SOME LIMITATIONS OF ENHANCED OIL RECOVERY IN INDONESIA

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ABSTRACT

Enhanced Oil Recovery (EOR) technologies are now being developed year by year. Some of technologies are already applied in pilot or commercial scale in actual oilfields. Meanwhile, conditions for the exploration of new oil fields are becoming more severe. Accordingly the qualification as being an operator in many oil companies is going to be justified in terms of their capability in EOR technology in addition to the capability of exploring new oil fields.

The term "Enhanced Oil Recovery" is used in a broad sense. It covers a wide range of improved oil recovery techniques, from waterflooding to more sophisticated techniques such as chemical flooding. EOR is an emerging technology with the potential to greatly increase oil recovery from discovered fields. At present,it is constrained by serious technological problems which result in unpredictable performance and high economic risks.

The potential for EOR depends on the state of technology, oil prices, development costs and the fiscal environment in which development takes place. This paper discusses the major EOR processes, screening criteria economic consideration and some limitations in Indonesian oilfields.

I. INTRODUCTION

EOR processes

In general terms the processes in the enhaced oil recovery are based on introducing some energy source into the deposits through the injection of gas,flooding with water,the introducing the surface-active agents (surfactant), the injection of water including additives to increase its viscosity (viscosifiers), the use of thermal methods, miscible gas floods and microbiology.

Method of enhanced oil recovery may be subdivided into secondary and tertiary processes. For simplicity no such distinction will be made in this review. Improved oil recovery is defined as oil recovery by processes which increase displacement over that obtained through primary and/or secondary recovery processes. Some of these processes function best when applied directly after primary production, while others can be applied after secondary production.

The oil recovery method usually considered for EOR application are shown in Figure 1. Each method is adapted to certain reservoir and crude oil type.

Thermal treatments are most suited to heavy, often tarry, low API gravity crudes which often will not flow at all in the reservoir under natural conditions.

The method involves injection either of hot water or steams and in situ combustions. Among those injection the steam injection have been used extensively on commercial scale in Duri Field, Central Sumatra.

Recovery in this case is enhanced by :

- Viscosity reduction of the crude
- Thermal expansion of the oil.

Chemical flooding utilizes a chemical slug which is injected in the reservoir to alter the interfacial forces between crude oil and brine, allowing the oil droplets to deform and flow through the constructions in the porous medium.

Major recovery processes included to this method are :

- Caustic floods
- Polymer floods
- Surfactant-polymer floods

Mechanisms for improved oil recovery by chemical injection will include :

Caustic floods

- Lowered oil-water interfacial tension.
- Emulsification of oil in water or water in oil combined with entrapment or entrapment.
- Wettability alteration.

Polymer floods

- Improve mobility
- Improve sweep efficiency

Surfactant-polymer floods

- Reduce interfacial tension between oil and water
- Efficiency displacement
- Improve mobility

Miscible flood is to reduce the capillary and interfacial forces which cause the oil to be retained in the rock, and to control the movement of the oil.

If miscibility is achieved, the adverse retaining forces become negligible and efficient displacements can be realized.

This is done by injecting a solvent in the reservoir, either high or intermediate hydrocarbon, CO_2, N_2 or combination of these.

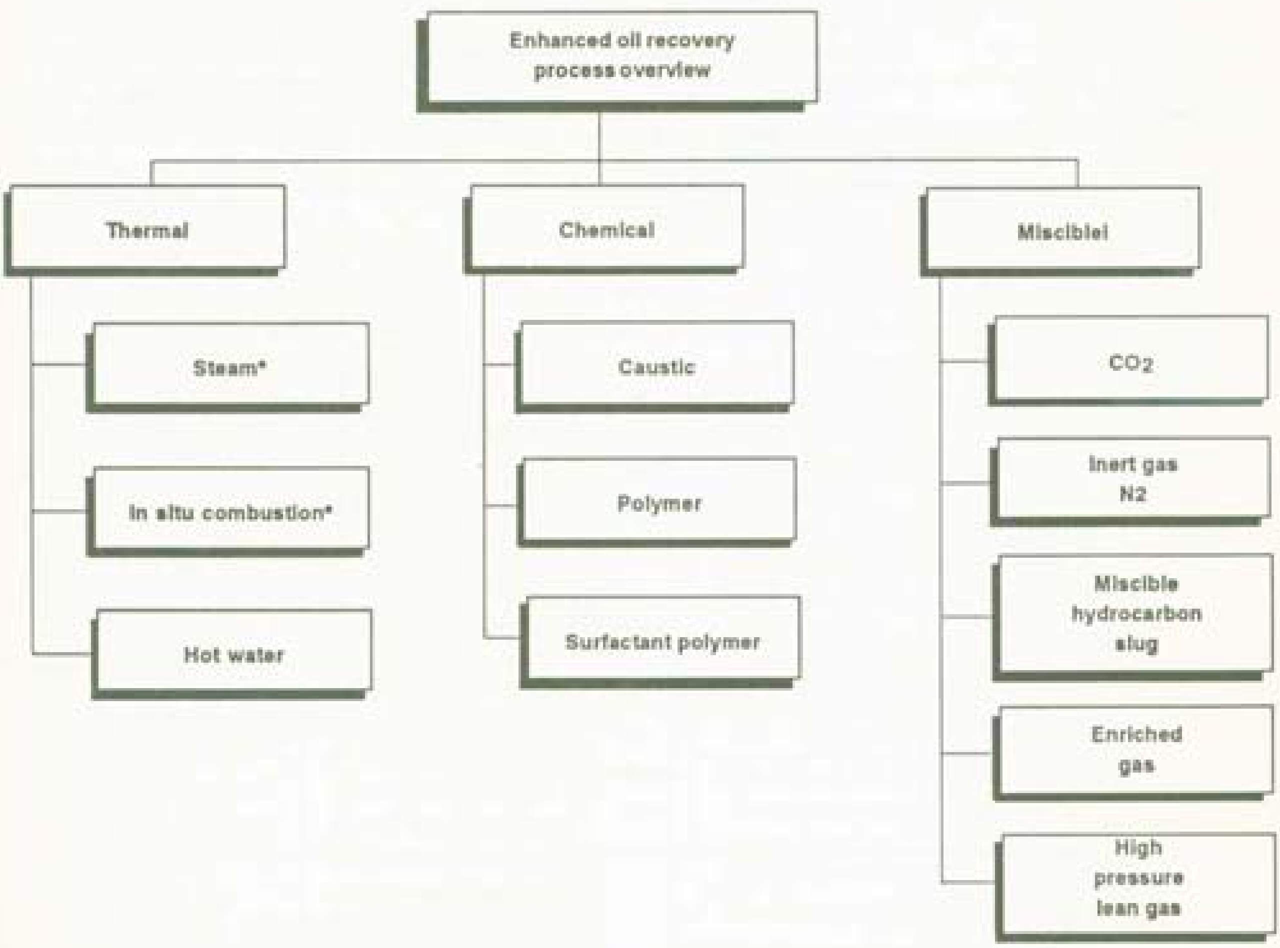

Figure 1. Enhanced oil recovery process overview

II. SCREENINGCRITERIA

Before applying technical screening criteria, some general considerations should be given to eliminate reservoirs not suitable for EOR methods such as :

- Low permeability
- Permeability variations (areal variation, vertical stratification and directional permeability)
- Extensive fractures and faults
- Little remaining reserves
- Existence of bottom water
- Existence of large primary gas cap

In general, oil reservoirs not suitable for waterflooding are not adequate candidate for further EOR processes.

A reservoir with high primary recovery factor due to strong natural water drive is usually not a good candidate for water flooding.

The initial evaluation based on suggested screening criteria is followed by laboratory and field tests.

Many of the screening criteria are the reservoir properties that are normally available for developed fields. However, the quality of available data has to be assessed, and if necessary, new data should be obtained.

Table 1
Guide for technical screening criteriea

Reservoir parameters	Dims.	Thermal		Chemicals			Miscible		
		Steam flood	Insitu comb.	Poly-mer	Surfac-tant	Alka-line	HC gas	N_2 gas	CO_2 Gas
Rock type	–	sst	sst	sst/lm	sst*	sst*	sst/lm	sst/lm	sst/lm
Net thickness	ft	>20	>10	NC	>10	NC	thin	thin	thin
Depth	ft	<5000	>500	<9000	<8000	<9000	>2000	>5000	>2000
Temperature	f	NC	>150	<200	<175	<200	NC	NC	NC
Ave. permeability	md	>200	>100	>40	>60	>20	NC	NC	NC
Ave. porosity	%	20	20	20	20	20	NC	NC	NC
Ave. oil saturation	%	40-50	40-50	>40	40-50	Sor	>30	>30	>30
Pressure	psi	1500	2000	NC	NC	NC	–	–	MMP
Oil gravity	Api	10-25	<25	>25	>25	13-35	>35	25-35	>25
Oil viscosity	cp	>20	>1000	<200	<40	<90	<10	<10	15
Oil composition		NC	asphal	NC	light	NC	light	heavy	heavy
Salinity (TDS)	ppm	NC	NC	<50,000	<30,000	100,00	NC	NC	NC
Wettability		OW	WW/OW	WW	WW	OW	WW/OW	WW/OW	WW/OW
Kh/u		5	5	NC	–	–	–	–	–
Φ.So		0.1	0.8	NC	–	–	–	–	–
Inject. water salinity	ppm	–	–	<50,000	20,000	–	–	–	–
Clay content	%	–	–	<10	<8	–	–	–	–

Note : NC - Not Critical
WW - Water Wet
OW - Oil Wet

sst - sandstone
lm - limestone (carbonate rock)
sst* - sandstone is preferable

EOR processes are site specific and a careful screening of the processes and an examination of implementation strategy of the selected process are extremely important in order to achieve and optimize the expected performance.

Screening criteria for EOR processes are summarized in Table 1. This screening is useful as primary feasibility study.

Geological and reservoir engineering data and production operating data such as depositional environment, rock and fluids properties, heterogeneity, result of past waterflooding and types of stimulation and workover should be studied.

III. ECONOMIC CONSIDERATIONS

Talking about the feasibility for each EOR process, it should analyze the following items based on the passed experience. There are :

- Oil recovery efficiency
- Process efficiency
- Example EOR pilot project costs

Oil recovery efficiency

Processes	Oil recovery
- Steam flooding	30 – 60
- In-situ combustion	15 – 25
- CO_2 miscibile flooding	20 – 30
- Polymer flooding	3 – 10
- Surfactant flooding	15 – 40
- Alkaline flooding	2 – 5

Process efficiency

Processes	Efficiency
- Steam flooding	4 - 6 Bbl steam/bbl oil
- In-situ combustion	15 - 20 Mcf air/bbl oil
- CO_2 miscible flooding	10 - 25 Mcf CO_2/bbl oil
- Polymer flooding	0.5- 2 lb.polymer/bbl oil
- Surfactant flooding	20-40 lb.surfactant with 1 - 2 lb.polymer/bbl oil
- Alkaline flooding	30-60 lb.alkaline/bbl oil

Example EOR pilot project costs

Estimated cost for 2,5 acre waterflood pilot project	
- Drill and complete 5 wells (Inverted 5 spot)	US$ 306,270
- Surface equipment	57,520
- Laboratory evaluation	10,000
- Operation cost for 2-years project	180,000
Total costs	US$ 563,780

Estimated cost for 2,5 acre polymer flood pilot project	
- Drill and complete 5 wells (Inverted 5-spot)	US$ 306,270
- Surface equipment	80,000
- Chemicals	50,000
- Transportation chemicals	3,000
- Laboratory work prior to project	75,000
- Operation cost for 2-years project	250,000
Total costs	US$ 764,270

Estimated cost for 2,5 acre miscellar-polymer pilot project	
- Drill and complete 5 wells (Inverted 5-spot)	US$ 306,270
- Surface equipment	83,950
- Chemical	200,000
- Transportation chemicals	13,000
- Laboratory works prior to project	180,000
- Operation cost for 2-years project	250,000
Total costs	US$ 1,033,220

Estimated cost for steam flood	
- Drill and complete 5 wells (Inverted 5-spot)	US$ 344,500
- Surface equipment	306,140
- Laboratory work prior to project	75,000
- Operation cost for 2-years project	400,000
Total costs	US$ 1,125,640

IV. SOME LIMITATIONS IN INDONESIAN OIL FIELDS

Eventhough Indonesia is considered a mature oil-producing country very few EOR projects have been undertaken.

The most active Indonesian operator in EOR is the national oil company, PERTAMINA, who currently have active projects in North and South Sumatra as well as in Kalimantan.

A. *North Sumatra basin*

The North Sumatra Basin has been producing for over 100 years with total production of over 500 million barrels. The vast majority of oil-bearing reservoirs are sandstone at relatively shallow depths wih "light" oil.

Study of waterfloods in the laboratory conducted on reservoir rocks from this area showed approximately 21 to 36 % of oil recovery from oil reservoirs (LEMIGAS,1992).

The major EOR projects in North Sumatra, waterflooding in the Rantau field, has reportedly been successful, although the high gravity oil prevalent in the basin may have an adverse effect on the mobility ratio and thus be a limiting influence on waterfloods. Asamera's Tualang field is also under waterflood program.

The presence of this light oil could also prohibit thermal and alkaline chemical processes. However,the good porosity and thick beds should aid sweep efficiency.

The availability of large quantities of carbon dioxide in North Sumatra is a factor in future EOR projects, although the low reservoir pressures are likely to limit any miscible flooding.

B. *Central Sumatra basin*

The Central Sumatra Basin is the most profilic in Indonesia, with currently over sixty fields in production, about three EOR projects are currently active (two water floods and one thermal project), with Duri field steamflood the most significant.

Laboratory study of waterfloods showed that oil can be produced from oil reservoirs about 33 to 46 % of oil recovery by waterflooding (LEMIGAS, 1992).

Duri field, with oil-inplace of over 6 billion barrels, has estimated primary recovery of only less than 7.5 %, thus, leaving a large target for production through EOR.

The CPI (Caltex Pacific Indonesia), initiated periodic cyclic steam injection ("Huff-and-Puff") in 1967, and larger steam and caustic flood pilot in 1975.

It is estimated that the steamflood will increase recovery from the primary recovery factor of 7.5 % to over 60 % of the oil-in- place.

This project is expected to cost over one billion dollars, but it is estimated to produce over three billion barrels of incremental EOR oil.

Almost all production in this basin is from sandstone reservoirs, thus, all EOR methods could potentially be applied in this basin, depending upon the particular field characteristics.

C. *South Sumatra basin*

The South Sumatra Basin has been explored more thoroughly and has the largest number of fields than any other in Indonesia.

Fields in South Sumatra generally have a greater degree of faulting which can influence reservoir continuity and sweep efficiency, but reservoir and fluid characteristics do not indisputably eliminate any EOR process, although the absence of available carbon dioxide and the presence of high watercuts are limiting factors. Laboratory studies conducted on reservoir rocks from this area showed that approximately 33 to 46 % oil recovery can be produced by waterflooding (LEMIGAS,1992).

Current EOR projects are underway in Tanjung Tiga, Jene, Pian and Kampong Minyak fields (waterfloods),with pressure maintenance through water injection in the Pendopo field, as well as a larger under taking in the Limau/Belimbing trend likely to in 1989, and also the Asamera plan waterfloods in the Ramba "B" and Tanjung Laban fields.

Table 2
EOR pilot projects in Indonesia

Provinces	Fields	EOR process	Companies
C. Sumatra	Kotabatak	Waterflooding	- CPI (Caltex)
	Pedada	Waterflooding	- CPI (Caltex)
	Bekasap	Waterflooding	- CPI (Caltex)
	Bangko	Waterflooding	- CPI (Caltex)
	Zamrud	Waterflooding	- CPI (Caltex)
	Balam.S	Waterflooding	- CPI (Caltex)
S. Sumatra	TTT	Waterflooding	- Pertamina-II
	Limau	Waterflooding	- JOB Pertamina Husky Oil
	Jambi	Waterflooding	- JOB Pertamina Asamera
	Lirik	Waterflooding	- JOB Pertamina Lirik Petr.
E. Kalimantan	Nonny	Waterflooding	- Tesoro
	Semboja	Waterflooding	- Tesoro
	Tanjung	Waterflooding	- JOB Pertamina Bow Valley
	Yakin	Waterflooding	- Unocal
Irian Jaya	Klamono	Chemical Flood	- Joint Study Pert.-JNOC
	Cenderawasih	Gas Injection	- Petromer Trend

In the past, EOR studies and pilots had been examined in the Jambi area (Tempino and East Ketaling fields), but have not been developed into active projects. A number of other fields had water and gas injection schemes, but are for pressure maintenance only, rather than for actual frontal movement.

D. *North-West Java basin*

The major onshore oil currently in production in the North-West Java basin is the Jatibarang field. This is a significant field, as it was discovered by PERTAMINA in 1969 and produces a 30 degree API, waxy, high pour point oil from fractured andesites and tuffs.

Laboratory studies of waterflooding on some reservoir rocks from the fields in this area, showed that waterflooding can produce approximately 13 to 38 % additional oil recovery (LEMIGAS,1992).

E. *East Java basin*

The East Java basin was a prolific producer in the first half of this century (more than 150 million barrels of oil produced from over 30 fields), but with little production over the past twenty years. The producing reservoirs are shallow sandstones,with paraffinic oils, oil gravities between 24 and 43 degree API and carbon dioxide present in some fields.

Laboratory study of waterflooding on the reservoir rocks in this area indicates oil recovery by waterflooding is approximately 17 to 39 % from oil reservoirs (LEMIGAS,1992).

F. *Kutei basin*

The Kutei basin has been explored with different level of activity for the past ninety years. The Sanga-sanga field was discovered in 1898 and has produced more than 260 million barrels, while the other major oilfield in the basin, Handil,was discovered in 1973, and a full scale waterflood in 16 reservoirs began in 1980 (Alibi,1982). Water injection is believed to be currently in excess of 150,000 barrels per day. Laboratory study of waterfloods showed approximately 37 to 49 % oil recovery can be produced from oil reservoirs in this area (LEMIGAS,1992).

Table 3
EOR full scale projects in Indonesia

Provinces	Fields	EOR process	Companies
N. Sumatra	Rantau	Waterflooding	- Pertamina Japex
C. Sumatra	Duri	Steamflooding	- CPI (Caltex)
	Libo-SE	Waterflooding	- CPI (Caltex)
	Minas	Waterflooding	- CPI (Caltex)
	Binjo	Waterflooding	- PT. Stanvac
	Ibul	Waterflooding	- PT. Stanvac
	Kerumutan	Waterflooding	- PT. Stanvac
	Merbau	Waterflooding	- PT. Stanvac
	Jene	Waterflooding	- PT. Stanvac
S. Sumatra	Tg.Laban	Waterflooding	- Asamera
	Ramba	Waterflooding	- Asamera
	Lirik	Waterflooding	- Pertamina II
	Molek	Waterflooding	- Pertamina II
	Benakat.B	Waterflooding	- Pertamina II
	Kampong minyak	Waterflooding	- Pertamina Triton
NW. Java	Arjuna	Waterflooding	- ARII
	Arjuna	Gas Injection	- ARII
	Rama-BR	Waterflooding	- Maxus
	Krisna-LBR	Waterflooding	- Maxus
E. Kalimantan	Bunyu	Waterflooding	- Pertamina Mainline
	Handil	Waterflooding	- Total Ind.

A chemical flood pilot has been tried in Handil, however, although results have not been published. Residual oil saturation from selected cores is low 26 - 29 percent, porosity is greater 25 percent, which together with high oil recoveries from coreflood tests, indicate that chemical flooding, even in watered out reservoirs, was feasible (Sureau et al,1984). Some of the potensial problems include large primary gas caps and multiple sands of varying thickness.

G. *Barito basin*

The Tanjung field, the largest field in this basin is currently undergoing a limited program of hot water injection to try and increase the mobility of the viscous (200 cp) paraffinic oil.

The producing sands in the Barito basin are more conglomeratic than the other parts of Indonesia with some lateral variations in permeability, which could affect sweep efficiency.

H. *Tarakan basin*

The majority of production has been from Pamusian, Bunyu and Sembakung fields and are characterized by strong water drive and multiple sands.

Low gravity oil (18 degree API) has been produced in Pamusian field, but primary recovery is estimated to be higher fifty percent (Rowley,1973) and a high water-cut is noticeable in all fields. Reservoirs characterized with multiple sandstone reservoirs could cause flooding problems.

I. *Salawati basin*

Over 95 % of total production in Eastern Indonesia has been from the Salawati basin, which currently pro-

Tabel 4
Main oilfiels in Indonesia (states 1 January 1985)

	Basin	Number of fiels	Productive formation	Capacity BOPD	Cumulative prod. 1-1-85 MMBO
1.	N. Sumatra	21	SST & LMST	119,700	530.00
2.	C. Sumatra	88	SST	703,600	5,690.00
3.	S. Sumatra	57	SST	62,680.00	1,680.00
4.	NW. Java	50	SST & LMST	242,800	984.00
5.	NE. Java	1	LMST	?	0.43
6.	Barito	5	SST	4,700	113.00
7.	Kutel	21	SST	291,900	1,465.00
8.	Tarakan	4	SST	13,00	299.00
9.	Salawati	16	LMST	36,600	280.00
10.	Bula	1	SST & LMST	760	13.00
11.	W. Natuna	1	SST	11,400	44.00

duces over 25,000 barrels per day from a number of carbonate reservoirs. The oil is characterized as moderate viscosity, low buble point and medium gravity. In some fields strong water drive is prevalent with over fifty percent primary recovery.

Laboratory studies of waterflooding showed oil recovery is approximately 42 percent in average from oil reservoirs by water injections (LEMIGAS,1992).

Some potential problems with EOR techniques are the high water cut, reservoir heterogeneity and natural fractures, possibility of carbonates being preferentially oil-wet.

V. CONCLUSIONS

1. Indonesia has very few active EOR projects compared to the other oil producing countries of similar reserves base and maturity.The reasons for these are small average field size, predominance of light oil, thin multiple reservoirs, multiple completions and reservoir discontinuities.
2. Data is very limited and is not available for a detailed screening of Indonesian reservoirs, thus any conclusions reached are meant only as a guide in the absence of a complete data set.
3. All the producing basins of Indonesia could, with the existing EOR technology, increase their recoverable reserves. Site specific limitations for individual processes are present, but overall the reservoirs and fluid characteristics are favorable for EOR in Indonesia, under suitable economic conditions. Most of study results indicate that waterflooding process is economically attractive in Indonesia.
4. Improved oil recovery can be less expensive than new discoveries or unconventional energy.

REFERENCES

1. **Adim, H.**, 1993, "Laboratory Studies of Waterflood from Oil Reservoirs in Indonesia", *Lemigas' Scientific Contribution 1/93*, ISSN : 0126-03501.
2. **Adim, H., Sudibjo, R.**, 1985, "Development of Core Analysis and EOR Laboratory in Lemigas", *EOR Seminar*, LEMIGAS-Mitsui Jakarta, February.

3. **Mc Kay, B.A.**, "Enhanced Recovery from Australian Oil Reservoirs", *The AMI Quaterly*,Vol.32 No.1

4. **Pinczewski. W. V., Cockroft, P.**, 1988, "Enhanced Oil Recovery", *Conference Proceeding*, August 24 -25, Jakarta.

5. **Sudibjo, R., Adim, H.**, 1992, "Capability of Lemigas Laboratories in Supporting EOR Studies", *Lemigas' Scientific Contribution 1/1992*, ISSN - 0126 - 3501. □