PROTEKSI ISI LAPORAN KEMAJUAN PENELITIAN TESIS MAGISTER

LAPORAN KEMAJUAN 2024

Rencana Pelaksanaan Penelitian Tesis Magister: tahun 2024 s.d. tahun 2024

1. JUDUL PENELITIAN

Pengembangan Chemical Flooding dengan Surfaktan Lerak untuk Peningkatan Perolehan Minyak Menuju Teknologi Ramah Lingkungan Menggunakan Sumber Alam Hayati Non-Edible

Bidang Fokus	Tema	Topik (jika ada)	Prioritas Riset
Energi	Teknologi Ketahanan, Diversifikasi Energi dan Penguatan Komunitas Sosial	Teknologi pendukung EOR	Green Economy

Rumpun Ilmu Level 1	Rumpun Ilmu Level 2	Rumpun Ilmu Level 3
ILMU TEKNIK	TEKNOLOGI KEBUMIAN	Teknik Perminyakan (Perminyakan)

Skema Penelitian	Strata (Dasar/Terapan/ Pengembangan)	Nilai SBK	Target Akhir TKT	Lama Kegiatan
Penelitian Tesis Magister	Riset Dasar	35.000.000	3	1 Tahun

2. IDENTITAS PENGUSUL

Nama, Peran	Jenis	Program Studi/Bagian	Bidang Tugas	ID Sinta
MUHAMMAD TAUFIQ FATHADDIN 0315026702 Ketua Pengusul Universitas Trisakti	Dosen	Teknik Perminyakan	1. Persiapan Alat 2. Persiapan Sampel Fluida 3. Uji Adsorpsi 4. Uji IFT 5. Uji Wettability 6. Uji Imbibisi 7. Uji Permeabilitas Relatif 8. Core Flooding 9. Pengolahan Data 10. Laporan Akhir dan Artikel	5973622
DWI ATTY MARDIANA 0325038104 Anggota Universitas Trisakti	Dosen	Teknik Perminyakan	1. Persiapan Bahan, 2. Uji aqueous stability, 3. Uji Phase Behavior, 4. Uji NMR, 5. Uji filtrasi, 6. Pengolahan Data, 7. Laporan Akhir.	5973934
FAJRI MAULIDA 171012200004 Mahasiswa Bimbingan Universitas Trisakti	Mahasiswa	Teknik Perminyakan	1. Persiapan Bahan dan Alat, 2. Uji Aqueous Stability, 3. Uji Phase Behavior, 4. Uji Filtrasi, 5. Uji Interfacial tension, 6. Uji wettability, 7. Permeabilitas Relatif, 8. Uji Coreflooding,	-

3. MITRA KERJASAMA PENELITIAN (Jika Ada)

Pelaksanaan penelitian dapat melibatkan mitra kerjasama yaitu mitra kerjasama dalam melaksanakan penelitian, mitra sebagai calon pengguna hasil penelitian, atau mitra investor

Mitra	Nama Mitra	Dana

4. LUARAN DAN TARGET CAPAIAN

Luaran Wajib

Tahun Luaran	Kategori Luaran	Jenis Luaran	Status target capaian	Keterangan
1	Artikel di Jurnal	Artikel di Jurnal Bereputasi Internasional	Accepted/Published	https://mjst.ustp.edu.ph/index.php/mjst

5. ANGGARAN
Rencana Anggaran Biaya penelitian mengacu pada PMK dan buku Panduan Penelitian dan Pengabdian kepada Masyarakat yang berlaku.

Total RAB 1 Tahun Rp34.120.000,00

Tahun 1 Total Rp34.120.000,00

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
Bahan	Bahan Penelitian (Habis Pakai)	Cuvette Glass	Unit	1	240.000	240.000
Bahan	Bahan Penelitian (Habis Pakai)	Laboratory schott duran bottle 500 ml	Unit	12	75.000	900.000
Analisis Data	Biaya analisis sampel	Uji Imbibisi	Unit	2	600.000	1.200.000
Analisis Data	Biaya analisis sampel	Uji permeabilitas Relatif	Unit	2	500.000	1.000.000
Analisis Data	Biaya analisis sampel	Uji Filtrasi	Unit	2	500.000	1.000.000
Pengumpulan Data	HR Pembantu Peneliti	Peneliti Pembantu	OJ	4	25.000	100.000
Pelaporan Hasil Penelitian dan Luaran Wajib	Biaya Pendaftaran KI	Hak Cipta	Paket	1	200.000	200.000
Pelaporan Hasil Penelitian dan Luaran Wajib	Biaya pembuatan dokumen uji produk	Biaya pembuatan dokumen Laporan dan jilid	Paket	1	200.000	200.000
Pengumpulan Data	Transport	Transport Penelitian : 2 kali untuk 1 org antar sampel	OK (kali)	3	300.000	900.000
Pengumpulan Data	Uang Harian	UH Rapat dlm kantor_Halfday meeting 4 orang @ Rp. 200.000	OH	5	150.000	750.000
Bahan	Bahan Penelitian (Habis Pakai)	Laboratory schott duran bottle 25 ml	Unit	20	40.000	800.000
Bahan	Bahan Penelitian (Habis Pakai)	Infrared Thermometer Gun	Unit	1	150.000	150.000
Bahan	Bahan Penelitian (Habis Pakai)	Heating Mantle	Unit	1	660.000	660.000
Bahan	Bahan Penelitian (Habis Pakai)	Magnetic Stirrer Bar	Unit	1	50.000	50.000
Bahan	Bahan Penelitian (Habis Pakai)	Ethanol Absolute Merck	Unit	1	800.000	800.000
Bahan	Bahan Penelitian (Habis Pakai)	N-Hexane 104367 2.5 L Merck	Unit	1	900.000	900.000
Bahan	Bahan Penelitian (Habis Pakai)	Lerak Powder	Unit	4	25.000	100.000
Bahan	Bahan Penelitian	Pembelian core Berea	Unit	2	3.000.000	6.000.000

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
	(Habis Pakai)					
Analisis Data	Biaya analisis sampel	Uji phase behavior	Unit	12	100.000	1.200.000
Analisis Data	Biaya analisis sampel	Uji aqueos stability	Unit	6	100.000	600.000
Analisis Data	Biaya analisis sampel	Uji Adsorpsi Statis	Unit	12	100.000	1.200.000
Analisis Data	Biaya analisis sampel	Uji Adsorpsi Dinamis	Unit	2	500.000	1.000.000
Analisis Data	Biaya analisis sampel	Uji Wettability	Unit	4	700.000	2.800.000
Analisis Data	Biaya analisis sampel	Uji Thermal Stability	Unit	2	1.000.000	2.000.000
Analisis Data	Biaya analisis sampel	Uji IFT	Unit	4	700.000	2.800.000
Analisis Data	Biaya analisis sampel	Uji NMR	Unit	1	900.000	900.000
Analisis Data	Biaya analisis sampel	Surfactant Flooding	Unit	2	700.000	1.400.000
Bahan	Bahan Penelitian (Habis Pakai)	Tabung Reaksi Test Tube	Unit	20	45.000	900.000
Bahan	Bahan Penelitian (Habis Pakai)	Blender BL-301 PL	Unit	1	180.000	180.000
Bahan	Bahan Penelitian (Habis Pakai)	Penggiling Meat Mincer	Unit	1	90.000	90.000
Bahan	Bahan Penelitian (Habis Pakai)	Lerak	Unit	1	20.000	20.000
Bahan	Bahan Penelitian (Habis Pakai)	NaCl	Unit	3	10.000	30.000
Bahan	Bahan Penelitian (Habis Pakai)	Kertas Saring Whatmann no. 41	Unit	2	700.000	1.400.000
Bahan	Bahan Penelitian (Habis Pakai)	Sarung Tangan Karet	Unit	6	50.000	300.000
Bahan	Bahan Penelitian (Habis Pakai)	Pipet Ukur	Unit	8	20.000	160.000
Bahan	Bahan Penelitian (Habis Pakai)	Distilled Water	Unit	10	10.000	100.000
Bahan	Bahan Penelitian (Habis Pakai)	Laboratory schott duran bottle 1000 ml	Unit	6	80.000	480.000
Bahan	Bahan Penelitian (Habis Pakai)	Masker3200 respirator catridge3301N filter 3N11CN	Unit	3	120.000	360.000
Bahan	ATK	Kertas	Paket	1	50.000	50.000
Bahan	ATK	Tinta printer Black & Colour	Paket	1	200.000	200.000

Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian meliputi data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

Penelitian ini telah dilaksanakan dengan kemajuan mencapai 85%. Metode penelitian telah dilaksanakan untuk mencapai tujuan penelitian serperti tercantum dalam proposal. Sesuai jadwal penelitian ini telah dilaksanakan dengan hasil sebagai berikut. Untuk mencapai tujuan peneltian seperti tercantum di dalam proposal yaitu pengembangan chemical flooding dengan surfaktan lerak (*Sapindus rarak*) untuk peningkatan perolehan minyak menuju teknologi ramah lingkungan menggunakan sumber alam hayati non-edible, maka telah dilaksanakan penelitian laboratorium mulai 16 Juli hingga 28 Agustus 2024 (Darwis, 2021; Hajimohammadi et al., 2017; Rajput dkk., 2021; Supiandi, 2019). Hasil penelitian yang diperoleh meliputi hasil pengukuran sifat fisik sampel core, pengukuran sifat fisik fluida, uji aqueous stability, uji filtrasi, uji kelakuan fasa (phase behavior), uji wettability, uji interfacial test (IFT) dan thermal stability, uji adsorpsi, serta uji core flooding (perolehan minyak).

1. Pembuatan larutan lerak

Beberapa konsentrasi larutan surfaktan dengan aditif dibuat dengan komposisi surfaktan lerak dan brine ditunjukan pada Tabel 1. Dihasilkan dua belas sampel larutan dengan variasi konsentrasi surfaktan dan salinitas berbeda.

Tabel 1 Komposisi pembuatan larutan surfaktan lerak

Sampel	Konsentrasi Lerak (%)	Salinitas (ppm)
1	0,50	6.000
2	1,00	6.000
3	1,50	6.000
4	2,00	6.000
5	2,50	6.000
6	3,00	6.000
7	0,50	10.000
8	1,00	10.000
9	1,50	10.000
10	2,00	10.000
11	2,50	10.000
12	3,00	10.000

2. Pengukuran sifat fisik sampel core

Pengukuran sifat fisik core meliputi pengukuran diameter, tinggi, bulk volume, gas porosity, gas permeability, dimensi core, berat kering serta berat basah. Batuan padatan yang digunakan dalam penelitian ini adalah berea core sandstone dikarenakan keseragaman parameternya sehingga cocok untuk dilakukan uji perbandingan (comparative test). Selain itu, average pore structure dan clay content pada berea core juga cenderung kecil (Febrian et al., 2015)

Tabel 2 Hasil pengukuran sifat fisik seluruh sampel core

Sampel *Core*	***Diameter* (cm)**	**Tinggi (cm)**	***Bulk Volume* (cc)**	***Gas Porosity* (%)**	***Gas Permeability* (mD)**	**Berat Kering (gr)**	**Berat Basah (gr)**
Core A	2,55	2,87	14,64	20	170	28,63	31,96
Core B	2,55	2,82	14,39	20	170	28,33	31,57

Core C	2,55	2,76	14,08	22	170	27,48	30,53
Core D	2,55	2,69	13.73	22	170	26,78	29,76
Core E	2,55	2,40	12,25	22	170	25,04	27,12

3. Pengukuran sifat fisik fluida

Terdapat tiga jenis pengukuran yang akan dilakukan yaitu pengujian densitas, specific gravity (SG), dan viskositas untuk larutan surfaktan lerak (Sapindus rarak). Hasil pengukuran dapat dilihat pada Tabel 3

Tabel 3 Hasil pengukuran densitas, SG, dan viskositas larutan surfaktan Sapindus rarak

No	**Konsentrasi (%)**	**Salinitas (ppm)**	**Densitas (gr/cc)**	***Specific Gravity* (SG)**	**Viskositas (cp)**
1	0,50	6.000	0,9884	1,0053	1,22
2	1,00	6.000	0,9922	1,0091	1,52
3	1,50	6.000	0,9936	1,0106	1,59
4	2,00	6.000	0,9960	1,0130	1,99
5	2,50	6.000	0,9985	1,0152	2,10
6	3,00	6.000	1,0005	1,0176	2,63
7	0,50	10.000	0,9923	1,0093	1,52
8	1,00	10.000	0,9958	1,0126	1,79
9	1,50	10.000	0,9974	1,0145	1,86
10	2,00	10.000	1,0000	1,0171	2,03
11	2,50	10.000	1,0028	1,0199	2,17
12	3,00	10.000	1,0051	1,0222	2,74

4. Uji Aqueous Stability

Pengujian aqueous stability merupakan salah satu tahap awal dalam proses screening surfaktan, dimana pengujian dilaksanakan selama 7 hari lamanya. Pengukuran aqueous stability merupakan pengukuran visual sehingga pengukuran yang diperoleh adalah pengukuran kualitatif. Untuk itu perlu dilakukan pengukuran kuantitatif yaitu uji transmitansi (%). Hal ini untuk mengidentifikasi apakah terdapat endapan, koloid, ataupun partikel kasar yang tidak dapat terlarut sempurna di dalam larutan surfaktan. Pengujian dilaksanakan menggunakan pipette tube dengan suhu oven sebesar 60 ºC. Dibawah ini terdapat Tabel 4 yang menampilkan hasil uji aqueous stability untuk 12 larutan surfaktan.

Tabel 4 Hasil pengujian aqueous stability selama 7 hari pada suhu 60 ºC

No	**Konsentrasi (%)**	**Salinitas (ppm)**	**Transmitansi (% T)**	**Aqueous Stability (168 jam)**
1	0,50	6.000	84,80	Endapan
2	1,00	6.000	82,40	Endapan
3	1,50	6.000	80,60	Endapan
4	2,00	6.000	77,20	Jernih
5	2,50	6.000	74,80	Endapan
6	3,00	6.000	72,50	Endapan
7	0,50	10.000	83,90	Endapan
8	1,00	10.000	81,50	Endapan
9	1,50	10.000	79,30	Endapan
10	2,00	10.000	76,80	Endapan
11	2,50	10.000	73,20	Jernih
12	3,00	10.000	70,60	Jernih

5. Uji filtrasi

Berdasarkan (Edward dan Hestuti, 2013) menyatakan bahwa, bila ditemukan hasil endapan atau pengotor banyak tertahan pada kertas saring, maka surfaktan dikatakan tidak baik karena hasil filtrasi akan mengurangi konsentrasi surfaktan tersebut. Oleh sebab itu, hasil dari pengujian filtrasi akan menentukan kualitas surfaktan. Surfaktan yang mampu melalui filter (kertas saring) dengan baik serta tidak mengalami penggumpalan menunjukkan bahwa surfaktan dapat berfungsi dengan efektif dalam proses EOR.

Tabel 5 menampilkan hasil uji filtrasi pada larutan surfaktan yang memiliki nilai filtration rate yang relatif kecil. Surfaktan Sapindus rarak memiliki kemiringan garis yang tidak konsisten, yang berarti terdapat kecenderungan molekul surfaktan untuk menyumbat saat surfaktan larut melintasi membran.

Tabel 5 Hasil pengujian filtrasi

Salinitas (ppm)	**Konsentrasi (%)**	**Volume *Effluent* Terhadap Waktu (ml)**						
		60 menit	**180 menit**	**300 menit**	**420 menit**	**540 menit**	**600 menit**	***Filtration Rate***
6.000	0,5	130	354	540	742	900	985,46	1,028
6.000	1,0	125	346	435	720	895	979,57	1,000
6.000	1,5	121	334	430	712	890	974,89	1,130
6.000	2,0	116	325	425	702	885	968,96	1,054
6.000	2,5	109	314	416	689	854	926,89	1,025
6.000	3,0	100	305	402	654	842	897,56	0,943
10.000	0,5	126	342	512	680	820	918,75	0,622
10.000	1,0	123	325	501	662	812	900,00	0,783
10.000	1,5	112	304	482	642	799	896,25	0,879
10.000	2,0	105	295	468	621	795	893,75	0,708
10.000	2,5	101	287	456	610	784	887,50	0,766
10.000	3,0	99	275	446	602	772	850,00	0,840

6. Uji kelakuan fasa (phase behavior)

Hasil pengujian phase behaviour secara keseluruhan, mulai dari volume emulsi, jenis fasa serta kestabilan volume fasa dapat dilihat pada Tabel 6 dan 7.

Tabel 6 Hasil pengujian phase behaviour pada salinitas 6.000 ppm

Jenis minyak	**Komposisi Surfaktan**	**Fasa**	**Volume (ml) pada Waktu Pengamatan (Jam)**									**Total Emulsi Fasa**	**Jenis Emulsi Fasa**
			0	0,5	1	2	24	48	168	336	504		
Light Crude Oil 45 API	Salinitas 6000 ppm 0,5% Surfaktan	Minyak	0,00	1,97	1,97	1,97	1,97	1,97	1,99	1,99	2,00	0,25%	Bawah
		Emulsi	2,75	0,28	0,13	0,09	0,05	0,04	0,02	0,02	0,01		
		Surfaktan	1,25	1,75	1,90	1,94	1,98	1,99	1,99	1,99	1,99		
	Salinitas 6000 ppm 1,0% Surfaktan	Minyak	0,00	1,75	1,80	1,86	1,95	1,95	2,00	2,00	2,00	0,75%	Bawah
		Emulsi	2,95	0,35	0,30	0,24	0,11	0,09	0,04	0,03	0,03		
		Surfaktan	1,05	1,90	1,90	1,90	1,94	1,96	1,96	1,97	1,97		
	Salinitas 6000 ppm 1,5% Surfaktan	Minyak	0,00	1,87	1,92	1,92	1,94	1,95	1,97	1,97	1,97	1,25%	Tengah
		Emulsi	3,20	0,18	0,13	0,10	0,08	0,07	0,05	0,05	0,05		
		Surfaktan	0,80	1,95	1,95	1,98	1,98	1,98	1,98	1,98	1,98		
	Salinitas 6000 ppm 2,0% Surfaktan	Minyak	0,00	0,15	1,50	1,80	1,93	1,97	1,97	1,97	1,97	2,00%	Tengah
		Emulsi	4,00	2,15	0,65	0,28	0,12	0,08	0,08	0,08	0,08		
		Surfaktan	0,00	1,70	1,85	1,92	1,95	1,95	1,95	1,95	1,95		
	Salinitas 6000 ppm 2,5% Surfaktan	Minyak	0,00	0,00	1,68	1,90	1,95	1,95	1,95	1,95	1,95	1,25%	Atas
		Emulsi	2,40	2,17	0,32	0,10	0,05	0,05	0,05	0,05	0,05		
		Surfaktan	1,60	1,83	2,00	2,00	2,00	2,00	2,00	2,00	2,00		
	Salinitas 6000 ppm 3,0% Surfaktan	Minyak	0,00	1,85	1,88	1,93	1,97	1,98	1,98	1,98	1,98	1,50%	Tengah
		Emulsi	4,00	0,20	0,17	0,09	0,05	0,04	0,04	0,06	0,06		
		Surfaktan	0,00	1,95	1,95	1,98	1,98	1,98	1,98	1,96	1,96		

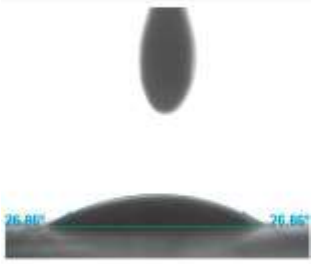
Tabel 7 Hasil pengujian phase behaviour pada salinitas 10.000 ppm

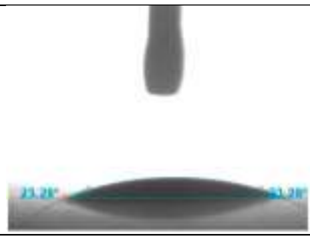
Jenis minyak	Komposisi Surfaktan	Fasa	Volume (ml) pada Waktu Pengamatan (Jam)									Total Emulsi Fasa	Jenis Emulsi Fasa
			0	0,5	1	2	24	48	168	336	504		
Light Crude Oil 45 API	Salinitas 10.000 ppm 0,5% Surfaktan	Minyak	0,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	0,25%	Bawah
		Emulsi	2,75	0,07	0,07	0,06	0,06	0,05	0,05	0,02	0,01		
		Surfaktan	1,25	1,93	1,93	1,94	1,94	1,95	1,95	1,98	1,99		
	Salinitas 10.000 ppm 1,0% Surfaktan	Minyak	0,00	1,95	1,95	2,00	2,00	2,00	2,00	2,00	2,00	1,25%	Bawah
		Emulsi	2,95	0,25	0,25	0,15	0,05	0,05	0,05	0,05	0,05		
		Surfaktan	1,05	1,80	1,80	1,85	1,95	1,95	1,95	1,95	1,95		
	Salinitas 10.000 ppm 1,5% Surfaktan	Minyak	0,00	1,90	1,98	1,98	1,98	2,00	2,00	2,00	2,00	1,00%	Bawah
		Emulsi	3,20	0,35	0,12	0,08	0,06	0,04	0,04	0,04	0,04		
		Surfaktan	0,80	1,75	1,90	1,94	1,96	1,96	1,96	1,96	1,96		
	Salinitas 10.000 ppm 2,0% Surfaktan	Minyak	0,00	1,95	1,95	1,95	1,95	1,95	1,95	1,95	1,95	1,50%	Tengah
		Emulsi	3,20	0,10	0,10	0,06	0,06	0,06	0,06	0,06	0,06		
		Surfaktan	0,80	1,95	1,95	1,99	1,99	1,99	1,99	1,99	1,99		
	Salinitas 10.000 ppm 2,5% Surfaktan	Minyak	0,00	1,97	1,97	1,97	1,97	1,97	1,97	1,97	1,97	3,30%	Tengah
		Emulsi	2,40	0,28	0,28	0,28	0,13	0,13	0,13	0,13	0,13		
		Surfaktan	1,60	1,75	1,75	1,75	1,90	1,90	1,90	1,90	1,90		
	Salinitas 10.000 ppm 3,0% Surfaktan	Minyak	0,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,50%	Bawah
		Emulsi	4,00	0,35	0,30	0,30	0,15	0,15	0,14	0,10	0,10		
		Surfaktan	0,00	1,65	1,70	1,70	1,85	1,85	1,86	1,90	1,90		

7. Uji wettability

Pengujian dilakukan menggunakan alat pendant drop di laboratorium EOR OGRINDO ITB. Hasil pengujian wettability dapat dilihat pada Tabel 8. Diketahui bahwa sudut kontak dari surfaktan Sapindus rarak 2,0% + 6.000 ppm brine ialah 26,86° serta sudut kontak dari surfaktan Sapindus rarak 2,5% + 10.000 ppm brine ialah 23,28° dimana $\theta < 90°$ dianggap water-wet.

Tabel 8 Hasil pengujian sudut kontak

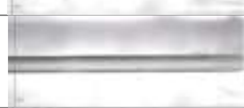
Jenis dan Konsentrasi Surfaktan	Jenis Batuan	Sudut Kontak	Visual
6.000 ppm *brine* + surfaktan Sapindus rarak 2,0%	berea *sandstone*	26,86°	

10.000 ppm *brine* + surfaktan Sapindus rarak 2,5%	berea *sandstone*	23,28°	

8. Uji IFT dan Thermal Stability

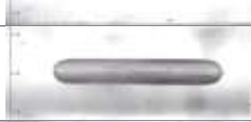
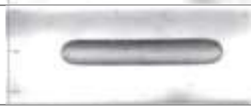
Pada pengujian IFT untuk surfaktan Sapindus rarak alat yang digunakan adalah spinning drop tensiometer TX 500D di laboratorium OGRINDO ITB. Hasil pengujian yang didapatkan dapat dilihat pada Tabel 9 dan 10. Dari Tabel 9 dan Tabel 10, diperoleh nilai IFT untuk salinitas 6.000 ppm dengan konsentrasi 2,0% sebesar 2,15 x 10^{-1} mN/m pada 0 hari dan 5,81 x 10^{-2} mN/m pada 12 minggu. Terjadi penurunan nilai IFT yang cukup signifikan dari 0 hari ke 2 minggu menjadi 5,16 x 10^{-2} mN/m dan mulai stabil hingga minggu ke 12. Waktu menjadi tolak ukur untuk membedakan konsentrasi surfaktan dan salinitas yang memiliki ketahanan dan kestabilan termal yang baik.

Tabel 9 Hasil pengujian IFT dan thermal stability konsentrasi 2,0% pada salinitas 6.000 ppm

Sampel Surfaktan	Waktu (Minggu)	IFT (mN/m)	Visualisasi pada Alat
Salinitas 6.000 ppm + surfaktan 2,0%	0	2,15E-01	
	2	5,16E-02	
	4	4,32E-02	
	6	4,86E-02	
	8	5,81E-02	
	10	5,48E-02	
	12	5,81E-02	

Tabel 10 Hasil pengujian IFT dan thermal stability konsentrasi 2,5% pada salinitas 10.000 ppm

Sampel Surfaktan	Waktu (Minggu)	IFT (mN/m)	Visualisasi pada Alat
Salinitas 10.000 ppm + surfaktan 2,5%	0	1,71E-01	
	2	1,71E-01	
	4	1,58E-01	

	6	1,58E-01	
	8	1,64E-01	
	10	1,92E-01	
	12	1,51E-01	

9. Uji Adsorpsi Statik dan Dinamik

Hasil uji adsorpsi statik pada salinitas 6.000 ppm dan 10.000 ppm ditampilkan pada Tabel 11 sedangkan pengujian adsorpsi dinamik terdapat pada Tabel 12.

Tabel 11 Hasil pengujian adsorpsi statik

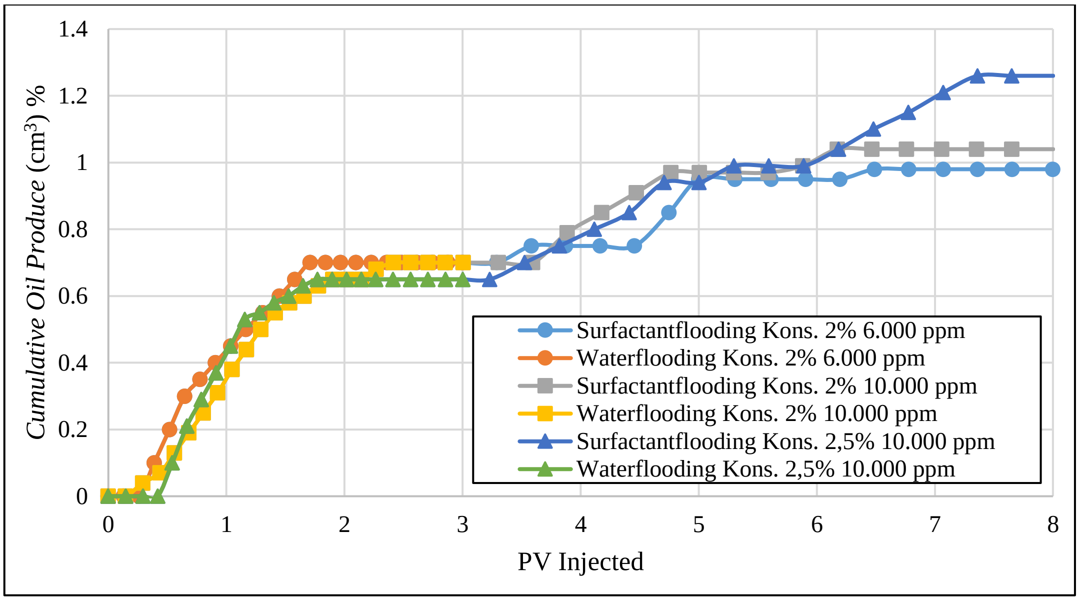
Jenis Surfaktan	Konsentrasi Awal (%)	Absorbansi Awal (AU)	Absorbansi Akhir (AU)	Konsentrasi Akhir (%)	Adsorpsi (mg/gr)
Sapindus rarak 6.000 ppm	0,5	0,65	0,54	0,003	955,89
	1,0	0,83	0,55	0,007	1.867,37
	1,5	0,84	0,56	0,015	2.719,68
	2,0	0,88	0,59	0,025	3.524,01
	2,5	1,23	0,64	0,045	4.097,90
	3,0	1,24	0,75	0,091	4.178,08
Sapindus rarak 10.000 ppm	0,5	0,84	0,75	0,05	906,54
	1,0	1,10	0,76	0,09	1.828,36
	1,5	1,13	0,80	0,21	2.591,08
	2,0	1,32	0,83	0,33	3.339,76
	2,5	1,48	0,92	0,64	3.704,19
	3,0	1,60	1,00	0,90	4.171,96

Tabel 12 Adsorpsi dinamik Sapindus rarak pada salinitas 6.000 dan 10.000 ppm

Sampel	Massa Surfaktan in (gram)	Massa Surfaktan Out (gram)	Nilai Adsorpsi (mg/g)
Sapindus rarak 2 % salinitas 6.000 ppm	0,337	0,187	5,262
Sapindus rarak 2,5 % salinitas 10.000 ppm	0,409	0,134	9,711

10. Uji Coreflooding

Uji coreflooding dilakukan untuk 3 sampel larutan surfaktan yaitu konsentrasi 2,0% salinitas 6.000 ppm, konsentrasi 2,0% dan 2,5% salinitas 10.000 ppm. Hasil pengukuran recovery factor dari ketiga uji coreflooding diperlihatkan pada di Gambar J.1. Penerapan injeksi surfaktan dengan konsentrasi 2,0% dan salinitas 6.000 ppm setelah injeksi air memberikan penambahan produksi minyak sebesar 0,28 cm3. Penerapan injeksi surfaktan dengan konsentrasi 2,0% dan salinitas 10.000 ppm setelah injeksi air memberikan penambahan produksi minyak sebesar 0,34 cm^3. Sedangkan, penerapan injeksi surfaktan dengan konsentrasi 2,5% dan salinitas 10.000 ppm setelah injeksi air memberikan penambahan produksi minyak sebesar 0,61 cm^3.



Gambar 1 Surfactantflooding larutan lerak konsentrasi 2,0% salinitas 6.000 ppm, konsentrasi 2,0% dan 2,5% salinitas 10.000 ppm

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaian setiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran melalui BIMA.

Penelitian ini telah menghasilkan paper yang disubmit pada jurnal internasional bereputasi Q3 yaitu Scientific Contribution Oil & Gas sesuai dengan tujuan.

Luaran penelitian adalah publikasi ilmiah yang disubmit pada jurnal internasional bereputasi, sebagai berikut:

Jenis luaran	Identitas	Status
Luaran wajib: Jurnal internasional bereputasi	Judul: Characterization of Biosurfactant from Sapindus Rarak for Enhanced Oil Recovery Jurnal: Scientific Contributions Oil and Gas Website: https://journal.lemigas.esdm.go.id/index.php/SCOG Penerbit: PPTMGB Lemigas	Review
Luaran tambahan	Judul: Application of Natural Surfactant from Morus alba, Soapnut, Sapindus rarak for Enhanced Oil Recovery – Critical Review Proceeding: IOP Conference Series: Earth and Environmental Science Website: https://iopscience.iop.org/article/10.1088/1755-1315/1339/1/012025	Publish
Luaran tambahan	Judul: Study of Sapindus rarak Properties as A Natural Surfactant for Enhanced Oil Recovery Injection Fluids Seminar: International Conference of Petroleum, Mining, Geology, Geiscience, Energy & Environmental Technology Website: https://icpmget.ftke.trisakti.ac.id/	Review (Sudah dipresentasikan)

E. **PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash* serta mengunggah bukti dokumen pendukung sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra dapat diunggah melalui BIMA.

Catatan:
Bagian ini wajib diisi untuk penelitian terapan, untuk penelitian dasar (Fundamental, Pascasarjana, PKDN, Dosen Pemula) boleh mengisi bagian ini (tidak wajib) jika melibatkan mitra dalam pelaksanaan penelitiannya

Tidak ada mitra dalam penelitian ini.

F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

Tidak ada kendala. Penelitian dan luaran sesuai dengan yang direncanakan.

G. RENCANA TAHAPAN SELANJUTNYA: Tuliskan dan uraikan rencana penelitian selanjutnya berdasarkan indikator luaran yang telah dicapai, rencana realisasi luaran wajib yang dijanjikan dan tambahan (jika ada) di tahun berikutnya serta *roadmap* penelitian keseluruhan. Pada bagian ini diperbolehkan untuk melengkapi penjelasan dari setiap tahapan dalam metoda yang akan direncanakan termasuk jadwal berkaitan dengan strategi untuk mencapai luaran seperti yang telah dijanjikan dalam proposal. Jika diperlukan, penjelasan dapat juga dilengkapi dengan gambar, tabel, diagram, serta pustaka yang relevan. Jika laporan kemajuan merupakan laporan pelaksanaan tahun terakhir, pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai.

Untuk menyelesaikan penelitan ini akan dilaksanakan 15% lagi penelitian hingga final yang meliputi tahap uji analisis perolehan minyak. Tahap berikutnya adalah pemodelan dan simulasi menggunakan Artificial Neural Network (ANN) dan Adaptive Neuro Fuzzy Inference System (ANFIS) yang akan berlangsung pada 30 September 2023. Penelitian diupayakan akan selesai pada akhir Oktober 2023, dengan rincian kegiatan sebagai berikut:

Tahap	Kegiatan	Capaian	Status
1	Persiapan sampel a. Persiapan core b. Pembuatan air formasi sintetis (brine) dengan variasi salinitas 6000 ppm dan10000 ppm c. Penyiapan sampel minyak d. Pembuatan larutan surfakatan Sapindus rarak dengan variasi konsentrasi 0.5%, 1%, 1.5%, 2%, 2.5%, dan 3%	a. Persiapan core, 100% selesai b. Brine, 100% selesai c. Dua belas larutan surfaktan, selesai 100%	Persiapan sampel selesai sesuai dengan rencana kerja proposal.
2	Uji karakterisasi larutan surfaktan a. Aqueous stability test b. Phase behavior test c. Uji filtrasi d. Uji viscosity	a. Aqueous stability test (100% selesai) b. Phase behavior test (100% selesai) c. Uji filtrasi (100% selesai) d. Uji viscosity (100% selesai)	Uji tahap 1 selesai sesuai dengan rencana kerja proposal.
3	Analisis interaksi fluida-batuan a. Uji adsorpsi b. Uji Wettability c. Uji Interfacial Tension (IFT) and thermal stability test	a. Uji adsorpsi, selesai 100% b. Uji Wettability, selesai 100% c. IFT and thermal stability test (100% selesai)	Uji tahap 2 selesai sesuai dengan rencana kerja proposal.
4	Analisis perolehan minyak	Uji waterflooding dan surfaktan flooding selesai 100%	Uji tahap 3 selesai sesuai dengan rencana kerja proposal.
5	Pemodelan dan simulasi a. Artificial neural network (ANN) b. Adaptive neuro fuzzy inference system (ANFIS)	Pemodelan dan simulasi direncanakan selesai pada akhir Sept 2024	Hasil analisis pemodelan dan simulasi akan diselesaikan paling lambat pada akhir Oktober 2024

H. DAFTAR PUSTAKA: Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan kemajuan yang dicantumkan dalam Daftar Pustaka.

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CHARACTERIZATION OF BIOSURFACTANT FROM SAPINDUS RARAK FOR ENHANCED OIL RECOVERY

KARAKTERISASI BIOSURFAKTAN DARI SAPINDUS RARAK UNTUK PENINGKATAN PEROLEHAN MINYAK

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ABSTRACT (INDONESIAN VERSION)

Surfaktan-hijau merupakan surfaktan yang berasal dari bahan alam seperti tumbuhan, hewan, dan mikroorganisme. Sapindus rarak mengandung saponin, salah satu jenis surfaktan alami yang sudah dikenal luas. Penelitian ini mengevaluasi efektivitas penyuntikan surfaktan menggunakan Sapindus rarak. Penelitian ini merupakan desain eksperimen dan analitik laboratorium dengan variasi salinitas 6.000 dan 10.000 ppm dan enam variasi konsentrasi dari 0,5% hingga 3,0% menggunakan inti batupasir Berea pada suhu 60°C. Pengujian kompatibilitas berdasarkan stabilitas air dan uji perilaku fasa menunjukkan bahwa hanya dua konsentrasi yaitu 2,5% dan 3,0% pada salinitas 10.000 ppm yang homogen. Pada uji perilaku fasa, volume emulsi terbesar untuk masing-masing salinitas adalah 2,0% pada 6.000 ppm dan 2,5% pada 10.000 ppm. Uji keterbasahan dimulai dengan hasil sudut kontak yang menunjukkan sudut basah air yang kuat sebesar 26,86° dan 23,28°. Hasil uji IFT untuk kedua sampel masing-masing adalah 2,15 x 10^{-1} dan 1,71 x 10^{-1} mN/m. Nilai stabilitas termal stabil selama 12 minggu masing-masing sebesar 5,81 x 10^{-2} dan 1,51 x 10^{-1} mN/m. RF variasi untuk penggenangan air adalah 35,35% dan 25,00%, sedangkan untuk penggenangan surfaktan masing-masing adalah 14,14% dan 23,49%.

Kata Kunci: biosurfaktan, sapindus rarak, salinitas, coreflooding, faktor perolehan

ABSTRACT (ENGLISH VERSION)

Green-Surfactant is a surfactant derived from natural materials such as plants, animals, and microorganisms. Sapindus rarak contains saponin, a well-known type of natural surfactant. This study evaluates the effectiveness of surfactant injection using Sapindus rarak. The study is a laboratory experimental and analytical design with salinity variations of 6,000 and 10,000 ppm and six concentration variations from 0.5% to 3.0% using Berea sandstone core at 60 ℃. Compatibility testing based on aqueous stability and phase behavior tests showed that only two concentrations of 2.5% and 3.0% at a salinity of 10,000 ppm were homogeneous. In the phase behavior test, the largest emulsion volume for each salinity was 2.0% at 6,000 ppm and 2.5% at 10,000 ppm, respectively. The wettability test began with contact angle results showing strongly water-wet angles of 26.86° and 23.28°. The IFT test results for both samples were 2.15 x 10^{-1} and 1.71 x 10^{-1} mN/m, respectively. Thermal stability values were stable for 12 weeks at 5.81 x 10^{-2} and 1.51 x 10^{-1} mN/m, respectively. The RF of the variations for waterflooding was 35.35% and 25.00%, while that for surfactant flooding was 14.14% and 23.49%, respectively.

Keywords: biosurfactant, sapindus rarak, salinity, coreflooding, recovery factor

I. INTRODUCTION

The use of surfactants aims to reduce the interfacial tension between 2 immiscible fluids. This causes the orientation of the intermolecular attraction on the water surface to change, which was previously oriented downward (into the water) to upward (towards the oil) after the surfactant is added. The upward attraction makes the molecules on the water surface active to attract other molecules on its surface (Gbadamosi et al., 2019). Surfactant flooding involves the use of chemical surfactants and natural surfactants or biosurfactants. The achievement of ultra-low IFT is usually accompanied by the presence of a middle phase microemulsion in the surfactant phase behavior test.

Green-surfactant is obtained from natural raw materials such as Lerak fruit (Sapindus rarak). Lerak fruit (Sapindus rarak) is a plant that is used as a raw material for natural soap because it contains saponins found in its seeds. The bioactive and physicochemical properties of natural saponins have been shown to be better than synthetic saponins, making them a promising source of natural surfactants, both for research and commercial purposes (Rai et al., 2021). Sapindus rarak contains saponins because mixing and stirring soapberry fruit with water will produce soap foam called 'saponin'. Utilizing organic resources more efficiently will make a positive contribution to a greener environment.

Saponins contain anti-bacterial and anti-fungal properties so they are safe for all types of industries that are for cleaning in terms of content and efficacy (Darwis, 2021). Saponins are a well-known type of plant surfactant. This type of surfactant can be produced with quite large added value and cost effects that can be used in environmental control efforts such as industrial emulsion processing, oil pollution control, industrial wastewater detoxification and bioremediation of contaminated soil (Hajimohammadi et al., 2017).

Soapnut is a tropical plant that is widely found in various countries including Indonesia and is abundant in Java and its surroundings. The leaves are 6 to 16 inches long with white fruit protected by brown skin in a round shape with a diameter of 1-2 cm. This fruit is known as a commodity that produces many derivative products such as soap, detergent and surface active agent (surfactant) (Fatimah et al., 2020). Sapindus rarak contains saponins, flavonoids, alkaloids, tannins, steroids, and triterpenes (Wayan et al., 2022). Before knowing green-surfactants as cleaning agents, most conventional detergents used surfactants in the form of phosphates, alkyl benzene sulfonates, diethanolamines and alkyl phenoxy. All of the compounds mentioned are included in the group of compounds that are harmful to the environment and toxic and come from non-renewable resources, namely oil.

Saponins are natural secondary metabolites from plants with surfactant properties, which are synthesized by plants and some marine organisms. In terms of chemical structure, saponins are classified as glycosides. The name saponin comes from its soapy nature, where the Latin word sapo means 'soap'. Saponin is able to reduce IFT from 48 to 9 dynes/cm which makes saponin have the same ability as conventional surfactants commonly used in chemical injection processes. An average contact angle of 50.24° was obtained which is in the relatively hydrophilic range (Shahri M P et al., 2012). Saponin contains a pH in the range of 8-11 and foam stability in the range of 13-200 mm (Nurrosyidah et al., 2023).

In aqueous solution, saponin reduces the surface tension of water and exhibits foam-forming properties. The detergent properties of saponin come from its amphiphilic structure, which consists of a hydrophobic skeleton known as aglycone (or genin) and a hydrophilic sugar group (glycone) (Anggraeni Putri et al., 2023). The two glycoside-forming parts are the basis of the structural variation of saponins in nature. The glycone part consists of one or more sugar chains, which are then bound to the aglycone through a glycosidic bond. The O-glycosidic bond separates the two structural parts of the saponin, acting as a boundary as shown in the Figure below. Saponins are mainly classified based on differences in aglycone structure or the number of sugar chains. The basic classification is based on the skeletal structure that distinguishes two main groups, steroids and triterpenoids.

Research (Rai et al., 2021) explains that the two classes of saponins (steroids and triterpenoids) have different numbers of molecules. There are molecules with 27 C atoms in steroid saponins and 30 C atoms in triterpenoid saponins. There are 2 types of steroid saponins, namely furostanol and spirostanol. Saponins from several families such as Solanaceae have steroid glycoalkaloids as the aglycone backbone. In addition to steroids, there are 3 types of triterpenoid saponins, namely: oleanane saponins (for example, sapindus mukorossi, and camellia oleifera), ursolic acid saponins, for example, ilex paragariensis, and dammarane saponins, for example, panax ginseng.

The purpose of the study was to analyze whether the Sapindus rarak surfactant solution is compatible with brine and light crude oil solutions based on aqueous stability testing, phase behavior testing, and wettability. In addition, this study is to observe the thermal stability of Sapindus rarak surfactant solution based on thermal stability and IFT tests. Furthermore, the main objective is to determine the recovery factor of surfactant flooding using Sapindus rarak for light crude oil.

II. METHODOLOGY

This research includes collecting materials and equipment for conducting laboratory experiments. The results of the experiments were used to evaluate the characteristics and performance of Sapindus rarak surfactants in increasing oil recovery.

A. Materials

The following are the materials used in the study, namely: Surfactant from Sapindus rarak fruit. Surfactant solutions were made with various concentrations of Sapindus rarak. Synthetic brine used to dissolve surfactants was made with low salinities. The crude oil used was light crude oil with a specific gravity of 42.92 ° API. The core sample used in the study was Berea core.

B. Equipments

The equipment used is in the laboratory of the Petroleum Engineering Department of Trisakti University such as the Enhanced Oil Recovery laboratory, Reservoir Rock Analysis Laboratory, and Reservoir Fluid Laboratory. In addition, some research is also conducted in the Oil and Gas Recovery Research for Indonesia laboratory at the Bandung Institute of Technology (OGRINDO ITB).

C. Laboratory Experiments

The studies conducted include:

1. Preparation of Sapindus rarak solution.
2. Measurement of fluid physical properties
3. Measurement of core physical properties
4. Filtration test
5. Aqueous stability test
6. Phase behavior test
7. Wettability test
8. IFT and thermal stability test
9. Coreflooding test

Surfactant solutions were made with variations in Sapindus rarak concentrations of 0.5%, 1%, 1.5%, 2%, 2.5%, and 3%. While the salinity of the brine used was 6,000 ppm and 10,000 ppm. The first to sixth experiments were carried out for solutions with various combinations of concentrations and salinities.

III. RESULTS AND DISCUSSION

3.1 Preparation of Sapindus rarak Solution

Surfactant solution was made with a combination of concentration and salinity. The concentration variation of Sapindus rarak ranged from 0.5% to 3%. While the salinity of the brine used was 6,000 ppm and 10,000 ppm. So there were twelve fluid samples used in the experiment as shown in Table 1.

Table 1
Twelve surfactant solutions with various combinations of surfactant concentration and salinity.

Solution	Concentration, %	Salinity, ppm
1	0.5	6,000
2	1	6,000
3	1.5	6,000
4	2	6,000
5	2.5	6,000
6	3	6,000
7	0.5	10,000
8	1	10,000
9	1.5	10,000
10	2	10,000
11	2.5	10,000
12	3	10,000

3.2 Measurement of Physical Properties of Fluids

The physical properties of the surfactant solution that were measured were specific gravity and viscosity. The results of the specific gravity and viscosity measurements for the twelve fluid samples are given respectively in Figures 1 and 2.

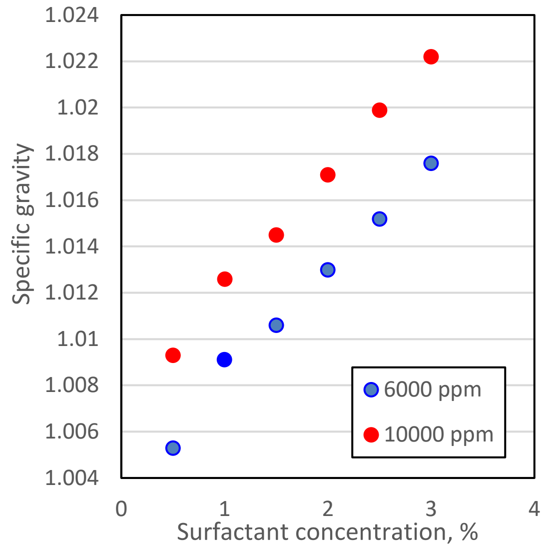

Figure 1
Specific gravity of surfactant solution

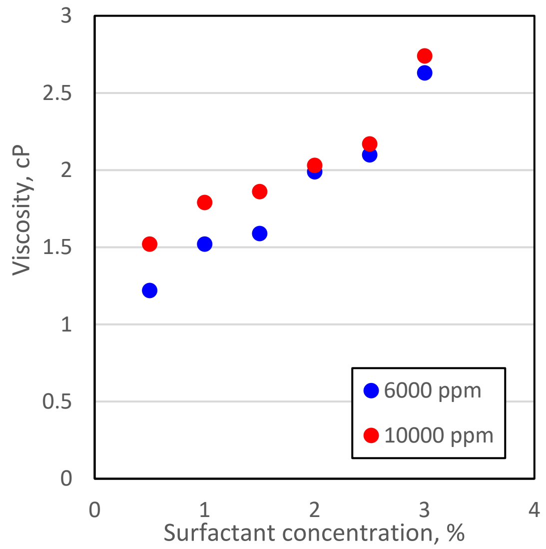

Figure 2
Viscosity of surfactant solution

Based on Figures 1 and 2, it can be seen that the specific gravity and viscosity increase with increasing concentration of surfactant solution. The average increase in specific gravity is 0.48% for every 1% increase in concentration. In addition, Figure 1 shows that the effect of salinity on the specific gravity of the solution is greater with increasing salinity.

Figure 2 displays the findings of the viscosity computations for different concentrations at salinities of 6,000 ppm and 10,000 ppm. The surfactant solution's viscosity ranges from 1.2190 cP to 2.6347 cP at a salinity of 6,000 ppm, as shown in the figure. With a salinity of 10,000 ppm, the viscosity varies from 1.5215 cP to 2.7473 cP, which is slightly higher.

The formation of micelles and the solution's viscosity can both be significantly impacted by the addition of salt to the surfactant solution. This is because electrolytes, like salt, can encourage the creation of additional micelles by reducing the CMC when they are present in the aqueous phase. As a result, the viscosity will initially rise as the NaCl concentration in the surfactant system increases until it reaches a particular maximum value because of the creation of micelles. Nevertheless, the viscosity will drop once more if the NaCl content rises above a particular point. This is thought to be caused by the breakdown of the micelle network structure and the decrease in hydration capacity, which causes the viscosity to drop (Jin et al., 2023). This implies that the maximum increase in viscosity can be achieved at an ideal salinity value.

The viscosity calculations for surfactant solutions with salinities of 6,000 ppm and 10,000 ppm at different concentrations are displayed in Figure 2. The viscosity values are directly correlated with the flow time, and the size of the surfactant concentration affects viscosity. The viscosity of the fluid increases with surfactant content. Salinity has a fluctuating impact. The average increase in viscosity at low surfactant concentrations (0.5–1.5%) was caused by the salinity change from 6,000 ppm to 10,000 ppm.

On the other hand, the increase in viscosity from 6,000 ppm to 10,000 ppm in salinity only led to an average of 0.08 cP for higher surfactant doses, ranging from 2.0% to 3.0%. This suggests that the magnitude of the surfactant concentration also affects the ideal salinity value for raising viscosity. Furthermore, the outcomes demonstrate that surfactant solutions with high concentrations have a lower ideal salinity value than surfactant solutions with low concentrations.

3.3 Measurement of core physical properties

The results of the measurement of the physical properties of the core are shown in Figure 3. Based on Figure 3, it can be seen that all cores used have almost similar physical characteristics, with an average porosity ranging from 20% - 22%. According to (Febrian et al., 2015), porosity above 20% is categorized as very good, as seen in the core porosity value in this study.

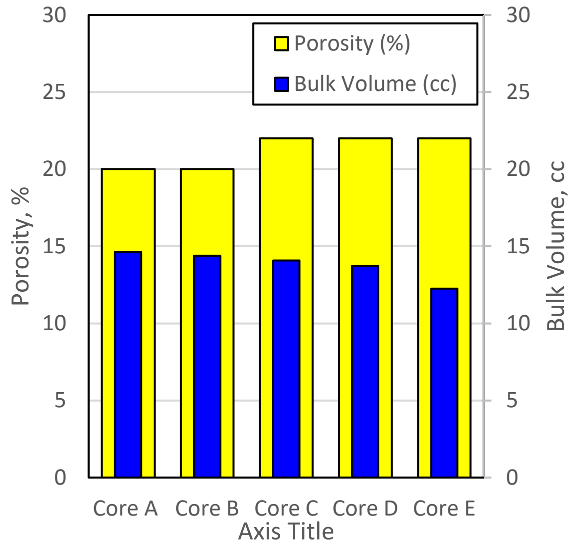

Figure 3
Porosity and bulk volume of five core samples

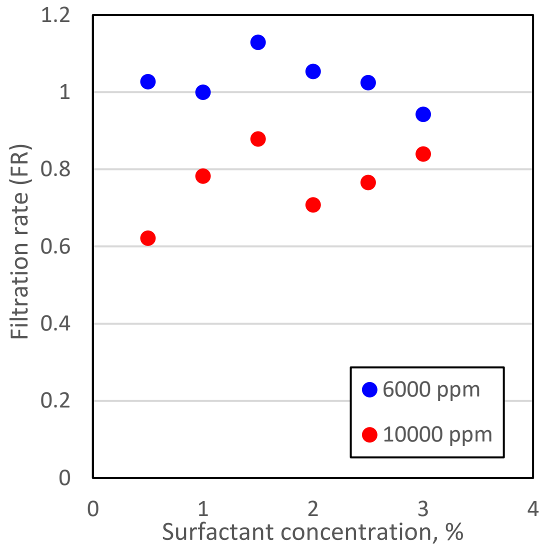

Figure 4
Filtration rate of surfactant solution

3.4 Filtration Test

Based on Edward and Hestuti (2013) stated that, if the sediment or impurities are found to be largely retained on the filter paper, then the surfactant is said to be not good because the filtration results will reduce the concentration of the surfactant. Therefore, the results of the filtration test will determine the quality of the surfactant. Surfactants that are able to pass through the filter (filter paper) well and do not clump indicate that the surfactant can function effectively in the EOR process. Figure 4 shows the results of the filtration test on a surfactant solution that has a relatively small filtration rate value. The Sapindus rarak surfactant has an inconsistent line slope, which means that there is a tendency for surfactant molecules to clog when the surfactant dissolves across the membrane. From the results of the study, it was found that the Sapindus rarak surfactant solution has good performance. This can be seen in Table IV.10 where the FR value obtained is close to the expected FR value, which is less than 1.2.

3.5 Aqueous Stability Test

Aqueous stability testing is one of the initial stages in the surfactant screening process, where the test is carried out for 7 days. Aqueous stability measurement is a visual measurement so that the measurements obtained are qualitative measurements. For this reason, quantitative measurements are needed, namely transmittance tests (%). This is to identify whether there are deposits, colloids, or coarse particles that cannot be completely dissolved in the surfactant solution. The test was carried out using a pipette tube with an oven temperature of 60 ºC. Below is Table 2 showing the results of the aqueous stability test for 12 surfactant solutions.

Table 2
Aqueous stability test results

Solution	Transmittance, %	Condition
1	84.8	Sediment
2	82.4	Sediment
3	80.6	Sediment
4	77.2	Clear
5	74.8	Sediment
6	72.5	Sediment
7	83.9	Sediment
8	81.5	Sediment
9	79.3	Sediment
10	76.8	Sediment
11	73.2	Clear
12	70.6	Clear

Table 2 shows that the transmittance value decreases with increasing concentration and salinity. Increasing the concentration and salinity of the surfactant solution causes a decrease in the amount of light that can pass through the material. So the clearer a solution is, the higher the transmittance value. Table 2 also shows that out of 12 solutions, only 3 concentrations, namely 2.0% concentration at 6,000 ppm salinity, 2.5% concentration and 3.0% at 10,000 ppm salinity, are clear for 168 hours (7 days). This test is very important because unstable surfactants in formation water can disrupt the distribution of surfactants and reduce the performance of surfactants in the EOR process.

3.6 Phase Behavior Test

Based on the results of previous experiments of 2 types of brine solutions and 6 combinations of surfactant concentrations with a total of 12 solutions, 2 best solution samples were selected, namely a solution with a concentration of 2.0% at a salinity of 6,000 ppm and a concentration of 2.5% at a salinity of 10,000 ppm for further testing, namely phase behavior test, wettability test and IFT.

Figure 5 shows the results of the phase behavior test at a concentration of 2.0% at a salinity of 6,000 ppm. Based on the figure, it can be seen that there is a change in the volume of the emulsion every hour where from 0 hours there is a full emulsion of 4 ml of surfactant and crude oil solutions, but at 504 hours the emulsion is in the middle phase (Winsor type III) with a volume of 0.08 ml. The total emulsion produced at stable conditions is 2.0%.

From Figure 6 shows the results of phase behavior testing of 2.5% concentration at 10,000 ppm salinity. As in the previous solution (Figure 5), there was a change in the volume of microemulsion (Winsor type III) where at 0 hours the volume of the emulsion was 2.40 ml and decreased to 0.13 ml at 504 hours (3 weeks). The total emulsion produced at stable conditions was 3.30%.

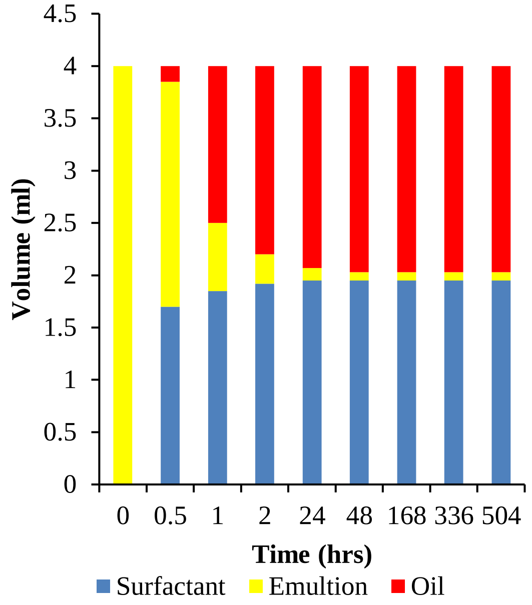

Figure 5
Phase behavior test results at a concentration of 2.0% at a salinity of 6,000 ppm

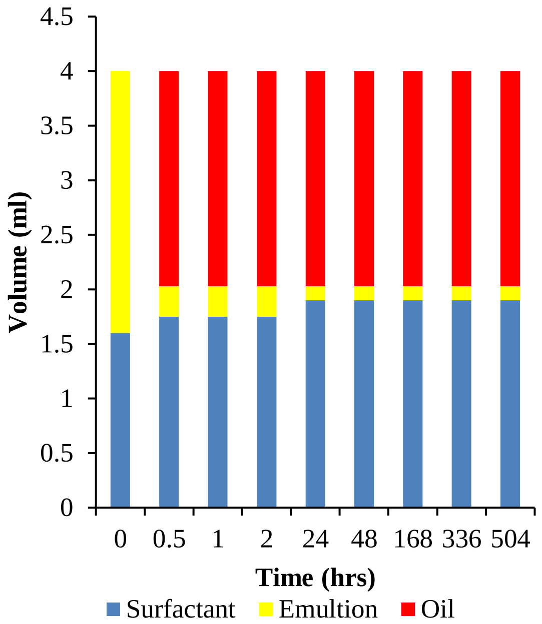

Figure 6
Phase behavior test results at a concentration of 2.5% at a salinity of 10,000 ppm

3.7 Wettability Test

The test was conducted using a pendant drop tool in the EOR OGRINDO ITB laboratory. The wettability test results can be seen in Table 3. It is known that the contact angle of the Sapindus rarak surfactant 2.0% + 6,000 ppm brine is 26.86° and the contact angle of the Sapindus rarak surfactant

2.5% + 10,000 ppm brine is 23.28° where θ <90° is considered water-wet.

Table 3
Contact angle test results

Surfactant Solution	Rock Type	Contact Angel	Visual
2.0%, 6000 ppm	berea *sand-stone*	26.86º	
2.5%, 10000 ppm	berea *sand-stone*	23.28º	

3.8 Interfacial Tension and Thermal Stability Test

In the IFT test for Sapindus rarak surfactant, the tool used was a spinning drop tensiometer TX 500D in the OGRINDO ITB laboratory. The test results obtained can be seen in Figure 7. From Figure 7, the IFT value for 6,000 ppm salinity with a concentration of 2.0% was 2.15 x 10^{-1} mN/m at 0 days and 5.81 x 10^{-2} mN/m at 12 weeks. There was a significant decrease in the IFT value from 0 days to 2 weeks to 5.16 x 10^{-2} mN/m and began to stabilize until the 12th week. Time is a benchmark for distinguishing surfactant concentrations and salinities that have good thermal resistance and stability.

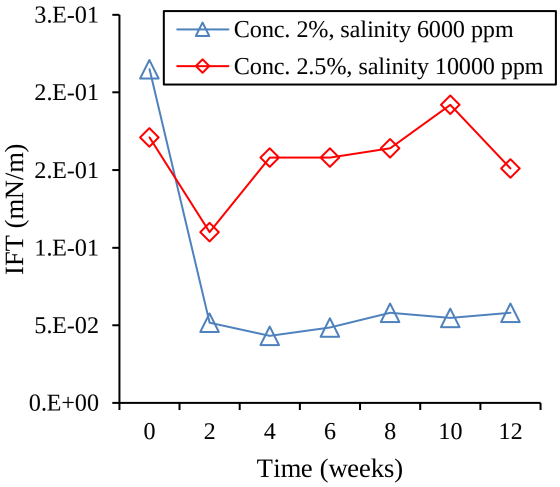

Figure 7
IFT and thermal stability test results

Figure 7 shows the IFT results based on thermal stability for 6,000 ppm salinity with 2.0% concentration and 10,000 ppm salinity with 2.5% concentration. Surfactant solution with 2.0% concentration of 6,000 ppm salinity can reduce surface tension more than 2.5% concentration of 10,000 ppm salinity.

3.9 Uji Coreflooding

Figure 8 shows the results of coreflooding tests of surfactant solutions with a concentration of 2.0% at a salinity of 6,000 ppm and surfactant solutions with a concentration of 2.5% at a salinity of 10,000 ppm based on the waterflooding and surfactant flooding processes.

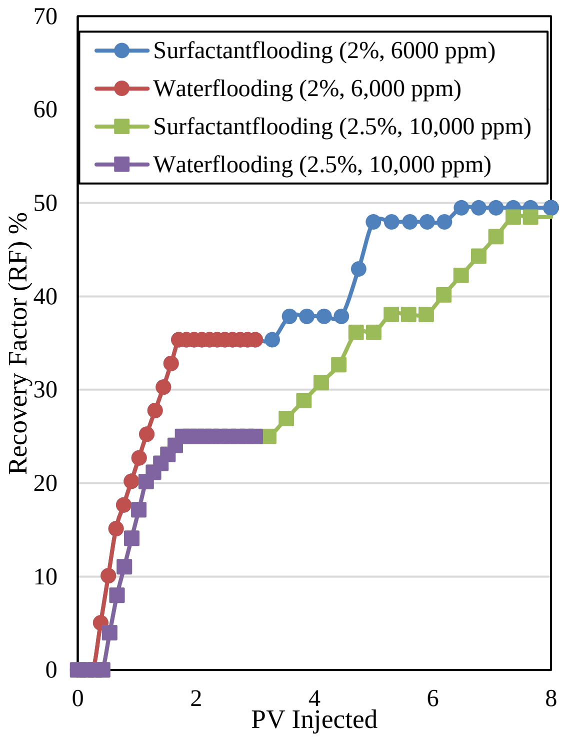

Figure 8
Coreflooding test results

Figure 8 shows that waterflooding with a salinity of 6,000 ppm gives a recovery factor of 35.35%. While waterflooding with a salinity of 10,000 ppm gives a recovery factor of 25%. So the addition of salinity tends to cause a lower waterflooding recovery factor. Waterflooding with low salinity often produces a higher recovery factor compared to high salinity (Yousef et al., 2012). This phenomenon has been explained in various studies and is influenced by several main mechanisms. Research by (Tang and Morrow, 1997) shows that low salinity water injection can increase RF by affecting the petrophysical properties of reservoir rocks. They found that low salinity water injection reduces the capillary tension between oil and rock and increases oil mobility, which contributes to increasing RF (Lager et al., 2008; Tang and Morrow, 1997).

Other information that can be obtained from Figure 8 is about the recovery factor based on the surfactant flooding scheme. The application of surfactant injection with a concentration of 2.5% salinity of 10,000 ppm provides an increase in the recovery factor of 23.49%. In this case, the recovery factor for a surfactant concentration of 2.5% salinity of 10,000 ppm is greater than that of a concentration of 2.0% salinity of 6,000 ppm with an increase in the recovery factor of only 14.14%. This can be caused by four factors, namely the volume of the middle phase emulsion, interfacial tension (IFT), viscosity and contact angle (wettability).

Three factors are owned by the surfactant solution with a concentration of 2.5% salinity of 10,000 ppm, namely a larger middle phase emulsion volume, higher viscosity and lower contact angle (strong water wet) which are positively correlated to the recovery factor. While the IFT value in the 12-week thermal stability test of the surfactant solution is higher than the solution with a concentration of 2.0% salinity of 6,000 ppm which is positively correlated to the recovery factor.

IV. CONCLUSIONS

Based on the results of the research that has been carried out, there are several conclusions from the research, namely:

1. In the aqueous stability test, there are 3 concentrations of Sapindus rarak surfactant solutions that are compatible with brine, namely a concentration of 2.0% salinity of 6,000 ppm and a concentration of 2.5% and 3.0% salinity of 10,000 ppm. While in the phase behavior test, surfactants with a concentration of> 1.5% at a salinity of 6,000 ppm and a concentration of 2.0% and 2.5% at a salinity of 10,000 ppm produce a middle phase emulsion type. 2. The thermal stability of surfactant concentration 2.0% salinity 6,000 ppm with oil 42.92 °API is concluded to be quite stable in weeks 2 to 12. While the thermal stability of surfactant 2.5% salinity 10,000 ppm with oil 42.92 °API is concluded to be quite stable for 12 weeks because it gives relatively the same value.
3. The results of the wettability test of Sapindus rarak surfactant at a concentration of 2.0% and salinity 6,000 ppm obtained a contact angle of 26.86°. While at a concentration of 2.5% and salinity 10,000 ppm the contact angle was 23.28°.
4. The results of the surfactant flooding test at a salinity of 6,000 ppm and a concentration of 2.0% increased RF by 14.14%. Meanwhile, at a salinity of 10,000 ppm and a concentration of 2.5%, RF increased by 23.49%.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
API	American Petroleum Institute gravity	
IFT	Interfacial Tension	mN/m
ϕ	Porosity	
μ	Viscosity	cP

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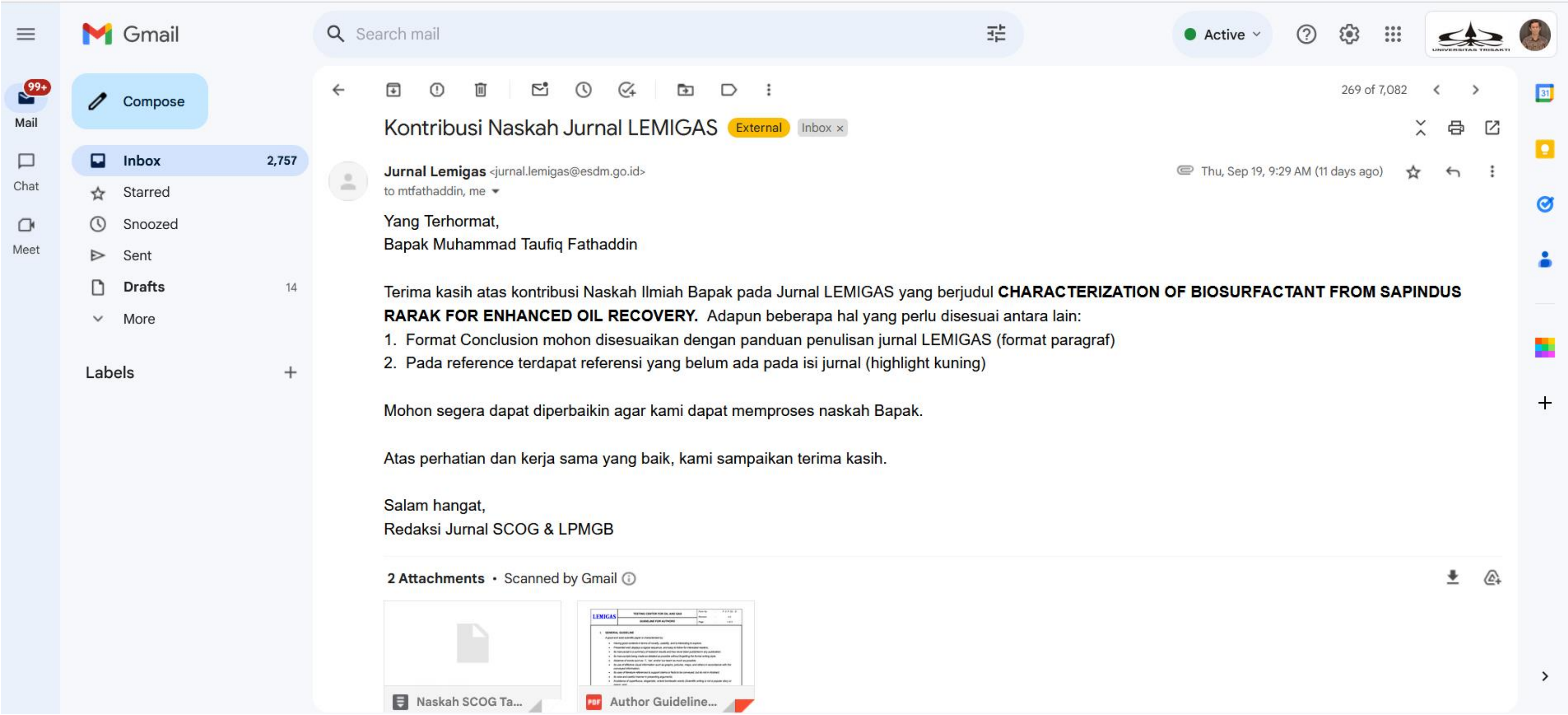

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