Surfactants

for Enhanced Oil Recovery

BASF
We create chemistry

Make your EOR operations more econonomic with Aspiro™ Surfactants

We support our customers to be more successful

The elaboration and implementation of cEOR Technologies is a highly sophisticated process. Selecting the right chemicals and components for developing a successful formulation is our key expertise. Each oilfield is different in its specific characteristics. In order to develop an effective and efficient solution many parameters have to be considered in the evaluation, such as reservoir temperature, brine composition (salinity, hardness), crude oil characteristics (total acid number (TAN), viscosity) as well as rock properties (permeability, rock type).

Using these practical considerations, BASF EOR Technology & Development teams evaluate and demonstrate feasibility of a cEOR flooding plan utilizing our Aspiro™ Surfactants formulations.

We develop successful formulations, even going back to the design of novel structures, perform fluid-fluid evaluations as well as flood-test the surfactant-oil-brine systems to identify the most successful solution for your well.

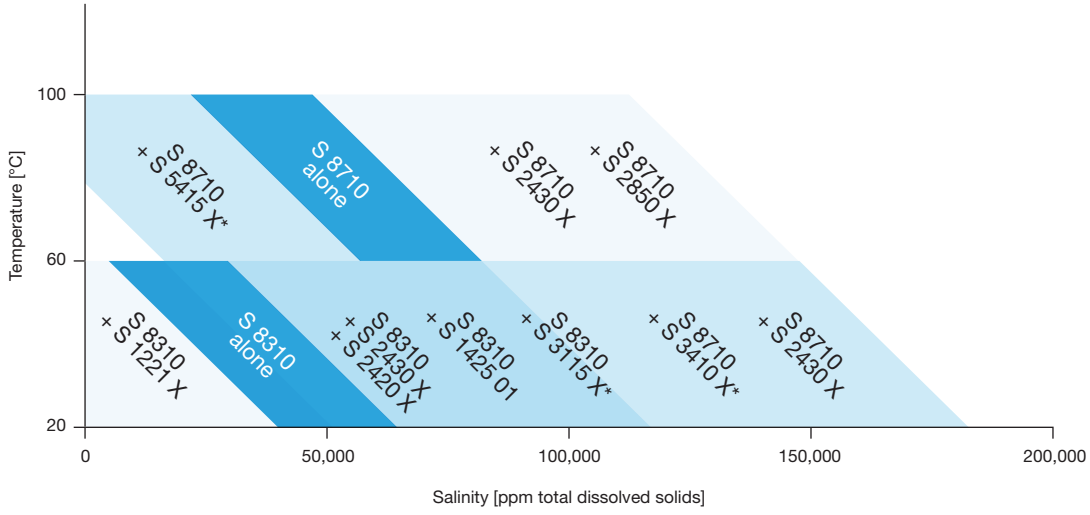
The Aspiro™ Surfactants product range

BASF offers a variety of different Aspiro™ Surfactants which can be formulated to match diverse crude oils and particularly diverse field conditions. In order to identify the right formulation for your optimal salinity target, the following Aspiro™ Surfactants are offered.

Surfactants	Co-surfactants
Aspiro™ S 8310	Aspiro™ S 1310
Aspiro™ S 8710	Aspiro™ S 1425 01
Aspiro™ S 2420 X	Aspiro™ S 1221 X
Aspiro™ S 2410	Aspiro™ S 1415 X
Aspiro™ S 2465 X	Aspiro™ S 2425 X
Aspiro™ S 2455 X	Aspiro™ S 2430 X
Aspiro™ S 2850 X	

BASF surfactant starting formulation guide

The technical development teams within BASF focus on further extending the range of our Aspiro™ Surfactants to match an even wider range of reservoir conditions, especially in the area of very low salinity as well as at high salinities combined with high temperatures. A formulation starting guide of BASF's EOR surfactants for the applicable salinity and temperature window is displayed below.



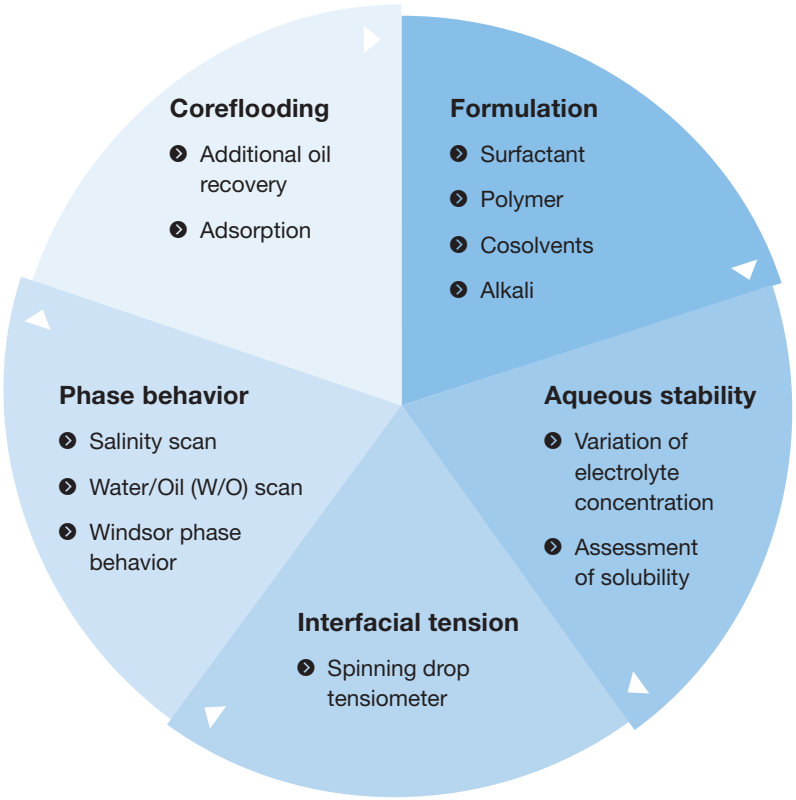
Please note that the displayed table and the starting formulation guide are not exhaustive; other grades are available upon request. The formulation guide does not include BASF's cosolvents being offered under the name of Aspiro™ CS, which are often required for the viscosity reduction of microemulsions in ASP and SP formulations.

*Still under development

Be more successful – with BASF Formulation and Testing capabilities

Our team of experts within BASF supports the whole oilfield value chain from lab evaluation to full field implementation through a thorough understanding of the crude oil-brine interaction.

BASF has developed and implemented laboratory evaluation capabilities to support your operations and make them more economic. Our testing capabilities cover a wide range from multiple core-flood set-ups for low and high temperature evaluations to phase behavior studies, interfacial tension measurement devices and long term stability testing in order to minimize the risk and maximize the yield for your operations. In our laboratory studies many factors are evaluated that can affect the surfactant flooding process as described in the following flow chart which shows the possible steps involved.



1. Solubility assessment and aqueous stability

This test is used to check if the identified surfactant formulation is compatible with the formation water and other production chemicals at injection temperature and reservoir temperature observing the solubility of the formulation in formation water or synthetic brine. The example given below shows the solubility assessment of formulation in synthetic brine and at increased salinity for an ASP flooding project.In addition, long term thermal stability can be assessed for high temperatures and low pH conditions in order to identify if hydrolysis is taking place.

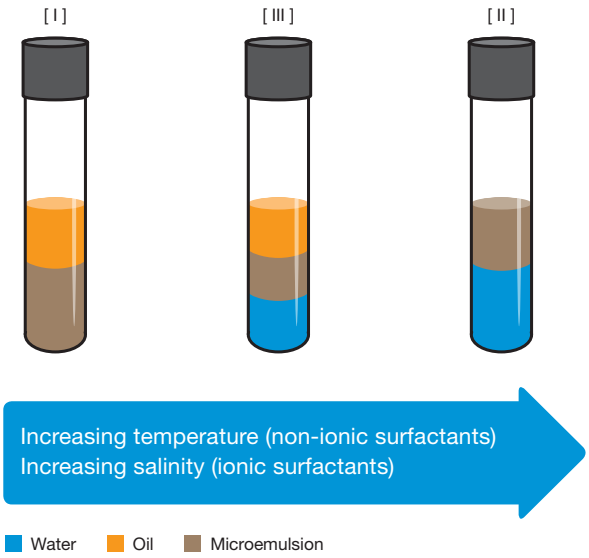
Evaluation conditions	ASP Formulation 1	ASP Formulation 1 + 0.5% Na_2CO_3	ASP Formulation 1 + 1% Na_2CO_3
Solution at reservoir temperature			
Assessment	Soluble & Stable	Soluble & Stable	Soluble & Stable

2. Windsor phase behavior study, salinity scan, w/o scan, activity map and interfacial tension

To guide the surfactant formulation design the developed system should have ultra low interfacial tension in order to increase the capillary number. The interfacial tension can either be determined directly by a spinning drop tensiometer and monitored over time or can be determined through the evaluation of the oil solubilization ratio, which needs to be higher than 10. While the tensiometer can give a specific value for the reduction in interfacial tension, the assessment is performed only on very small volume of oil and at a water-oil ratio (w/o ratio) that might be very different from the actual w/o ratio in the field.

The solubilization ratio however cannot give a specific number for the interfacial tension, but this method takes changes in w/o ratio into account and can better simulate the w/o interaction. So in the ideal case both methods should be assessed to have a specific interfacial tension and describe the w/o interaction via a phase behavior study as described in the following.

Phase beavior tests
(Windsor type emulsion evaluation)

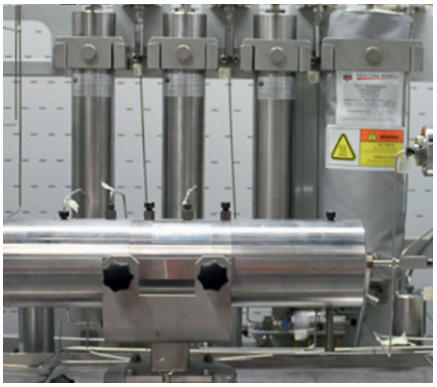


3. Studying water/oil interaction

As a first part of the phase behavior evaluation the formulations are tested for the ability to form a Windsor type III microemulsion. When the right formulation is identified a salinity scan (shown above) is performed at a w/o ratio of 1 to evaluate the changes from Windsor type I to Windsor type III to Windsor type II (see Windsor evaluation plot). The solubilization ratio can be obtained by the volume fraction diagram which can be determined from the salinity scan information. It has been shown that a large number of anionic surfactants exhibit a good correlation between solubilisation parameter and interfacial tension. Depending on the oil type it is easier to assess the IFT by direct measurement or via the solubilization determination.

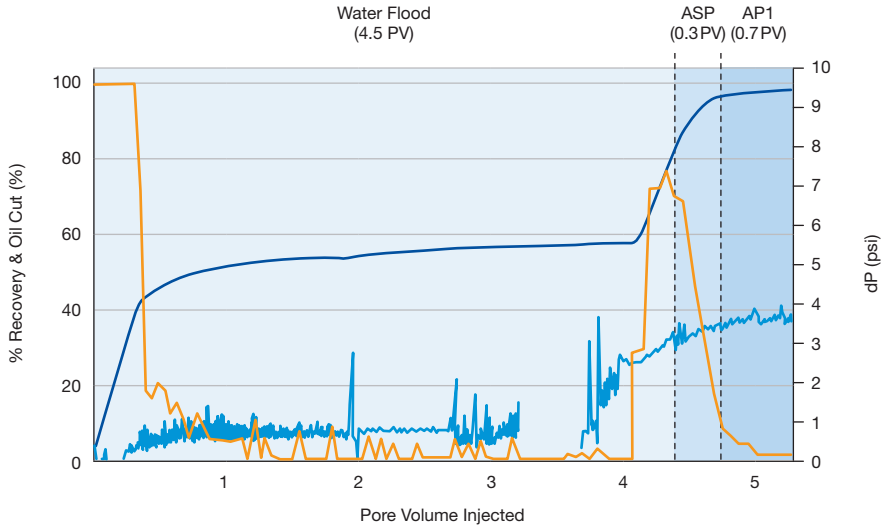
The ideal identified solution should also perform well when the w/o ratio changes. In order to evaluate if this is the case a w/o ratio scan is performed. Another important factor to achieve good flooding results is the microemulsion viscosity, which can be qualitatively assessed during the phase behavior experiments. Surfactants are prone to form viscous microemulsions, liquid crystal phases or even gels under varying conditions which can be difficult to pump through a perforation and may cause propagation issues. Additionally, high interfacial viscosities might prevent the coalescence of oil droplets to form an oil bank. Thus, developed formulations should always be checked for microemulsion fluidity. Once a system with an ultra-low IFT, a wide microemulsion type III window, and a low microemulsion viscosity is identified the solution will be further studied in a core-flooding experiment in which the surfactant adsorption and the potential for additional oil recovery will be studied.

Interfacial tension measurement for formulation screening



4. Core-flooding of formulations

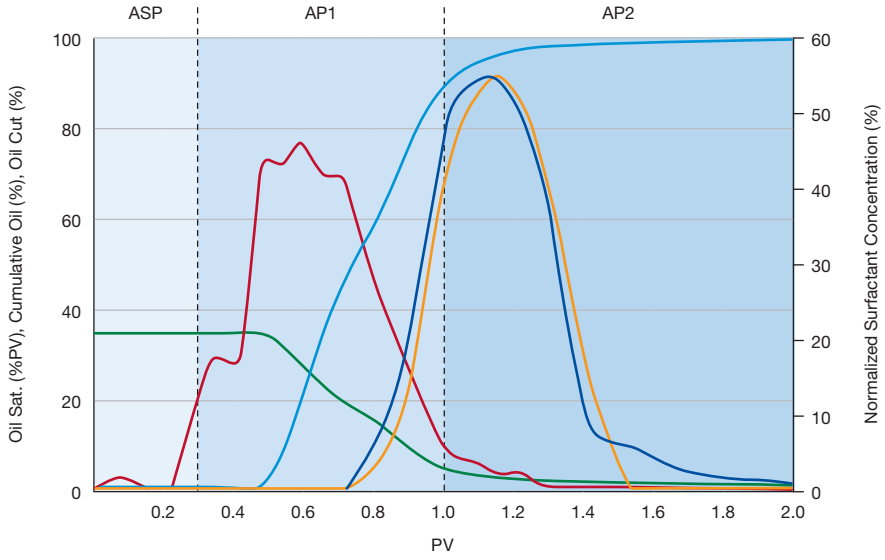
Core-flood experiments are one important tool to identify the most economic formulation for your field. In our dedicated core-flooding laboratories we investigate the level of additional oil recovery that can be achieved with a developed formulation and also study the crude oil/brine/rock interaction that determines the displacement efficiency. In our dedicated core-flooding laboratories we can analyze retention and adsorption of surfactant formulations via HPLC and TOC analysis and also identify chromatographic separation phenomena. Furthermore, also the additional oil recovery and the shape of the oil bank can be determined.



Coreflooding experiment performed in Bentheimer 12" core in presence of oil at 63 °C; brine composition: 6,100 ppm TDS

Slug sequence:

1. Water flood
2. ASP with 2% alkali, 0.3% surfactant and 0.25% polymer
3. AP with 2% alkali and 0.25% polymer



Analysis of oil production (1st y-axis), and surfactant concentration in effluent by HPLC (2nd y-axis) of coreflood experiment above

Formulations, Logistics and HSE (Health, Safety and Environment)

We provide solutions to our customer on a global scale while fully complying with all HSE regulations. BASF is committed to ensure that all products are produced, stored and applied with responsible care. We also support our Aspiro™ Surfactant customers in meeting their HSE requirements. We produce our products to the highest industry standards and have full quality control (QA/QC) processes in place.

We are also constantly working on simplifying your operations, by supplying concentrated products or surfactant formulation which do not require handling of individual components. When desired BASF can develop customer specific, concentrated blends. This development takes local conditions such as local climate, local logistics and storage capabilities as well as special handling into account. Given the different influencing factors those developments can only be done in a close collaboration with our customer.

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