HELMHOLTZ-INSTITUT FREIBERG
FÜR RESSOURCENTECHNOLOGIE

Grenzflächenverfahrenstechnik II

7. Vorlesung

31. Januar 2020

Dr. sMartinterface Rudolph

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8 Applikationen
8.1 (Surfactant) Enhanced Oil Recovery

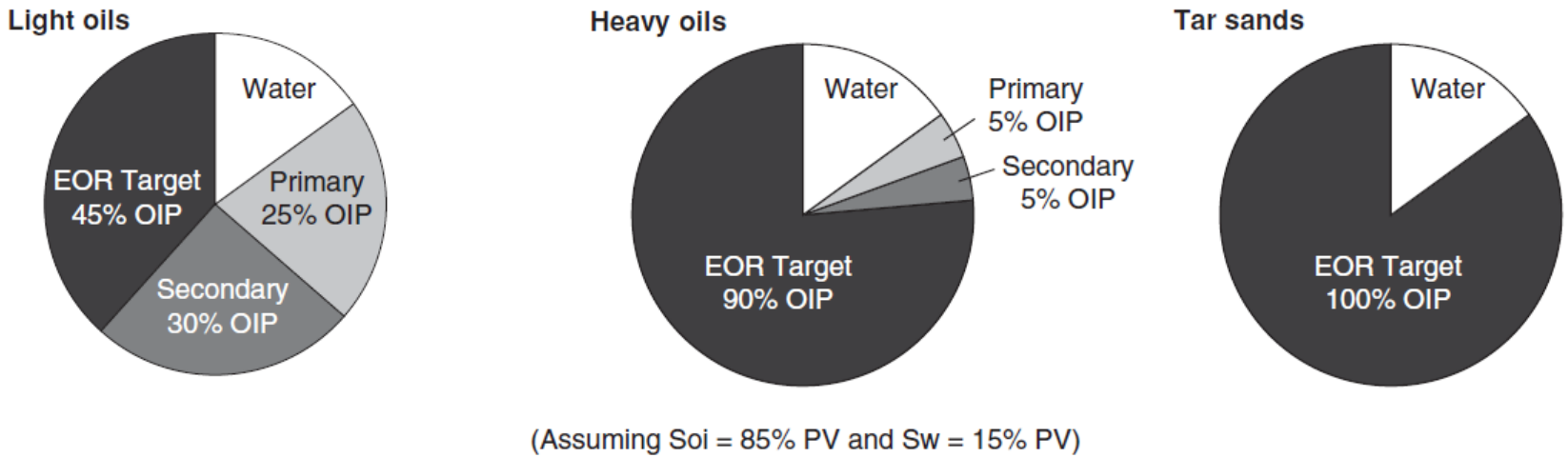

Figure 1

EOR targt for different hydrocarbons.

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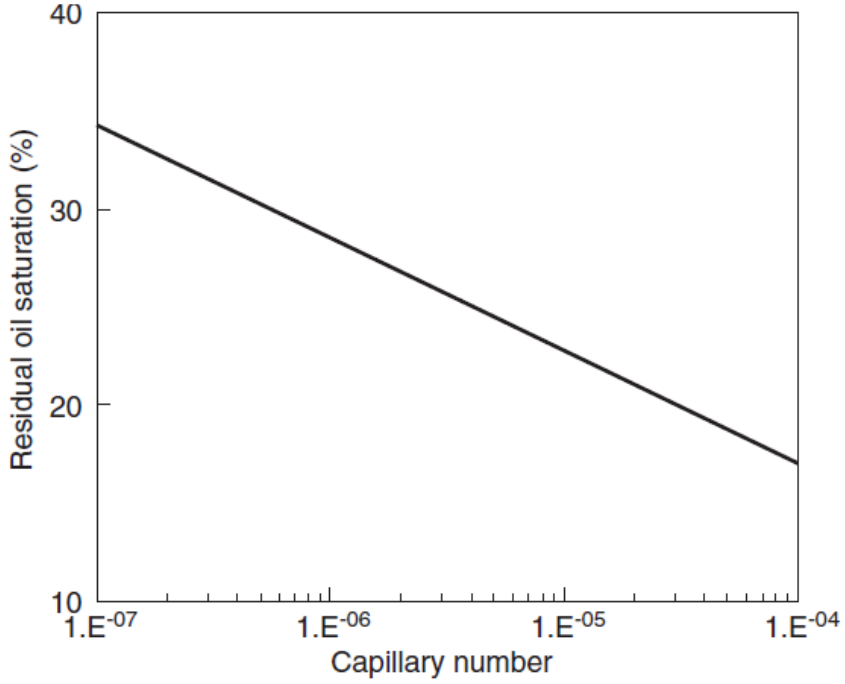

Figure 2

Effect of capillary number on residual oil saturation.

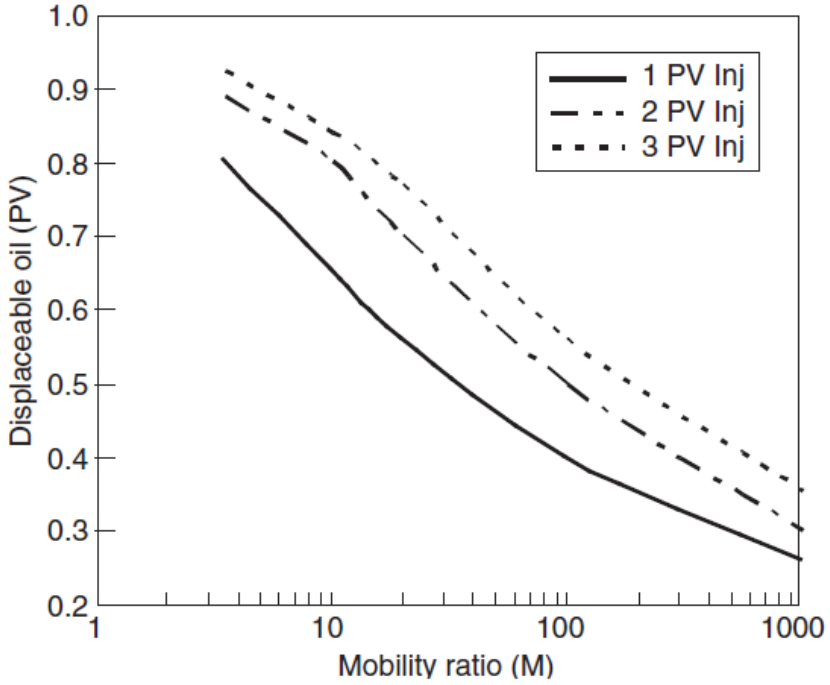

Figure 3

Effect of mobility ratio on displaceable oil.

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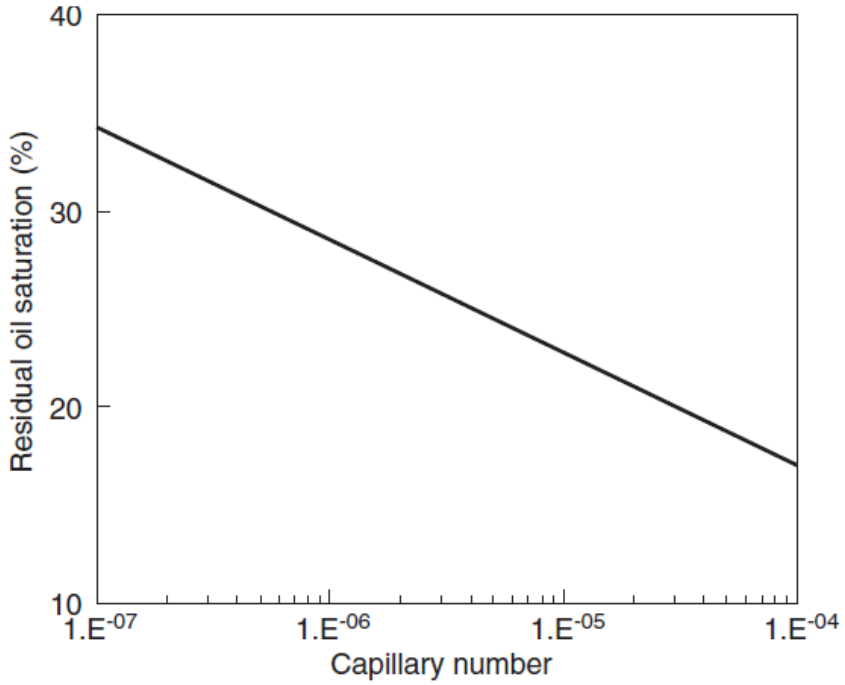

Figure 2

Effect of capillary number on residual oil saturation.

$$N_C = \frac{\nu \cdot \mu}{\gamma}$$

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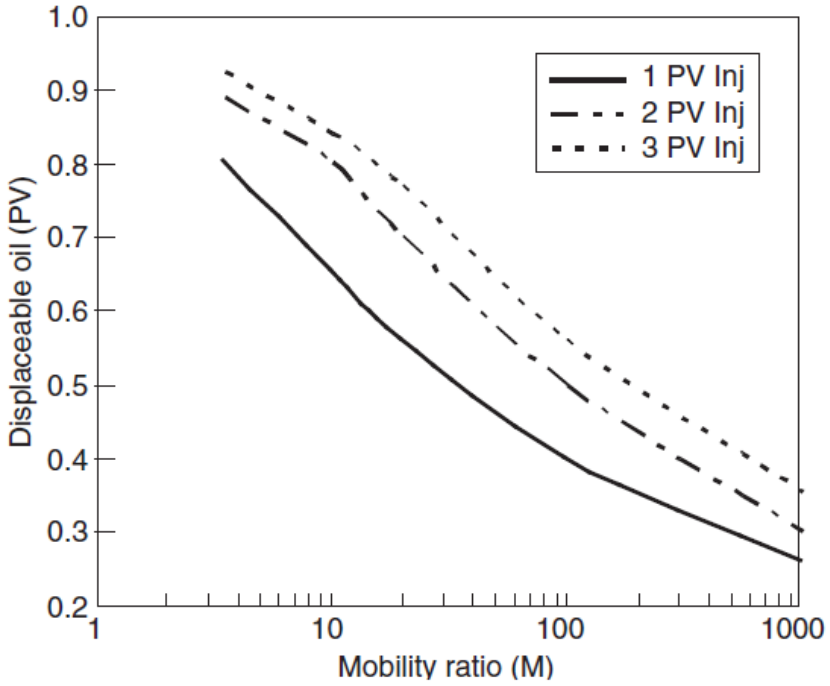
Mobility ratio is defined as $M = \lambda_{ing} / \lambda_{ed}$, where λ_{ing} is the mobility of the displacing fluid (*e.g.* water), and λ_{ed} is the mobility of the displaced fluid (oil). ($\lambda = k/\mu$, where k is the effective permeability, (m^2) and μ is the viscosity (Pa.s) of the fluid concerned). Mobility ratio influences the microscopic (pore level) and macroscopic (areal and vertical sweep) displacement efficiencies. A value of $M > 1$ is considered unfavourable, because it indicates that the displacing fluid flows more readily than the displaced fluid (oil), and it can cause channelling of the displacing fluid, and as a result, bypassing of some of the residual oil. Under such conditions, and in the absence of viscous instabilities, more displacing fluid is needed to obtain a given residual oil saturation. The effect of mobility ratio on displaceable oil is shown in Figure 3, the data for which was obtained from calculations using Buckley-Leverett theory for waterflooding. The three curves represent 1, 2 and 3 pore volumes of total fluid injected, respectively. Displacement efficiency is increased when $M = 1$, and is denoted a "favourable" mobility ratio.



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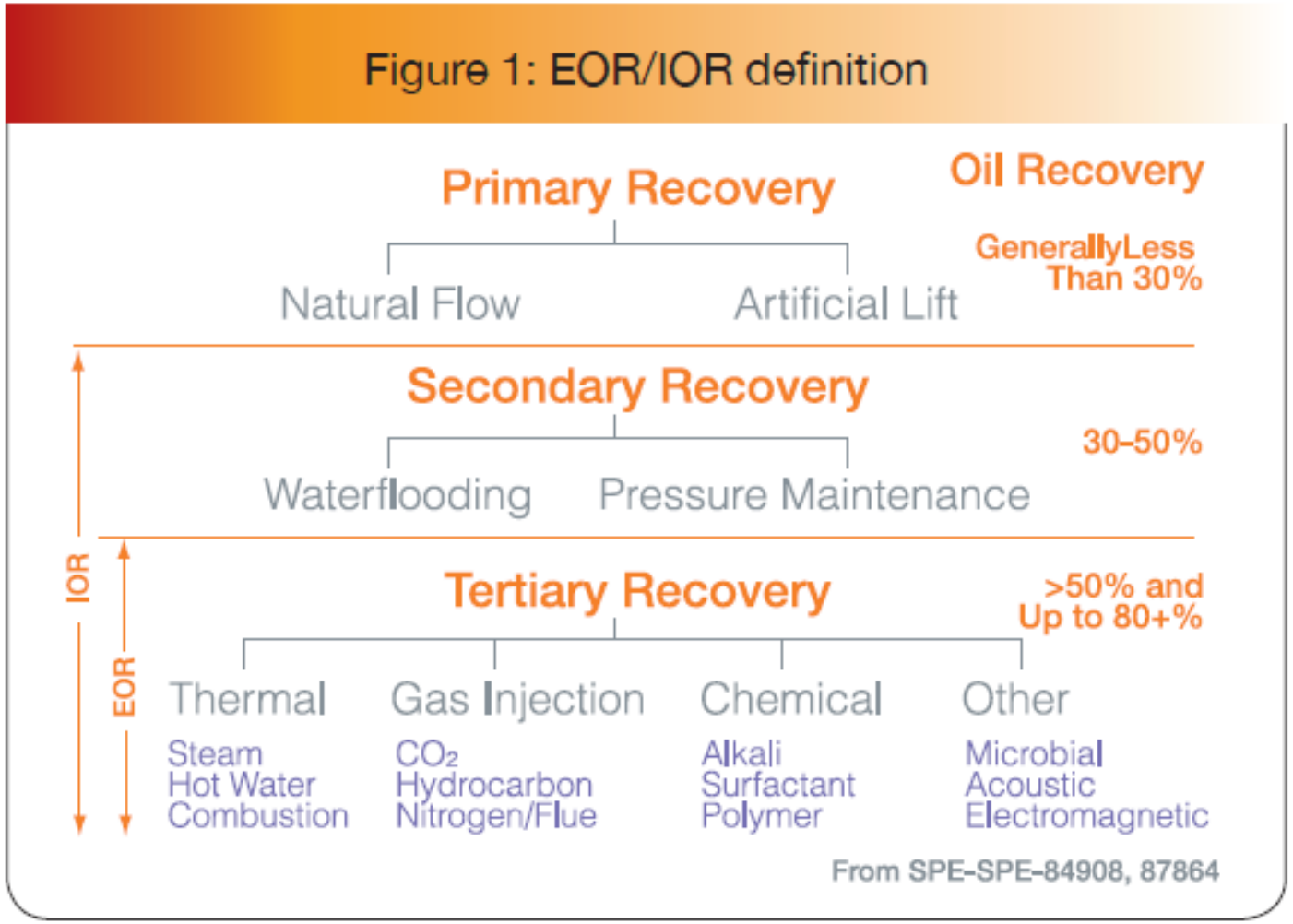

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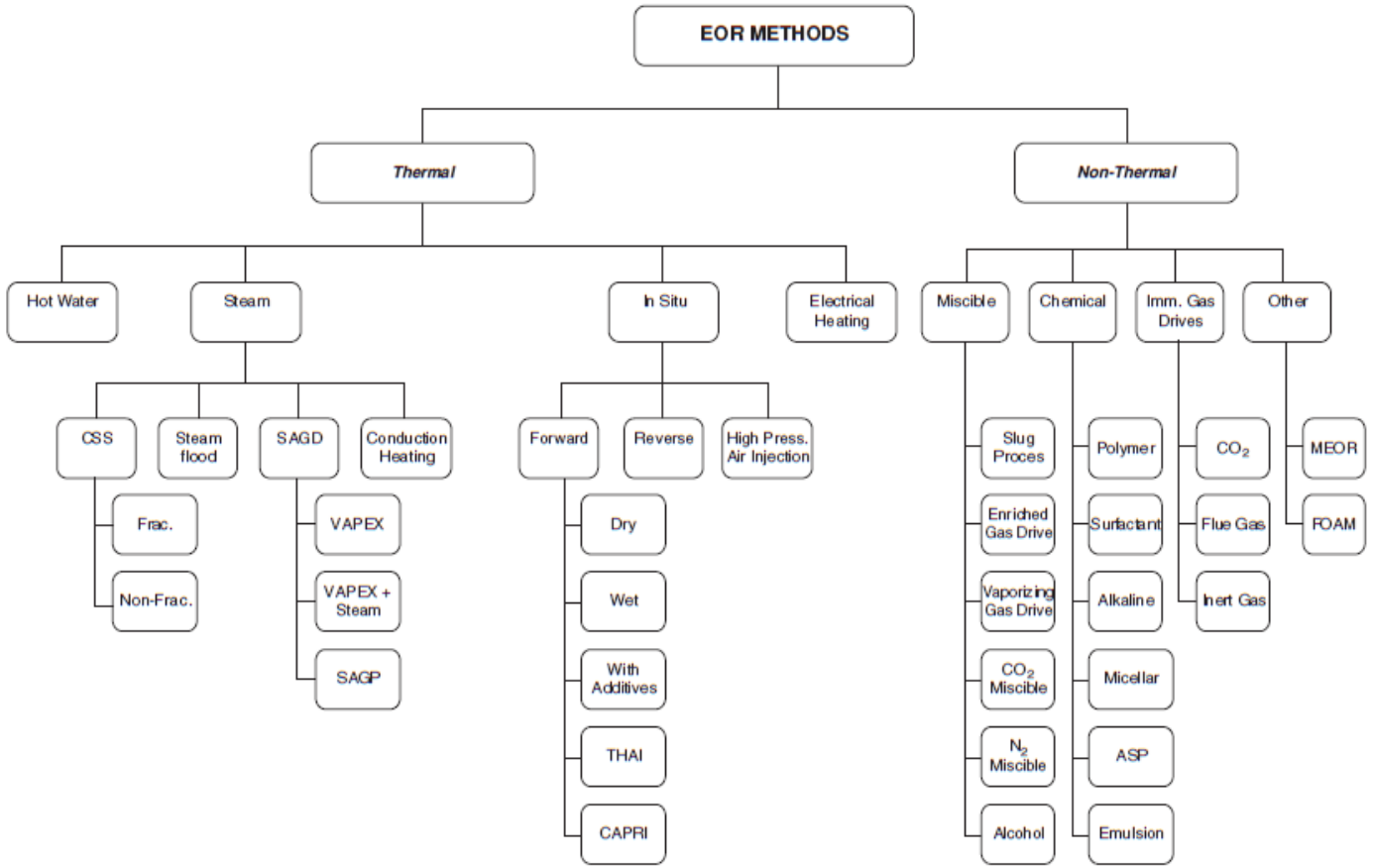

Figure 4
Classification of EOR methods.

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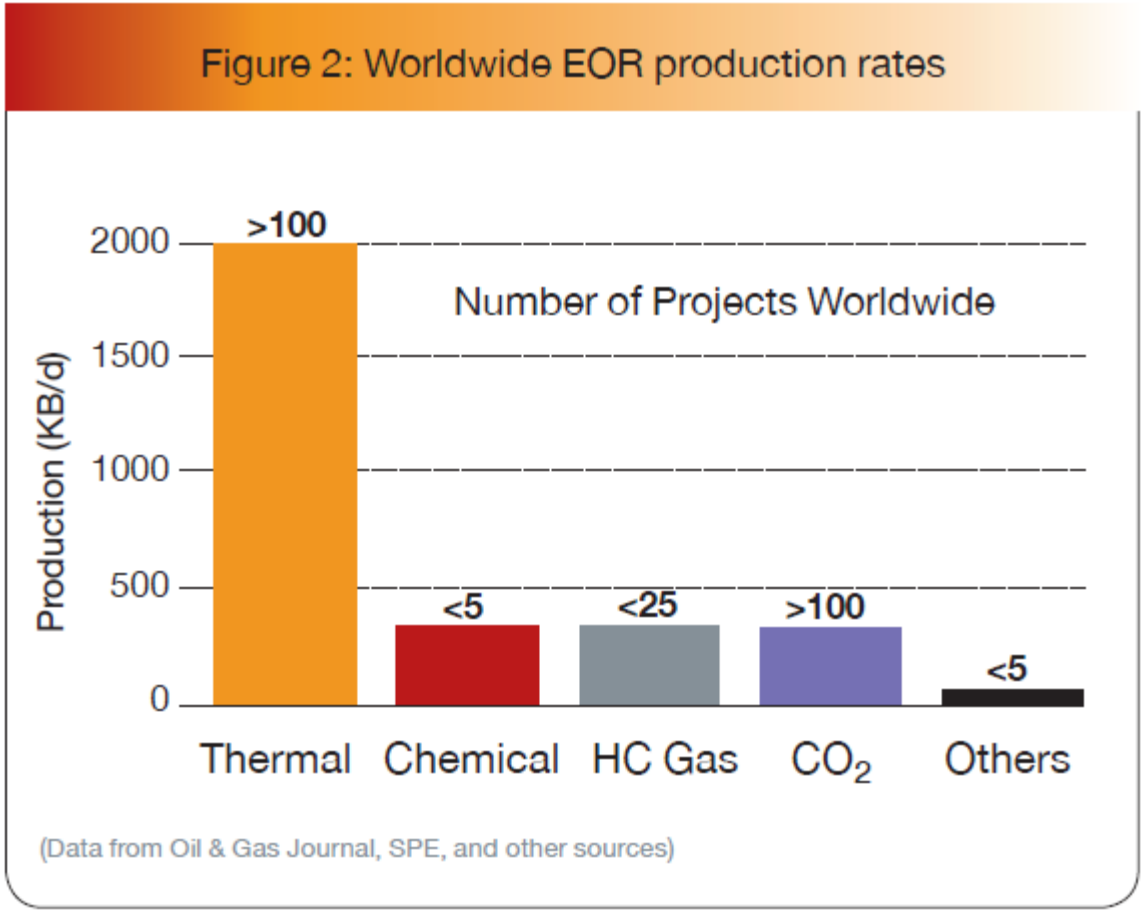

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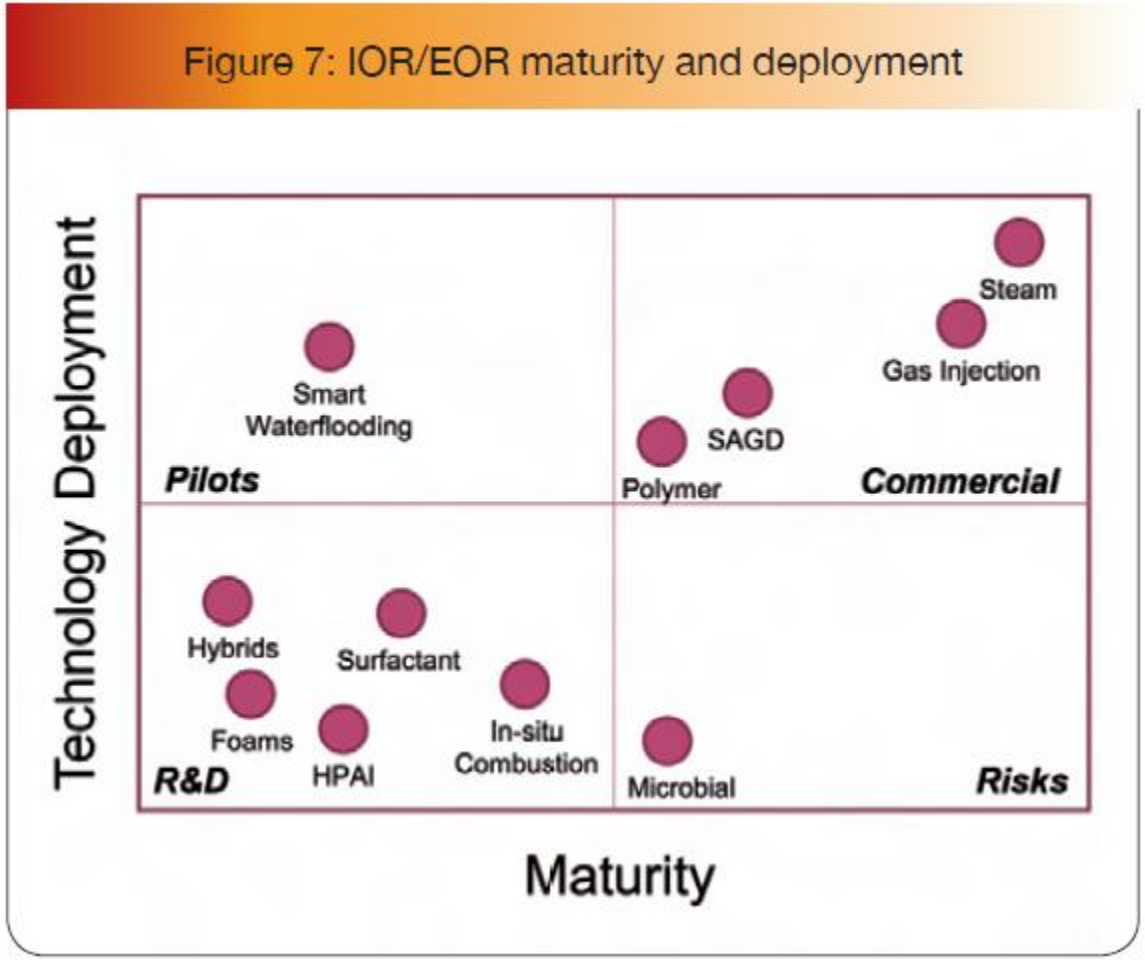

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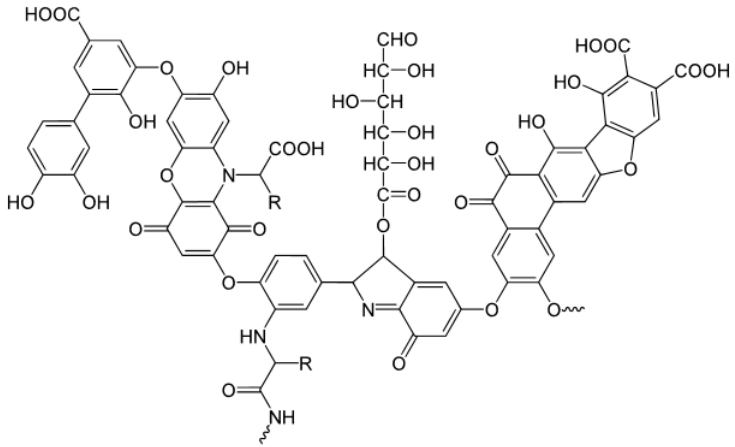
8.1 (Surfactant) Enhanced Oil Recovery
Modifizierte Huminsäure als grenzflächenaktive Substanz



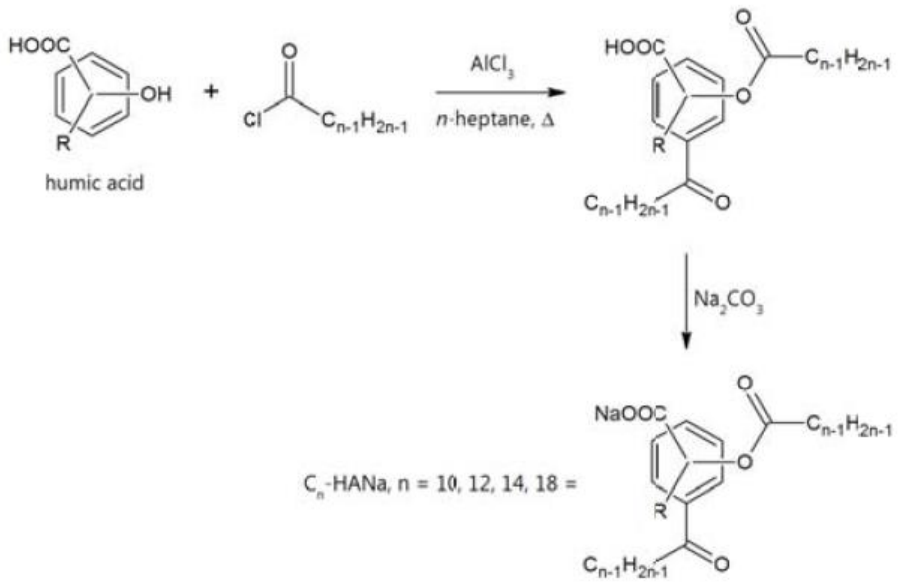


Fig. 2: Chemical modification of humic acid and structure of hydrophobically modified sodium humate (C_n-HANa). Figure as adapted from Ref. [3].

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Modifizierte Huminsäure als grenzflächenaktive Substanz

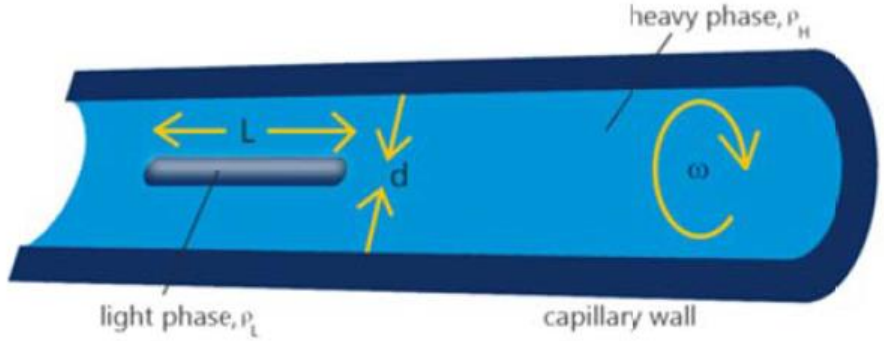

Fig. 3: Schematic setup of a fully prepared glass capillary for spinning drop tensiometry.

$$\gamma = \frac{d^3 \cdot \omega^2 \cdot \Delta\rho}{32}$$

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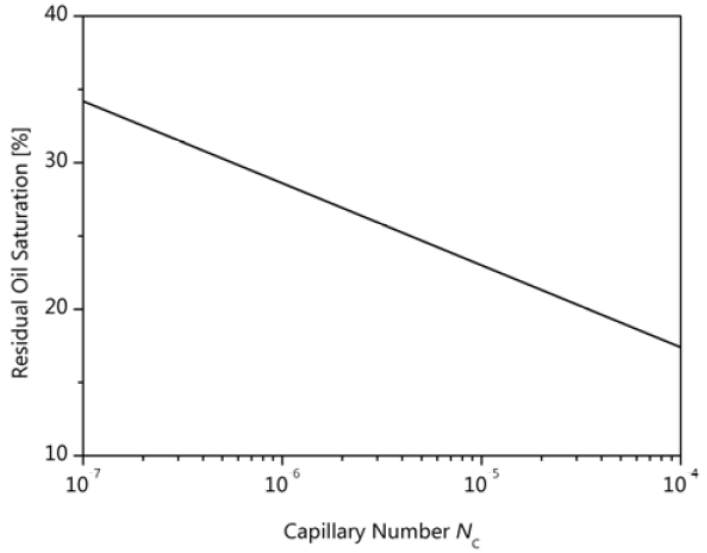

Fig. 1: The residual oil saturation as a function of the capillary number N_C. Decreasing the IFT between displacing fluid and crude oil increases N_C, ultimately lowering the residual oil saturation. Figure as adapted from Ref. [1].

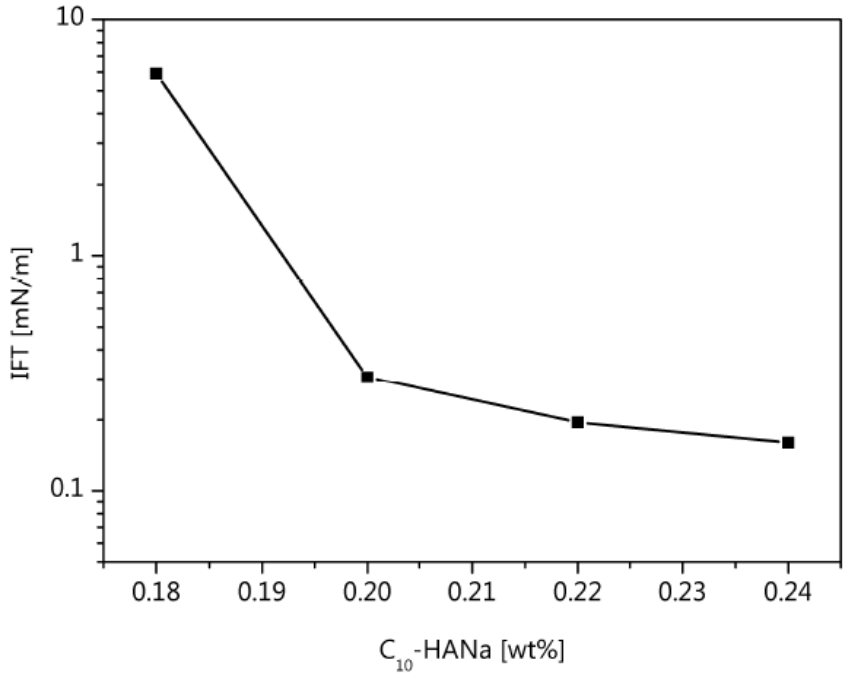

Fig. 4: The IFT between crude oil and aqueous solutions with different concentrations of surfactant C_{10}-HANa. Figure as adapted from Ref. [3]. Data taken with a KRÜSS SITE100.

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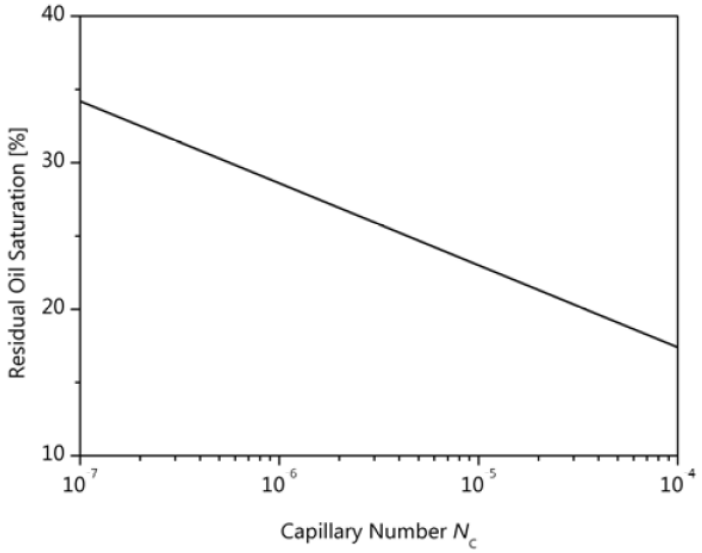

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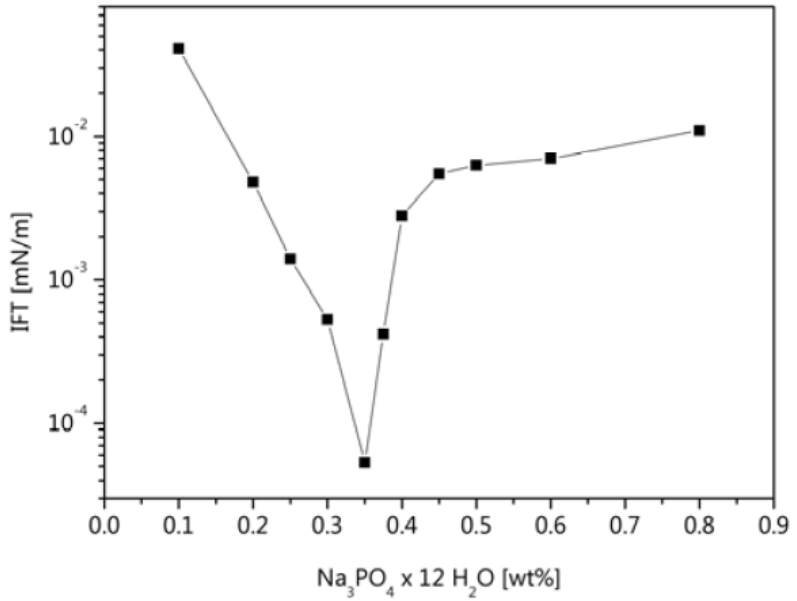

Fig. 5: The influence of chemically modified humic acid (0.12 % C_{12}-HANa) and alcohol (4 % *n*-propanol) on the IFT at different alkali concentrations. Figure as adapted from Ref. [3]. Data taken with a KRÜSS SITE100.

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Benetzungseinfluss bei Alkali EOR

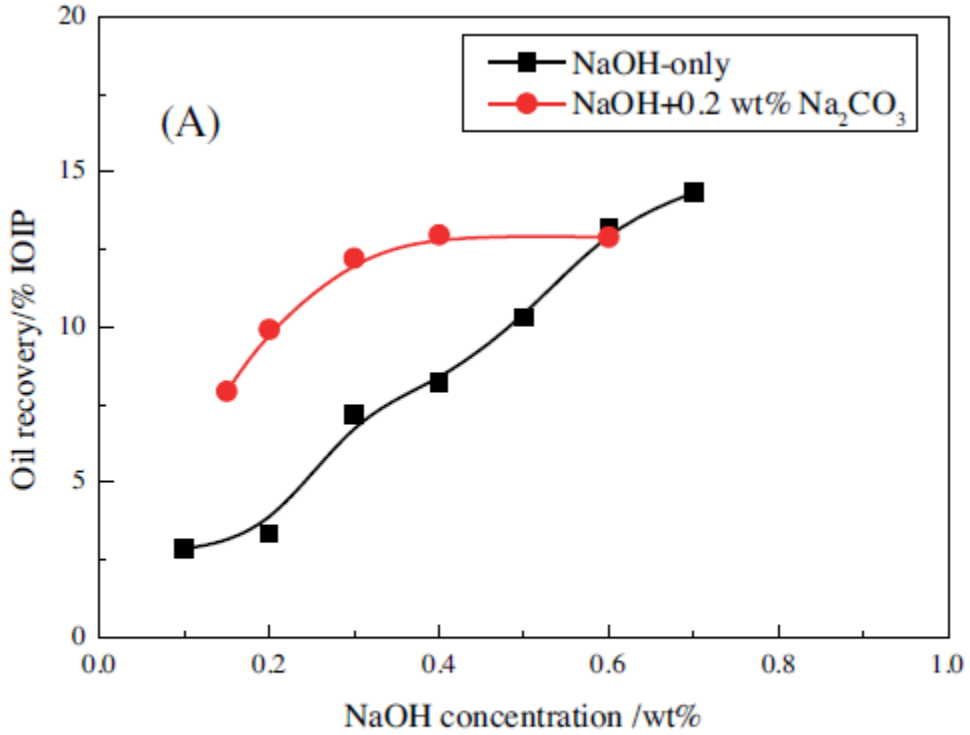

Fig. 3. Effect of NaOH concentration on tertiary oil recovery in alkaline injection.

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8.1 (Surfactant) Enhanced Oil Recovery
Benetzungseinfluss bei Alkali EOR

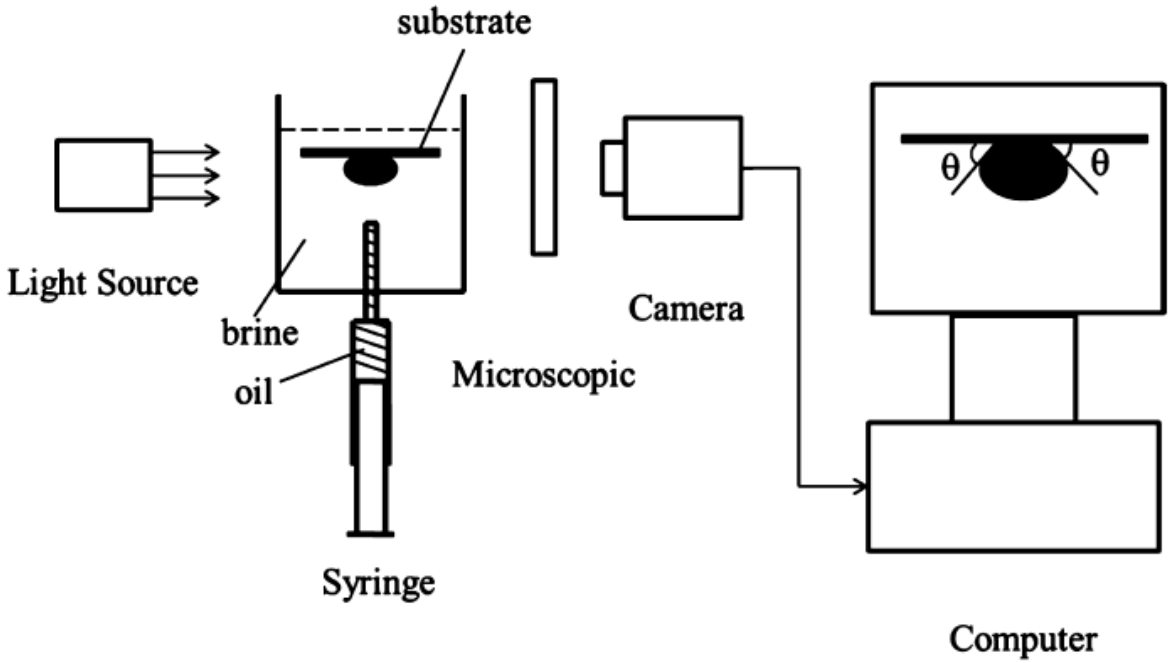

Fig. 2. Schematic diagram of contact angle measurement.

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8 Applikationen
8.1 (Surfactant) Enhanced Oil Recovery
Benetzungseinfluss bei Alkali EOR

Table 2
Static contact angles for a heavy oil–brine/Na_2CO_3–quartz system.

Contact angle (°)	24	42	68	143	167
Concentration (wt%)	0	0.10	0.20	0.30	0.40

Fig. 8. Digital image of sessile oil drops on a quartz substrate, in brine with different NaOH concentrations, at equilibrium state and ambient temperature. (A) 0; (B) 0.1 wt%; (C) 0.2 wt%; (D) 0.3 wt%; (E) 0.4 wt%; (F) 0.5 wt%.

4. Conclusions

The mechanisms and the effects of wettability alteration on the displacement of heavy oil by alkaline flooding have been investigated. The conclusions can be summarized as follows.

(1) The tertiary oil recovery can be greater than 10% of the initial oil in place (IOIP) by NaOH-only flooding or NaOH and Na_2CO_3 mixed flooding systems.
(2) The wettability of the pore walls in the micromodel had been changed from water-wet to oil-wet, which can help block water channeling and thereby improve the sweep efficiency.
(3) Contact angle can be changed from water-wet to oil-wet under the action of NaOH or Na_2CO_3. The wettability alteration is one of the important mechanisms for enhanced heavy oil recovery by alkaline flooding.

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8 Applikationen
8.2 Textilindustrie
Oberflächenenergie

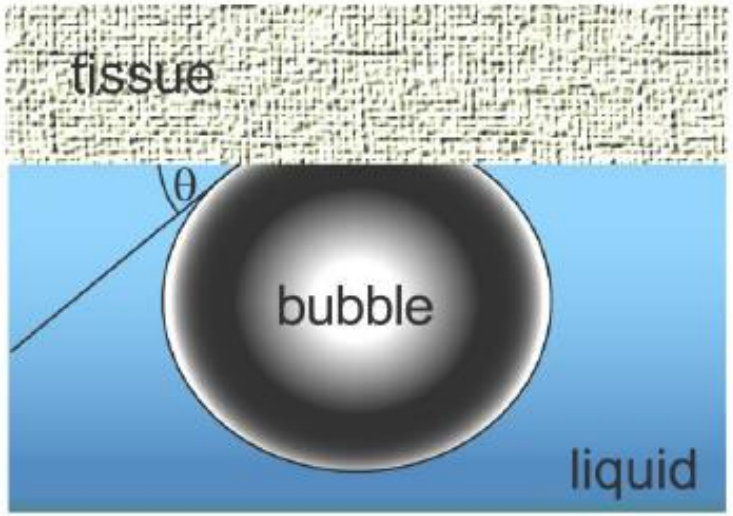
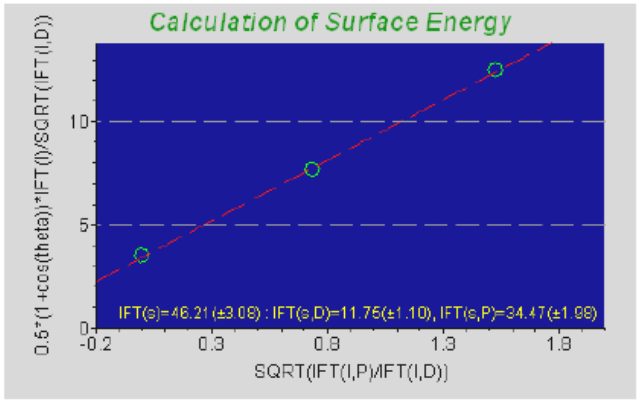


Fig. 1: Schematic view of the captive-bubble arrangement



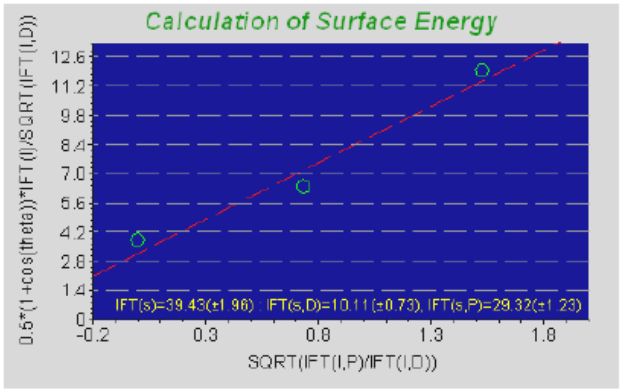


Fig. 2: Evaluation according to OWRK for pure cotton (top) and polymeric compound material (bottom)

	Pure cotton material	Polymeric compound material
Surface energy (mN/m)	46.2	39.4
Polar part (mN/m)	34.5	29.3
Dispersive part (mN/m)	11.7	10.1

Tab. 1: Surface energy of two textile samples

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8 Applikationen
8.2 Textilindustrie
Reinigung

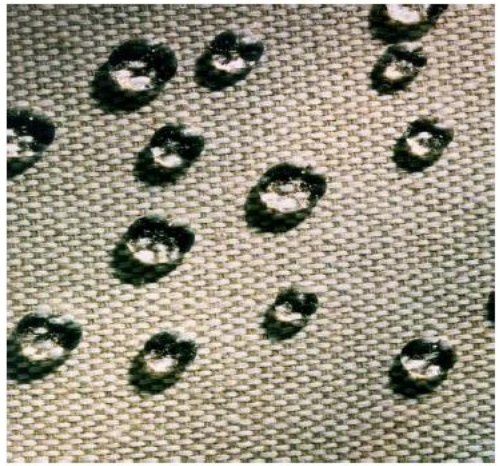

Fig. 1: Drops of water on hydrophobic fabric

Fabric	Contact angle CA (°)
Cotton, scoured	136.1
Cotton, bleached	138.3
Cotton, colored	116.2

Table 1: Static contact angle measurements with water on textile fabrics

Fabric	Contact angle (°)
Cotton, scoured	85.3°
Cotton, bleached	90.1°
Cotton, colored	74.9°

Table 2: Static contact angle measurements with an aqueous surfactant solution (APG 2761, c_0 = 2.31 g/l) on textile fabrics

Fabric	Contact angle CA (°)	Free standard wetting enthalpy $\Delta_{Ben}G^0$ (mJ/m^2)
Cotton, scoured	16.8	-24.18
Cotton, bleached	13.5	-24.56
Cotton, colored	11.5	-24.75

Table 3: Contact angles and free standard wetting enthalpies for textile fabrics with optimized cleaning solution (15% V/V 2-methyl-propanol-(1) + 85% V/V aqueous surfactant solution APG 2761,c_o= 7.30 g/l)

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