Drag Reducing Agent for Water System Using Natural Polymer

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DISSERTATION REPORT

Submitted to the Petroleum Engineering Program in Partial Fulfilment of the Requirements for the Degree Bachelor of Engineering (Hon.) Petroleum Engineering

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

Drag Reducing Agent for Water System Using Natural Polymer (Hibiscus leaves)

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Ahmed Nabil B Zakaria

A project dissertation submitted to the
Petroleum Engineering Programme
Universiti Teknologi PETRONAS
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(PETROLEUM ENGINEERING)

Approved by,

____
(PN. MAZUIN BT JASAMAI)

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CERTIFICATION OF ORIGINALITY

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

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AHMED NABIL B ZAKARIA

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Abstract

The flow of fluid in the pipeline results in frictional energy losses which cause the pressure of the fluid to decrease along the pipeline in the direction of the flow. These will reduce the flow rate of the fluid which is travelling through the pipeline. Therefore, the usage of the drag reducing agents, DRA is important to reduce the frictional resistant in turbulent flow. The elastic property which is also exhibit in hibiscus leaves as well as the commercial DRA, will absorb the energy in the streak which will reduce the turbulence. Thus, the project which the author does for the Final Year Project (FYP) is the drag reducing agent for water injection using natural polymer (hibiscus leaves). This project is to study the effectiveness of hibiscus leaves in reducing the pressure drop and to prove that hibiscus leaves is a potential drag reducing agent to be used in the industry for transporting hydrocarbons in pipeline. It is also a new discovery for cheap alternative to the current commercial DRA in the market as has abundant of resource all over Malaysia. This drag reducing agent is the answer for the problems that arise from the oil and gas industries in the transportation of hydrocarbons.

This is an experiment-base project where the author needed to conduct experiment to acquire the valuable data which is needed to prove the effectiveness of the hibiscus leaves as DRA. The experiment that the author performs is to investigate the effectiveness of the hibiscus concentration as DRA. The experiment is conducted by using an open flow test; where water is being pump from the storage tank to the pipeline, and the natural polymer is injected at the injection point into the flow system where it will mix with the flowing water. The flowing water is then travels through the 12.5m galvanized pipe and passes two pressure gauges which is set at different point of the pipe and finally to the outlet point. The pressure at the two points is recorded during the experiment and the drag reduction, flow throughput and flow rate is calculated.

From the result of the experiment, it is observed that as the concentration of the hibiscus leaves increases the drag reduction decreases, this shows that the hibiscus leaves is more effective at higher concentration compared to lower concentration. The increase in the drag reduction efficiency prove that hibiscus leave have the potential to be drag reducing agent.

Acknowledgement

Alhamdulillah praises to Allah (SWT) for giving me the strength and patient to complete this Final Year Project report entitled Drag Reducing Agent for water system using Natural polymer which is hibiscus leaves. This Final Year Project is prepared for the Petroleum Engineering Department of the Universiti Teknologi PETRONAS (UTP) in order to fulfill the requirement to complete the undergraduate program.

First and foremost the author would like to thank Pn. Mazuin bt Jasamai for giving him the opportunity to work under her supervision and sharing her knowledge related to the project. She also provide guidance and support when the author facing any difficulties during the project. Even though she is busy with her schedule, she will find time for author to discussion and keeping her updated with the author progress in doing the project. Without the generous help from her, it is impossible to finish this report.

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Last but not least, the author would like to give the deepest gratitude to his family for giving him the morale boost throughout the duration of time of the project. There are a lot of obstacles and challenges that the author required to face through in order to complete the project. The author would like to thanks again to the entire person who directly or indirectly giving support to the author in order to finish his project.

Chapter 1

1.0 Introduction

1.1 Project Background

Drag is also known as friction. It is define as forces that oppose the relative motion of an object through a fluid. The transfer of a matter from a point to another point leads to a significant loss in motion potential given an environment as hostile as a pipeline. As a result, the energy loss reduces the flow capacity of the fluid along the conduit. From the definition, drag reducing agent is a chemical additive which is used to reduce or minimize the turbulent flow of a transportation fluid which causes the drop in pressure friction along the pipeline and makes the fluid flow through the pipeline more easily.

a chemical In the oil and gas industries nowadays, fluid such as oil, gas, and water are being transported through hundreds and thousands of kilometer pipeline from the platform to the process facilities and lastly to the consumers. This is because by using the pipeline it is the fastest way to supply the fluid to it desire location as demand by the client. One of the major problems that faced when using the pipeline is the pressure drop along the pipeline due to the drag between the fluid and the pipe wall. In most of the pipeline the hydrocarbons flow in turbulent regime.

The usage of drag reducing agent (DRA) in the oil and gas industries which is added in to the liquid reduce the frictional resistant in turbulent flow. It is also define by Savin (1964) that to increase the pump ability of a fluid by adding certain polymer in the pipeline. DRA interact with the process of the turbulent flow and reduce the frictional pressure loss throughout the pipeline. This will increase the flow capabilities of the pipeline.

Well-known phenomena known as Tom Effect suggested by Toms (1948) stated that the addition of small concentration of high molecular weight polymer to water or other solvent can produce large reduction in frictional pressure drop for turbulent flow hence leading to the possibility to maintain the flow energy resulting increment in pipeline capacities.

The first successful applications of DRA in the industry was in 1965, where guargum were used to reduce the cost of pumping aqueous for fracturing fluid as stated from Pruitt, Simmons and Neil (1965).

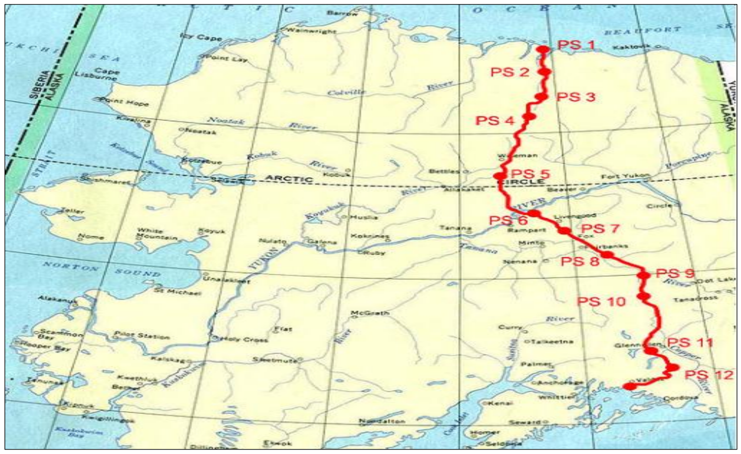

Figure 1 : Picture of TAPS

The usage of DRA in the oil transportation was first used in the Trans- Alaskan pipeline, TAPS where DRA was initially injected in the pipeline at pump station one in in July 1979, which is two years after it start up (Burger, Munk, and Wahl, 1982). With the length of eight hundred miles of pipeline, the capacity of the Trans-Alaskan pipeline flow had increase to 1.5 million barrels per day on the year 1980; with approximately 200,000 barrels per day is the result of injecting a drag reducing agent (Wahl, Beatty, Dopper and Hass, 1982).

Figure 2 : Picture of TAPS

Moreover, there are 11 pump stations located at intervals of approximately 50 to 100 miles. TAPS was firstly designed for 12 pump stations; Pump Station 11 was never built due to the usage of DRA. Only seven pump stations are being operated which is pump stations 1, 3, 4, 5, 7, 9, and 12. Pump stations 2, 6, 8, and 10 were placed on standby in 1996 and 1997, while Pump Stations 7 and 12 may be placed on standby over the next 5 to 10 years (http://tapseis.anl.gov.cfm).

1.2 Problem Statement

This study is to test whether hibiscus leave are possible to reduce the drag force in a pipeline in order to make sure that the oil, gas or water from the well reaches the delivery location at the desire amount with the minimum loss. Long distance of fluid transportation cause a significant problem towards pressure drop along the pipeline, since most of the well is located in a remote area. The high pressure drop which is mostly due to the friction between the fluid and the pipe wall will reduces the volume of oil that is being transported to their desire destination as the fluid travel in a turbulent flow. The turbulent flow has many unique features that must be evaluated in each situation. However, high axial pressure gradient phenomenon is nearly always undesirable in the, resulting large energy usage per unit volume of liquid throughput (Bari, 2011).

The need of booster station to be installed along the pipeline is one of the solutions to reduce the pressure drop along the pipeline. This will make sure that that the fluid in the pipeline is flowing at the desire flow rate to reach their destination. The installation, maintenance and operating booster station will increase the additional capital and operating cost. The economic dictate the size and number of pump station for pipeline is limited. Thus, it will cause the flow rate of the fluid that is being transported to be less than the desire amount of rate.

In order to overcome the problem existing in the transportation of the crude oil by using pipeline, research have been done to increase the maximum flow rate of the fluid by reducing the pressure drop in the line. This is done by reducing the drag of the fluid within the pipeline and increasing the volume flow rate of fluid at constant pressure due to additional of material known as drag reducing agent.

1.3 Objective

The main objectives of the project are:

1. To prove that hibiscus leaves have the potential to be a drag reducing agent.
2. To investigate the effectiveness of the natural polymer, the hibiscus leaves to reduce the pressure along the pipeline.
3. To determie the best concentration of the hibiscus leaves solution to be the drag reducing agent.

1.4 Scope of Studies

In order to limit the scope, boundaries, and parameters of study, two types of variable is establish during the experiment, which is:

1. The manipulated variable
2. The constant variable

The manipulated variables in this study are as below:

1. Four different concentrations of DRA (800, 900, 1000 & 1300ppm).
2. Variable temperature measured using thermometer.
3. Variable pressure measured using barometer.

The constant variable which is set as the limitations are as below:

1. 0.0254 diameter of galvanized iron pipeline with length of 4m.
2. Water is used as the transportation liquid.
3. Types of natural polymer which is Hibiscus Leaves
4. Constant flow rate.

Table 1: Physical properties of water

Water properties @ 25°C	Values
Viscosity ($\mu_{water @ 25°C}$)	0.8973×10^{-3} Pa.s
Density ($\rho_{water @ 25°C}$)	997.08 kg m^{-3}

1.5 Relevancy of the Project

This project is to study about the most suitable natural polymer to be used as the drag reducing agent (hibiscus leaves) with the purpose to reduce the turbulent flow of fluid especially in long distance pipeline such as the Trans-Alaska Pipeline. The usage of the natural polymer as the drag reducing agent will provide an environmental friendly condition as it is biodegradable and will not cause harm to any living creature. Moreover, the abundant of the natural resources in our country give the advantage as it is easy to acquire to do the project.

If the project is successful it will give a huge impact towards the industrial application especially in the long distance pipeline system in transportation hydrocarbon products. This will be an alternative way towards reducing the power loss in transporting the fluid through pipeline, decrease the cost of pumping and also the pump equipment, reduce energy consumption, and lastly it will increase the production of the hydrocarbon. The usage of drag reducing agent will not only improve the flow of the fluid, but it will also reduce the corrosion of the surface equipment. This will definitely reduce the overall capital expenditure (CAPEX) and operational expenditure (OPEX) of the operating company.

Chapter 2

2.0 Literature Review

2.1 Introduction

Drag which is also known as a frictional pressure drop is cause by the flowing or moving fluid contacting with the surface of known solid, such as the inner wall of a pipeline. Drag reducing agent reduce is chemical solution which is injected in to the flowing fluid that will cause the frictional drag reduction in the flow of the fluid in the pipeline. This effect simultaneously reduces the fluid mechanical force (turbulence) that exerts to the wall of the pipeline and improved the efficiency of fluid transportation. DRA provide strong binding to the metal surface of the pipeline wall.

2.2 Types of Flow

Generally there are three types of fluid flow in pipeline which is the laminar, transitional and turbulent flow. The friction pressure experimental in laminar flow cannot be changed unless the physical properties of the moving fluid are changed. In this study, the DRA injected in the flowing fluid supposedly does not change the fluid properties but only interact with the turbulent flow.

The shear stress created in a flowing fluid near a boundary is given by the Newton's law of viscosity:

$$\tau \propto \frac{du}{dy} \dots \dots (1)$$

This shows that the shear stress, τ, in a fluid is proportional to the velocity gradient with the rate of change of velocity across the fluid path. For Newtonian fluid:

$$\tau = \mu \frac{du}{dy} \dots \dots (2)$$

Where constant of proportionality, μ, is known as the coefficient of viscosity.

Reynolds number, Re, which is a non-dimensional number, is used to determine which type of flow that occur in the pipeline:

$$Re = \frac{\rho v d}{\mu} \dots \dots (3)$$

For a pipe:

Laminar flow:	Re<2000
Transitional flow:	2000<Re<4000
Turbulent flow:	Re< 4000

For the value of Reynold's number which is less than 2000 the flow exists in laminar in pipes. With the increase in value of Re number between the ranges of 2,000 to 4,000 the fluid will be flowing in transitional flow. While the Re number is larger than 4,000 the fluid is in turbulent flow and it is fully turbulent when it is above 10,500.

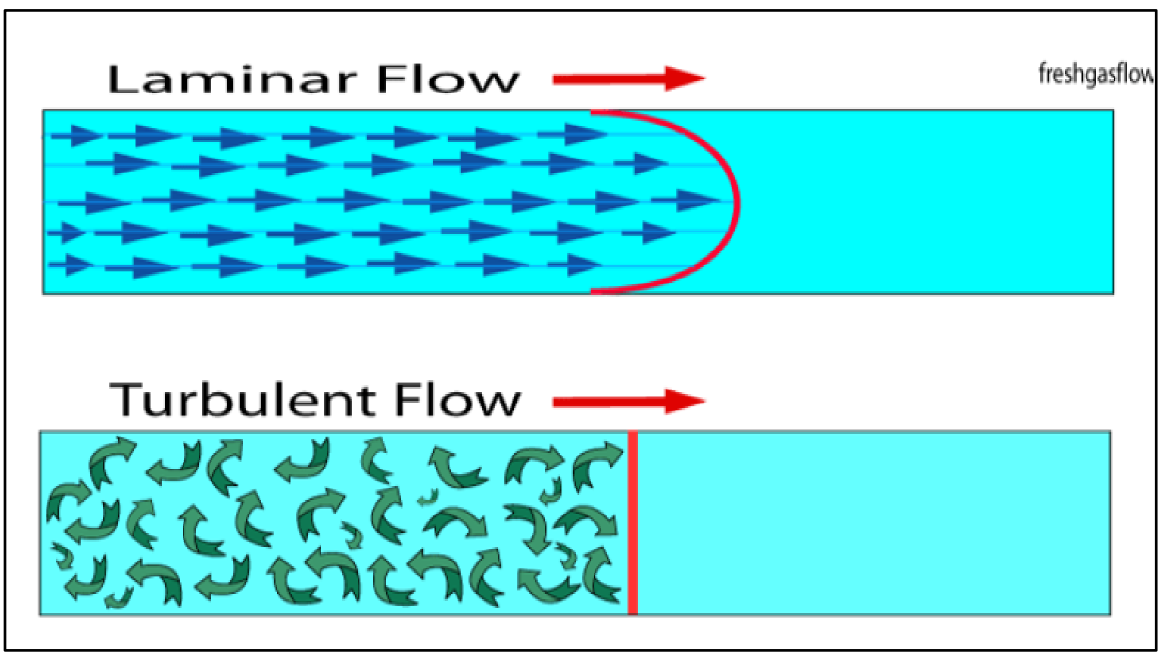

Figure 3: Flow Regime in pipeline

According to Sleigh & Goodwill(2008), it is important to know the flow type as this govern how the amount of energy lost to friction related to the velocity of the flow. And hence how much the energy must be used to move the fluid so that it will arrive to its designated location.

2.2.1 Laminar flow

Laminar flow is defined as steady state flow in which the liquid flows through the pipe smoothly. It can also be consider as a uniform stable streamline flow without any mixing between layers. It is a smooth motion of fluid as the object goes through it. The laminar flow exists in low friction or vicious flow in which no eddies or turbulence exist. Therefore as the flow of the fluid increases and more disturbances due to friction due to frictional pressure loss

2.2.2 Turbulent Flow

When the speed of the moving fluid increases, at one point, the transition is made to turbulent flow. In this flow, unsteady vortices appear on many scales and interact with one another. The flow is also resulted from certain factor such as the surface roughness of the pipeline wall, high velocities, and mechanical waves. This flow causes the loss of energy and thus causing the pressure drop to occur along the pipeline. As stated by Berge & Solsvik, (1996) in general terms, the higher the degree of turbulence (largerN_{Re}) of fluid will result in higher drag reducing performance. Increasing the velocity and decreasing the viscosity enhanced the drag reducing performance.

Flow in pipes is usually turbulent. Random fluctuating movements to the fluid particles are superimposed on the main flow, these movements are unpredictable (Sleigh & Goodwill, 2008).

2.3 DRA Mechanisms

There are several theories that describe the mechanism of DRA. One of the earliest theory states that the stretching of randomly coiled polymer increases the effective viscosity (J. L. Lumley, 1969). This is when the small eddies are damped, which lead to thickening of the vicious sub-layer and thus reduce the drag of the flowing fluid.

Recent theory proposed that drag reduction is caused by the elastic rather than vicious properties (P. G De Gennes, 1990). This is shown when drag reduction in experiment where polymer were active at the center of the pipe where viscous force did not play a role in reduction of the drag.

As stated by Jubran, Zurigat & Goosen (2005), in the very center of the pipeline is a turbulent core where the eddy currents are located and the flows are in turbulent. It is the largest area and which most of the fluid in the pipe. The nearest to the pipeline wall is the laminar sub-layer, where the fluid move laterally sheet in laminar flow. Between the laminar zone and the turbulence core is the buffer zone. This is where the turbulence is formed. A portion of laminar sub-layer called 'streak' occasionally will move to the buffer zone, the streak then begins to vortex and oscillate, moving faster as it get closer to the turbulent core. Then streak become unstable and breaks up as it throws fluid into the turbulent core of the flow, this is known as the "turbulence burst". This bursting motion and the growth of the number of the burst in the turbulence core results in wasted energy.

The Drag reducing agents interfere with the bursting process and reduce the turbulence in the core. The drag reducer absorbs the energy in the streak like the shock absorber, therefore reducing the subsequent turbulent burst. These polymers are most active in the buffer zone as it increases the thickness of the laminar sub-layer to reduce convection heat transfer (Hamouda & Evensen, 2005).

As stated by Mironov, Animisov and Matjukhatov(1985), the longer the polymer will be best suited to break up the turbulence burst during the flow of fluid. The hydrodynamic volume of the polymer is better critical factor than the molecular weight.

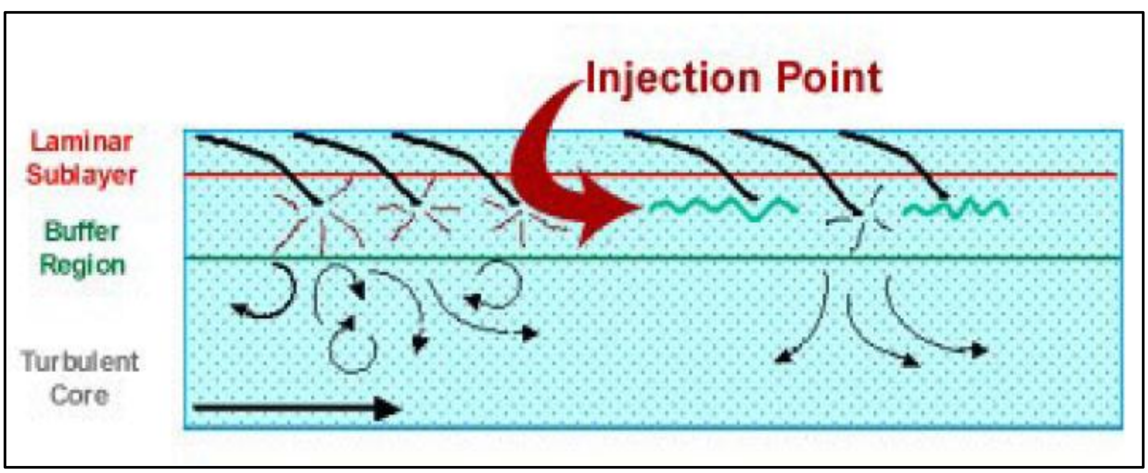

Figure 4 : Turbulent flow process and the injection point

2.4 Usage of DRA in Multiphase well

From the experiment that had been carried out by C. Kang and W.P. Jepson(2000), by using 36m long and 10cm diameter of pipe in horizontal phase system. The DRA effectively reduce the average pressure drop for all superficial liquid and gas velocities in both slug and annular flow with the average pressure drop of 82% for slug flow and 47% for annular flow. He also said that with the increase of superficial liquid velocity the effectiveness for the slug flow decreases. While, the maximum pressure drop across the slug flow in the pipeline reduces with the increase of DRA. The flow pattern changed from slug flow to the stratified flow at superficial liquid and gas velocity of 0.5 and 2m/s by decreasing the slug frequency to 0slug per minute. From the experiment that C. Kang and W. P. Jepson, it is conclude that the effective height of liquid film decrease with the addition of DRA.

2.5 Characteristic of DRA

The use of drag reducers in crude pipelines presents special requirements which is

1. Effective at low concentration. This is because the drag reducers alter the flow behavior and turbulence generation within the treated fluid. It does not coat the pipe wall, although it is near-wall phenomenon. Continuous use in long pipeline operation requires the polymer to be injected continuously. Therefore large amount of chemical additive are required even at low concentration.
2. Shear-stable during line flow. DRA are characteristically long-chain polymer causing the higher molecular weight polymers to outperform identical but lower molecular weight polymers. In dilute solution, the molecules degrade seriously by the high shear level within the pump line. In this scenario concentrated additive needed to be injected downstream of the pipeline booster pump. The diluted polymer must be stable when subjected to turbulent shear force existing within the pipe as the crude travel to the next station.
3. Must not cause any downstream refining problems. Increased in the amount of fluid flow is not economical if the treated crude causes refinery problems which lead to increase in the cost of maintaining and repairing the surface equipment will be increasing.

4. The drag reducing agent is best to have elastic in properties in order to absorb the high energy that exists in the streak which will cause turbulent burst.
5. Ultra High Molecular Weight are the most effective drag reducing agent as it has long chain polymer which is best to break the turbulent burst. High molecular weight improves the drag reducing performance but the disadvantage stated by Brostow (1983) is that it has high polymer degradation. Hunston (1976) had concluded that the drag reduction and degradation depend mostly on molecular weight distribution.

2.6 Theory

DRA concentration is calculated on total volume basis as follows:

$$VO_{DRA} = \frac{c_{DRA} \times V_{TL}}{1 \times 10^6} \dots \dots (4)$$

V_{TL}=total liquid velocity, m/s C_{DRA}=DRA concentration, ppm VO_{DRA}=DRA volume,m^3

The effectiveness of the drag reducer is expressed in terms of percent drag reduction (%DR) at the given flow rate.

$$\%DR = \frac{\Delta p - \Delta p_p}{\Delta p} \times 100 \dots \dots (5)$$

Where Δp is the base pressure drop of the untreated fluid and Δp_p is the pressure drop of the fluid which containing the drag reducing agent.

2.7 Entrance Length

The entrance length is the point where the DRA is injected in to the pipeline. The best entrance length is at the point which the fluid flow in the pipeline has been fully developed in to turbulence flow. This is because the DRA work best in turbulent flow to reduce the pressure drop. Given is the formula for the entrance length:

$$E_{Lturbulent} = 4.4Re^{1/6} \dots \dots (6)$$

Chapter 3

3.0 Methodology

3.1 Research Methodology

Below are the work flows of the project showing from the starting of the project which is the Selection of topic until the end of the project which is the conclusion:

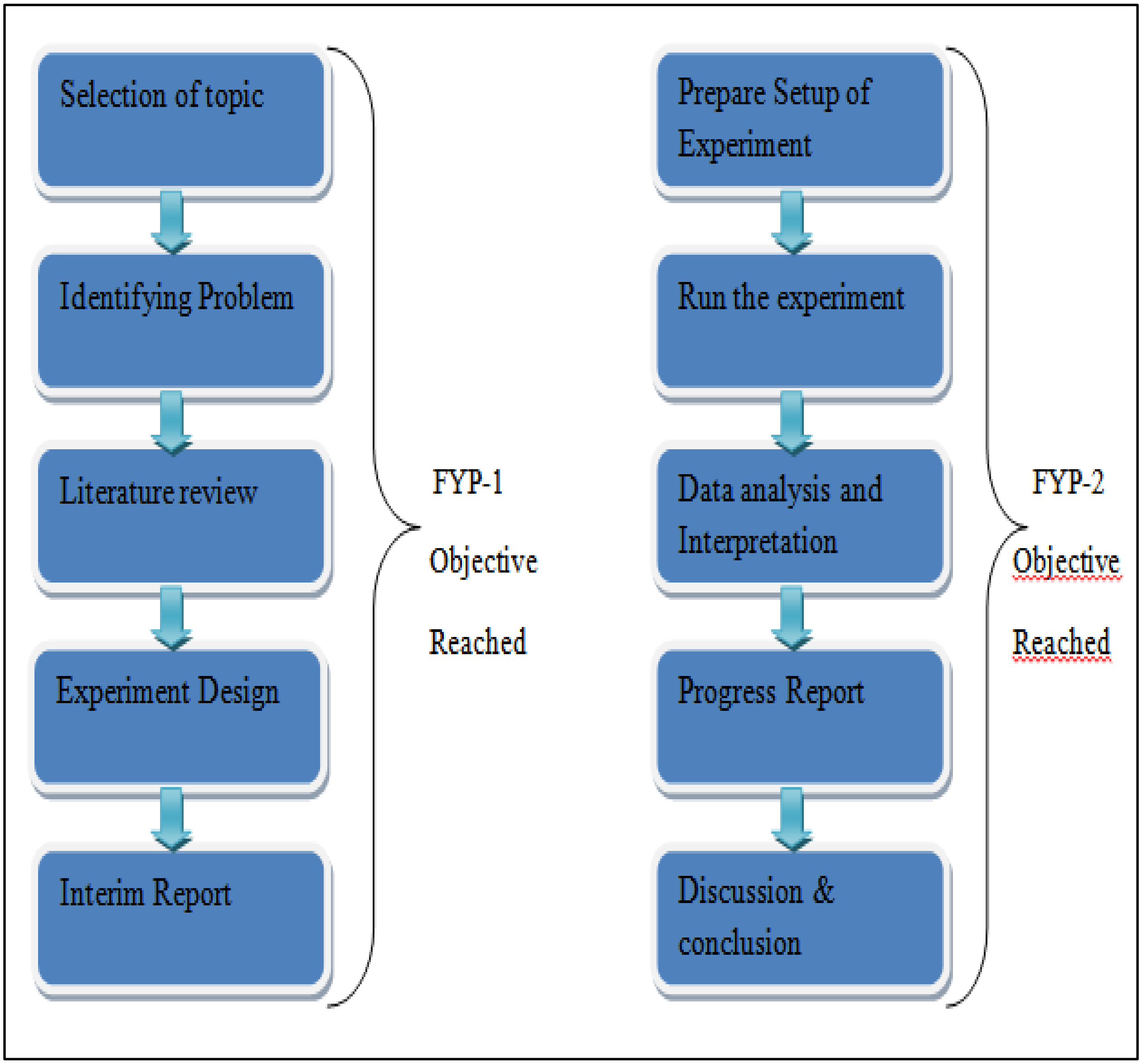

Figure 5 : Flow chart of the Project

The Project started off with the selection of project during FYP-1 which the author proposed a topic of the project which is the Drag reducing agent in water system by using the natural polymer; hibiscus. The project is unique due to the first research done for drag reducing agent by using hibiscus leaves due to its ability to reduce pressure drop in pipeline. Next stage is to identify the problems that exist in the transportation of fluid in pipeline in the industry, where it is found that the main reason of the drag is due to high pressure drop across the pipeline. Then in the literature review, the author does study and review journals, articles and books related to the project proposed for deeper understanding of the concept involved and for experiment purpose. Some of the study that the author had done is on the turbulent flow of fluid, the mechanism of drag reducing agent, the entrance length, and etc. After finishing with the literature review, then went to the experiment design. This is where the author needed to design the procedure of the experiment and prepare on the equipment and chemicals needed to be used during the experiment. This stage consists a lot of time due to the chemical and some materials needed to be ordered from the third party. At the end of FYP-1 interim report had to be done to be submitted to the FYP-1 coordinator.

At the starting of FYP-2, all of the equipment had arrived in UTP, and the project is continued with the preparation of setup of the experiment. After all the setups have completed, the pilot run of the experiment is done. It is a dry run in which there is no injection of DRA into the pipeline. Then the experiment is continued with the first concentration of hibiscus leaves which is 800ppm until the last concentration of hibiscus which is 1300ppm. The data of the experiment which is the pressure and the flow rate of the fluid passing through the pipeline are recorded. Then, all of the data is analyze and interpret for making the conclusion of the project.

3.2 Experimental Methodology

There are two procedures that needed to be done in order to complete the project:

3.2.1 Preparation of the natural polymer solution:

Below are the steps in preparing the hibiscus leaves solution which will be used in the open flow test experiment.

1. The hibiscus leaves is hand pick from the flower park inside the campus.

2. Then 800g of leaves is weighted by using the digital weighing scale machine.

3. After that, the leaves are crushed by using the stone mortar until it becomes mucilage.

4. Add a few amount of water in the container of the stone mortar and stir it slowly, until the pulverized leaves well mix with the distilled water.

5. Make sure that the pulverized leaves don't left in the container of the stone mortar.

6. The mixture is then poured in to the beaker, before adding the distilled water until it reaches the 1000ml.

7. Then put 5 drops of formaldehyde, and then stir the solution by using the magnetic stirrer for 30 minutes.

8. Once complete, filter the solution by using muslin cloth to separate the big colloid from the solution.

9. Repeat the procedure by changing the mass of the leaves in order to create series of DRA solution concentration.

Table 2 : Concentration of DRA

Mass(g)	0.8	0.9	1.0	1.3
Concentration (ppm)	800	900	1000	1300

3.2.2 Flow test experiment

The laboratory experiment will be done by using the open flow test system. The main part of the system consist of the water pump, cylinder galvanized iron pipe, water tank, sump tank, pressure gauge and the injection point. The injection point of the DRA is situated after the water pump. Two pressure gauges are installed along the pipeline, one is situated near the injection point and the second pressure gauge is situated at the end of the pipe. This pressure gauge will read the pressure drop along the pipeline.

Below are the procedures in doing the open flow test experiment with the addition of hibiscus leaves solution as DRA:

For dry run; no addition of DRA

1. Before starting the experiment, filled up the water tank with tap water. Make sure that valve 1 and 2 are closed.

2. The experiment begins when the pump is switch on, and the valve 1 is open. This is to allow the water to flow from the water tank to the sump tank through the 4m galvanized pipe.

3. The pressure at both pressure gauges are recorded during the experiment while the time is taken for the water to fill the sump tank until it is full.

5. Then the flow rate and the pressure are recorded in the table given.

For DRA run:

1. Closed valve 1 and filled the water tank with tap water until it is full.

2. Open the valve 3 while closing the valve 2, pour 1litre of 800ppm DRA (hibiscus leaves solution) into the injection point.

3. After finish pouring, closed the valve 3 and ready to start the experiment. Make sure that the entire valve is closed before proceed to next step.

4. The experiment begins when the hydraulic pump is switch on and valve 1 is open. This is to allow the water to flow from the water tank into the galvanized pipe.

5. Let the valve 2 open to let the DRA mix with the flowing water soon after the water pass through the hydraulic pump.

6. The pressure drop reading is recorded during the experiment, and will be compared to the pressure drop reading for the dry run.

7. The procedure 1 till 6 is repeated for each concentration; 900ppm, 1000ppm, and 1300ppm to test its effect on the drag reduction operation.

8. The pump is switched off after getting the entire pressure drop for the entire concentrations.

9. Tabulate and plot the recorded data

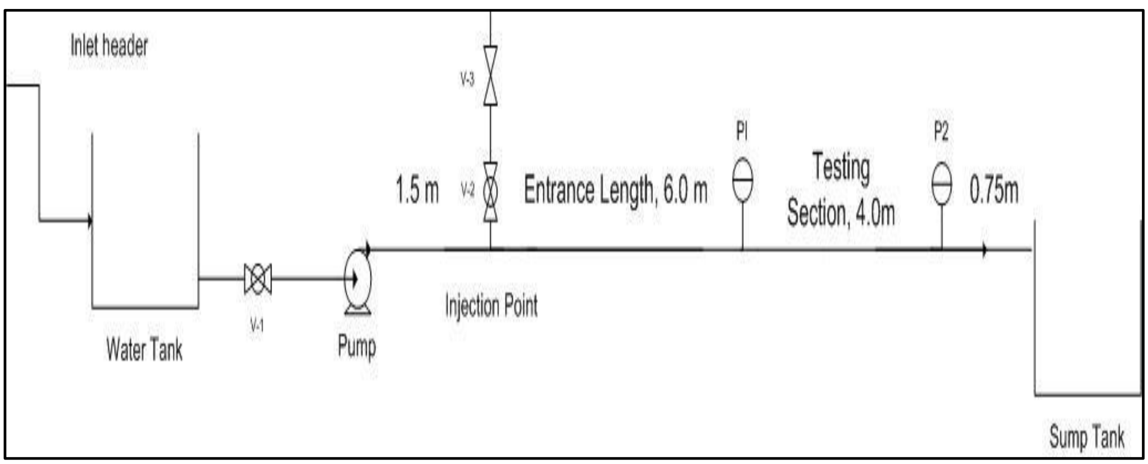

Figure 6 : Schematic Diagram

3.2.3 Experiment Apparatus

Figure 7: Hydraulic pump

Figure 8: Galvanized pipe

Figure 9: Water Tank

Figure 10: Injection skid

3.3 Material, equipment and tool

3.3.1 Tool for experiment

1. Water Pipeline
2. Pressure gauge
3. Water tank
4. Sump tank
5. Water pump
6. Magnetic stirrer
7. Digital weighing scale machine
8. Pulverized rock
9. Density meter

3.3.2 Material used in experiment

1. Distilled water
2. Tap water
3. Hibiscus leaves

3.3.3 Chemical for experiment

1. Formaldehyde

Figure 11: Stone mortar

Figure 12: Stirring plate

3.4 Key mile stone & Gant Chart

Table 3 ; Key Mile Stone & Gant Chart

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■	Mid-Semester Break								
2	Submission of Progress Report									●							
3	Project Work Continues									■	■	■	■	■			
4	Pre-EDX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation (soft bound)														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation (Hard Bound)																●

● Suggested milestone

■ Process

Chapter 4

4.0 Result and Discussion

4.1 Experiment Calculation

Percentage drag reduction

Pressure drop reading which is recorded throughout the experiment, before and after the drag reducing agent additions, is to calculate the percentage of the drag reduction, $\%DR$ as shown in the equation below:

$$\%DR = \frac{\Delta P - \Delta P_{DRA}}{\Delta P} \ x\ 100 \ldots \ldots (5)$$

Percentage of the flow increase

The percentage drag reduction is needed to calculate the percentage of the flow (or throughput), as shown in the equation below:

$$\%FI = \left\{ \left[\frac{100}{100 - \%DR} \right]^{0.556} - 1 \right\} x\ 100 \ldots \ldots (7)$$

From the experiment conducted in the lab, below are the data that shows the results of the experiment.

Table 4 : Result of experiment

Concentration (ppm)	Average Pressure Drop(psi)	Average Flow Rate(gpm)	%DR	%FI
0	13.5	28.53	0	0
800	9.5	36.81	29.63	21.58
900	8.5	37.91	37.04	29.33
1000	8	38.55	40.74	33.77
1300	7.75	39.22	42.59	36.15

4.2 Data Analysis

Table 4, shows the result of the experiment which have been done by using the open flow test. The zero concentration of hibiscus leaves indicate the dry run of the test without any hibiscus leave being injected into the pipeline. It has the highest pressure drop of 13.5 psi across the pipeline; this is due to the high friction pressure exerted by the flowing fluid, which cause the fluid to flow in turbulent form. The lowest average flow rate also recorded at the dry run with the value of 28.53gpm due to the loss of fluid in along the pipeline.

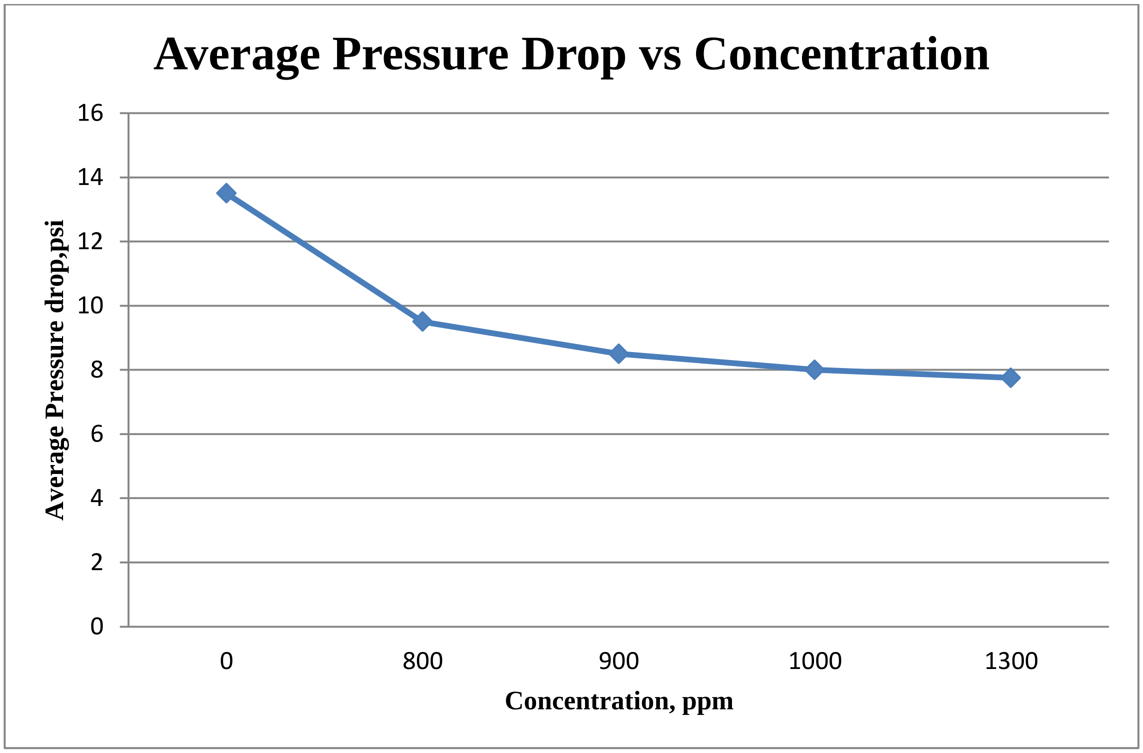

Figure 13 : Pressure drop vs Concentration of Hibiscus DRA

Average pressure drop shows the different of pressure between two points along the pipeline due to the effect of the concentration of the hibiscus leaves. The high pressure drop along the pipeline at zero concentration (dry run) is mainly due to the turbulent flow of the flowing water inside. The result of injecting the hibiscus leaves solution at the injection point into the pipeline can noticeably be seen by the reduction of pressure drop from 13.5psi to 9.5psi at 0ppm to 800ppm. From the figure above it is observed that there is small reduce in the average pressure from one point of concentration to the other point after the hibiscus leaves solution is injected into the pipeline. As the concentration of the hibiscus leaves increases the average pressure drops of the flowing water decreases. The curve show a steep descending from 0 to 800ppm while from 800 to 1300ppm shows gradually descending curve. The hibiscus drag reducing agent polymer interferes with the bursting process of the streak which results in reduction of the turbulence in the core. It absorbs the energy possess in the streak similar as the shock absorber from producing the turbulent burst (A. A. Hamouda and F.S Evensen, 2005). As conclusion the concentrations of hibiscus DRA affect the average pressure drop of the flowing water in the pipeline.

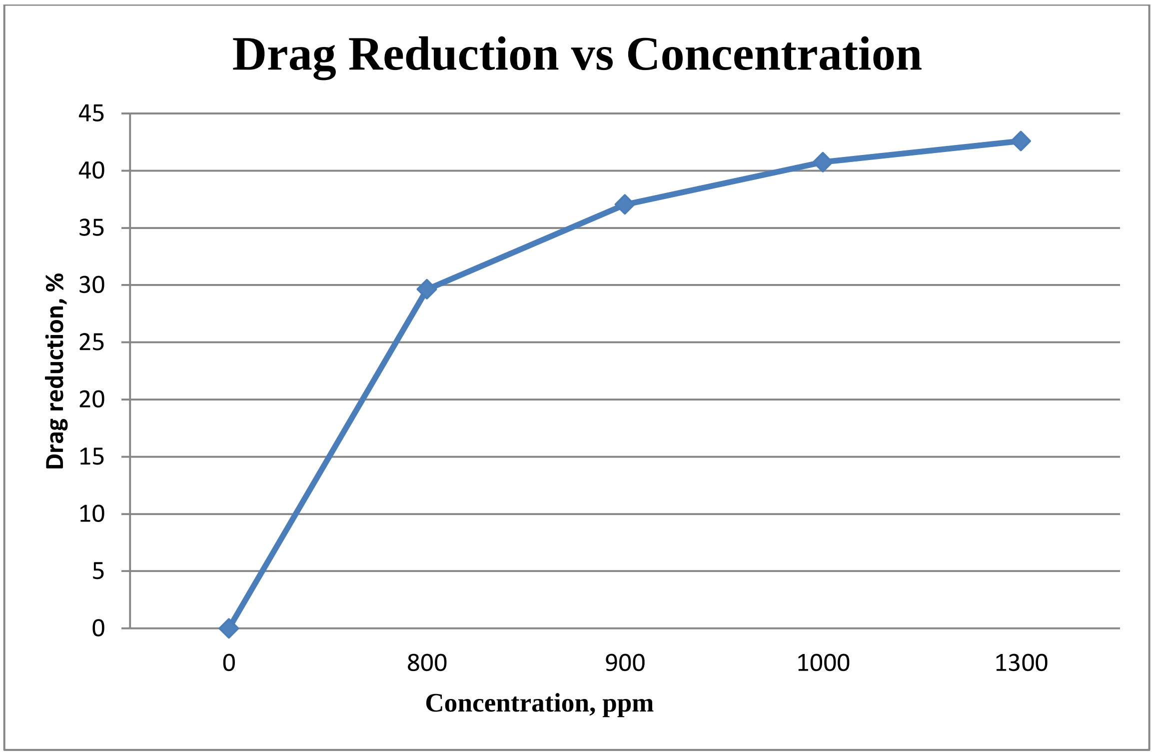

Figure 14: Percentage of Drag Reduction vs Concentration of Hibiscus DRA

Figure 14 shows the graph of percentage drag reduction against the increasing of concentration of Hibiscus DRA. Percentage of drag reduction shows the effectiveness of the drag reducing agent in reducing the drag inside the pipeline. The highest percentage of drag reduction is at 42.5% at 1300ppm, while the lowest is 29.6% at 800ppm when the hibiscus leaves solution is injected into the pipeline. From the graph the drag reduction increase rapidly when first concentration of hibiscus leaves which is 800ppm is injected into the pipeline. Then the pattern of the line shows a steady increase of the drag reduction as the concentration of the hibiscus leaves increases from 800ppm to 1300ppm. This shows a positive improvement of the flow of the water inside the pipeline with the additional of concentration due to low pressure drop across the pipeline. High concentrations of hibiscus leaves have the highest percentage of drag reduction due to the high amount of polymer in it. The high amount of polymer manages to alter the flow behavior and the turbulent generation, therefore reducing the pressure drop between two points in the pipeline. The higher the drag reduction across the pipeline the better the DRA will be.

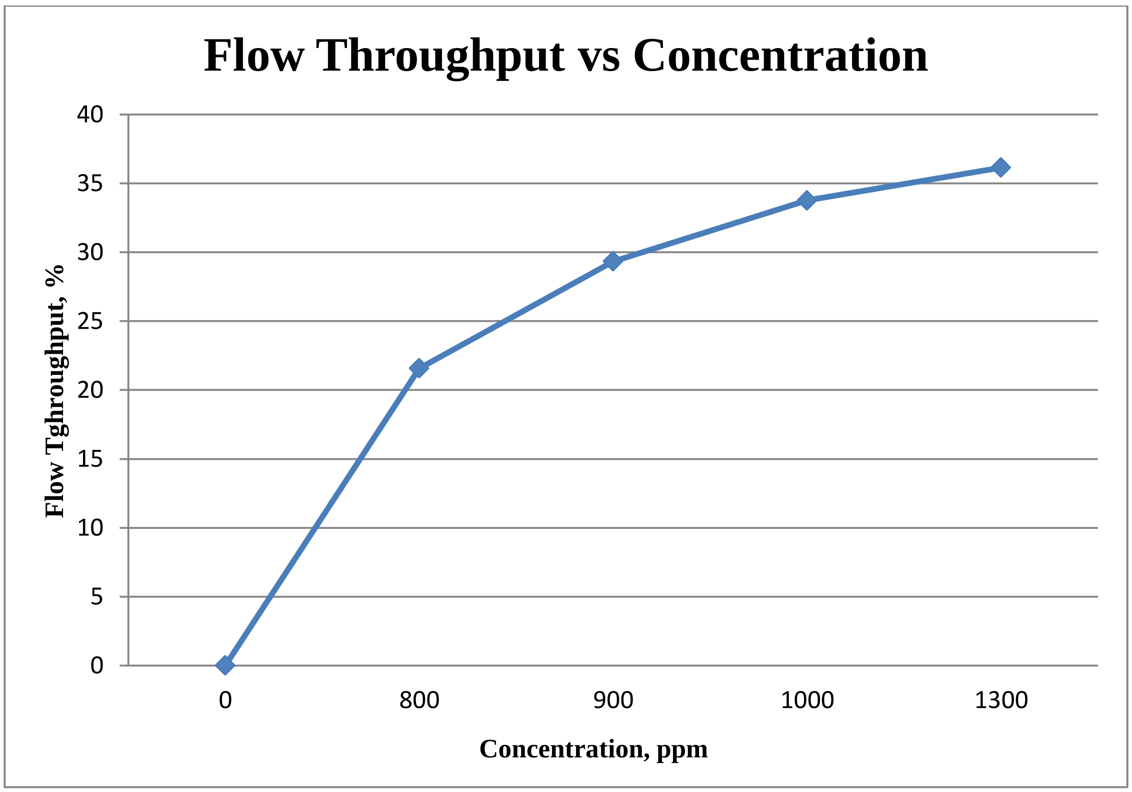

Figure 15 : Percentage of Flow Increase vs Concentration of Hibiscus DRA

Flow throughput shows the increment of the flowing fluid in the pipeline due to the influence of the concentration of the hibiscus DRA. From the observation of the graph in figure 15, the flow increases as the concentration of the hibiscus DRA increases. The line from the graph shows that the percentage flow increases gradually from the 800ppm to 1000ppm and slightly reduces in gradient of the line as it approaches the 1300ppm. The smallest percentage increment can be seen at the hibiscus concentration of 800ppm with the value of 21.6%, and the highest is at the concentration of 1300ppm with the value of 36.1%. The high percentage of flow increase at 1300ppm is due to the high amount of flowing energy that still exist in the water as result from the hibiscus DRA which have reduce the frictional energy loss created by the turbulent flow and also the wall of the pipeline. Therefore, the high concentrations of hibiscus leaves give affect toward the flow increase in the pipeline.

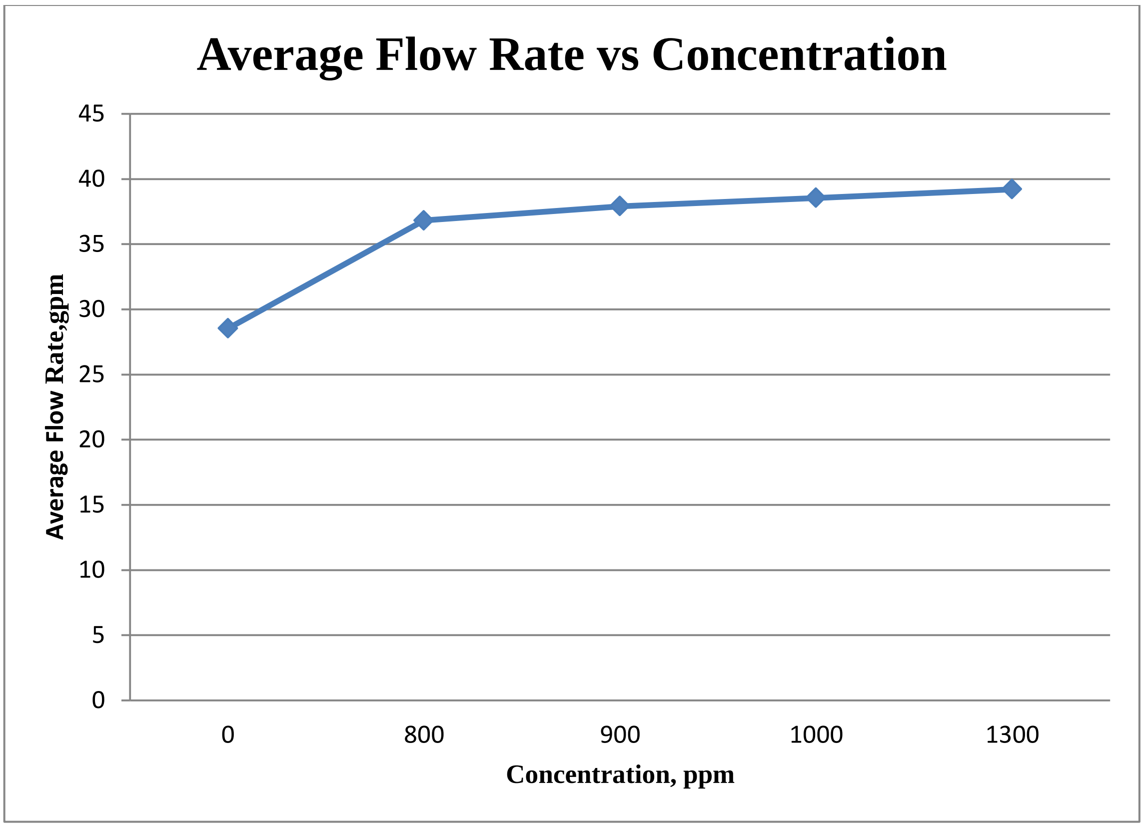

Figure 16 : Average Flow rate vs Concentration of Hibiscus DRA

Figure 16 shows the average flow rate of the water flow in the pipeline versus the concentration of the hibiscus DRA. From the graph, it is observed that the average flow rate increases rapidly after the hibiscus DRA is injected into the pipeline. The higher the amount of flow rate will result in better flow assurance. The trend for the graph as witnessed is the increase in the amount of flow rate as the concentration of the hibiscus DRA increases; with the highest average flow rate at 1300ppm with value of 39.2gpm and the lowest is at 800ppm with the value of 36.8gpm.The average flow rate increase with the increase in concentration of the hibiscus DRA due to the high energy of the flowing water, less turbulent flow and small pressure drop along the pipeline. Therefore, high concentration of hibiscus DRA improves the flow rate of the water in the pipeline.

From the four graphs shown above, the hibiscus successfully reduces the pressure drop of the flowing water along the pipeline by altering the flow behavior and reducing the turbulence generation. Thus, allowing high energy flow to be retained from the starting point of the delivery to the end point of delivery, and to maximize flow efficiency of the water in the pipeline

4.3 Data comparison between aloe-vera natural polymer and hibiscus leaves natural polymer.

The result of the drag reducing agent for water system by using aloe-vera is been compared to the drag reducing agent for water system by hibiscus leaves. This comparison is done due to the same type polymer that is used as the drag reducing agent which is the natural polymer. Both of the plants are abundant in resources in Malaysia and have the jellification effect which reduces the pressure resistance that exists during the flow of water along the pipeline. Both of the experiments were done with the same amount of concentration of the natural polymer which starts at 800ppm, 900ppm, 1000ppm, and 1300ppm. Below are the graphs that show the comparison between the aloe-vera solution and hibiscus leaves solution.

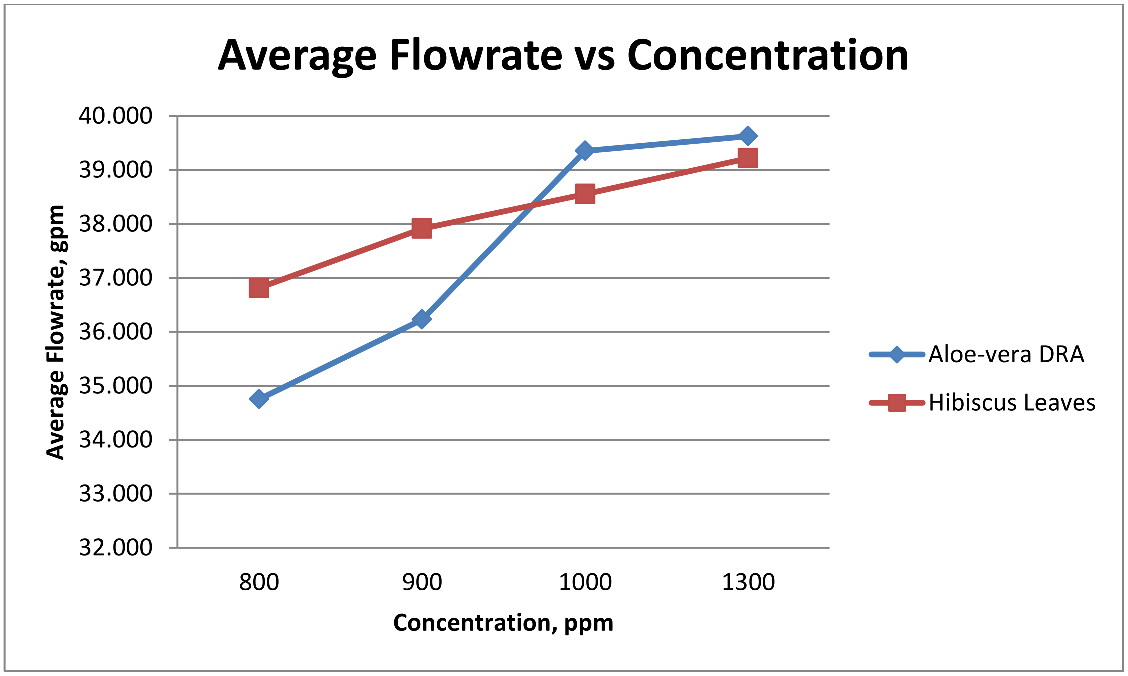

Figure 17 : Average Flowrate vs Concentration graph

The average flowrate vs concentration graph shows that as the concentration of the solution increases the average flowrate of the flowing water increases. From detail analysis we can see that the concentration of the solution of hibiscus has a higher flowrate as compared to aloe-vera at the concentration of 800ppm to 900ppm (low concentration). As the concentration of the solution increases from 1000ppm to 1300ppm it is shown that the aloe-vera flowrate increase rapidly and having a higher flowrate as compared to the hibiscus. The stability of the hibiscus solution can be clearly seen from the graph, as there is no data fluctuation along the concentration from 800ppm to 1300ppm. For the aloe-vera solution, significant changes in data behavior have been observed along the concentration of 800ppm to 1300ppm. This gives rise to incorrect data prediction for extrapolated concentration values as the behavior might not possess such linearity.

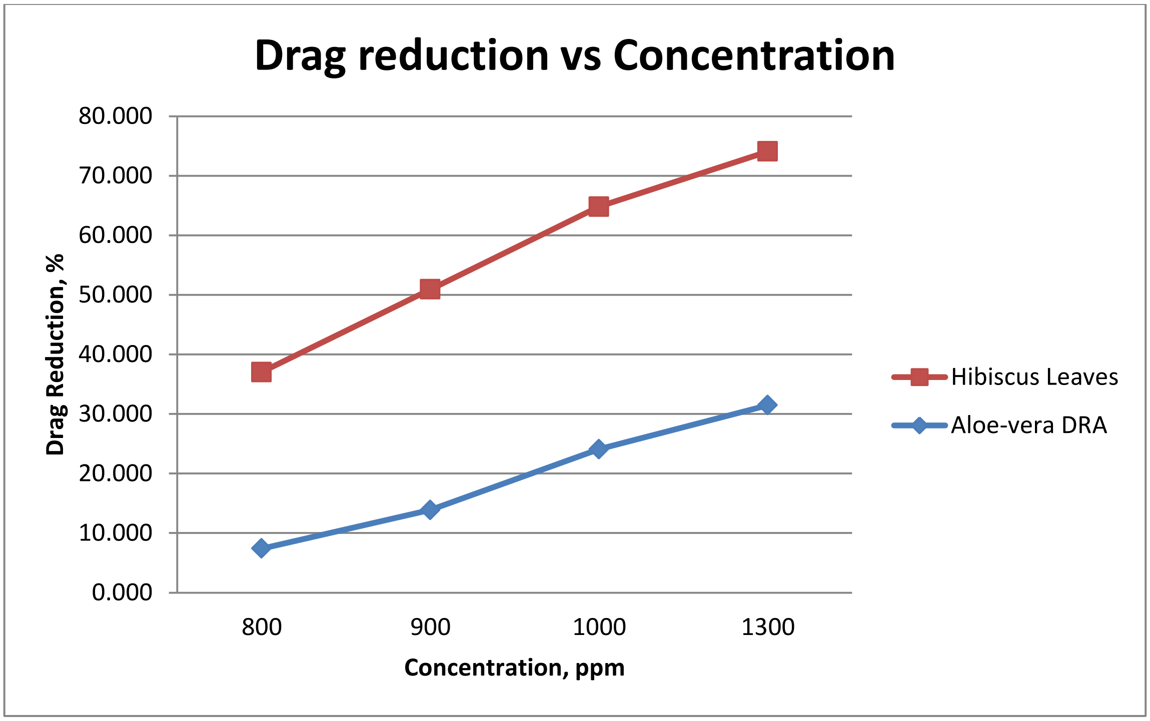

Figure 18 : Drag reduction vs Concentration

From the graph above, it is observed that the drag reduction for both solutions is significantly different. The hibiscus leaves clearly shows that it has better drag reduction as compared to the aloe-vera. The minimum drag reduction for aloe-vera at the same concentration is only 7.4% as compared to the hibiscus leaves which record a drag reduction of 29.6%. The difference of the drag reduction for the hibiscus leaves and the aloe-vera at the concentration of 1300ppm is 11.1%. Therefore from the above graph shows that the hibiscus leaves has a better drag reduction capability as compared to the aloe-vera.

Chapter 5

5.0 Conclusion

The experiments have been carried out to investigate the effectiveness of hibiscus leave as drag reducing agents in water system. The flow characteristics such as pressure drop drag reduction (%DR), flow throughput increase (%FI) and flow rate with DRA concentration of 800ppm, 900ppm, 1000ppm, and 1300ppm has been studied.

This is the first time hibiscus leaves which have been used as the drag reducing agent for study purpose, as previously research has done only with the okra mucilage and aloe-vera which both have high amount of natural polymers as the hibiscus leave. From the experiment and the literature research that the author have done, it is proven that hibiscus leaves have the potential to be a commercial drag reducing agent. This is because it is able to reduce the pressure drop along the pipeline up to 42.6% at the concentration of 1300ppm. Low pressure drop along the pipeline give a significant affect towards the flow rate of the fluid. It is observed that the reduction in pressure drop improve the flow rate of the fluid in the pipeline.

Furthermore, hibiscus leaves prove to be a better drag reducing agent from the comparison between the hibiscus leaves and the aloe-vera. This is shown from the graph of drag reduction versus concentration graph where hibiscus leave has almost 11.1% more drag reduction as compared to the aloe-vera.

5.1 Recommendation

There are some recommendations needed to be done in order to further improve the result of the experiment. First, it to improve the setup for the open flow test by using a proper water tank and the sump tank which have a measuring scale. The water pump also needed to be change as it is not functioning at the best state as it gave fluctuating result. The analog pressure gauge needed to be changed with the digital pressure gauge for better accuracy in reading the value. The experiment should also been done at different operating temperature and pressure, as this element can affect the drag reduction during the operation. If all of the recommendation is being done, the result of the experiment will be more accurate and can give a big contribute towards the oil and gas industry.

In the future experiment, the author would like to suggest that all of the properties of the natural DRA are taken such as the viscosity, elasticity and the density. These properties can be used for comparing to the existing commercial DRA. Furthermore, it can also be used in the calculation of the Reynold's number.

Nomenclature

ΔP= pressure drop, psi.

ID= inside diameter, m.

DRA= drag reducing agents.

ppm= parts per million.

gpm= gallon per minute

Chapter 6

6.0 References

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