can be used to calculate the so-called Lorentz coefficient ($L_c$) that is a measure of how heterogeneous the flow is. $L_c$, ranges from 0 for completely homogeneous flow to 1 for completely heterogeneous flow.

From the fraction of produced over injected tracer mass (zeroth moment of the residence time distribution) about 1/5 of the water injected in B-83 in travel towards B-81. These fractions correspond to the area under the tracer curves in Figure 3.

The sweep volumes can be compared to the physical pore volume and used to assess the sweep efficiency. A good sweep manifests itself with a relatively small. From sweep volumes and $L_c$ in the pilot area in Bocksted, we can conclude that the area between the injector and both the producers is well swept, in agreement with the fact that the reservoir is a relatively homogeneous sandstone reservoir.

**Field example 3: Quantification of remaining oil saturation using partitioning tracers.**

The partitioning inter-well tracer test (PITT) is a non-intrusive low-cost test that can provide measurement of oil saturation in the region between injectors and producers in an oilfield. Lack of stable partitioning tracers has previously limited the application of PITTs in petroleum reservoirs. A recent field test in the Total operated Lagrave oil field proved the stability and reliability of six new partitioning tracers at reservoir conditions.

In PITTs remaining oil saturation is given by:

$$S_0 = \frac{T_p - T_w}{T_p + T_w(K-1)}$$

Where $T_p$ and $T_w$ are retention times for the partitioning and water tracers, respectively, and $K=C_0/C_w$ is the oil/water partition coefficient. Based on retention times the six new tracers yielded $S_0 = 24 \pm 1\%$. This result was later verified and corresponds very well to saturation measurements on core samples.

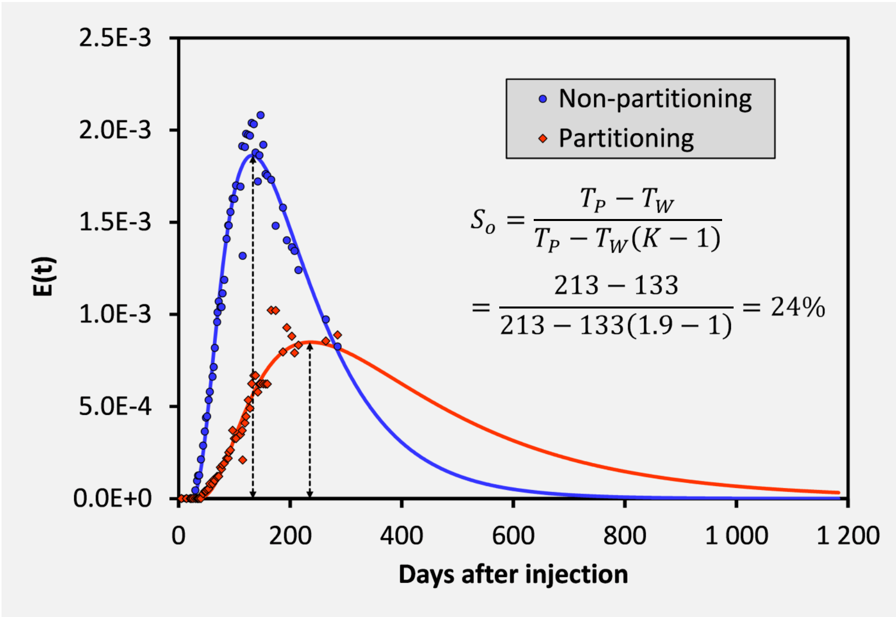


*Figure 4. Tracer response of partitioning and non-partitioning tracers in Lagrave well LAV-1. The difference in arrival times and the partitioning coefficient K yields a saturation of 24% between injector and producer.*

## Useful links

JPT

[Petroleum Engineering Certification]

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# Produced Water Sand Management

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The amount of produced water increases as an oil field matures. While the worldwide average for water cut is around 75%, for some reservoirs it may increase to 98%. Managing the increasing volume of produced water is one of the main challenges the petroleum industry is dealing with today. With increasing environmental regulations, more and more produced water is being reinjected.

PWRI (produced water reinjection) typically leads to a decrease in operational cost, an increase in hydrocarbon recovery and a decrease in surface disposal of water. But like all other operations, reinjection of produced water poses some challenges. According to SPE, 70% of oil fields produce sand, or other types of sediments. The removal of solids from the water, prior to reinjection, is a key operation operators have to deal with. Presence of solids in reinjection water can result in injectivity decline (blocked pores), failure of water injection pumps and shut downs. Excessive amount of solids cause serious damage to the rotary equipment (PWRI pumps), valves as well as the system pipe work. Consequentially, water injection would be unsustainable with frequent equipment failures.

According to BP, damage to the produced water reinjection system, caused by solids present in reinjection water, is the main source of production deferrals on ETAP (Eastern Trough Area Project)*. On ETAP solids erode pumps, isolation and choke valves resulting in 1 mmbbls/yr in deferred production, £2M maintenance costs and a demand of 600 POB per year. According to BP, with the water cut (WC) and gas oil ratio (GOR) increasing, and reservoir depleting, the risk of deferrals and integrity failures is also likely to accelerate making solids management one of the main issues to be addressed.

From an economic perspective, effective sand management in produced water – whether it is reinjection, discharged, or processed water – means more efficient operations, less downtime and decreased maintenance costs. Avoiding solids in the produced water system helps minimize injectivity loss over time and maintain PWRI pumps utilization. In order to eliminate failure of water injection pumps due to entrained solids, minimize erosion on piping and down time it is important to implement an effective sand management strategy.

The FourPhase surface solids removal system, called QuadFlow, is designed for permanent installation with focus on minimal logistical impact, and with emphasis on safe and quick installation. QuadFlow is a cost efficient and effective tool for protecting your top side equipment from unwanted solids and eliminating damage to PWRI pumps that can result in costly downtime. The QuadFlow uses next generation cyclone technology that has a proven solids separation efficiency of 99.8% for particles ≥ 20micron.

With space being a premium on many offshore installations the QuadFlow unit is designed to be compact – measuring 2.0 x 2.5 meter footprint. In addition to market leading solids removal technology, FourPhase has a solutions driven team of experts with more than a hundred years of combined experience – FourPhase is a trusted expert in solids management.

Contact us for more information on how our solids removal system can help solve solids challenges related to produced water reinjection.

**Sand Management on ETAP: A multidiscipline approach, 6th European Sand Management Forum 26th March 2014