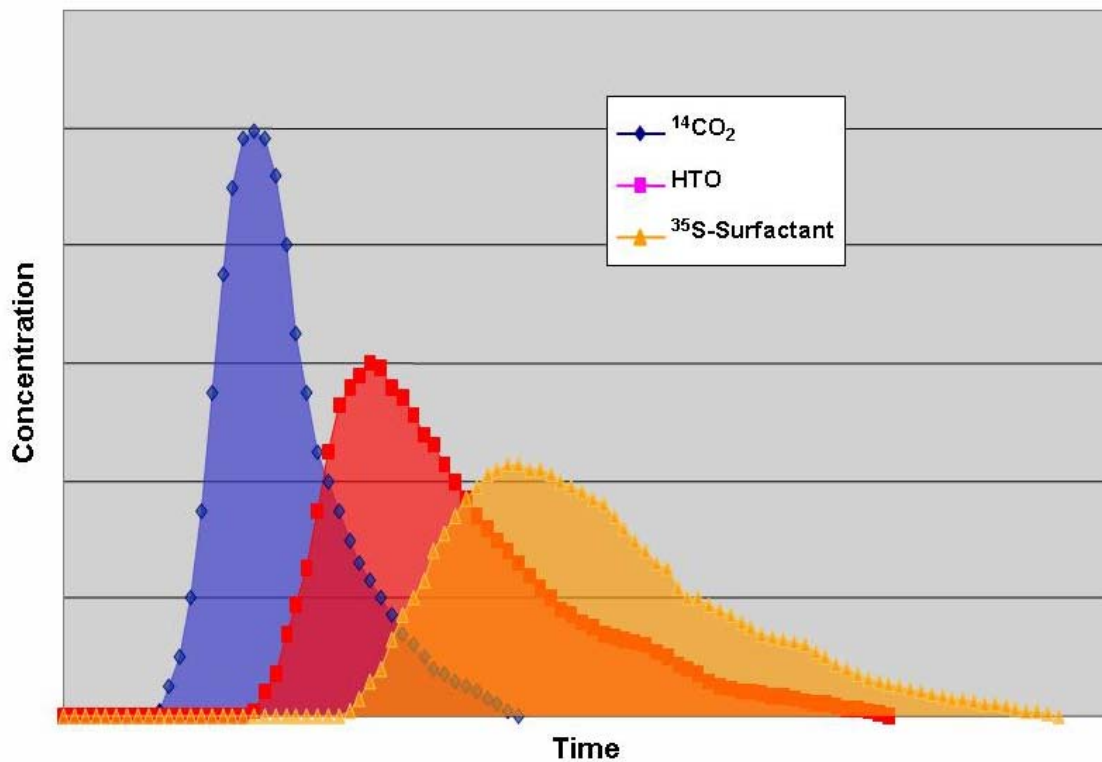


## Reservoir and Exploration Technology - 2009

### Tracer Technology for monitoring of EOR processes.

The Tracer Technology Section develops tracers and methods for monitoring fluid and component transport in oil/gas reservoirs. The development is carried out in several JIP programs supported by major oil companies (Statoil, Total, ENI, ConocoPhillips, Wintershall, Aramco, RWE, GdF). Specific focus has been on using tracers, both in reservoir and in laboratory, to study transport of EOR (polymers, surfactants and additives) chemicals. Tracers can be used to improve the understanding of transport of chemicals in porous media and thereby increase the efficiency. Optimisation of use of chemicals will reduce the amount needed and thereby also reduce discharge to the environment. Radioactive labelling techniques have been used to carry out mechanistic studies in the laboratory. Unique radiolabelling allows detailed studies of dispersion, retention and degradation on component level.



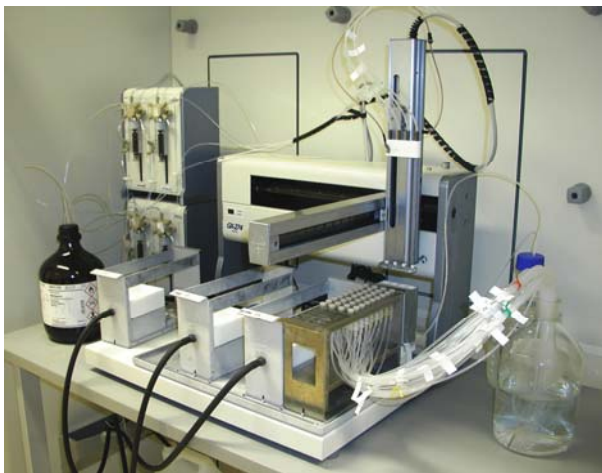
Relative flooding mode of  $\text{CO}_2$ , water (HTO) and surfactant in a porous medium

## Tracer Analysis Laboratories

During 2009 RELE's Section for Tracer Analysis moved into new modern laboratory facilities. This is the latest highlight in the long and successful history of IFEs Tracer Technology for the petroleum industry that started 25 years ago. Since then a considerable number of tracers and new applications have been developed and qualified in close co-operation with major oil companies. Besides radioactively labeled tracers, a large portfolio of new non-radioactive tracers with various properties has been developed in Joint Industry Projects (JIPs) together with leading oil companies through these years. Most of these have become industry standards. One reason for the success of IFEs Tracer technology is the continuous development of highly sensitive analytical techniques that enable the determination of tracer molecules in produced waters or other difficult samples matrices at the ppt or even ppq concentration level.



**Sample preparation laboratory for tracer analysis**



**Robot for preparation of tracer samples**



**HPLC spectra of tracers**



**Operation of HPLC**

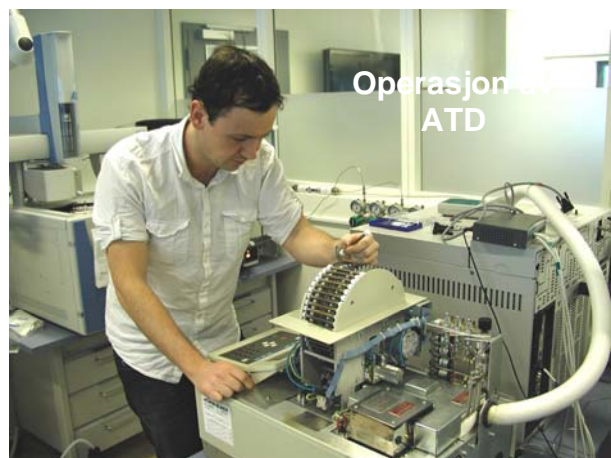


**Filtration of water samples**

With the new laboratory facilities at the Section for Tracer Analysis the tracer activity at IFE is even better positioned to face the many challenges of today and tomorrow. On about 400 m<sup>2</sup> several preparative laboratories are gathered around an analytical instrument park that is quite unique in Norway. Advanced equipment for chemical analyses, such as HPLC, GC, GC/MS/MS, UV/VIS, LIF and other instrumentation including thermal neutron activation analysis for detection of non-radioactive species (“needle-in-the-heystack”) are available. Advanced instrumentation for detecting radiotracers, e.g ultra low background liquid scintillation counters and alpha- and gamma-spectrometry, are also included in the suite of tracer-analytical methods. Presently, samples are received from throughout the world for tracer analysis mainly from field examination programs where RELE’s Section for Field Studies has performed the field operations.



**Operation of GC/MS/MS**



**Operation of ATD**

## International co-operation

Since year 2000 Department for Reservoir and Exploration Technology (RELE) has participated in various multilateral research projects organized by the International Atomic Energy Agency, IAEA, in Vienna. This leads to co-authorships in several IAEA-related reports and publications where IFE's contribution is considerable. This year, a program entitled "Validation of tracers and software for interwell investigations", with participation from 10 countries (Argentina, Brazil, Canada, China, France, Indonesia, Norway, Pakistan, Philippines and Vietnam) has been finalized. The main publication from the program will be a "Guidebook" which will be published by IAEA during 2010. Department RELE is, in addition, participating in the IAEA-program entitled "Evaluation and validation of radionuclide generator-based radiotracers for industrial applications" where 15 countries take part and contribute. The last progress meeting was arranged at IFE/Kjeller in September 2009. The picture below shows the participants and participating countries. This program is directly overlapping with our internal strategic program entitled "Development of radiotracer generators for industrial applications".



*From left: Rubens Moreira (Brazil), Jinfu Li (China), Jorge Isaias Borroto Portela (Cuba), Nares Chankow (Thailand), Celso Vargas Elizondo (Costa Rica), Christian Priesley Kofi Dagadu (Ghana), David Jenkins (UK), Luis Muñoz Anrique (Chile), Patrick Brisset (France), Ghiyas-Ud-Din (Pakistan), Joon-Ha Jin (IAEA), Sung-Hee Jung (Korea), Amenonia Ferreira Pinto (Brazil), Frank Rösch (Germany), Francisco Pablo Ramírez García (Mexico), Jacek Maria Palige (Poland), Rubel Chakravarty (India), Stuart Charlton (Australia), Tor Bjørnstad (Norway)*

## Tracer modelling and simulation

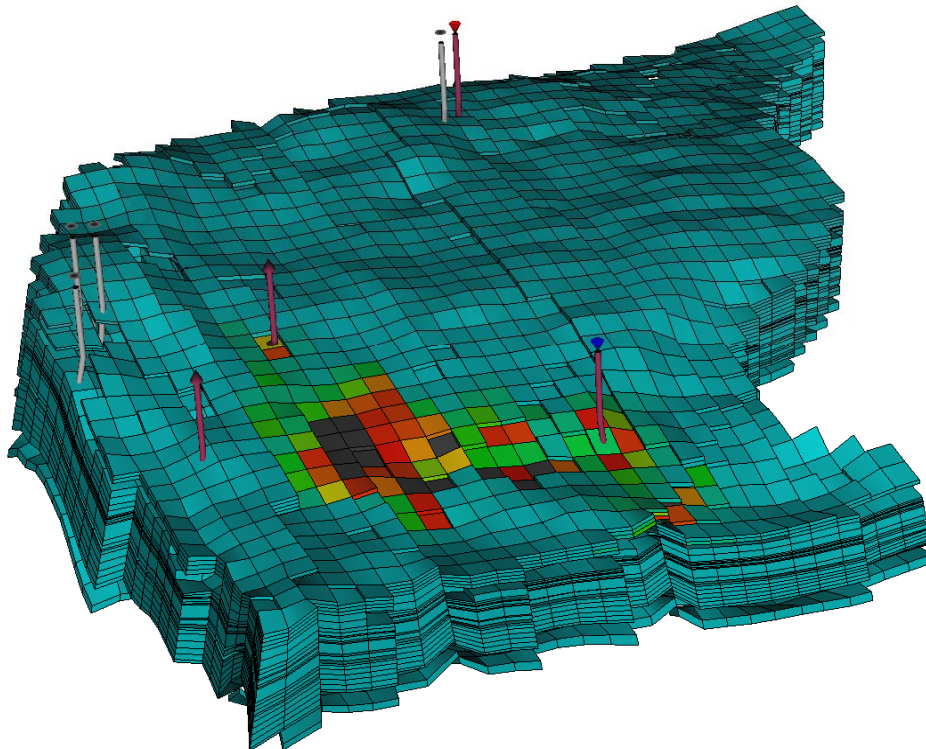
In 2009 the reservoir modeling section at IFE has delivered ARTSim, a new tracer simulation tool, to Statoil and Total. ARTSim avoids shortcomings of traditional simulation tools, and include adequate options for modeling of gas tracers.

The ARTSim tracer simulator has been tested on several real reservoir simulation examples from the North-Sea, and we find that additional CPU time needed for the tracer simulation are small (typically 1% of the reservoir simulation itself). This new tracer simulator includes separate time step control and separate tracer grid-refinement to improve accuracy of the solution - at very low computational cost.

The improved simulation capabilities of ARTSim have been used to predict realistic tracer breakthrough times in a North Sea reservoir.

The tracer simulator has also been coupled with assisted history matching methodologies based on the Ensemble Kalman filter (EnKF). The value of tracer data in the EnKF approach has been demonstrated on North Sea based examples. These examples show that tracer data can be used successfully in an automatic updating scheme, not only by the traditionally manual updating.

IFE ARTSim tracer results



**ARTSim tracer simulation results of a water tracer moving from an injector towards a producer in a North Sea reservoir.**