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Polymer EOR - Part I: Rheology

Polymer Enhanced Oil Recovery

After the primary depletion and even after secondary recovery (i.e. waterflooding) as much as 70% of the original oil in place (OOIP) can remain (Sorbie, 1991). Thus, there is large demand for improved or enhanced oil recovery (EOR), which aim to increase the oil recovered by 10-35%. Polymer flooding is a popular technique that has the benefit of being both relatively simple to implement and has a proven track record (Thomas et al., 2013). Polymer flooding operates by altering the mobility ratio ($M = \lambda_O/\lambda_W$) between water and oil. During a waterflood the mobility ratio is much lower than unity (M<<1), by viscosifying the water with polymer, the mobility ratio can be reduced to approach unity (M=1) or below. For mobility ratios much greater than unity (M>>1) the flood would show a more piston-like displacement.

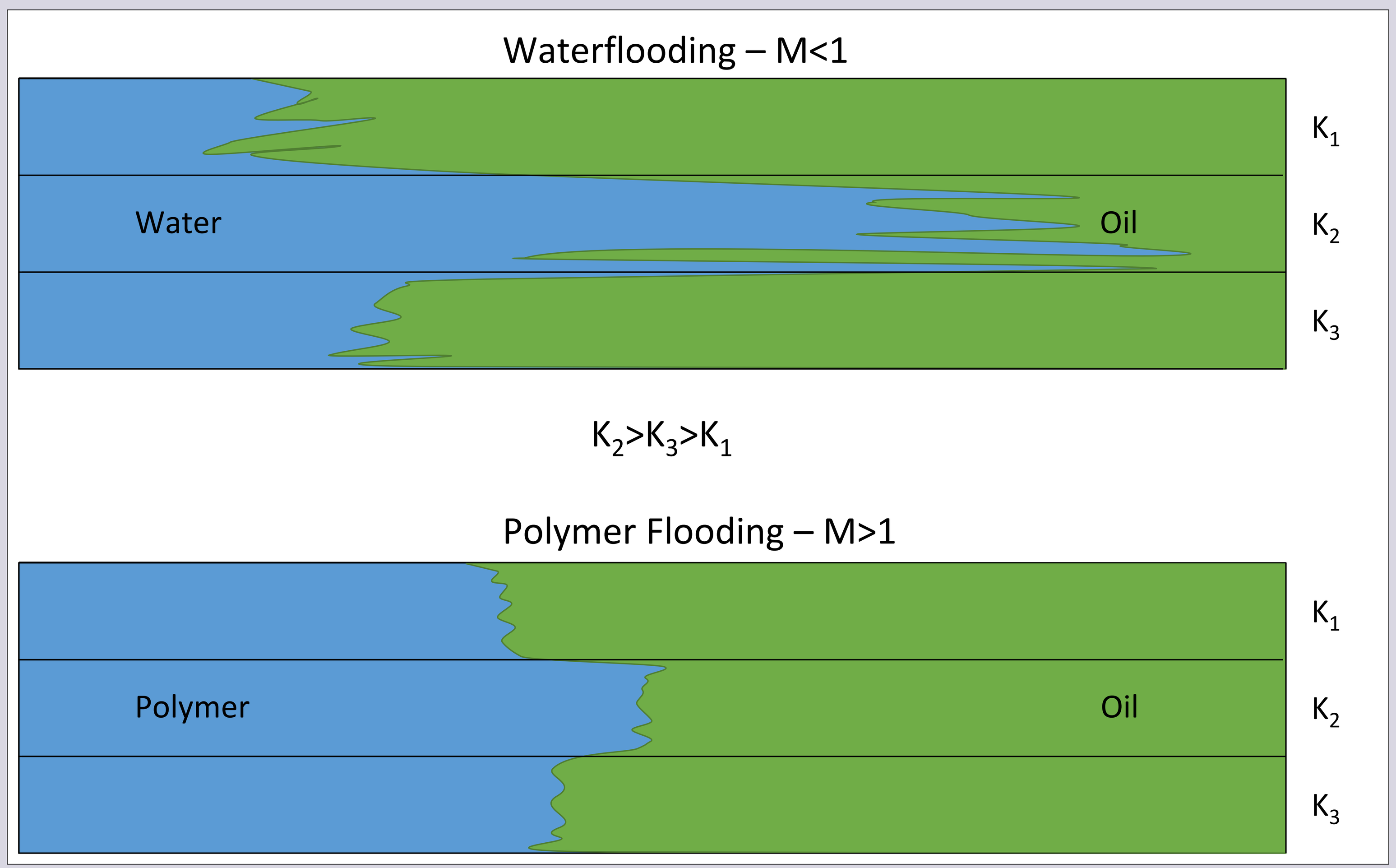

Figure 1. Schematic diagram of the effect of mobility ratio on viscous fingering (Sorbie, 1991)

Partially Hydrolysed Polyacrylamide

Partially hydrolysed polyacrylamide (HPAM) tends to be the polymer of choice for EOR projects. A recent review of field polymer floods (Standnes and Skjevrak, 2014) found that out of the 72 fields examined, 57 used HPAM while biopolymer (including Xanthan) was only employed in 5. HPAM has a flexible chain structure, and due to its polyelectrolyte nature, it is sensitive to the ionic strength of the aqueous solvent. In brine solutions the charged polymer species are shielded by the electrolytes from the brine, resulting in a decrease in viscosity due to increased coiling.

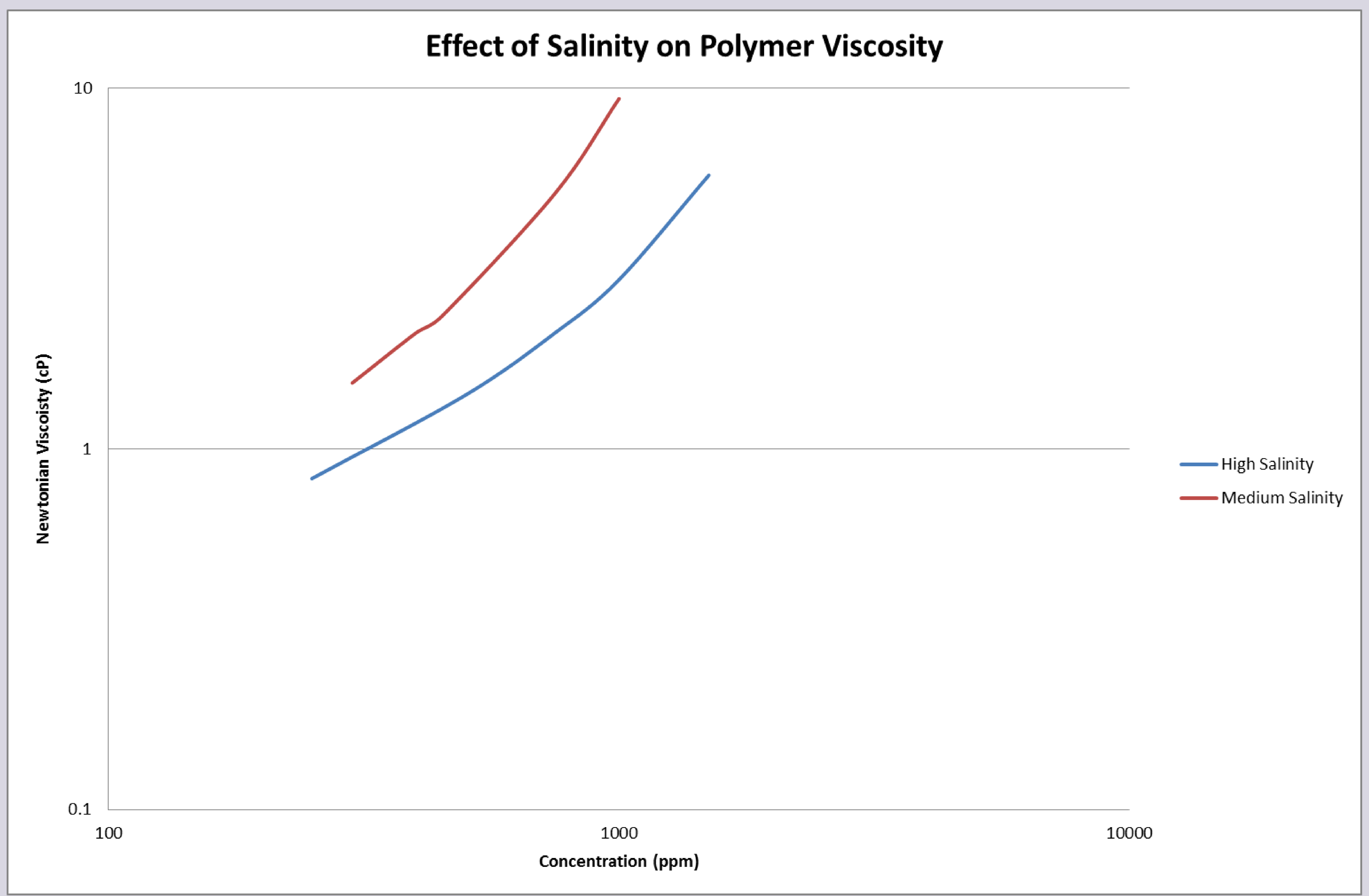

Figure 2. Effect of Salinity on Polymer Viscosity

Polymer Molecular Weight

The polymer molecular weight (Mw) can be tuned to improve the tonnage required and the project economics, with a higher Mw requiring less gram of chemical for equivalent viscosification. The pore throat size must also be taken into account, as there is a direct relation between the Mw of the polymer and its ability to fit through the pore throats.

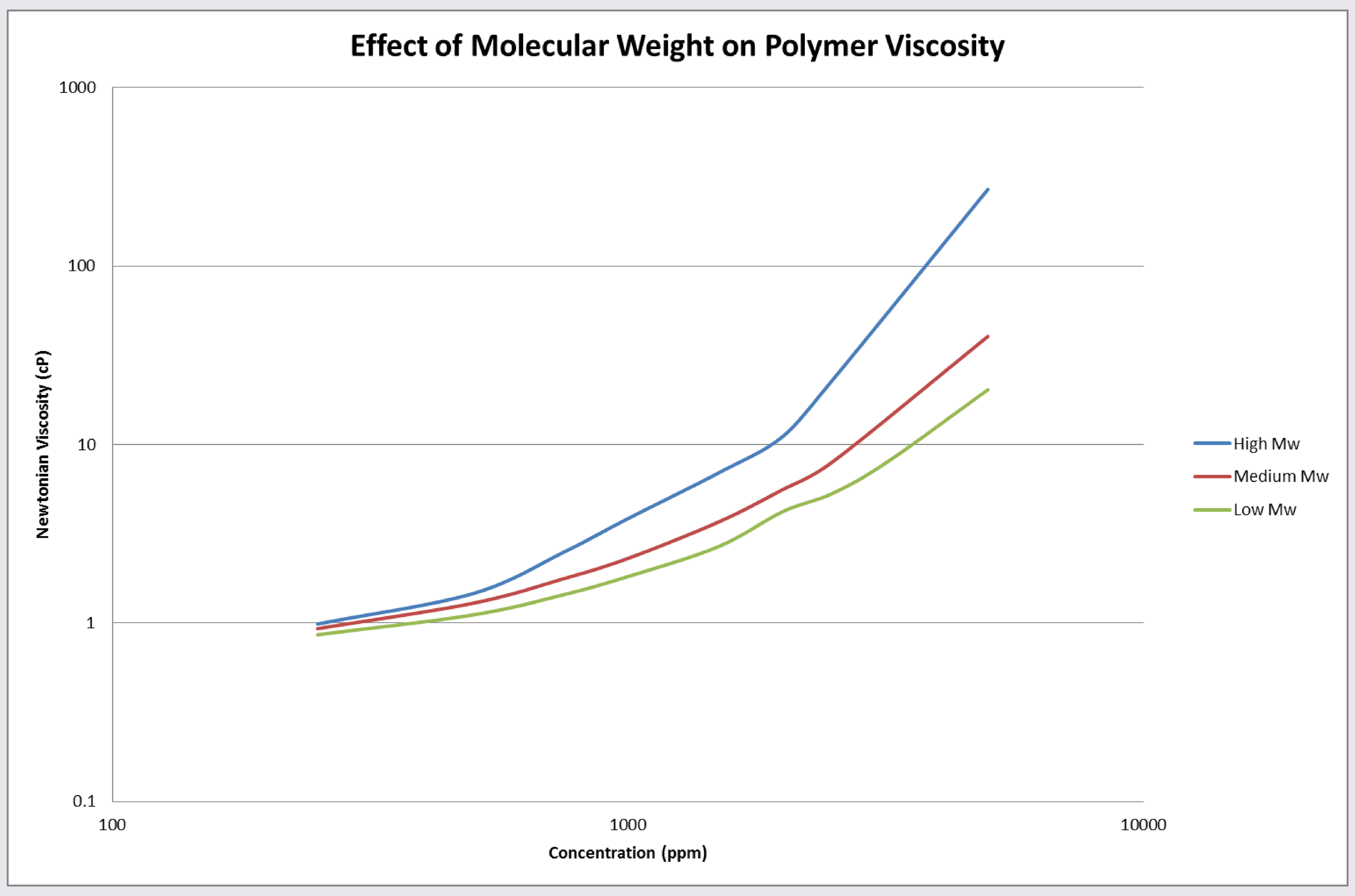

Figure 3. Effect of Molecular Weight on Polymer Viscosity

Polymer Viscosity Under Shear

Polyacrylamides are non-Newtonian fluids, and display shear thinning (pseudo-plastic) behaviour. At high shear rates the viscosity is lower. This behaviour can be attributed to the entangled nature of the long polymer coils, as the shear rate increases the molecules disentangle to a certain extent – lowering the apparent viscosity.

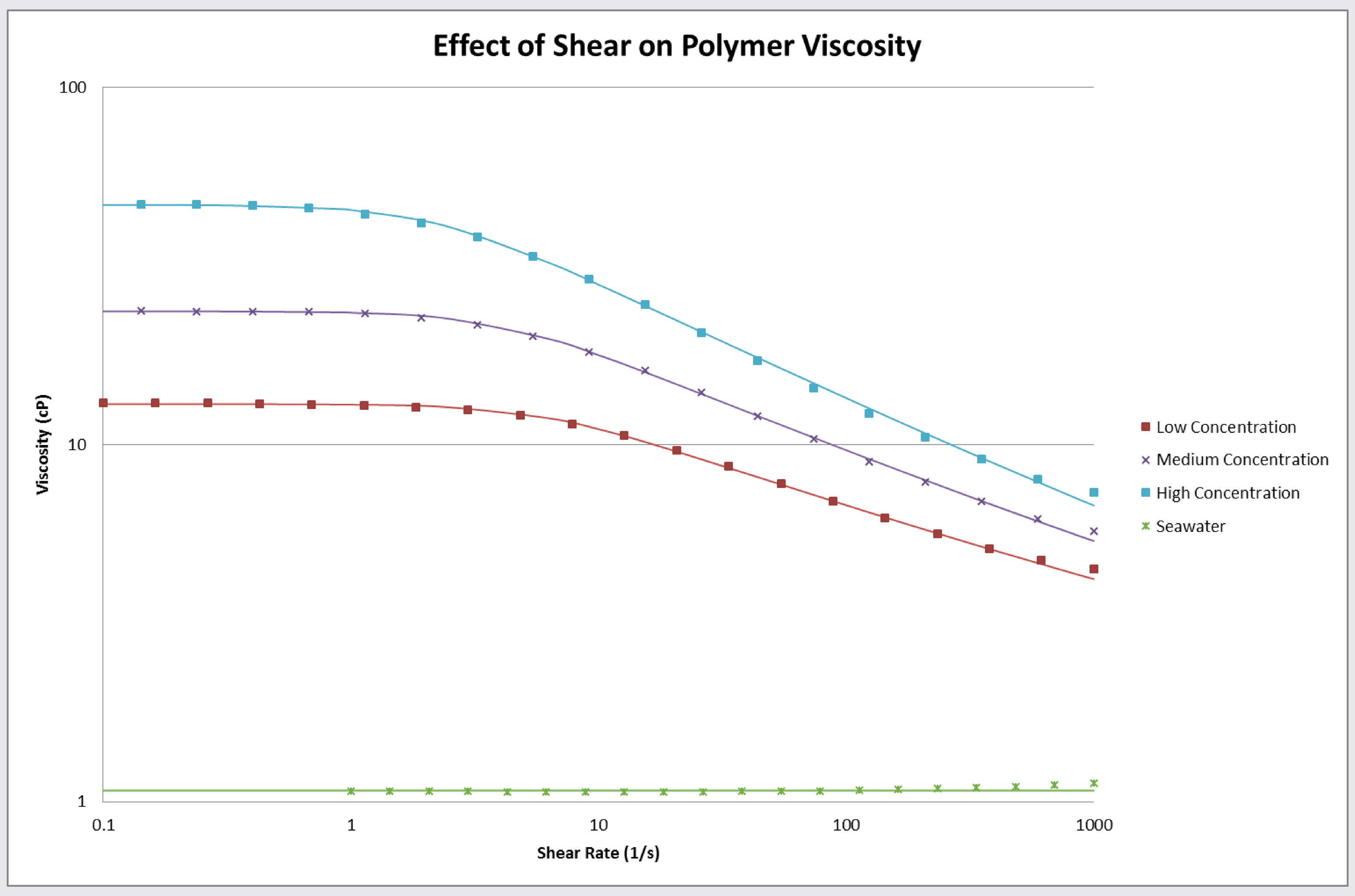

Figure 4 Effect of Shear on Polymer Viscosity

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References:

- Sorbie, K.S., 1991. Polymer Improved Oil Recovery. Blackie.
- Standnes, D.C. and Skjevrak, I., 2014. Literature review of Implemented Polymer Field Projects. Journal of Petroleum Science and Engineering
- Thomas, A., Gaillard, N. and Favero, C., 2013. Some Key Features to Consider When Studying Acrylamide-Based Polymers for Chemical Enhanced Oil Recovery. Oil & Gas Science and Technology – Rev. IFP Energies Nouvelles.