RISK ASSESSMENT OF IN-RESERVOIR PETROLEUM BIODEGRADATION BY MEANS OF NUMERICAL BASIN MODELING

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Degraded crude oils with low API gravity and poor producibility are encountered frequently in different geological settings. The decrease in oil quality has been attributed to various in-reservoir alteration processes. These include water washing, evaporative loss of volatiles, inorganic oxidation, deasphalting, thermal alteration/thermal cracking, gravity segregation, thermochemical sulphate reduction and biodegradation. During the last decades, biodegradation has been recognized as an issue of major importance due to its potentially dramatic consequences on both oil quality and producibility and its wide occurrence. In consequence, there has been an increasing demand for procedures and methods to predict the biodegradation risk on the basis of information available with respect to the geological history and the dynamic evolution of petroleum reservoir systems. Our work combines the mechanisms of biodegradation with routine basin modeling to predict the extent and consequences of microbial alteration. For this purpose, it has been attempted to formulate the present-day concepts of biodegradation in a consistent and quantitative way and to link these conceptual models to up-to-date basin modeling software.

It is widely accepted that the first-order parameters controlling in-reservoir biodegradation of crude oils are temperature and nutrient supply. Therefore, in a static oil column, the degree of biodegradation and, in consequence, oil quality will be determined by the temperature history of the reservoir and nutrient supply which is considered to be linked to the presence of a water leg. Diffusion of nutrients or substrate towards the site of biodegradation, the oil-water contact, is a potentially limiting process. Consequently, different conceptual reservoir types and geometries which have specific effects on diffusion will be defined. When predicting oil quality these parameters have to be taken into account and related to the oil charge history because the final composition of crude oil and hence its viscosity and API gravity are determined by the relative masses of biodegraded oil vs. non-biodegraded oil or by the extent of mixing between biodegraded and fresh oil (e.g. Horstad & Larter, 1997; Head et al., 2003; Larter et al., 2003). In addition to the fresh oil migrating into the reservoir, oil spilled out of the reservoir is also considered.

The biodegradation rate model used is based on microbial growth rate curves (Ratkowsky et al., 1983; Fig. 1). Our approach assumes that biodegradation is caused by a consortium of different microorganisms all of which contribute to the overall biodegradation rate in terms of overlapping growth rate curves. Growth rates are assumed to be linearly proportional to the bio-degradation rate. Because biodegradation in petroleum reservoirs is commonly considered to be limited by nutrient supply (Larter et al., 2003; Wilhelms et al., 2004) the growth rate curves will usually never reach their maxima. In consequence the growth rate curves are replaced by a constant plateau value in the low temperature range (<80°C; Wilhelms et al., 2001) and a decline of the all over growth rate curve beyond a threshold temperatures (Fig. 1). The effect of paleopasteurization (Wilhelms et al., 2001) has also been integrated in the biodegradation rate function. At present, the biodegradation rate is implemented as a zero order reaction with respect to the substrate and normalised to a unit interface area. The resulting unit is kg/m²/my.

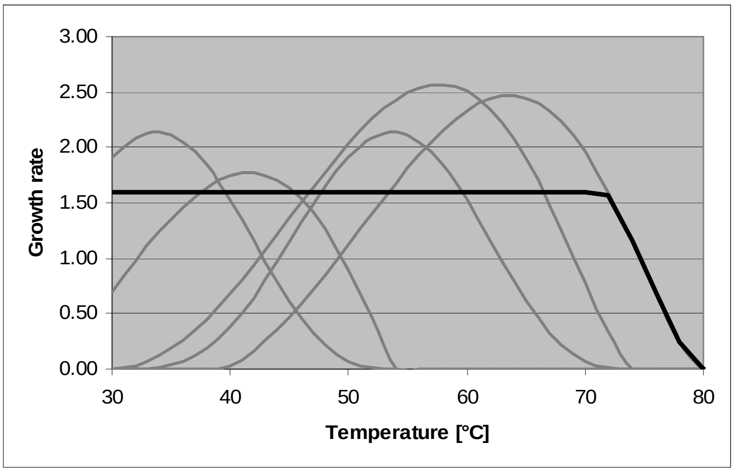

Fig. 1 Degradation rate vs. temperature. Grey: growth rates of individual organisms; Black: overall growth rate; NB: due to the assumed limitation of nutrient supply no organism can achieve its maximum growth rate; Growth rates functions after Ratkowsky et al., 1983

The numerical simulation scheme for biodegradation has been set up as a Microsoft Excel® based "workbench" to allow for flexible modifications as well as correct mass balance calculations. This is especially straightforward with the first of several approaches for mass concepts that conceptually subdivides the oil in a degradable and a non-degradable fraction in terms of biodegradation. Optionally, degradation of the saturate fraction as a whole may also be calculated. Furthermore, compound-specific information from basin modeling can be used to simulate biodegradation on a compound group level. Each group is attributed a relative biodegradation rate and a factor defining its biodegradability i.e. to which extent it is susceptible to biodegradation. Biodegradation of inidvidual compound groups may be computed as simultaneous or sequential processes (cf. Peters & Moldowan, 1993).

Results are given as predictions of the petroleum composition. After complete implementation into the basin modeling software it will be possible to derive directly GOR,

°API and the corresponding phase envelopes. A major task for future work will be to quantify the products of biodegradation.

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