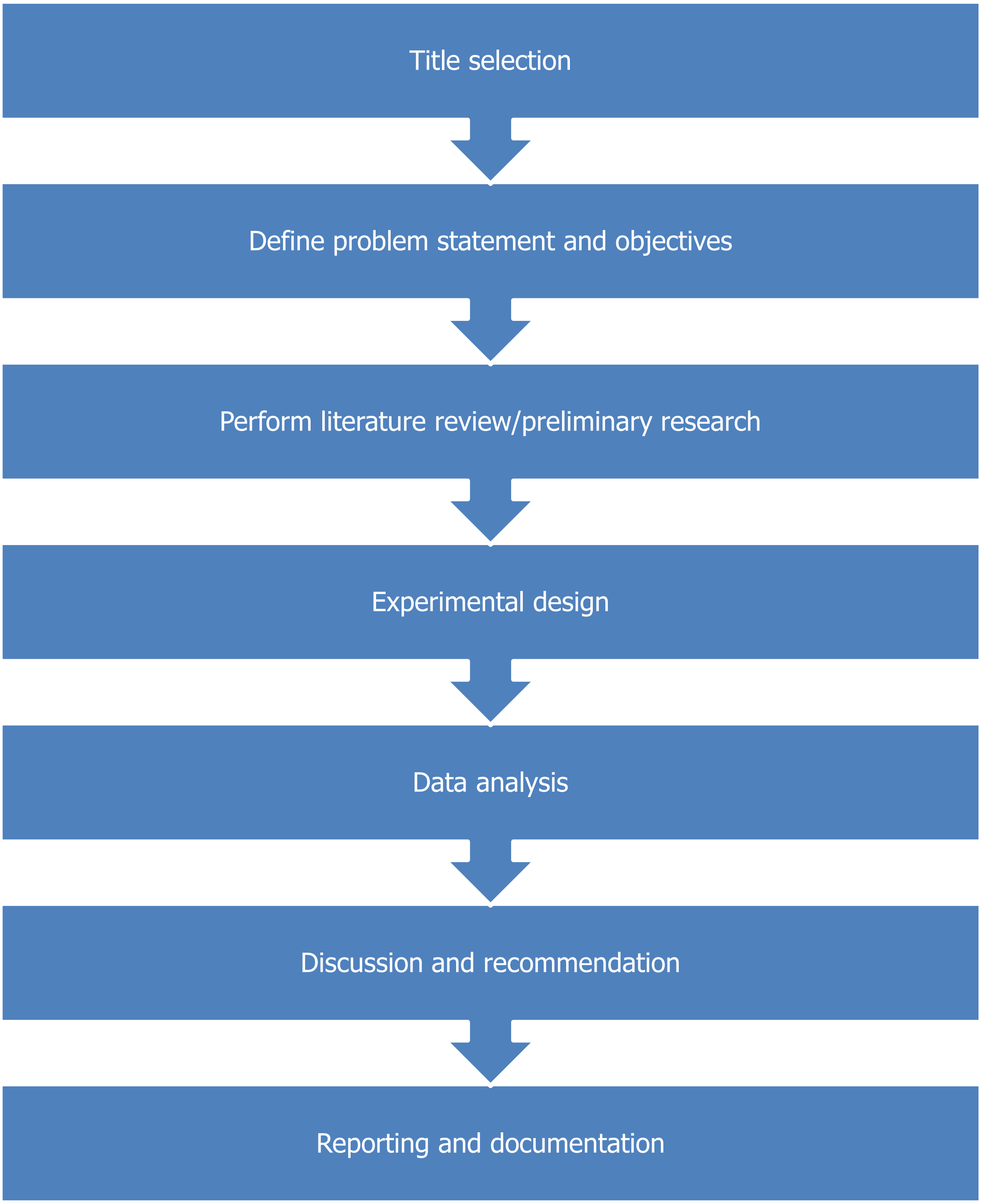


Figure 3.1: Project flow chart

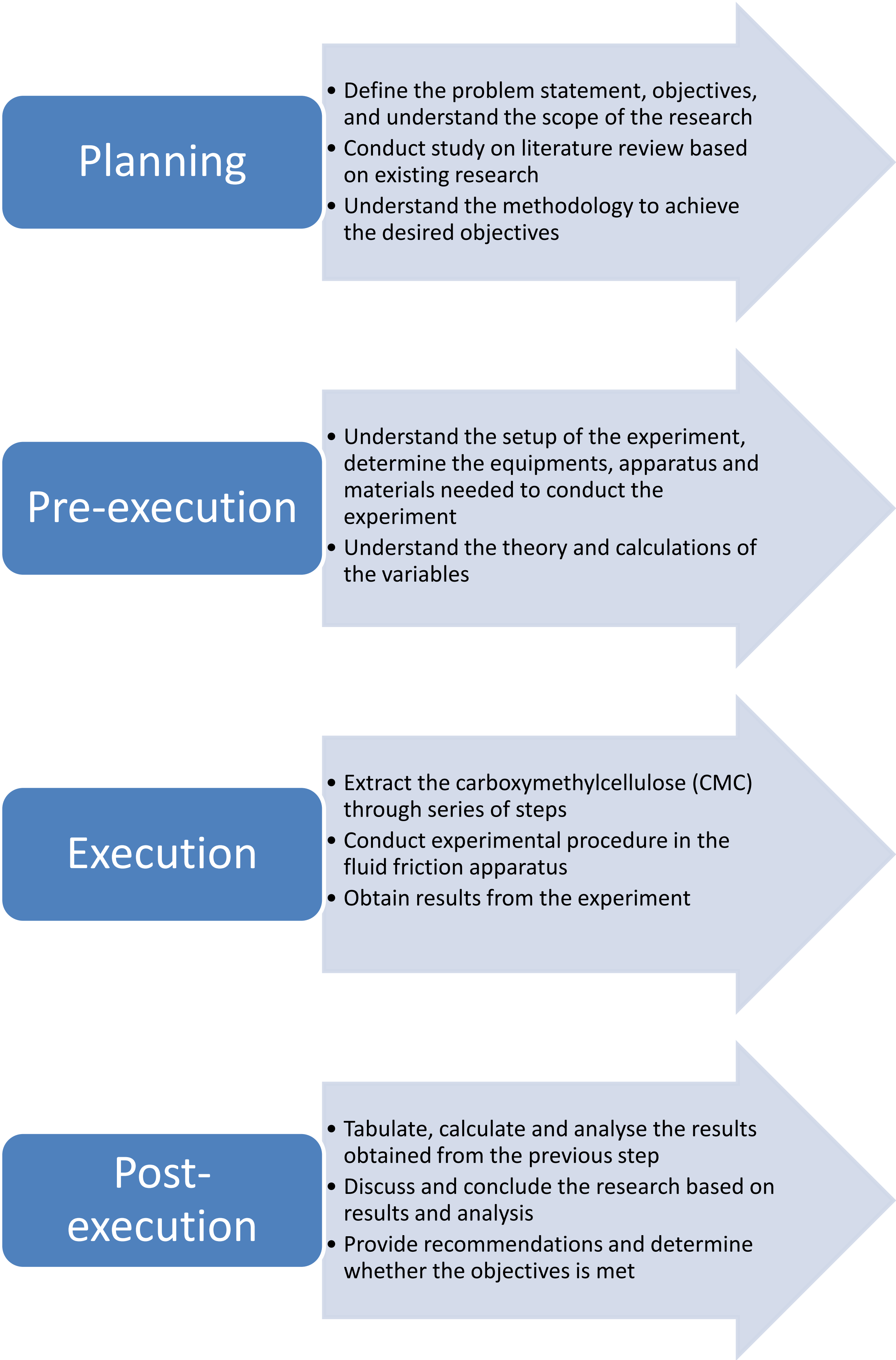


Figure 3.2: Project planning

3.2. Project Activities

In order to accomplish the objectives stated in Chapter 1, the research methodology for this project comprises of laboratory experimental investigation. From the preparation of the materials and chemicals to the analysis of the project, the experimental works are prepared and divided into several phases. The purpose of this division is to ensure the experiment can be done effectively and according to the plan. They are divided into:

i. Extraction of cellulose
    - The materials and chemicals needed for the cellulose extraction are purchased and prepared.
    - The equipment required for the extraction is listed down and set up.
    - The procedures for synthesizing the polymer from coconut residue are revised from "The Study of Drag Reduction Ability of Naturally Produced Polymers from Local Plant Sources" paper by Singh and Jaafar (2013).

ii. Fluid friction apparatus test
    - To determine the effectiveness of DRA extracted from natural waste materials in different levels of salinity.

3.2.1. Cellulose extraction

A sack of coconut residue was purchased from a grocery store at Taman Maju. Coconut residue was chosen as the source to extract the CMC because it is easy to find and the coconut residue is abundant in source. In additional, the important feature of coconut residue is that it is rich in cellulose contents and total dietary fibre which make it very suitable for CMC extraction. Other than that, the chemicals used throughout the experiment were purchased from a chemical supplier located in Ipoh which is Irama Canggih Sdn Bhd. The chemicals used for the extraction and synthesis of CMC are listed as follows:

i. Isopropanol AR QREC PR141-1-2500
ii. Sodium hydroxide pellets AR QREC S5158-1-1000
iii. Chloroacetic acid for synthesis MERCK 412

iv. Acetic acid AR QREC A1020-1-2500
v. Methanol AR QREC M2097-1-2500
vi. Ethanol 96% denatured AR QREC E7045-1-2500

Procedures:

1. Coconut residue was rinsed and washed with tap water before being dried using oven at 250^{o}F for 30 minutes.
2. After the coconut residue had been dried, it was grinded using Cole Parmer mortar grinder until become powder-size approximately less than 20mm. The grinder was set at 3 minutes for each run.

Figure 3.3: Cole Parmer mortar grinder

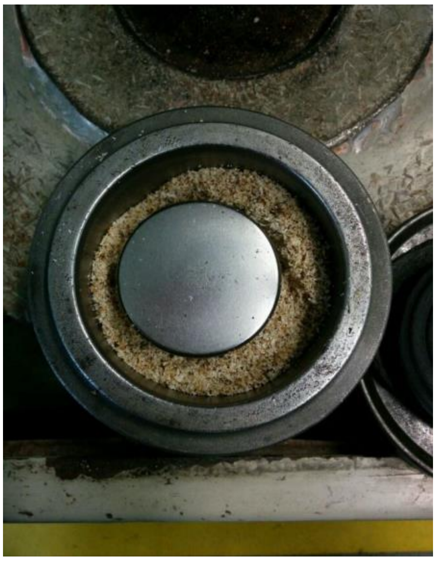


Figure 3.4: Before grinded

Figure 3.5: After grinded

After the entire coconut residue was completely grinded, it was kept in air-tight container to avoid the coconut residue to vaporize.

3. Then, 1M of NaOH was prepared in a beaker to be mixed with dried coconut residue. It was cooked using magnetic stirrer hot plate at 150^{o}C and stirred at 200RPM for 1 hour. The amount of coconut residue added to the solution of NaOH should not be too much since it will be hard for the magnetic stirrer to dissolve the thick residue into the solution. The purpose of this step is to eliminate the impurities and unwanted products from the coconut residue. After some time of stirring, the colour of the mixture of coconut residue with the NaOH solution will turn from brownish to reddish-purple.

Figure 3.6: Mixture of coconut residue and NaOH solution

4. After 1 hour, the solution was let to be cooled down first before filtered using tea bag to get the residue. The residue that left in the tea bag then rinsed with tap water until the colour of reddish-purple is gone.

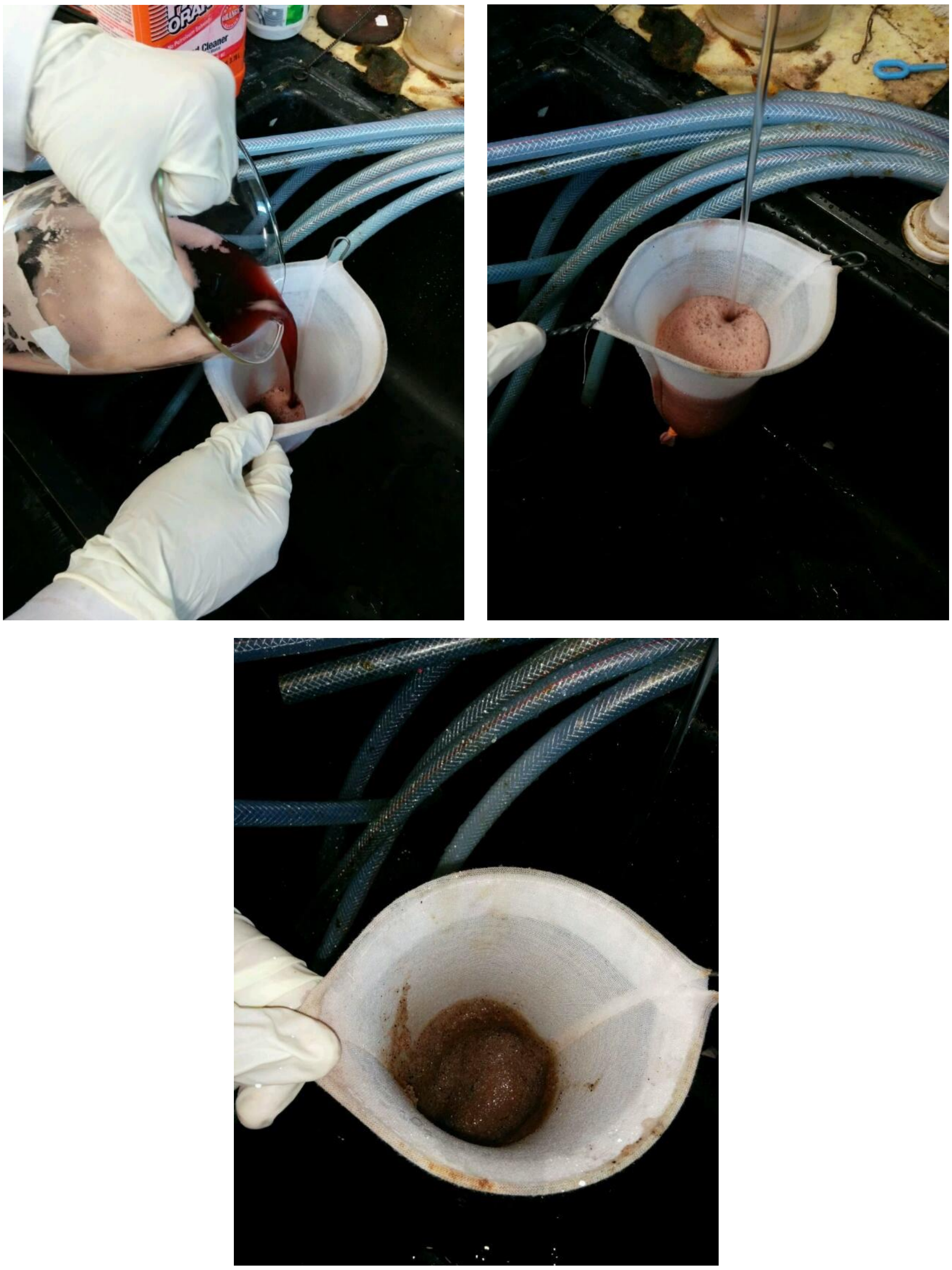


Figure 3.7: Residue rinsed with tap water until the reddish-purple colour is gone

5. Later, the coconut residue that had been filtered and rinsed was dried again using oven at 250^{o}F for 30 minutes. This process is to ensure the residue is dry enough for the CMC extraction.
6. Next, 15.0g of the residue were mixed with 50ml of NaOH with 40% concentration and 450ml isopropanol and stirred it using magnetic stirrer at 200RPM for 30 minutes. After that, 18.0g of monochloroacetic acid was added into the solution to initiate carboxymethylation reaction. Again, it was

stirred at 200RPM for 30 minutes to guarantee the biopolymers are mixed thoroughly until the polymer solutions are visibly homogeneous.

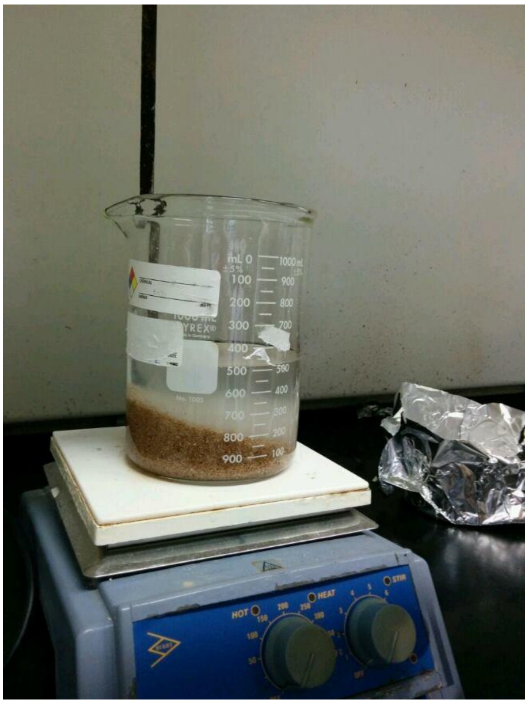


Figure 3.8: Mixture of coconut residue, 40% concentration of NaOH, isopropanol and monochloroacetic acid

7. Then, the solution phase was removed and the solid phase is kept by using sieve before suspending the solids into 100ml of methanol (70% v/v). After that, the suspended solids were neutralized by pouring glacial acetic acid into the beaker of methanol solution. Later, the neutralized solids were filtered from the solution by a funnel and filter paper.
8. To finalize the extraction of CMC, the filtrates were suspended for 10 minutes in 300ml of ethanol (70% v/v). This step is done to ensure the unwanted byproducts are removed. Then, the filtrates were washed using 300ml of absolute methanol and filtered. This rinsing and washing activity was conducted with 5 repetitions. The final filtrates filtered from the absolute methanol were dried in the oven at 55^{o}C for a total of 24 hours, continuous 8 hours per day for 3 days. The samples of CMC were obtained after the 24 hours of drying period completed. Finally, the samples were grinded into fine powder using mortar grinder and kept in air-tight container.

3.2.2. Fluid friction apparatus test

The purpose of this test is to study the effectiveness of the DRA (CMC extracted from coconut residue). The prepared DRA samples were added to tap water with different levels of salinity. Then, each solution was tested by using fluid friction apparatus to observe the performance of the DRA. For the preparation of DRA samples and different salinity levels of water, the minimum requirement of the equipment setup was taking into the account. In this case, the minimum of 20 liters of water used to ensure the flow of the water is smooth and no bubble in the pipe.

Figure 3.9: Fluid friction apparatus

For the preparation of different salinity levels of water, different amount of salt was mixed with tap water. 5 samples with different salinity were prepared.

Table 3.1: Sample preparation

Sample	Salt (gram)	Water (liter)	Salinity (ppt)
A	200	5	40
B	400	5	80
C	600	5	120
D	800	5	160
E	1000	5	200

As shown in Table 3.1, large volume of water (5 liter) used to dissolve different amount of salt to ensure the solution is not concentrated and salt can dissolve 100% in the solution. A magnetic stirrer was used at 200RPM until all the salt dissolve in the water for each sample. Each sample was labelled accordingly.

For the DRA sample preparation, 8 grams of DRA sample mixed with 1 liter of water to get the concentration of 8000 ppm. Again, magnetic stirrer was used at 200RPM for 2 hours in this step until homogenous mixture was visible. This solution was mixed later with 19 liters saline water to have a total of 20 liters of mixture with 400 ppm concentration of DRA.

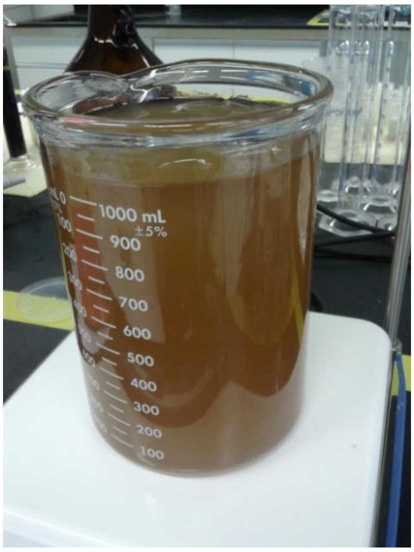


Figure 3.10: Mixture of DRA sample

The following equations were used for the preparation of different salinity levels of water and DRA sample to determine their concentration assuming the tap water have a mass of 1 kilogram per liter:

$$\text{Salinity (ppt)} = \frac{Mass\ of\ salt}{Volume\ of\ water} \times 1000$$

$$\text{DRA concentration (ppm)} = \frac{Mass\ of\ DRA}{Volume\ of\ water} \times 10^6$$

After all the samples were prepared, the saline water for each sample (5 liter) was mixed with DRA solution (1 liter) and 14 liter of water to have a total of 20 liters of mixture. They are mixed accordingly to get the required concentration for each sample as in Table 3.2. This was done for the preparation of fluid friction apparatus test.

Table 3.2: Preparation of fluid friction apparatus test

Sample	Saline water (liter)	DRA solution (liter)	Water (liter)	Total solution (liter)	New salinity (ppt)	New DRA concentration (ppm)
A	5	1	14	20	10	400
B	5	1	14	20	20	400
C	5	1	14	20	30	400
D	5	1	14	20	40	400
E	5	1	14	20	50	400

The fluid friction apparatus test setup has the following components attached together in a closed-loop system:

i. 35 liters tank capacity
ii. Manometers
iii. Venturi section
iv. Orifice plate section
v. Centrifugal pump
vi. Flow control valve
vii. Variable area flowmeter

In this study, the venturi section and the orifice section were not used since the effectiveness of DRA will be based on the pressure drop in a horizontal pipe with same inside diameter. As shown in Figure 3.11, the pressure was taken at point X and Y and the reading were observed from the manometer. Since DRA only works in turbulent flow condition, the calculation of Reynolds number for each flow is shown in Chapter 4 to prove that the flow is in turbulent flow regime.

The fluid friction apparatus test was done to determine two outcomes which are:

- The potential of CMC extracted from natural waste materials as DRA
- The effectiveness of DRA from natural waste materials in different levels of salinity

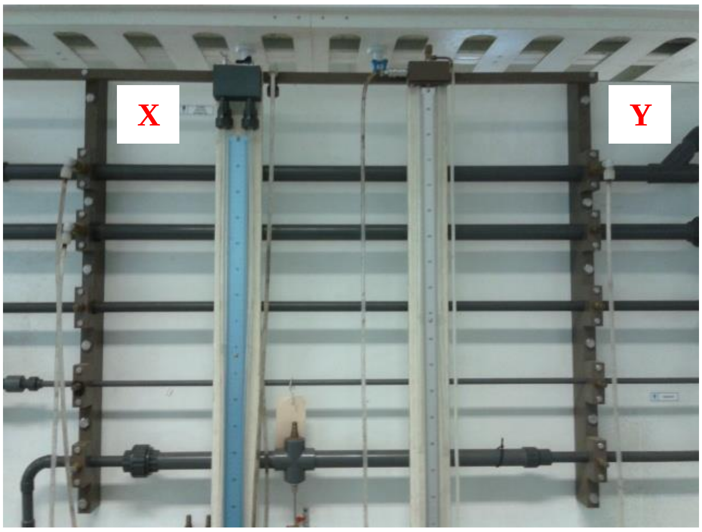


Figure 3.11: Measured point

Procedures:

1. The tank of the fluid friction apparatus was filled with 20 liters of water
2. The centrifugal pump was switched on and flow control valve was opened slowly as precautionary measure and to ensure full circulation of water into the system.
3. The variable flowmeter was set to $1m^3$/hr and the readings of manometer was observed and recorded as base case after the flow let to stabilize for 3 minutes.

Figure 3.12: Variable flowmeter

4. The flow control valve was then completely closed and the pump was switched off after the readings of manometer were recorded.
5. The drain valve at the side of the tank was completely opened to drain all the water from the tank.
6. The tank was filled with the mixture of 19 liters of water and 1 liter of DRA solution for the new run.
7. Step 2 to 5 was repeated and the recorded manometer readings were compared with the base case as in Table 4.1 to determine the potential of the CMC extracted from natural waste materials as DRA.
8. Next, in order to determine the effectiveness of DRA in different levels of salinity, the tank was filled with sample A as prepared in Table 3.2.
9. Again, step 2 to 5 was repeated and for this test, the mixture of 19 liters of water and 1 liter of DRA solution was made as the base case as in Table 4.2.
10. Step 8 and 9 repeated with using different sample as prepared in Table 3.2.

All the observed manometer readings from the test were recorded and presented (Table 4.1 & Table 4.2) in Chapter 4.

3.3. Project Key Milestones

3.3.1. FYP I

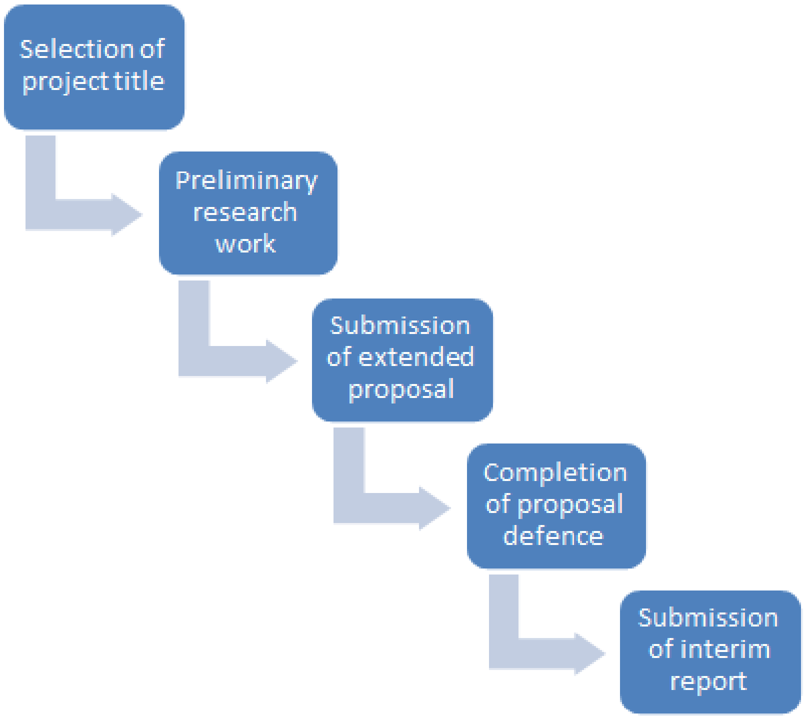


Figure 3.13: FYP I Key Milestones

3.3.2. FYP II

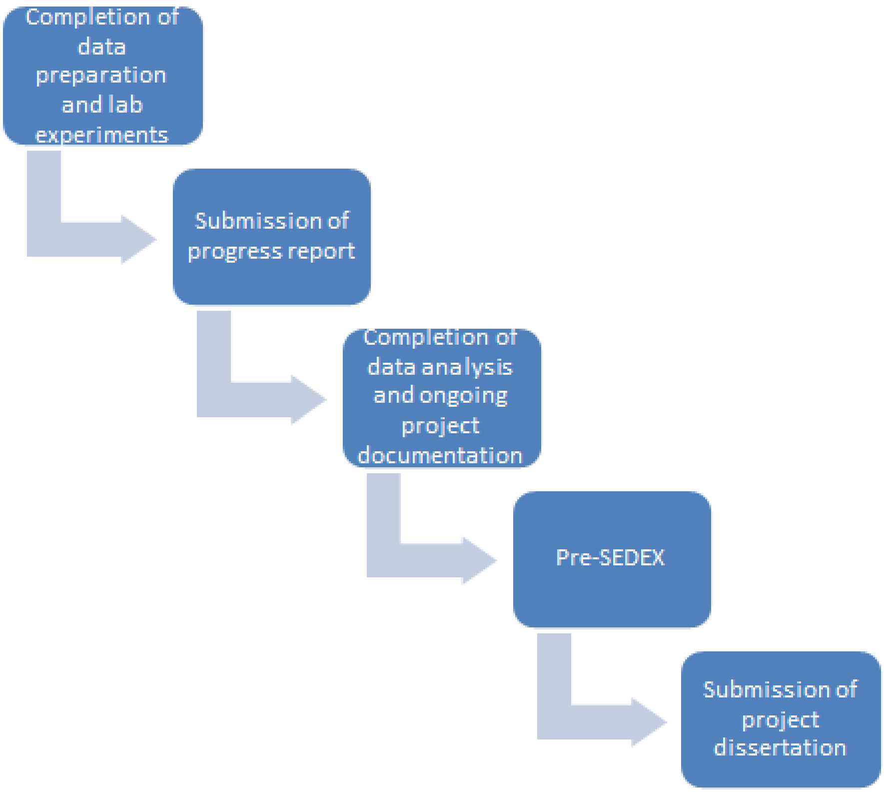


Figure 3.14: FYP II Key Milestones

3.4. GANTT CHART

3.4.1. FYP I

Table 3.3: FYP I Gantt Chart

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
2	Preliminary Research Work														
3	Submission of Extended Proposal														
4	Proposal Defence														
5	Project Work Continues														
6	Submission of Interim Draft Report														
7	Submission of Interim Report														

Suggested Milestone

Process

3.4.2. FYP II

Table 3.4: FYP II Gantt Chart

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continues															
2	Submission of Progress Report															
3	Project Work Continues															
4	Pre-SEDEX															
5	Submission of Final Report Draft															
6	Submission of Dissertation (Softbound)															
7	Submission of Technical Paper															
8	Viva															
9	Submission of Project Dissertation (Hardbound)															

Suggested Milestone

Process

3.5. List of Equipment, Apparatus, Chemicals & Software

Table 3.5: List of equipment

No.	Equipment	Purpose
1	Mortar Grinder	To grind the coconut residue into powder-size form
2	Magnetic stirrer with hot plate	To stir the mixture with desired speed and temperature
3	Electronic weighing scale	To measure the weight of the chemicals and materials to be used precisely
4	Drying oven	To dry the powder and filtrates
5	Fluid friction apparatus	To do the flow test to determine the pressure drop in different solution in turbulent flow condition
6	Viscometer	To determine the viscosity of solution
7	Density meter	To determine density of solution

Table 3.6: List of apparatus

No.	Apparatus	Purpose
1	Beakers	For heating and stirring activities and to keep the solution
2	Measuring cylinder	To measure the volume of solutions and chemicals accurately
3	Filter funnel	To filter any solution to obtain the filtrates
4	Filter paper	To filter any solution to obtain the filtrates
5	Aluminium foil	To cover the beaker that containing solution to prevent evaporation
6	Air-tight container	To store the powder and prevent from exposure to the surrounding
7	Sieve	To separate solid phase and liquid phase
8	Stopwatch	To measure time during the test

Table 3.7: List of chemicals

No.	Chemicals	Source
1	Distilled water & tap water	UTP Laboratory
2	Isopropanol AR QREC PR141-1-2500	Irama Canggih Sdn. Bhd.
3	Sodium hydroxide pellets AR QREC S5158-1-1000	Irama Canggih Sdn. Bhd.
4	Chloroacetic acid for synthesis MERCK 412	Irama Canggih Sdn. Bhd.
5	Acetic acid AR QREC A1020-1-2500	Irama Canggih Sdn. Bhd.
6	Methanol AR QREC M2097-1-2500	Irama Canggih Sdn. Bhd.
7	Ethanol 96% denatured AR QREC E7045-1-2500	Irama Canggih Sdn. Bhd.

Table 3.8: List of software

No.	Software	Purpose
1	Microsoft Office Word 2010	To write report
2	Microsoft Excel 2010	For plotting graph and calculations

CHAPTER 4: RESULTS AND DISCUSSION

For the result of the experiment, it was divided in two parts. One part is for the result of the testing of the CMC extracted from natural waste materials to determine whether it has potential to be used as DRA. Other part is for the result of the DRA performance in different levels of salinity. The variables and assumptions that had been made in this experiment also included in this chapter.

4.1. Variables

4.1.1. Constant

i. Volume of solution in mixing tank (20 liter)
ii. Volume of DRA solution (1 liter)
iii. Pipe inside diameter (7 cm)
iv. Pipe length of the fluid friction apparatus
v. Type of pipe of the fluid friction apparatus
vi. Concentration of DRA mixed in the tank (400 ppm)
vii. Water temperature at room temperature (25^{o}C)

4.1.2. Manipulated

i. Concentration of salt (10 ppt, 20 ppt, 30 ppt, 40 ppt and 50 ppt)

4.1.3. Responding

i. Manometer readings

4.2. Assumptions

i. The prepared DRA sample was dissolved completely with the water. The DRA was mixed with water and stirred using magnetic stirrer at 200RPM for 2 hours. By this rate, it is assumed the DRA mixed 100% with the water.
ii. For the sample of different levels of salinity, all salt that mixed with water dissolved completely in water. This is because, the remaining salt that not dissolve may disturbed the flow pattern of the water in pipeline.

4.3. Results

4.3.1. Potential of CMC extracted from natural waste materials as DRA

Table 4.1: Drag reduction percentage

DRA (ppm)	Salinity (ppt)	Manometer reading (mm)		ΔP	Drag reduction percentage (%DR)
		X	Y		
0 (base case)	0	30.2	14.7	15.5	-
400	0	29.9	23.6	6.3	59.35

From Table 4.1, it is showed that by adding the DRA into the solution, 59.35% of drag is reduced. This is occurred due to the ratio between the degree of turbulent and DRA molecule is increased when the DRA exist in the solution. The DRA molecules that react with the turbulent structure will disturb and reduce the turbulence degree as well as will decrease energy loss and friction pressure loss. This result proved that the prepared CMC extracted from natural waste materials (coconut residue) is potential to be used as DRA.

4.3.2. Performance of DRA in different levels of salinity

Table 4.2: Drag increase percentage

DRA (ppm)	Salinity (ppt)	Manometer reading (mm)		ΔP	Drag increase percentage (%DI)
		X	Y		
400 (base case)	0	29.9	23.6	6.3	-
400	10	30.2	23.3	6.9	9.52
400	20	30.2	22.5	7.8	23.81
400	30	30.0	21.8	8.2	30.16
400	40	29.9	21.1	8.8	39.68
400	50	30.1	20.6	9.5	50.79

From Table 4.2, it is showed that by increasing the salinity levels, the pressure drop is increased and the drag increase percentage (%DI) showed an increment.

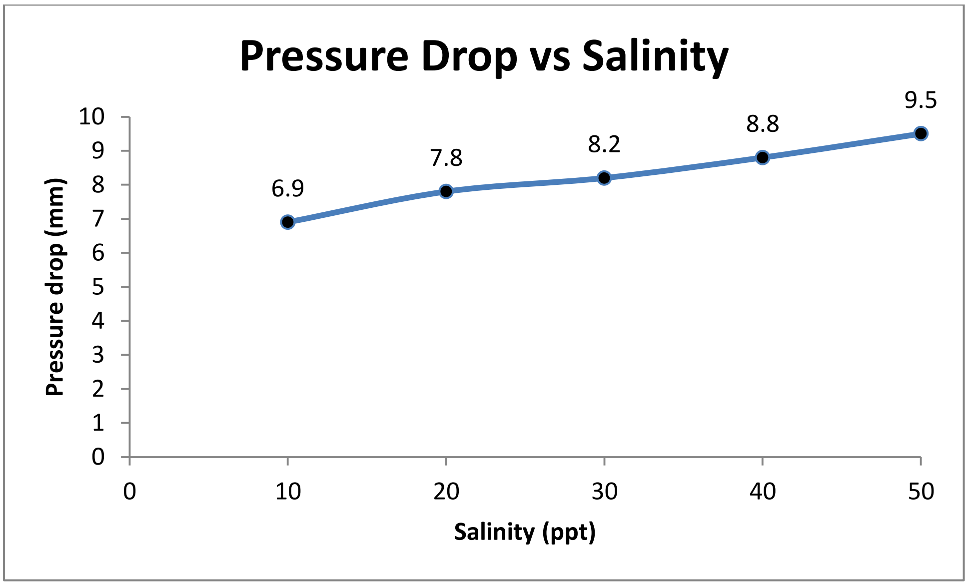


Figure 4.1: Pressure drop vs salinity

Figure 4.1 shows the relationship between pressure drop and salinity. It showed that as the salinity increase, the pressure drop also increase. However, the increasing pressure drop is not so high and significant when the salinity increase. From the graph, the lowest pressure drop is at 10 ppt which is 6.9mm and the highest pressure drop is at 50 ppt which is 9.5mm. Yet, the highest pressure drop is still lower compared to the pressure drop cause by the base case solution in Table 4.1. It indicated that the DRA is still efficient but not completely effective when the salinity increase up to 50 ppt.

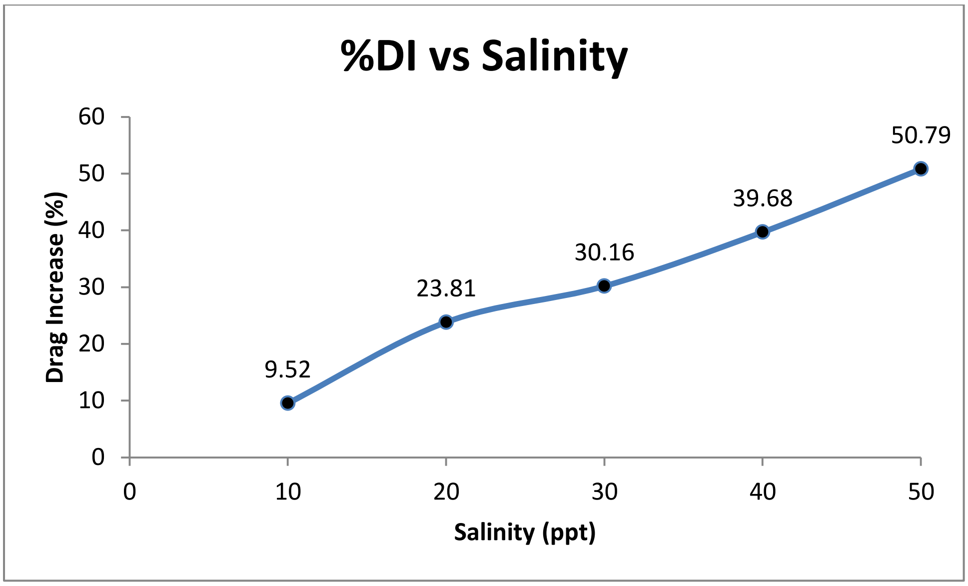


Figure 4.2: %DI vs salinity

From Figure 4.1, it showed that with increasing salinity, the pressure drop increase which indicated that drag is increased. Hence, instead of calculating the percentage of drag reduction, percentage of drag increase will be calculated. Figure 4.2 shows the relationship between drag increase percentage and salinity. It showed that as the salinity increase, the percentage of drag increase also improve. Based on the graph, salinity of 10 ppt give the lowest drag increase percentage which is 9.52% while salinity of 50 ppt give the highest drag increase percentage up to 50.79%. In other word, the performance of the DRA is reduced when the salinity increase. It is occurred due to the chemical degradation because of the level of salinity. The presence of salt concentration in the solution disturbed the DRA molecular structure and causes its drag reducing capability to reduce. This occurrence is agreed with what Choi et al. (2000) stated in their study.

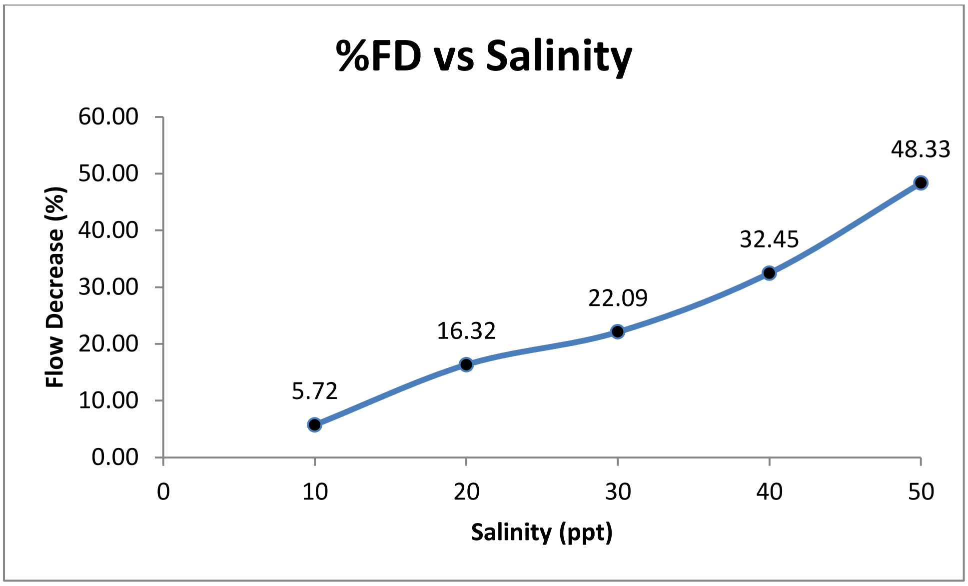


Figure 4.3: %FD vs salinity

Figure 4.3 shows the relationship between percentage of flow decrease and salinity. It showed that as the salinity increase, the percentage of flow decrease also increase. As specified in Chapter 2, to calculate flow increase percentage, drag reduction percentage will be used. Since the result from this study is calculating the drag increase percentage, the flow decrease percentage will be calculated. From the graph shown in Figure 4.3, the highest salinity which is 50 ppt give the highest percentage of flow decrease, 48.33%. On the other hand, the lowest salinity, 10 ppt give the lowest percentage of flow decrease at 5.72%. It is also worth to observe that the graph trends for Figure 4.3 is similar to the Figure 4.2 plot.

4.3.3. Reynolds number

To ensure the DRA is working in reducing the drag and frictional pressure drop, the flow must be in turbulent flow regime (Nre > 4000). The calculation of Reynolds number for each run is crucial to determine the type of flow regime. This part showed the calculation of Reynolds number for each run by using following equation:

$$Re = \frac{\rho v d}{\mu}$$

Where ρ = fluid density (kg/m^3)

v = velocity (m/s)

d = diameter (m)

μ = fluid viscosity (kg/m.s)

Following data were obtained from fluid friction apparatus test:

Flow rate: $1 m^3/hr = 2.78 \times 10^{-4} m^3/s$

Pipe inside diameter: 0.07 m

Area of pipe: $3.85 \times 10^{-3} m^2$

To find velocity of the flow inside the fluid friction apparatus, following equation was used:

$$V = \frac{Q}{A} = \frac{2.78 \text{ x } 10^{-4} m^2/s}{3.85 \text{ x } 10^{-3}\ m^2} = 7.22 \text{ x } 10^{-2}$$

By identifying those parameters, Reynolds number for each flow can be calculated to determine the flow regime. Table 4.3 showed Reynolds number and type of flow regime for each flow for different properties of solution used:

Table 4.3: Reynolds number for each solution

DRA (ppm)	Salinity (ppt)	Fluid density (kg/m^3)	Fluid viscosity (kg/m.s)	Reynolds number	Type of flow regime
0	0	1000	8.94×10^{-4}	5653.24	Turbulent
400	0	1000	8.94×10^{-4}	5653.24	Turbulent
400	10	1004	9.09×10^{-4}	5582.20	Turbulent
400	20	1012	9.27×10^{-4}	5517.42	Turbulent
400	30	1019	9.48×10^{-4}	5432.52	Turbulent
400	40	1027	9.69×10^{-4}	5356.51	Turbulent
400	50	1034	9.93×10^{-4}	5262.67	Turbulent

From Table 4.3, it is verified that all the solution is flowing in turbulent flow regime.

4.3.4. Drag increase percentage calculation

The calculation of drag increase percentage is based on the following equation:

$$DI(\%) = \frac{|\Delta P_b - \Delta P_{salinity}|}{\Delta P_b} \text{ x } 100$$

Where ΔP_b = friction pressure drop with 0 ppt salinity in flowing liquid (base case)

$\Delta P_{salinity}$ = friction pressure drop with different levels of salinity in flowing liquid

4.3.5. Flow decrease percentage calculation

To calculate the percentage of decrease in flow, this equation can be used:

$$\%FD = [(\frac{100}{100-\%DI})^{0.556} - 1] \text{ x } 100\%$$

Where FD = flow decrease

%DI = Percentage of drag increase

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In conclusion, the objectives for this project which are to extract carboxymethylecellulose (CMC) from natural waste materials to be used as DRA and to study the performance of DRA from natural waste materials in different levels of salinity were achieved. For the extraction of CMC, coconut residue had been used as the source of natural waste materials. Several procedures and methods were used to obtain CMC from the coconut residue. Once the CMC sample is obtained, it was tested to determine the potential of it as DRA. From the result, it is proved that the extraction of CMC from coconut residue can be used as DRA when it contributes up to 59.35% of drag reduction percentage. For the study of DRA performance in different levels of salinity, 400 ppm of DRA concentration sample were prepared to be mixed with different salinity solution (10 ppt, 20 ppt, 30 ppt, 40 ppt & 50 ppt) in total mixture of 20 liter. Pressure drop, drag increase percentage and flow decrease percentage had been plotted against salinity. From the result, it was observed that those parameters were increased as salinity increase. Therefore, it can be concluded that CMC extracted from natural waste materials is potential to be used as DRA. However, the effectiveness of DRA will be decreased as the salinity increase.

5.2. Recommendation

Due to time constraint and limitation of equipment, there are several parameters that have not been studied and covered in this project. Thus, some recommendations listed so that this research can be done efficiently and also to reduce the error that may be occurred throughout the project as well as for improvement for the future study. Following are several recommendations that can be made:

1. Use transparent pipeline so that the reaction of DRA can be observed
2. Explore and study the properties of other natural waste materials available that is potential to be used as DRA
3. Study the performance of DRA in the common type of water used in waterflooding
4. Test the DRA in different size of pipeline as drag reduction may varied in different size of pipeline
5. Use different concentration of DRA and observe the drag reduction in different concentration of DRA
6. Determine the effect of DRA on the properties of rock like permeability and porosity

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