SELECTED INDONESIAN MICROBES POTENTIALS FOR MEOR

by

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ABSTRACT

Oil recovery can be increased through the activities of microbes in a process known as Microbial Enhanced Oil Recovery (MEOR). MEOR technology has been implemented in a number of oil producing companies and has proven to have a good prospect, environmentally friendly and low cost.

The microbes which proliferate in Indonesian oil fields should be subjected to laboratory identification. Samples of formation water, oil, and soil were taken from various oil fields. These oil fields were selected on account of their reservoir temperatures which promise optimum growth of microbes. In order that MEOR can be applied in these oil fields, the existing microbes in their oil wells were isolated and identified.

Based on the results of isolation and identification activities several indigenous bacteria species were obtained from the oil well environment. The potential of each bacteria species for use in MEOR process depends on their ability to live and grow in the reservoir environment as well as the bioproducts produced, such as biosurfactant, bioacid, and biosolvent. The bioproducts produced depend on the inherent capability of the isolate as well as the support of the medium and environmental condition.

From the tests of their capability to grow in hydrocarbons, and live in semianaerobic condition, 12 isolates, were selected and some isolates were found to produce such bioproducts. The selected microbes and nutrient have been experimented by using microbial core flooding apparatus. The result has a good prospect for implementation in the oil field.

I. INTRODUCTION

Research groups in many countries have conducted studies of enhancing oil recovery by means of various media such as gas, steam, water, chemicals and bioproducts. The approach in general, is to effect improvement to the physical-chemical characteristics of reservoir fluid and rocks.

The technology which is currently being developed for improvement of reservoir fluid and rocks is the Microbial Enhanced Oil Recovery (MEOR) techniques in which microbes are activated, either in-situ or ex-situ, to produce bioproducts or microbial mass which may effect enhanced oil recovery from the reservoir.

The research object was to find a number of dominant microbes in the oil well and to determine their characteristics for future study and studying the conditions of the substrate from which the microbes were isolated.

It is carried out in the laboratory and includes the following activities; a) isolating and identifying the microbes from various oil wells, b) studying and testing the media (nutrients) which are suitable for the selected microbes. The object of this activity test was to find several potential microbes and their suitable media for use in microbial core flooding test.

In preparation of the microbial core flooding test, the potential microbes were tested with respect to their growth, bioproducts, and their selected media. The bioproducts were tested for their capability in reducing interfacial tension, acidity, and viscosity. The results of the study indicated that the MEOR technology which is now being developed has a good prospect for implementation.

The application of MEOR technology has promising prospects since it is supported by; a) simple technology and equipments which are easy to operate, b) the process can be easily monitored, c) it is environmentally friendly and does not cause pollution, d) it is low cost

water were not very high, being 3-11‰.

Nearly all reservoirs in Prabumulih oil field, such as Tanjung Miring Timur, Limau Barat, and Belimbing consisted of sandstone and had paraffinic oil. They were quite deep i.e. 1,200-1,656 MBDF so that they had quite high temperature (86-112°C) and pressure (32-125 atm).Their formation water had quite high salinity, being 17-20‰.

After applying the oil field criteria as described above, the oil wells were selected based on the following reservoir parameters:

Remaining Oil Saturation. Large quantity of remaining oil will assist the microbes to enter and distribute in the pores of the reservoir rock. The process will assist oil recovery. The lowest level of remaining oil that can be recovered by MEOR application is 25%.

Distance Between Wells. The flow into the wellbore is radial in nature; beyond the outer limit no fluid can enter the radial system. The quantity of gas produced by the microbes assists in maintaining the pressure in the system. Too close distance between wells will cause interference and affect production. The distance between wells should not be more than 40 acres.

Well Base Temperature. For MEOR application, the well temperature should such that allow the microbes to grow and proliferate, and quickly produce metabolites. Certain thermophilic microbes can grow well at a temperature of 55-85°C. The experiments were limited to temperature of 57°C, so that the wells selected for field test should be those which have a temperature of 57°C. If MEOR injection is planned to wells with higher temperature, then laboratory tests should be first conducted at that temperature.

Depth of Reservoir. The deeper a reservoir, the higher its temperature. Very high pressure would not only modify the morphology of the microbes, but also influence their metabolism mechanism, which may result in inhibiting or stopping their growth. Therefore the depth of the reservoir should be limited to 8000 ft or 2438 m.

Salinity of Formation Water. Besides inhibiting microbial growth, too high salinity would exerts pressure on the electrically charged double layer between the surface of the rock and the bacteria, and this increases their adhesion, and thus hampers the transportation of the bacteria in the oil reservoir. The composition and concentration of the salts are important in determining the type of microbes which are compatible with the condition. Generally the NACl concentration that can be tolerated is no more than 10%.

Trace Minerals. Trace minerals such as As, Hg, Ni and Se concentrations should not be more than 10-15 ppm. Higher trace mineral contents would limit microbial growth.

Permeability. Microbe cells should flow through the reservoir layers which still contain oil and produce metabolites there. The contact between the metabolites and oil would eventually result in more oil flowing in the reservoir pores towards the wellbore. Low permeability would limit microbial penetration. Good oil flow and microbial penetration would occur, if layer permeability is no less then 50 md.

Oil Gravity. Crude oils with higher gravity than 15° API have hydrocarbon chains that can be used by the microbes as their carbon source. At this situation the microbes will become active and produce bioproducts that will be useful for enhancing oil recovery.

Isolation and Identification of Bacteria. To obtain isolates of bacteria from an oil field, samples must be taken from oil field environment. Samples that represent oil field environment can be those of formation water, crude oil, or soil collected near the wellhead. From the isolate taken from such sample, a pure culture can be prepared and bacteria presence can be determined. Each pure isolate was then identified to determine the type of bacteria.

Isolation of Bacteria. Prior to isolation the samples were prepared for the purpose. Crude oil and soil samples were first extracted with water. Formation water samples, on the other hand, being already a suspension of microbes needed no prior extraction. Isolation of microbes was then conducted from the suspension. Inoculation was made and each one was incubated at temperature of 30°C and 55°C for a period of 24–48 hours, until colonies were observed.

Identification and Determination. A number of bacterial isolates had been obtained from the activity. To differentiate the isolates from one another, identification and determination procedures were applied to each isolate. The genus/species of each bacterial isolate was determined. This was done by observing the morphology and testing the activity of the bacteria by various treatment. Isolate identification and determination were based on the macroscopic and microscopic observation as well as biochemical testing of the isolate.

The identification and determination activities allowed the worker to differentiate one isolate from another. Each isolate was then given identification coded number as

shown in Tables 1 through 6. The isolates were of the genera *Staphylococcus, Bacillus, Corynebacterium, Flavobacterium, Enterobacter, Alcaligenes, Actinobacillus, Neisseria, Pseudomonas, Hafniae, Chromobacterium, Micrococcus,* and *Streptococcus.*

IV.TEST ON ISOLATES AND SELECTION OF POTENTIAL MEDIUM FOR MEOR

Based on the results of isolation and identification activities several indigenous bacteria species were obtained from the oil well environment. The bacteria were expected to have the ability to transform substances of oil field environment, but it was not known whether all had the potential for application in MEOR. To test the capability of each bacteria in this respect, a series of tests were conducted on each isolate.

Table 1
Cepu oil field microbes isolated at 30°C

No.	Isolate Code	Genus/Species Code
1.	GAN-1	Bacteria KKL-1
2.	GAL-1	Bacteria KKL-2
3.	GAK-1	Bacteria KKL-3
4.	GAK-2	Bacteria KKL-4
5.	GMK-1	Bacteria KKL-5
6.	GMN-1	Bacteria KKL-6
7.	GMN-2	Bacteria KKL-7
8.	GMN-3	Bacteria KKL-8

Table 2
Cirebon oil field microbes isolated at 30°C

No.	Isolate Code	Genus/Species Code
1.	GAJ-1	Bacteria KKL-9
2.	GAC-1	Bacteria KKL-10
3.	GAC-2	Bacteria KKL-11
4.	GAC-3	Bacteria KKL-12
5.	GAT-1	Bacteria KKL-13
6.	GMJ-1	Bacteria KKL-14
7.	GMT-1	Bacteria KKL-15
8.	GMC-1	Bacteria KKL-16
9.	GTJ-1	Bacteria KKL-17

The potential of each bacteria species for use in MEOR process depends on their ability to live and grow in the reservoir environment as well as by the bioproducts they produced. The bioproducts produced depend on the inherent capability of the isolate as well as the support of the medium and environmental condition. It was

Table 3
Rantau oil field microbes isolated at 30°C

No.	Isolate Code	Genus/Species Code
1.	GAR-1	Bacteria KKL-18
2.	GAR-2	Bacteria KKL-19
3.	GAR-3	Bacteria KKL-20
4.	GAP-1	Bacteria KKL-21
5.	GAS-1	Bacteria KKL-22
6.	GAS-2	Bacteria KKL-23
7.	GAS-3	Bacteria KKL-24
8.	GAS-4	Bacteria KKL-25
9.	GMR-1	Bacteria KKL-26
10.	GMS-1	Bacteria KKL-27
11.	GMS-2	Bacteria KKL-28
12.	GMP-1	Bacteria KKL-29
13.	GTP-1	Bacteria KKL-30

Table 4
Prabumulih oil field microbes isolated at 30°C

No.	Isolate Code	Genus/Species Code
1.	GATM-3	Bacteria KKL-31
2.	GATM-4	Bacteria KKL-32
3.	GATM-1	Bacteria KKL-33
4.	GMTM-2	Bacteria KKL-34
5.	GMTM-3	Bacteria KKL-35
6.	GMLB-3	Bacteria KKL-36
7.	GATM-6	Bacteria KKL-37
8.	GMTM-5	Bacteria KKL-38
9.	GATM-12	Bacteria KKL-39
10.	GMTM-1	Bacteria KKL-40
11.	GALB-1	Bacteria KKL-41
12.	GATM-2	Bacteria KKL-42
13.	GATM-5	Bacteria KKL-43
14.	GMTM-4	Bacteria KKL-44

therefore necessary to conduct tests on the isolate at various environmental condition, and in a variety of media which may support its bioproduction.

Isolate Testing. The isolates tested were bacteria culture grown in a common liquid medium. Each culture was then subjected to activity test at several reservoir conditions. This would give information concerning the ability of the isolate to live and grow in oil environment. Therefore the tests were directed to observe the capability of each culture: a) to grow in hydrocarbon medium, b) to move, c) to live in semi-anaerobic/aerobic condition, and d) to produce the required bioproducts.

Tests in Hydrocarbon Medium. The results of the identifications and determination activities over fifty bacteria isolates were obtained. Each isolate was subjected to activity test to know its capability to live in oil environment. Those that could live and grow in such environment would be those that could use hydrocarbon as their nutrient. Therefore tests were conducted on the ability of each isolate to live in a medium which contained hydrocarbon for the carbon source.

Each isolate was then grown in two kinds of medium, one which had non-hydrocarbon and another which had hydrocarbon as the carbon source. It was then incubated for a certain period in a shaking incubation at a certain temperature. Culture isolated at 30°C were tested at 30°C and those isolated at 55°C were tested at 55°C.

The test parameter used was the growth rate of each isolate, that is by comparing the growth rate in non hydrocarbon and hydrocarbon medium. If the growth rate is higher in hydrocarbon medium than the non-hydrocarbon, then it means that the isolate lives better in hydrocarbon medium.

A growth rate of each isolate was based on the population count at the beginning of and the end of incubation period. The formula used was as follows:

$$\mu = \frac{22.3 \log (X_t - X_o)}{t}$$

where:

μ = growth rate coefficient
X_t = population count at time t
X_o = population count at time 0
t = incubation time

The result of a 24 hour test pointed to a number of isolates that can live in hydrocarbon medium. The results of the test at 30°C were presented in Table 7, while those of 55°C test at Table 8. There were 28 isolates that lived well at 30°C and 3 at 55°C.

Motility Test. Some bacteria have cells that are equipped with an organ called flagella, which enable the bacterial cells to move on their own. Only curve form cells have such organ, as do some rod shape ones. Coccus type bacteria rarely have such organ. Those that have flagella may have it in single form or in a bundle. The organ may be found at one or both ends of the cell or may cover the whole surface.

The movement of a bacterial cell is influenced by the environmental condition, cells that

Table 5
Jambi oil field microbes isolated at 30°C

No.	Isolate Code	Genus/Species Code
1.	GAKT-1	Bacteria KKL-45
2.	GMKT-1	Bacteria KKL-46
3.	GMKT-3	Bacteria KKL-47
4.	GMKT-4	Bacteria KKL-48
5.	GAKA-1	Bacteria KKL-49
6.	GMKA-1	Bacteria KKL-50
7.	GASL-1	Bacteria KKL-51
8.	GMSL-1	Bacteria KKL-52
9.	GAST-1	Bacteria KKL-53
10.	GMST-1	Bacteria KKL-54

Table 6
Microbes from five oil fields in Indonesia, isolated at 55°C

No.	Isolate Code	Genus/Species Code	Oil Field
1.	GAN/T-1	Bacteria KKL-55	Cepu
2.	GAR/T-1	Bacteria KKL-19	Rantau
3.	GAS/T-1	Bacteria KKL-56	Rantau
4.	GAJ/T-1	Bacteria KKL-56	Cirebon
5.	GAJ/T-2	Bacteria KKL-9	Cirebon
6.	GAC/T-1	Bacteria KKL-55	Cirebon
7.	GAT/T-1	Bacteria KKL-19	Cirebon

Table 7
Bacteria isolated at 30°C that can live in hydrocarbon

No.	Isolate code	Genus code/species
1.	GAL-1	Bacteria KKL-2
2.	GAN-1	Bacteria KKL-1
3.	GAK-2	Bacteria KKL-4
4.	GAJ-1	Bacteria KKL-9
5.	GAT-1	Bacteria KKL-13
6.	GTJ-1	Bacteria KKL-17
7.	GMN-1	Bacteria KKL-6
8.	GAS-2	Bacteria KKL-23
9.	GAR-1	Bacteria KKL-18
10.	GAR-2	Bacteria KKL-19
11.	GMN-2	Bacteria KKL-7
12.	GAS-1	Bacteria KKL-22
13.	GMC-1	Bacteria KKL-16
14.	GMP-1	Bacteria KKL-29
15.	GMS-1	Bacteria KKL-27
16.	GATM-1	Bacteria KKL-33
17.	GATM-2	Bacteria KKL-34
18.	GATM-6	Bacteria KKL-37
19.	GMTM-1	Bacteria KKL-40
20.	GMTM-3	Bacteria KKL-35
21.	GMTM-4	Bacteria KKL-44
22.	GAKT-1	Bacteria KKL-45
23.	GAKA-1	Bacteria KKL-49
24.	GMSL-1	Bacteria KKL-52
25.	GAST-1	Bacteria KKL-53
26.	GAC-2	Bacteria KKL-11
27.	GATM-12	Bacteria KKL-39
28.	GMKT-4	Bacteria KKL-48

Table 8
Bacteria isolated at 55°C that can live in hydrocarbon

No.	Isolate code	Genus/Species code
1.	GAT/T-1	Bacteria KKL-19
2.	GAC/T-1	Bacteria KKL-55
3.	GAS/T-1	Bacteria KKL-56

Table 9
Bacteria isolated at 30°C that have flagella

No.	Isolate code	Genus/Species code
1.	GAJ-1	Bacteria KKL-9
2.	GAK-1	Bacteria KKL-3
3.	GMK-1	Bacteria KKL-5
4.	GATM-12	Bacteria KKL-39
5.	GTJ-1	Bacteria KKL-17
6.	GMN-1	Bacteria KKL-6
7.	GAR-3	Bacteria KKL-20
8.	GAP-1	Bacteria KKL-21
9.	GAS-2	Bacteria KKL-23
10.	GAC-3	Bacteria KKL-12
11.	GAR-1	Bacteria KKL-18
12.	GAR-2	Bacteria KKL-19
13.	GMN-2	Bacteria KKL-7
14.	GAS-3	Bacteria KKL-24
15.	GAC-2	Bacteria KKL-11
16.	GMN-3	Bacteria KKL-8
17.	GAS-4	Bacteria KKL-25
18.	GMS-1	Bacteria KKL-27
19.	GAT-1	Bacteria KKL-13
20.	GMJ-1	Bacteria KKL-14
21.	GATM-4	Bacteria KKL-32
22.	GATM-6	Bacteria KKL-37
23.	GATM-2	Bacteria KKL-42
24.	GMKT-1	Bacteria KKL-46
25.	GMKT-4	Bacteria KKL-48
26.	GMSL-1	Bacteria KKL-52

have no flagella move only by the movement of the substrate. The presence of the flagella enables the bacteria cell to migrate from one place to another, although the displacement was quite slow. Some of the bacteria isolated at 30°C and 55°C that have flagella are listed in Table 9 and 10. Some 26 isolates of 30°C had such flagella, as well as 4 isolates of 55°C.

Test at Semi-anaerobic/Anaerobic Conditions. Based on their needs for oxygen, bacteria are classified into two classes. The first is the aerobic or aerobic obligate bacteria, which needs oxygen to support their life. The second is anaerobic or anaerobic obligate bacteria which cannot sustain their life at oxygen concentration

of more than 0.4%. Besides those two, there are bacteria that can live in both conditions; these are facultative aerobic or semi-anaerobic bacteria. Anaerobic or semi-anaerobic microorganisms are expected to live better in reservoir condition.

To determine whether a microorganisms is a semianaerobic/anaerobic type, an activity test was conducted at treat condition. Each isolate was grown in semisolid medium and incubated for 48 hours at 55°C. From its growth performance it can be determined whether or not an isolate is a semi-anaerobic/anaerobic one. Those that grow well in such medium are semi-anaerobic/anaerobic microbes.

Based on the result of this test as well as the ability to live in hydrocarbon medium, and 12 isolates, some of which have flagella, were selected for further test. These are listed in Table 11.

Tests on the Abilities to Produce the Required Bioproducts. The potential of a microorganisms to be useful for MEOR is reflected by the bioproducts it produces during its activities. Those that can produce such bioproducts as surfactant, acid, solvent, polymer, gas could be subjected to further test to determine their potential for use in MEOR. If they produce the bioproducts which are compatible with the specific reservoir condition, and in sufficiently large quantity, they could be used to enhance oil recovery.

Tests on the ability to produce bioproducts were based on several parameters. These were: a) Measurement of interfacial tension between oil and the medium (formation water). This would indicate the ability to produce biosurfactant by the microorganisms in the liquid medium. A processor tensiometer and a spinning drop tensiometer were used in this test. b) Measurement of pH of the medium (formation water). This would show whether or not the microbes produce bioacids. The measurement was made with pH meter. c) Measurement of viscosity of the crude oil. This would indicate the production of biosolvent that would reduce the viscosity of the crude oil. The measurement was made with viscosimeter.

Table 10
Bacteria isolated at 55°C that have flagella

No.	Isolate code	Species code
1.	GAC/T-1	Bacteria KKL-55
2.	GAR/T-1	Bacteria KKL-19
3.	GAS/T-1	Bacteria KKL-56
4.	GAJ/T-2	Bacteria KKL-9

Table 11
Bacteria isolated from Indonesia oil field that have flagella

No.	Isolate code	Genus/Species code	Oil field	Sample
1.	GAC-2	Bacteria KKL-11	Cirebon	Formation water
2.	GAN/T-1	Bacteria KKL-55	Cepu	Crude oil
3.	GAR-1	Bacteria KKL-18	Rantau	Formation water
4.	GAS-3	Bacteria KKL-24	Rantau	Formation water
5.	GAR-2	Bacteria KKL-19	*Rantau*	Formation water
6.	GAS/T-1	Bacteria KKL-56	Cirebon	Formation water
7.	GAT-1	Bacteria KKL-13	Cirebon	Formation water
8.	GATM-12	Bacteria KKL-39	Prabumulih	Formation water
9.	GMK-1	Bacteria KKL-5	Cepu	Crude oil
10.	GAST-1	Bacteria KKL-54	Jambi	Formation water
11.	GMKT-4	Bacteria KKL-48	Jambi	Crude oil
12.	GMTM-1	Bacteria KKL-40	Prabumulih	Crude oil

Figure 1
Sampling location in Indonesia

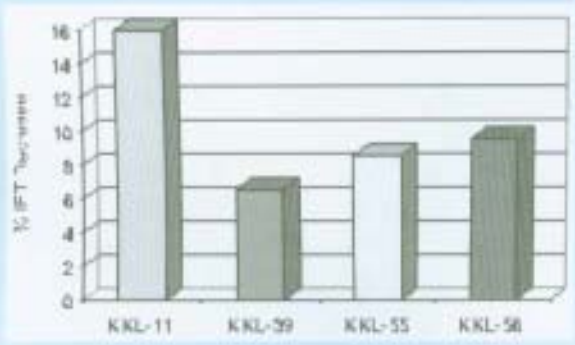

Figure 2
Effect of the activity single culture of bacteria (KKL-11, KKL-39, KKL-55, and KKL-56) with respected to interfacial tension

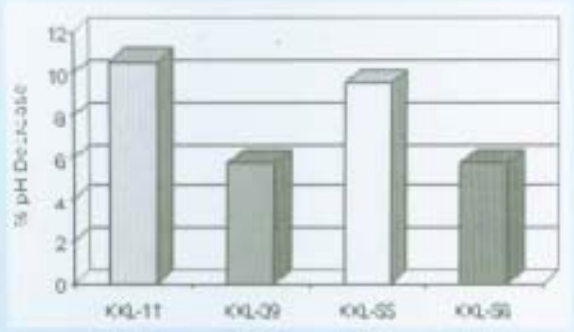

Figure 3
Effect of the activity single culture of bacteria (KKL-11, KKL-39, KKL-55, and KKL-56) with respected to pH of medium

Those three parameters were used to measure the ability of the microorganisms to produce useful bioproducts. All the twelve selected isolates were subjected to these tests. Test was also conducted on the mixed culture existing in the formation water, and on each single culture as well as mixed culture of the twelve isolates. In addition, tests. The tests were conducted in a simple medium for a certain period at 55°C. Synthetic formulation supplemented with nitrogen source and yeast extract was used as the tests medium.

Test on Twelve Single Cultures. The twelve isolates tested were obtained as the result of the selection procedure reported above. The test was conducted by measuring interfacial tension, and pH at the beginning and end of 48 hours incubation.

Test on Isolate Activities with Respected to Interfacial Tension. Measurement of the activity of each culture was done in this case by measuring the interfacial tension between oil and water medium at the beginning and end of incubation. The results were quite variable, some showed increase, while others decrease of interfacial tension. Decrease of interfacial tension occurred in the medium containing single culture of bacteria KKL-11, KKL-39, KKL-55, and KKL-56. The decrease, however, was only small (see Figure 2) i.e. 15.96% for KKL-11, 7.08% KKL-56. Based on the results only four isolates have potential to produce biosurfactant, while the other eight do not produce biosurfactant at the test condition in the medium.

Test on Isolate Activity with Respect to pH Change. The effect of each of the single culture of the twelve selected isolate on the pH of the medium was quite variable. Some isolates gave reduction in pH, some increase in pH and others indifferent. Those that gave pH reduction are shown in Figure 3. The decrease in pH showed that the bacteria produced bioacid. Four isolates were noted for decreasing pH, these are KKL-11 which gave 10.53% pH reduction, KKL-19 which gave 5.84%, KKL-55 9.54% and KKL-56 3.81 %.

The results showed that only four isolates gave pH reduction by producing bioacid while the other eight did not produce bioacids. At different media and condition other isolate may produce bioacids while the above four may not. This means that bioacid production depends on the type of the microorganism, medium, and environmental condition.

Selection of Potential Medium. In order to have potential for application in MEOR, the microbes must have the capacity to produce suitable bioproducts. Their

capability to produce bioproducts is determined by several factors. One of the important factors is the medium. Therefore it is necessary to formulate a medium which effectively stimulate the activity of the microorganisms in producing the required bioproducts.

The media tested consisted of several formulas; these were a basic medium and those with supplemental materials. The basic medium consisted of a synthetic formulation of water and crude oil, with supplemental standard materials modified of pepton, molasses, NPK, yeast extract and other materials. Fourteen formulas were tested in this work. Each one was tested with a mixed culture from an oil reservoir. The objective of the test was to obtain a potential formula which effectively supports bioproduct production. The test was conducted for a certain period at 55°C, in a shaking incubator at semi-anaerobic condition.

Effect of Various Media on IFT. In this test, mixed culture of B-12 was grown in fourteen media. The decrease of interfacial tension after 72 hours incubation are shown in Figure 4. Five media gave decrease of IFT, these were M-3 were 3.0% decrease, M-4 were 42.2% decrease and M-6, M-7, and M-12 each gave 5.2%, 5.3% and 4.6% decrease, respectively.

The highest IFT decrease was obtained in medium M-4, which gave 4.49 mN/m decrease, or 42.2% of the initial IFT. There was indication, during the test, that as surfactant was produced in the media that gave significant IFT reduction. Such large decrease was not found with M-3, M-6, M-7 or M-12. The decreases in these media were quite small, and their capacities produce biosurfactant were not established. Other media among the fourteen did not show any potential to stimulate biosurfactant produce bacteria.

Effect of Various Media on pH Change. The test conducted in the culture B-12 and 14 media gave varied results. pH measurement of the media showed that 8 media had pH decrease. Significant decrease were obtained with M-1 which gave 10.6% decrease, M-2 13.7%, M-5 29.8% and M-8 11.1 % decrease (see Figure 5). The highest pH decrease was obtained in medium M-5, which gave 29.8% of the initial pH. There was indication, during the test, that as acid was produced in the media that gave significant pH reduction. Insignificant pH decrease were observed with M-3, M-4, M-6, and M-7.

Effect of B-12 Activity on Viscosity Change in Various Media. This test was aimed at finding out in which medium the culture B-12 produces viscosity reducing agent for crude oil. Viscosity reduction was found

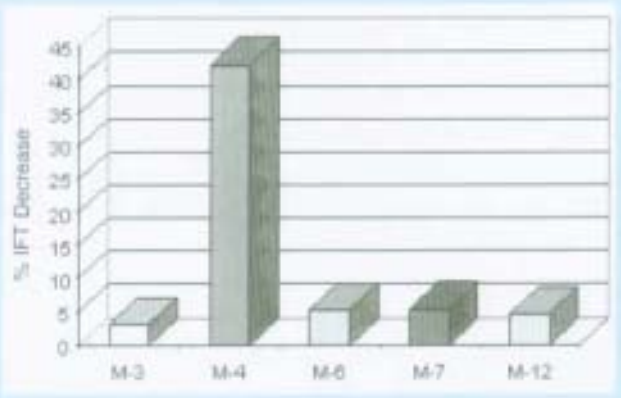

Figure 4
Activity test of mixed cultures of bacteria (JTB-175) in various media gave decrease interfacial tension

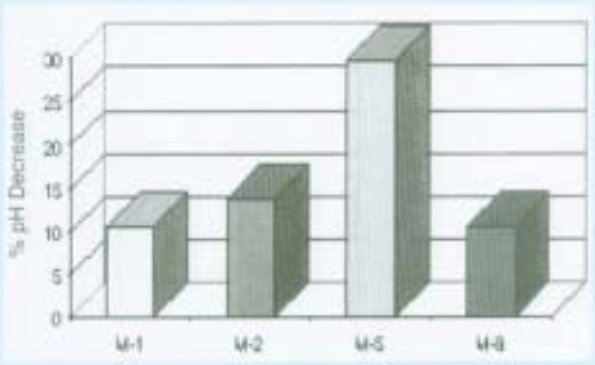

Figure 5
Significant decrease of pH during the growth of JTB-175 in various media

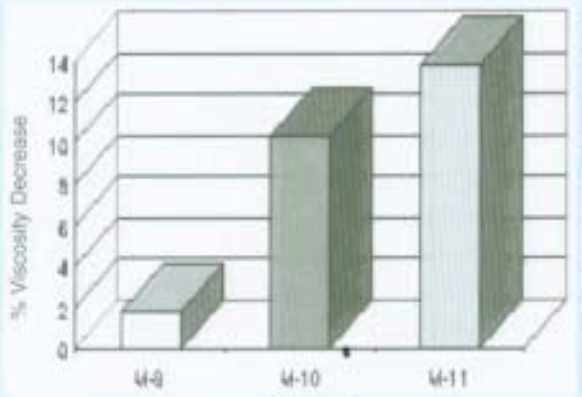

Figure 6
Viscosity reduction by the growth of JTB-175 in various media

to occur in medium M-8, i.e. 1.7%, in M-10 10.3%, and in medium M-11 13.8%, as shown in Figure 6. The results showed that of the 14 media tested only three gave viscosity reduction. The viscosity reduction in media M-10 and M-4 was probably caused by biosolvent/viscosity, reducing bioproduct of the microbes. In medium M-8 the reduction was very small that it was not evident that this medium allowed biosolvent products by the culture B-12. In other media then these three no viscosity reduction was observed.

The selected microbes and nutrient will be using for microbial core flooding test.

V. CONCLUSIONS

The results of the study can be summarized as follows:

1. Microbiology analysis of formation water, crude oil and soil samples collected from Cepu, Cirebon, Rantau, Prabumulih, and Jambi oil fields showed the existence of microbes which grew well at 30°C. On the other hand, microbe population growths were observed also at 55°C in only some samples.
2. From the samples taken from Cepu, Cirebon, Rantau, Prabumulih, and Jambi, 54 isolates have been identified and determinate at 30°C as well as 7 isolates at 55°C.
3. Based on their capability to grow in hydrocarbons, and live in semianaerobic condition, 12 isolates, of which some have motility, were selected for further study concerning their capabilities in producing the required bioproducts for MEOR.
4. From the tests concerning bioproduct production of the 12 single culture isolates as well as their mixed culture, some isolates were found to produce such bioproducts as biosurfactant, bioacid, and biosolvent which are useful for MEOR.
5. Based on activity test of the mixed culture B-12 in 14 media, three media were selected, namely M-4 (which support biosurfactant production), M-5 (which support bioacid production), and M-11 (which support biosolvent production). Further tests which used mixed culture in formation water, showed that the medium M-4 has better potential for MEOR in comparison with media M-5 and M-11.

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