# Institute of Hydrochemistry

# Chair for Analytical Chemistry

# Annual Report

# 2007

Institute of Hydrochemistry
Chair for Analytical Chemistry
Technische Universität München
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Editor: Dr. Thomas Baumann

# Editorial

Dear coworkers, friends and colleagues,

I am happy to present you the scientific summary of a satisfying year in this annual report. Even though the funding situation in the previous years was at least "improvable", we managed to spent five PhD stipends from our savings. I am more than delighted, that these young scientists are now working on national and international funded projects in the fields of aerosol research and microarray technology. In the meantime 7 PhD students are designing and validating immunochips for the detection of trace concentrations toxins, bacteria, and antibiotics. I'm also very proud on our latest chip reader technology, a fully automated, computer-controlled chip-based analysis station, which will hit the market in 2008.

Another novel analytical technique, photophoresis of particles, was developed from scratch to a real world application. We proved that dispersed particles can be separated by photons in liquids and air. Some particles show funny movements (e.g. loopings) when entering the laser beam. However, it also seems possible to select particles for further characterization and treatment.

Our micro soot sensor found broad acceptance for diesel engine development. More than 150 sensor systems were sold to major car manufacturers around the world. Even the spark discharge soot aerosol generator, developed 20 years ago, reveled a revival. Dirt & dust seem to be an everlasting topic, even for analysts. In this context we started some research in the field of biodiesel, a possible replacement for petroleum. Currently, together with many colleagues from this university, we will address biogas, a matrix much more complicated than expected.

Last year saw a steep increase in students number, again. In 2008 we will have to master a high number Bachelor theses with the Masters following to the end of this decade. On the other hand, "hard core science" (I mean physics and engineering!) seems to become more and more unpopular. There are several open PhD positions with no applicants with appropriate and convincing profiles to be seen.

In Fall 2007, the open position in our small but extraordinary productive workshop was filled with Julius El Masry, a young and talented precision mechanic. Just a few weeks ago they launched a new family of photoacoustic sensor systems under the auspices of Dr. Haisch.

Finally, I'm very grateful for the efforts of all the institute's members. I would also like to thank the various funding institutions, and especially our "Freundeskreis" for preserving our freedom of research through their financial contributions. Especially, we would like to acknowledge our new Renault Trafic which ensures the mobility, not only of the Hydrogeology group.

All the best for the year 2008!

Reinhard Niessner
Head of the Institute

Head of the Institute and Group Leaders 2007

C. Haisch, D. Knopp, M. Seidel, T. Baumann, R.Nießner

# 1 Research

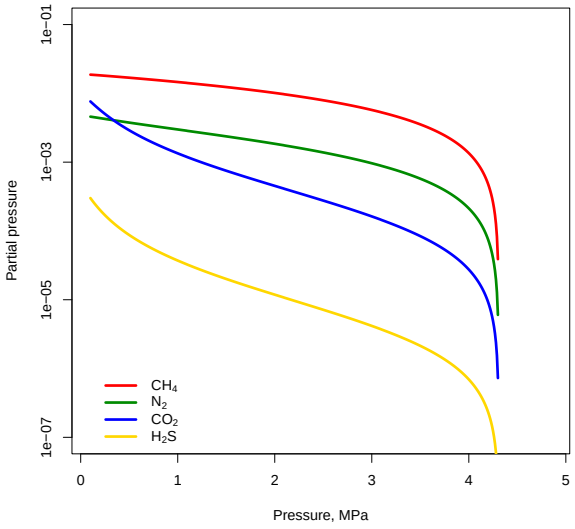
## 1.1 Hydrogeology and Hydrochemistry

### 1.1.1 Gas Composition the Malm Aquifer

*Funding: Private Enterprises*

The Malm aquifer beneath the Molasse Basin is a main target for the exploration of geothermal energy. The hydrodynamic and hydrochemical conditions in the Braunauer Basin, east of the Landshut-Neuötting-Barrier received significant attention during the past years. The data base for this region is reasonable. In contrast, each well in the western basin produced data which does not readily fit into the hypothetical framework.

During a pumping test at a geothermal well hydrogensulfide concentrations in the 2% [v/v] range were measured. Hydrogensulfide concentrations in this range are known from sour gas production wells, but have not been reported before for any groundwater well in the Malm aquifer of the Molasse Basin. Even though concentrations in the mg/L range for dissolved sulfide are common for groundwaters in the Malm aquifer such high concentrations in the gas phase of the Malm groundwater have not been measured before.




Isotopic measurements revealed a heavy signature for $^{34}S$ in the gas phase as well as in the water phase. This suggests that hydrogensulfide originates from the reduction of sulfate rather than from an impregnation with sour gas.

In the production well, the pressure decreases from 200 MPa to 1 MPa. At approx. 4 MPa a gas develops because of the high partial pressure of methane. As soon as a gas phase is present, dissolved gases can equilibrate with this gas bubble according to Henry's law: the methane gas bubbles are stripping other gases from the solution.

The findings of this project are important for the assessment of corrosion and the long term stability of the geothermal wells.
(*T. Baumann*)

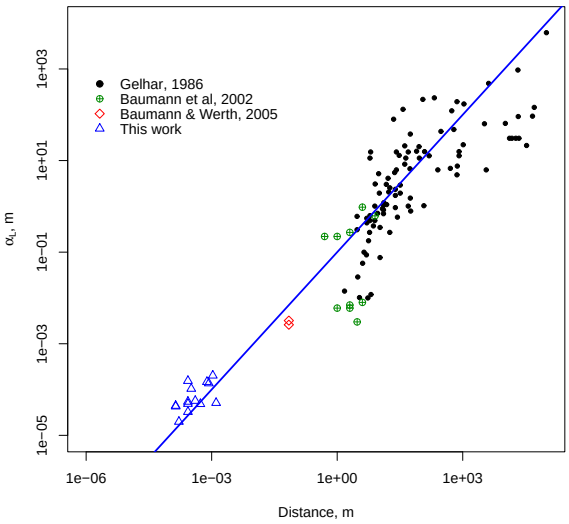
### 1.1.2 Dispersion of Colloids in Multiphase Systems

*Funding: DFG*

Transport of colloids and colloid mediated transport are important for the assessment of contaminant spreading. Contaminants can adsorb to colloids in which case the transport properties of the colloid are controlling contaminant transport and the properties of the contaminant become irrelevant. Under saturated conditions colloid transport is influenced by size exclusion, charge exclusion, and filtration effects. It is well known that these effects lead to colloids traveling faster than the bulk water flow. Colloid breakthrough curves also suggest that longitudinal dispersion of colloids is less than longitudinal dispersion of a conservative tracer.

In this research we used the micromodel technique (pore structures etched into silicon wafers) to measure colloid dispersion at the pore scale in three different pore

structures. The experiments were run with fluorescent colloids. The colloid concentration, the flow velocity, and the ionic strength were varied. Video images were analysed using particle tracking software: First a background image was subtracted from the image series to exclude occasional particles from previous runs. Then the center of mass is calculated for each particle in each frame of the series. The coordinates of the single colloids are then handed over to the particle tracking software where the single colloids are connected to trajectories.




The precision and accuracy of the tracking was validated with hand tracked data. Most of the trajectories were in perfect agreement although some did not match. The particle tracking had problems with colloids moving in out of focus, only. Even better, a comparison of the velocity distribution showed no bias. The trajectories were then analysed to calculate the displacement along the flow direction, the true length of the flow path the particle velocity, and the values of the longitudinal and transverse dispersivity.

In general there is a linear relation between the flow distance and the longitudinal dispersivity which is on the order or even higher than published values for macroscopic systems (Gelhar et al., 1983). This was quite surprising, because it seems not to be consistent with column scale and field scale data. The transverse dispersivity was affected by scale of the observation. Values where the flow length was on the order of the periodicity of the micromodels pore structure were on the expected order. Values for shorter flow distances were much higher.

Colloid dispersion on the pore scale is controlled by viscous forces, colloid-colloid, and colloid-matrix interactions. Repulsive colloid-matrix forces can make it impossible for colloids to enter into smaller pores even if they would physically fit into, thus affecting dispersion. The diffusion coefficients for colloids are governed by Stokes-Einstein equation and significantly lower compared to a dissolved tracer. Colloid-colloid interactions do cause an increase of dispersion at higher colloid concentrations, but seemed not to drive diffusion as predicted by Fick's second law.

Upscaling from the micromodel to the field scale emphasizes the main parameter controlling colloid transport which is colloid filtration. It can safely be assumed that with increasing flow distance only colloids traveling on flow paths which are well connected, wide, and with a low tortuosity will survive. This will act like a highpass filter to the velocity distribution of the colloids. As a result colloid dispersion on the field scale is smaller than tracer dispersion.
(*L. Toops, C. Mayr, T. Baumann*)

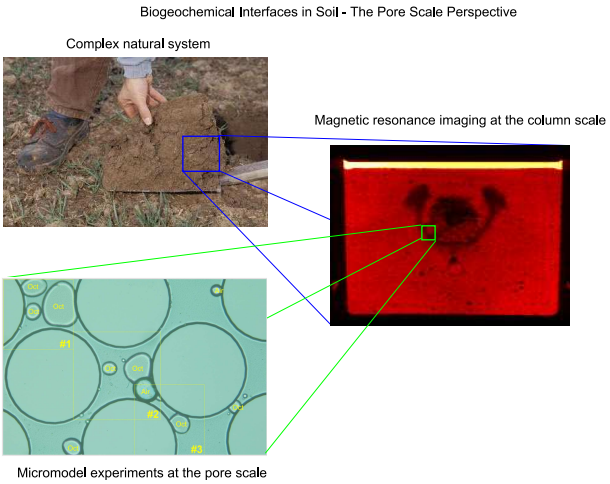
### 1.1.3 Application of Magnetic Resonance Imaging to Visualize and Quantify Dynamic Subsurface Processes

*Funding: DFG*
*Cooperation: DFG SPP 1315*

Biogeochemical interfaces serve as initial "reactive filters" in soil, and as such control the fate of organic and inorganic substances in subsurface. For a better understanding

of the processes at these interfaces it is necessary to explore the spatial and temporal dynamics of the interfaces itself and the processes associated with them.

Magnetic resonance imaging (MRI) is a good choice to visualize and quantify dynamic processes in porous systems. This research project aims at the development of techniques to visualize and quantify the interfaces in soil and the fate of phenanthrene and hexadecane in selected soils. The method will be based on MRI making heavy use of spectroscopic features of the MRI signal. Redox changes will be looked at using the paramagnetic effect of oxygen, and the different relaxation times of hexadecane and water will be used to visualize the two fluids. Using spin-labelled antibodies and humic acids, the accumulation and possible degradation of the contaminants at the interfaces will be measured.




Experiments on the pore scale in simplified pore network provide access to the interface dynamics. The high spatial and temporal resolution of the data obtained in this project provides the background for the interpretation of experiments at the column and the batch scale.

The key objectives of this research project are:

- Development of markers to access the spatial distribution of selected organic chemicals in soil
- Visualization of biogeochemical interfaces in soil
- Development of a technique to characterize the activity of biogeochemical interfaces in the spatial and temporal domain

The synthesis of nanoparticles with paramagnetic properties that can be bound to antibodies started with several approaches to functionalised $Gd^{3+}$ containing nanoparticles by precipitation of gadolinium oxide and polyethylene glycol under several different conditions (pH and temperature). The addition of the biocompatible polymer diamino polyethelene glycole (DAPEG) was chosen for the covalent immobilization of antibodies. Different methods are used for the characterization of precipitated DAPEG/$Gd^{3+}$ nanoparticles. For size determination SEM (scanning electron microscopy) and AF4 (asymmetrical flow-field-flow fractionation) are deployed. The gadolinium content is determined by ICP-MS (inductively coupled plasma mass spectroscopy). The nanoparticles have a size of approximately 5 nm. The antibodies were coupled to the nanoparticles after treatment with succinic anhydride and the well-known EDC/NHS chemistry.

(*T. Baumann, S. Heinrich, M. Seidel*)

### 1.1.4 Development of a Strategy to Decrease Well Aging at a Multiple Contamimated Site

*Funding: MDSE*

The Bitterfeld-Wolfen Area is known for lignite mining for its chemical industry, but also for its contaminations in groundwater and soil. There are some 5000 contaminations spread over an area of 10 km$^2$. These contaminations are far too complex to be treated individually.

There are numerous groundwater wells to ensure an appropriate groundwater level in the city of Bitterfeld and to prevent the propagation of contaminants into the surroundings. Recent investigations show massive incrustations in some of those wells, pumps, draining pipes. The incrustations are hindering a proper operation of the wells and also increase the costs for the hydraulic barrier.

The reason for the incrustations are local spills of sodium hydroxide at production sites and handling sites. Close to the spills the pH of the groundwater can reach values up to 13. Also the concentration of organic carbon increases due to alkaline extraction of lignite residues. The groundwater contamination is stratified and mixing is likely in wells. When mixing occurs both organic carbon and carbonates are precipitating from the solution and cause a clogging of the pore space.

In order to increase the lifetime of the extraction wells and pumps the groundwater close to the wells will be enriched with carbon dioxide to prevent precipitation during mixing. Future wells will be adapted to the stratified structure of the contamination.

Column tests indicate, that carbonated water is not causing additional precipitation, but might lead to an extended lifespan of the groundwater wells. Clogging seems to be reduced and existing incrustations are likely to be removed gradually. A field test is starting early 2008.

(*S. Lauber, C. Muhr, T. Baumann*)

## 1.2 Bioanalytics

### 1.2.1 Effect-directed Analysis of Toxins in Surface and Tap Water Using HPLC Combined with Flow-Through Biodetectors

*Funding: BMBF 02WU0331*
*Cooperation: Institute of Technical Biochemistry (Stuttgart), Helmholtz Centre for Infection Research (Braunschweig)*

In environmental analysis the complexity of matrices constitutes a major problem. In daily routine, the identification of all chemical compounds present in a sample is not possible. Generally, only potentially hazardous compounds are monitored. The coupling of bioassay assessment with chemical analysis is an effective means to gain more information than either of these assessments individually. The so-called effect-directed analysis (EDA) combines physicochemical separation, chemical identification and biological testing. Especially online analysis is a way to get fast and easy-to-use screening methods.

In this project, two different biological detectors were developed which make use of luminescent bacteria *Vibrio fischeri* and protein phosphatase 1$\alpha$ (PP1$\alpha$). The basic principle consists in the following. The sample is introduced to the LC system. After separation, analytes are mixed with a buffer solution containing bacteria or PP1$\alpha$. An air-segmented flow was applied to maintain the separation obtained by preceding liquid chromatography. Incubation of analytes and target is done in a fused silica reaction coil. For the determination of enzyme activity of PP1$\alpha$ a substrate has to be added to the incubation loop and the fluorescent product is measured after removing air-bubbles with a stripper in front of the fluorescence detector.

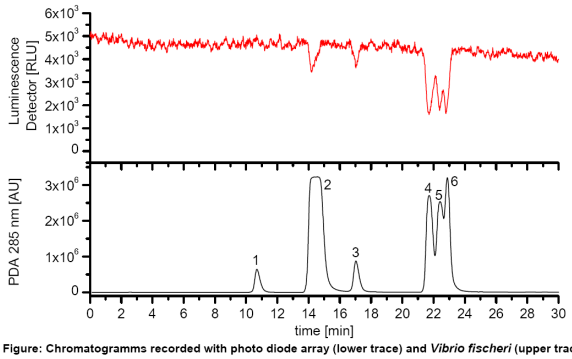


Figure: Chromatogramms recorded with photo diode array (lower trace) and *Vibrio fischeri* (upper trace)
1: 4-Fluorophenol, 2: 4-Nitrophenol, 3: 4-Chlorophenol, 4: 3,4-Dichlorophenol, 5: 3,5-Dichlorophenol, 6: DNOC

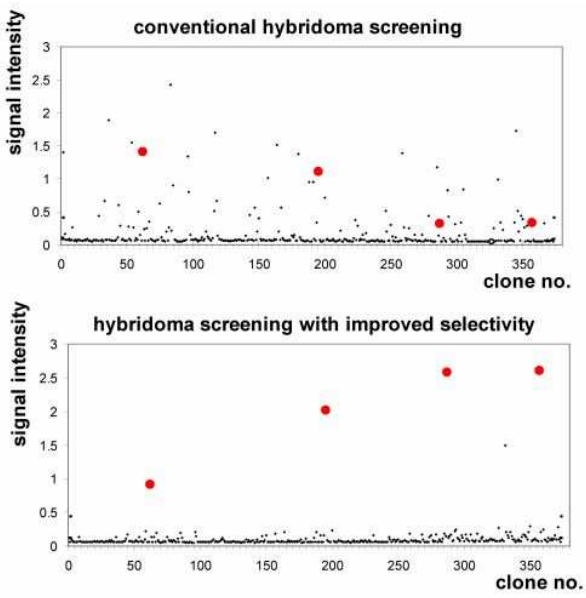
With *Vibrio fischeri*, tests are performed using a manual injection valve to avoid problems caused by gradient HPLC separation. First, optimization of various parameters such as temperature, concentration of bacteria and used solvents was performed. It appeared that the best diluent for the bacteria was a growth medium enriched with adenosine 3',5'-cyclic(phosphate) and N-acyl-L-homoserin lactone.
(*P. Stolper, D. Knopp*)

### 1.2.2 Development of Improved High-Throughput Methods for the Generation of Hapten-Specific Monoclonal Antibodies

*Funding: IWC*
*Cooperation: Institute of Physiological Chemistry, Martin-Luther-Universität Halle-Wittenberg*

Monoclonal antibodies (mAbs) are useful biological tools for various analytical applications, e.g. in clinical chemistry, food analysis, and environmental monitoring. In addition, antibodies are increasingly used as human therapeutics. Immunization of animals, mainly mice, in combination with the so-called hybridoma technology is still the most common and successful method for the generation of mAbs.

The bottleneck for the applicability of immunoanalytical methods often is the availability of high-quality, i.e. high-affinity antibodies. In contrast to a polyclonal




antiserum, mAbs can be produced by cultivation of selected hybridoma cells. Such cell lines are artificial immortalized fusion products of B-lymphocytes (the antibody-producing cells of a previously immunized mouse) and myeloma cells.

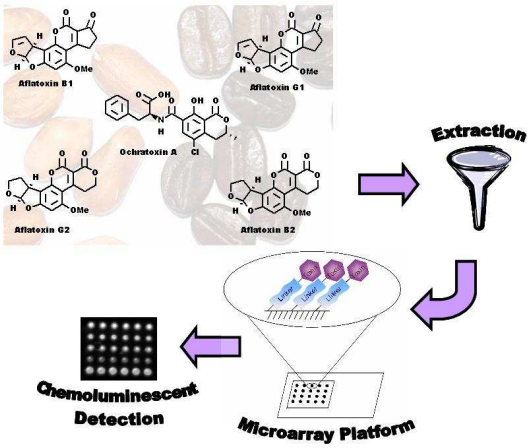
This project focuses on the development of improved methods for hybridoma screening, which is one of the very crucial steps for a successfull generation of high-affinity mAbs against small molecules. Excellent selectivity and speed of such high-throughput hybridoma screening (i.e. the selection of the interesting high-affinity antibodies) is very important.

By applying novel and improved methodologies for hybridoma screenings, as well as for affinity measurements by enzyme-linked immunosorbent assay (ELISA), we were able to generate mAbs against aflatoxins of excellent affinity. Aflatoxins are extremely carcinogenic food contaminants produced by molds. With our high-affinity mAbs, trace concentrations of aflatoxins as low as in the ng/L-range can be detected.
(*C. Cervino, D. Knopp*)

### 1.2.3 Hapten Microarray-based Screening of Mycotoxins in Food Samples

*Funding: BMBF*
*Cooperation: Eurofins Analytik GmbH, Wiertz-Eggert-Jörissen, Hamburg, and Ring Engineering Ltd., Azur, Israel*

Mycotoxins are toxic secondary metabolites produced by several species of fungi that pose important risks to human health. In particular, aflatoxins and ochratoxin A are isocoumarine-like compounds that can be found in food products as diverse as nuts, coffee, corn and milk. Contamination of food can occur in any of the multiple steps involved in the production process. The number of countries that are setting low limit values for mycotoxins, and particularly aflatoxins, increased in the past few years. Due to the broad diversity of food matrices, there is no universal, reliable, easy, cost-effective and fast analytical method available for the determination of trace amounts of aflatoxins. Such a method is desirable for monitoring and controlling the toxin content.




The past decade has seen a boom in analytical screening methods that take advantage of the so-called "lab-on-a-chip" technology, particularly the DNA and protein microarrays. Using this approach, mycotoxin-derived haptens at microliter volumes are delivered and directly immobilized on chemically modified surfaces (for example glass or polypropylene) by means of suitable linkers and subsequently probed for specific antibody binding using a direct competitive immunoassay format. Based on newly generated monoclonal antibodies the microarray approach

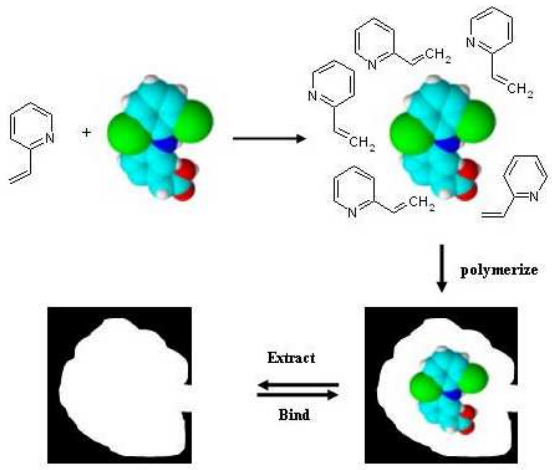
is focussed on the parallel detection of the four most important aflatoxins, AFB1, AFB2, AFG1, AFG2, and ochratoxin A directly in raw food extracts.
(*J. Sauceda, C. Cervino, D. Knopp*)

### 1.2.4 Preparation of MIPs for Trace Analysis of Non-steroidal Anti-inflammatory Drugs

*Funding: IWC*

Non-steroidal anti-inflammatory drugs are detectable at the ppb level in waste water. Generally, for analysis of low concentrations preliminary sample preparation i.e. analyte enrichment is required. Solid phase extraction (SPE) is commonly used for this purpose, however, conventional SPE materials often show some limitations such as low recoveries of target analytes and lack of selectivity. Due to the above reasons, highly selective molecularly imprinted polymers (MIPs) have been synthesized and applied for trace detection of pharmaceuticals in environmental water samples.

This project is mainly focused on the preparation and application of MIPs for diclofenac. Synthesis was successfully performed with 2-vinylpyridine (2-VP) as the functional monomer, ethylene glycol dimethacrylate (EGDMA) as cross-linker, and toluene as porogen. The interaction between monomer and template molecules was performed by 1H NMR analysis. The 1H NMR data show that hydrogen bonding and ionic interaction are the major interaction forces. Prepared MIPs were characterized using HPLC/UV. Finally, the MIP was successfully applied for the enrichment of diclofenac from tap water, surface water, and municipal waste water samples.
(*Z. Sun, D. Knopp*)



### 1.2.5 Isotope-labeled Aflatoxins for LC-MS/MS Stable Isotope Dilution Analysis of Foods

*Funding: IWC*
*Cooperation: Chair of Food Chemistry, Technische Universität München*

Aflatoxins are a group of extremely carcinogenic mycotoxins that can be found on a wide range of food commodities. In this project, the first stable isotope dilution assay (SIDA) using high-performance liquid chromatography coupled to tandem mass spectrometry (LC-MS/MS) for the determination of aflatoxins in foods was developed. Such SIDAs generally reveal superior validation data in terms of precision and accuracy compared to commonly used methods, especially for trace analytes in complex matrices.

A crucial prerequisite for the applicability of a SIDA method is the availability of isotope-labeled analytes, especially in the case of complex natural compounds such as mycotoxins. We were able to obtain two different isotope-labeled aflatoxins in high purity by means of synthetic chemistry. Using these substances as internal standards for food analysis, an analytical method was developed together with our cooperation partner, enabling the quantitation of all four aflatoxins of interest for which maximum legal limits exist. The method was fully validated by determination of limits of detection, inter-assay reproducibility, and recovery rates for two model food matrices, as well as by analyzing a standard reference material. The method was successfully applied to determine trace levels of aflatoxins in diverse food matrices such as peanuts, nuts, grains, and spices.
(*C. Cervino, D. Knopp*)

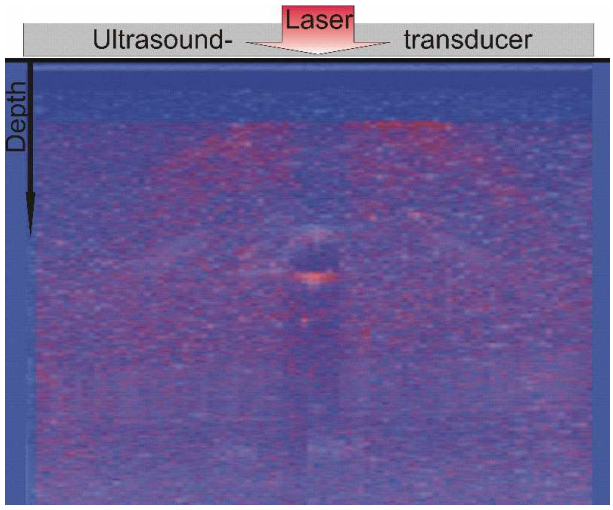
## 1.3 Applied Laser Spectroscopy

### 1.3.1 OPUS - Optoacoustics in Combination with Ultrasound for Breast Cancer Detection

*Funding: Bayerisches Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie, Program: BayMed*
*Cooperation: General Electric, München; InnoLas, München*

Ultrasound imaging is, next to mammography, the most common screening method for breast cancer diagnosis. The objective of our work is to develop optoacoustical imaging as an add-on to a conventional ultrasound system. Ultrasound imaging is based on the reflection of sound waves and therewith displays acoustical properties of the tissue. The acoustic properties of different tissue differ only slightly which makes it difficult to distinguish them. On the other hand tissues show a specific variation in their optical properties. The optoacoustic effect describes the generation of sound waves by the absorption of nanosecond laser pulses. Therewith, the optoacoustic images show an optical contrast in the acoustic output.

For our studies we employed a 100 Hz laser at 532 nm with 7 ns pulse duration (Spitlight 600, InnoLas, Krailling) coupled to an Optical Parametric Oscillator (OPO) (GWU, Erfstadt) for wavelength-dependent measurements to generate the optoacoustic signal. For signal reception we use a marginally modified commercial ultrasound scanner (L9, BT04, GE - Global Research, Garching b. München). Optical coupling between laser and tissue is established using optical fibres. The fiber is mounted to the ultrasound transducer such that the optical signal generation is within the acoustical field of view.




Combining ultrasound imaging and optoacoustic imaging allows us to overlap ultrasound and optoacoustical images to achieve the acoustic as well as the optical properties simultaneously. An overlap of an ultrasound and an optoacoustic image of a channel filled with an absorbing dye (indocyanine green) with an absorption coefficient of $\mu = 21.4\,\mathrm{cm}^{-1}$ is illustrated in the figure. The specific spectral dependency of hemoglobin can be observed in a wavelength range from 760 nm to 880 nm which enables the measurement of blood oxygen saturation.
(*K. Zell, C. Haisch*)

### 1.3.2 Photophoretic Particle Separation

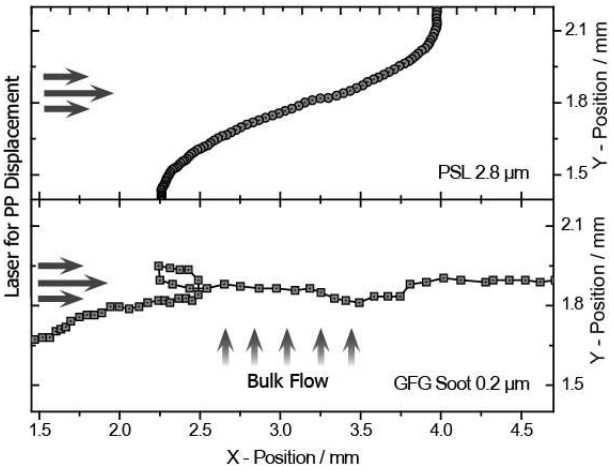
*Funding: DFG*

Photophoresis (PP) denotes the phenomenon that small particles suspended in gas (aerosols) or liquid (hydrosols) start migrating when illuminated by an intense beam of light. In case of transparent particles with an index of refraction larger compared to the surrounding medium, particles move in forward direction away from the light source. The migration is induced by momentum transfer from incident photons. Interestingly, motion can occur in the direction of light (positive PP) and in the opposite direction (negative PP) as well. If the particle absorbs the incident light, a temperature gradient

can be developed which causes the migration according to its thermal and optical properties and is termed Thermo-PP.

**Photophoresis of Aerosols** We characterized an experimental setup for the measurement of photophoretic velocities. It allows a continuous monitoring of PP velocities of a large number of particles in a short time, where each particle is measured separately. With the measured velocities deductions on the optical and thermal conductivity properties of the particles are possible.

In combination with other techniques, especially size separation, the opto-thermal absorption of the particles can be calculated. A next step in this direction is the integration of a parallel measurement of thermophoretic velocities within the same instrument in order to distinguish optical and thermal properties.




At present we analyze the uncommon PP behavior of soot agglomerates which reach velocities up to two orders of magnitude higher in comparison to spherical PSL particles. Moreover, with a certain range in size of the particles, the soot particles do not have a preferred direction of movement due to the excitation laser at all. With experiments using different coating material we influence that specific behavior of the soot particles. The figure shows a nearly perfect superposition of the pump driven force and the PP force of a spherical PSL particle (upper part) in comparison to the behavior of soot where even loops are possible (lower part).

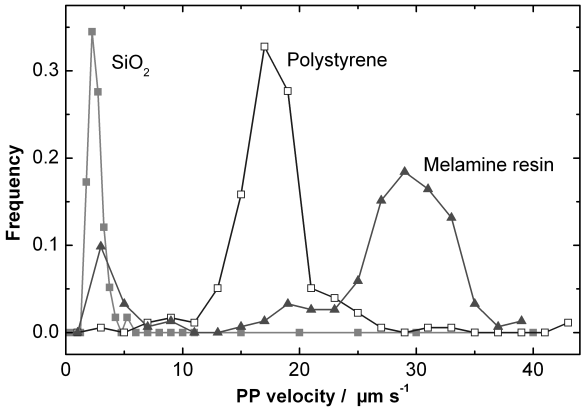
To our knowledge there is no other experimental method available which reveals optical properties of large numbers of particles rather than ensemble properties, as e.g. photoacoustic spectroscopy does. Beyond characterization and statistical evaluation we present an approach to physically separate particles of different optothermal properties, i.e. different susceptibilities to photophoresis.

Further work will be dedicated to the application of different wavelengths and the systematic assessment of different particle systems and properties (e.g. internally mixed particles, and surface-coated particles) concerning PP susceptibility. Possible applications are on the one hand the atmospheric aerosol, its migration due to photophoresis and its influence on the global radiation balance, on the other hand the characterization of industrial aerosol, e.g. for dye-stuff pigments, paint or in cosmetics. A large field of application may be the synthesis of particulate chemical catalysts. An optical characterization system based on PP may allow to directly distinguishing externally mixed aerosol from internally mixed particle systems.

**Photophoresis of Hydrosols** The velocity analysis of particle migration induced by light is a new technique for the characterization of single particles and is termed photophoretic velocimetry. By determination of a substantial number of velocities, the particle velocity distribution function (PVDF) of a sample is obtained. As the PP velocity is linked to intrinsic particle properties e.g. radius, refractive index n, shape or absorption index, the evaluation of the PVDF can reveal valuable information about the physical properties of the particle. By calibration of the instrument with spherical particles of different sizes, the particle size distribution function (PSDF) of e.g. cells

can be estimated. In the same manner the refractive index can be calculated by the PP velocity, if the particle size is known.

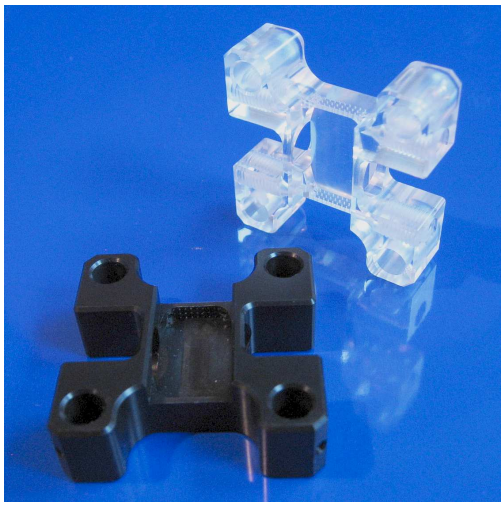
A Gaussian shaped intensity profile of a focused laser beam perpendicular to a bulk flow was applied in order to manipulate selected particles. Friction force and optical force balance at equilibrium velocity, the PP velocity. The PP behaviour of the particles is recorded by a CCD camera on top of an in-house made flow cell. The PP velocity of single particles is determined by means of image processing performed by adapted routine in Matlab.




The statistical analysis of velocity distributions of monodisperse polystyrene particles with diameters of 2 $\mu$m, 3 $\mu$m, and 4 $\mu$m reveals that the system is capable of resolving a particle mixture with a polydispersivity > 1.2. Besides size discrimination, particles of same size but different refractive index were characterized. The PP velocities of ≈200 single particles of each, polystyrene (n = 1.59), Melamine (n = 1.68) and $SiO_2$ (n = 1.42) particles with a diameter of 2 $\mu$m are well defined and distinct (see figure). By using a high power Nd:YAG laser ($\lambda$ = 532 nm, P = 1.2 W) the PVDF of *Escherichia coli*, Salmonella enteritidis, and yeast cells were recorded.

A further step beyond mere characterization is the application of optical forces for separation. The strong correlation of migration behaviour and intrinsic particle properties can be applied for high resolution separation according to distinct properties, e. g. size, and refractive index. Moreover, optical forces can be of great value in the realm of sample enrichment. Flow cells with optimized geometry have been realized and are under evaluation regarding efficiency and practical handling qualities (see photograph).

Light induced forces offer gentle sample treatment with high resolution and contact-free sample handling. This outlines techniques on the basis of photophoresis as excellent tools for the characterization and manipulation of particles, cells and bacteria in various fields.

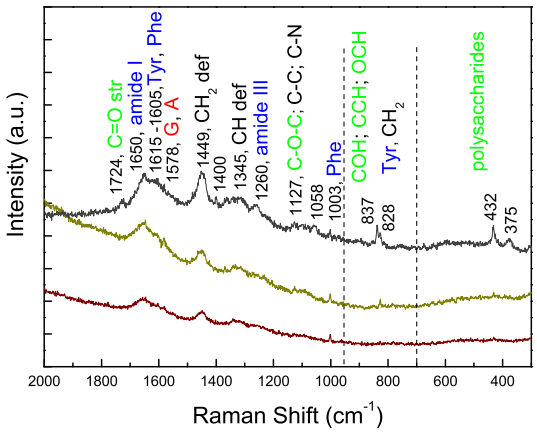


(*C. Helmbrecht, C. Kykal, C. Haisch*)

### 1.3.3 Non-destructive Chemical Analysis of Biofilm Matrix by Raman Microscopy

*Funding: DFG*
*Cooperation: TUM, Institute of Water Quality Control*

Biofilms present universal way of microbial life in natural environment and can occur at solid-liquid, solid-air and liquid-air interfaces. Biofilms are aggregates of microorganisms which are embedded in a matrix formed by extracellular polymer substances (EPS). The EPS are biopolymers of microbial origin such as polysaccharides, proteins, glycoproteins, nucleic acids (DNA and RNA from lysed cells), lipids and phospholipids. For in situ assessment of the biofilm structure, the Confocal Laser Scanning Microscopy (CLSM) has been proved to be a powerful technique. However, staining is required to distinguish specific components in biofilm. Moreover, EPS are a complex mixture of different polymers with large number of potential binding sites that makes difficult the staining of total EPS. The combination of CLSM with some technique that would allow us to overcome these limitations and would provide additional chemical information about biofilm components and their distribution is needed for better understanding of composition and structure of biofilm matrix.




Raman Microscopy (RM) is non-destructive spectroscopic analytical technique that provides fingerprint spectra with spatial resolution of an optical microscope. It requires no or limited sample preparation. Raman spectra are characterized by high specificity and low water background. Recently RM was applied to describe the spatial distribution of the biofilm biomass and characterize the microorganisms in biofilm.

In order to explore the potential of RM for detailed label-free chemical analysis of biofilm matrix a broad range of reference samples (polysaccharide, proteins) that may be present in EPS matrix, as well as microorganisms and encapsulated bacteria were analyzed. The characteristic frequency regions and specific marker bands for different biofilm components were found. This can be applied for the analysis and identification of various macromolecules in complex biofilm matrix.

Study of different multispecies biofilms have shown that RM can provide detailed information about the chemical composition of complex biofilm matrix (figure). The results of RM analysis of biofilms are in good agreement with the data of CLSM studies. Thus RM can be an efficient tool for non-destructive analysis of biofilm matrix. Moreover the combination of RM with CLSM analysis for study of biofilms grown under different environmental conditions can provide new insights into complex structure-function correlations in biofilm.
(*N. P. Ivleva, C. Haisch*)

### 1.3.4 Online Monitoring of Biofilm Structure by Thermal Lens Microscopy

*Funding: Ministry of Education, Science, Sports and Culture, Japan*
*Cooperation: Department of Applied Chemistry, University of Tokyo*

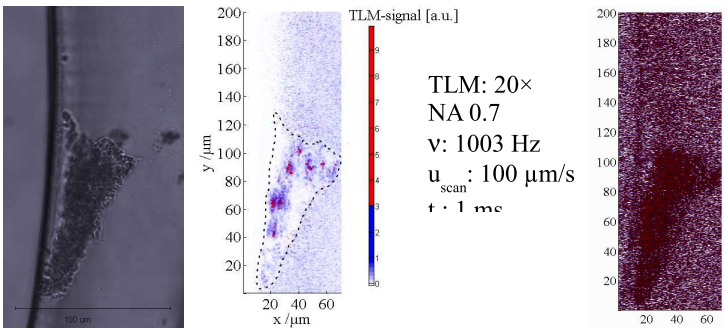
Biofilms are agglomerations of bacteria in a polysaccharide matrix. They predominantly develop at phase borders in contact with water. They are responsible for adverse effects like biofouling or corrosion. To control biofilm growth and removal and

to study basic processes in biofilms, on-line three-dimensional observation methods are required. One of those methods is thermal lens microscopy (TLM).

In TLM, a modulated excitation laser beam is absorbed by the sample, causing local heating. This leads to a refractive index gradient which acts as a lens on a collinear probe laser beam. The change of focus of the probe beam is monitored through a pinhole with a photodiode as intensity change. It is recorded with a lock-in amplifier.

A three-dimensional scan of a sample is conducted by a scanning table. During each scan the absorption and the thermal characteristics of the sample are recorded simultaneously. This way two images of the sample are obtained.

An example of biofilm imaging with TLM is given in the figure. The biofilm was grown in the well-defined flow of a microchannel of 200 micrometer width.
(*T. Rossteuscher*)



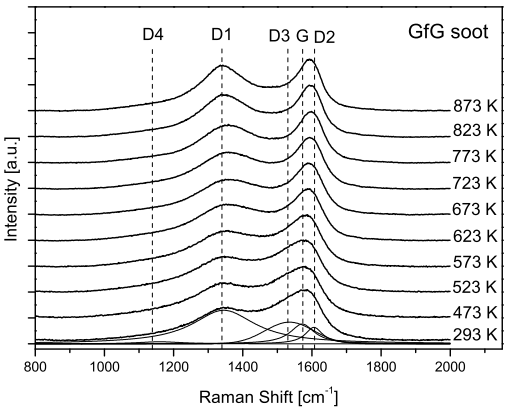
## 1.4 Aerosol Research

### 1.4.1 Changes in Structure and Reactivity of Soot during Oxidation Studied by Raman Microscopy and Temperature Programmed Oxidation

*Funding: DFG*
*Cooperation: Fritz-Haber- Institute of the Max-Planck-Society, Berlin*

The attention to the relationship between quality of air and human health has been increasing in the last years. Atmospheric aerosol particles generated from a wide range of natural and anthropogenic sources have been cited as a risk to human health. Especially soot particles emitted by diesel engines are hazardous environmental pollutants. A wide range of particle trapping and exhaust aftertreatment technologies have been proposed and are currently under development. These traps have to be regenerated periodically and the behaviour of this regeneration step is strongly depending on the reactivity of the deposited soot particles. A new way of solving the regeneration problem would be to create highly reactive soot. Therefore it is necessary to establish a rapid analytical tool to determine the reactivity of different types of soot.

Experiments concerning the reactivity of soot are usually done by Temperature Programmed Oxidation (TPO) and for investigation of soot structure High Resolution Transmission Electron Microscopy (HRTEM) is usually applied. However, TPO and HRTEM measurements are very time and cost consuming. On the other hand Raman spectroscopy can be used to get detailed information about the reactivity of soot by measuring the structure.




Raman spectroscopy in general provides fingerprint spectra and allows a characterization of a wide range of chemical substances. Raman Microscopy (RM, which combines the analytical capabilities of Raman spectroscopy with the spatial resolution of an optical microscope) has been applied for the structural characterization of different soot samples. For quantitative spectral analysis the five band fitting has been used.

RM and TPO combined with FTIR gas analysis have been applied to determine structural changes and oxidation behaviour in samples of spark discharge (GfG) and heavy duty engine (EURO IV) soot upon oxidation by oxygen in a temperature range between 293 K and 873 K. For GfG soot the changes in Raman spectroscopic parameters (figure) suggest a rapid preferential oxidation of highly reactive amorphous carbon. This is in good agreement with the mass conversion determined by $CO_2$ emission with FTIR and gravimetry. In contrast to GfG soot the spectral parameters of EURO IV soot remained mostly unchanged during the oxidation process, so that EURO IV soot shows just minor changes in structure upon oxidation.

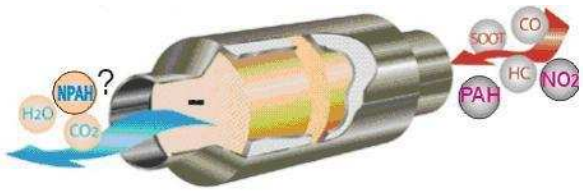
Overall, Raman spectroscopic parameters provide information about changes in structural order of graphitic and amorphous carbon fractions during oxidation and can be used to analyze oxidation readiness of soot. Thus RM may become a rapid analytical tool for the determination of soot reactivity by analysis of the structure.
(*M. Knauer, N. P. Ivleva*)

### 1.4.2 Nitro-PAH Formation in Diesel Exhaust

*Funding: DFG*

Nitrated polycyclic aromatic hydrocarbons (Nitro-PAHs) can be either directly emitted from combustion sources as diesel engines or formed from their parent PAHs by atmospheric OH or $NO_3$ radical initiated reactions. Nitro-PAHs that are produced from combustion reactions are generally formed via electrophilic nitration reactions in the presence on $NO_2$. PAH and their nitro-derivatives with a number of rings $< 3$ are mostly present in gaseous form, on the other hand, larger PAHs and Nitro-PAHs are adsorbed on soot surfaces. Those that adsorbed are suspected to be more genotoxic. The mutagenic character of diesel exhaust particulate matter (PM) is mainly attributed to Nitro-PAHs.

In Diesel vehicles equipped with a Diesel Particulate Filter (DPF), most soot particles produced by the engine are trapped within the filters. Considerable amount of PAH emissions (due to incomplete combustion and due to PAHs already present in the fuel that mostly survived the combustion) may reside on these particles. Therefore the aim of the project is to understand whether DPF, due to the high $NO_x$ emissions constantly passing the DPF, could be very productive in generating Nitro-PAHs.




Reactions and their products occurring in a Diesel Particulate Filter between $NO_2$ and PAHs to form nitro-derivates have to be characterized and the role of soot in the reaction has to be evaluated.

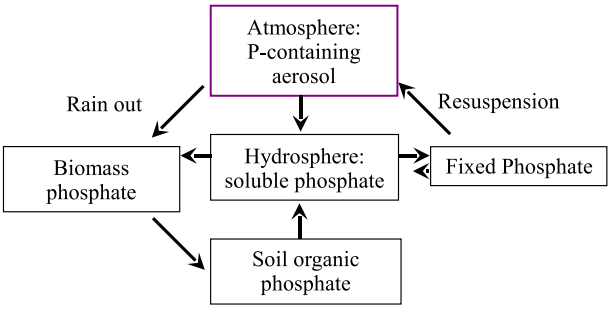
First experiments involve a spark discharge soot generator to produce model aerosol particles with similar size distribution to Diesel soot. These particles are then coated with pyrene and trapped on a filter. This filter is then exposed to a gas mixture similar to Diesel exhaust parameters. The effect of $NO_2$ concentration, water vapor content, temperature, residence time, and in future also particle distribution, are at the moment still under investigation.

The Nitro-PAHs analysis is carried out by mean of High Performance Liquid Chromatography coupled to a fluorescence detector. The weak fluorescence exhibited by most Nitro-PAHs requires a reduction procedure of the Nitro-PAHs to the corresponding Amino-PAH. To accomplish that a reduction column densely packed with 5% Pt on aluminum is placed after the reverse phase analytical column use for the separation. (*M. Carrara*)

### 1.4.3 Characterization of Organic and Inorganic Phosphorus-containing Ambient Bioaerosols

*Funding: IWC*

A major part of atmospheric aerosol particles with a diameter larger than 1 $\mu$m has a biological origin. Such bioaerosols have its origin as parts and products of microorganisms, as well as plant materials. Its variability is still not widely known. For microbial metabolism and cell construction, important building blocks such as nucleotides, phospholipids and phosphorus-containing proteins can be used as tracer substances, as an evidence for the presence of microorganisms. Trace analytical processes for identifying those organic phosphorus components have not yet been established. Therefore, their source and their relevance in atmospheric aerosols is not well established.




Within this research project, a new analytical method will be developed using a coupling between ultrafiltration and inductively-coupled plasma mass spectroscopy (ICP-MS), already known for its superiority in elemental selectivity, low detection levels and high sensitivity. This technique would allow an overview of the total phosphorus amount in an aerosol. Through the quantification of adenosine triphosphate as a marker substance using a bioluminescence process, the biological component of different fractions of particles is determined. These studies will contribute for the establishment of analytical processes for determining phosphorus-containing compounds in aerosols, in order to characterize the importance and the variability of biological particles in the atmosphere as well as to enlarge the understanding of the biogeochemical cycle of phosphorus.
(*M. Loussouarn*)

## 1.5 Bioseparation and Microarray Technology

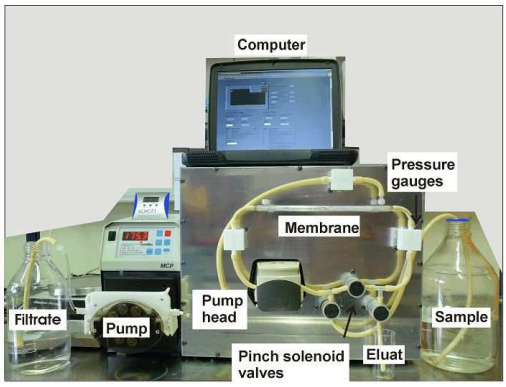
### 1.5.1 Determination of Water-suspended Bacteria by Automated Immuno Chip Technology

*Funding: DFG*

Pathogenic germs in drinking water can be a great danger for human health. Since currently applied routine methods for the monitoring and quality management of drinking water are often very time consuming, labour intensive, and nonselective. The development of a fast, sensitive and especially multianalyte online system for the detection of microorganisms in drinking water is of high interest at the moment.

**Enrichment of Microorganism in Drinking Water with Crossflow-Filtration** To improve the sensitivity of techniques for bacterial detection, a prior enrichment step is necessary. The crossflow microfiltration offers the possibility to concentrate bacterial organisms in a single process by using size-exclusion-based filtration shortly and combining then to bioanalytical detection methods.

Crossflow filtration is a cell separation technique which has been the focus of much research in the last two decades. In contrast to the conventional dead-end filtration, where the feed flow is perpendicular to the membrane surface, in the cross-flow filtration the feed flow is parallel to the membrane surface. The feed stream is separated into the permeate (filtrated product, purified water) and retentate (unfiltrated product) stream. The cross-flow circulation pattern with recirculation of the retentate reduces fouling of the membrane and makes it possible to filter large volumes of water while maintaining the organisms in suspension.



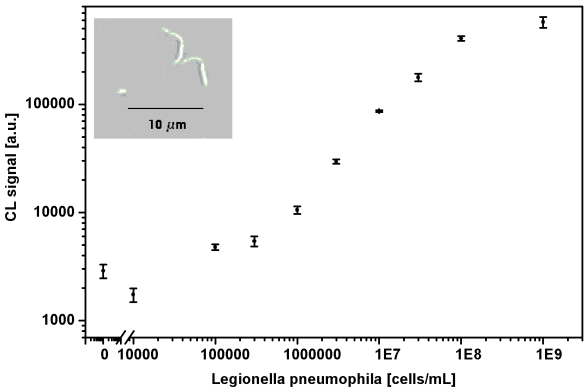

The purpose of the work was to determine the feasibility of hollow-fiber filter modules to efficiently concentrate bacteria from water. The recovery of the microorganisms depends on the membrane, the form of the filter module and the transmembrane pressure. For thus purpose a fluidic system was built and the transmembrane pressure, feed, and crossflow velocity were adjusted and controlled.

The recovery of the microorganisms should be >90% and the cells should not be damaged during the process. The test organism in the experiments was *E. coli* and known quantities were introduced and concentrated. For the quantification and discrimination of the enriched microorganisms several validation methods were tested. As reference method for the detection and quantification of *E. coli* the Colilert®-18 tests from IDEXX was used. That gives results in 18 hours. Faster enumeration (15 minutes) was acchieved by labelling the cells with Syto 9 and subsequent viability analysis with flow cytometry. The results of staining 100% living cells were compared to the Colilert®-18 test. The flow cytometry test showed good correspondence for cell concentrations between $\cdot 10^3$ and $\cdot 10^6$ cells/mL with very small standard deviation. The viability of the cells were analysed with afterstaining the Syto 9 -labelled cells with PI. PI has a stronger affinity for nucleic acid and will displace Syto 9 in dead cells. In the work the decrease of the Syto 9 labelled cells was used for the analysis of the viability of the cells. The results were also validated with two methods, the Colilert®-18 test and the BacTiter-Glo™ Microbial Cell Viability Assay from Promega. The decrease of the Syto 9 - intensity shows a good correlation to the two standard methods.

In the filtration experiments the effect of the trans-membrane pressure (TMP) on

the permeate flow during cross-flow microfiltration of drinking water spiked with cells is studied experimentally. The experiments show no permeate flow decline with increasing TMP because of the large surface area of the module. The recoveries of the microorganisms were over the TMP of 0.05 bar constant and were reproducible at 90%. It was possible to enrich 10 L drinking water with a permeate flow of 700 mL/min in 15 min to 50 mL with a recovery of 90% of the bacteria without losing the viability of the cells.

**Antibody Microarrays for the Detection of Microorganisms in Drinking Water** By transferring Enzym-linked Immunosorbent Assays (ELISA) to microarray platforms a quick and simultaneous quantification of all relevant germs becomes possible in one single experiment. At the Institute of Hydrochemistry an automated chemiluminescence microarray readout system for the rapid and simultaneous analysis of a variety of different analyts in aqueous samples has been developed in the past. The limit of detection observed with these kinds of sensor systems is generally in the range of $1 \cdot 10^3$ to $1 \cdot 10^4$ cfu/mL. In order to meet the legal regulations that demand the detection of a single germ in a 100-mL water sample a prior enrichment step is to be integrated in the online setup. For the quantification of microorganisms in water an array-based chemiluminescence-sandwich-ELISA has been developed. Herein antibody microarrays serve as selective binding platforms for microorganisms and biotin-streptavidin-horse radish peroxidase is used as reporter system for detection. Generated chemiluminescence signals are detected by a CCD camera which is integrated in the microarray readout system.




Antibodies against various pathogenic germs have been evaluated for their suitability to quantify the corresponding antigens simultaneously on the microarray surface.

Heat-killed *E. coli* O157:H7 cells were detected on a microarray chip with polyclonal antibodies to *E. coli* O157:H7 in the working range of $4 \cdot 10^4$ - $7 \cdot 10^5$ cells/mL. The LOD was $6.6 \cdot 10^3$ cells/mL. *S. typhimurium* cells (heat-killed) were detected in the linear range of $4 \cdot 10^6$ - $5 \cdot 10^8$ cells/mL with an LOD of $2.2 \cdot 10^5$ cells/mL and *L. pneumophila* (heat-killed) could be detected in the linear range of $\cdot 10^6$ - $\cdot 10^8$ cells/mL with an LOD of $3 \cdot 10^5$ cells/mL. The assay time was 13 min each. Living *E. coli* cells need a higher incubation time within the heterogeneous phase. Therefore, a strong signal of living *E. coli* cells ($2 \cdot 10^8$ cells/mL) is detected after an incubation time of 30 min.

(*A. Wolter, C. Peskoller, M. Seidel*)

### 1.5.2 Development of a regenerable immunosensor array for the rapid parallel detection of antibiotics in milk

*Funding: Forschungskreis der Ernährungsindustrie AiF FV 197ZN II*
*Cooperation: LMU Munich, Institute for Hygiene and Technology of Milk*

Antibiotics are widely used in animal husbandry as growth promotors, for treatment and prophylactics purposes. The presence of antimicrobial residues in food hold the risk of undesirable human health effects. The resulting contamination of milk can result in the occurrence of allergic reactions and bacterial resistance to antibiotics and in the production problems of cultured products (yoghurt and cheese) due to the inhibition of starter cultures. In order to protect the consumer and to maintain food quality the EU has established residue limits (MRLs) for several antibiotics in bovine milk. In the past few years a parallel affinity array (PASA) for the analysis of antibiotics in milk has been developed using multianalyte immunoassays.

Based on this high sensitive biosensor system, a new kind of automated chemiluminescence microarray chip reader (MCR 3) is created to afford the rapid simultaneous online detection of 13 different antibiotics directly at the dairy farm. The prototype is constructed as a mobile immunosensor array in which a temperature-controlled flow cell with 2 measuring channels is integrated.

The principle of the assays is based on an indirect competitive ELISA (enzym-linked immunosorbent assay) with a hapten microarray format. Reactive hapten derivatives are immobilized covalently to a silanized glass surface via polyethylene glycol (PEG) diamine linkers. This PEG surface is intended to resist unspecific binding of proteins. It possesses a higher durability and shows a better regenerability for frequent use than chips based on conventional surface chemistry. To create such a hapten microarray, the glass slide is silanizated with 3-glycidyloxypropyl trimethoxysilane (GOPS) after several washing steps. Then the PEG diamine linkers (2 kDa) are attached to the terminal epoxy groups of the modified glass surface. The PEG coatings are formed in the smelter in a sandwich format. For the direc coupling of the hapten derivatives to the substrate on the biochip, the terminal free amine groups of the PEG diamine linkers have to be activated first by introduction of hydrophobic epoxy groups with PEG diglycidyl ether. The haptens are immobilized as micro spots (⌀500 $\mu$m) with a contact spotting system from Bio-Rad (BioOdyssey Calligrapher Miniarrayer ) on the PEG biochip, which is inserted into the flow cell of the biosensor where all incubations and reactions are carried out. The complete surface treatment and microarray production is optimized and the possibility of regeneration is proved and tested with different analytes like sulfonamides, aminoglycoside and $\beta$-lactam antibiotics. The hapten microarrays can be used for more than 50 measurements. Up to now, we can determine 5 antibiotics in parallel without any sample preparation (detection limits): sulfamethazine (0.7 $\mu$g/L), sulfadiazine (6.8 $\mu$g/L), streptomycin (2.2 $\mu$g/L), ampicillin (7.9 $\mu$g/L), and cloxacillin (0.35 $\mu$g/L). The microarray is designed for parallel analysis of 13 different antibiotics in fresh milk. The immobilization of the other antibiotics is currently under investigation. One assay requires no sample preparation and be carried out within 6 minutes including washing cycles of the milk syringe pump. One regeneration cycle takes 2 minutes.

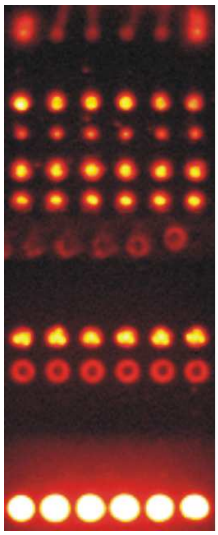
(*K. Kloth, M. Seidel*)

### 1.5.3 AQUASens: Development of a CMOS-based Platform for the Detection of Microorganisms in Water

*Funding: BMBF*
*Cooperation: Siemens AG, FRIZ Biochem Gesellschaft für Bioanalytik mbH, Inge AG, IWW Rheinisch-Westfälisches Institut für Wasserforschung GmbH, Technologiezentrum Wasser Karlsruhe*

The goal of the AQUASens project is to enable a monitoring of human pathogens in water on a daily basis with results available within hours. Microbiological cultivation methods are usually used to detect indicator microbes in water. Pathogen concentrations are not analyzed on a daily basis, as it is very time consuming and cost-intensive. In addition, results are obtained only after 3-7 days. Therefore, the project aims to develop a rapid detection system. The setup consists of a dead-end microfiltration unit, an immunomagnetic separation (IMS) unit for pre-selection and pre-concentration, a PCR amplification step, and an electrochemical microarray readout for quantification. The chemiluminescence microarray readout system, developed at the IWC, serves as reference system.

**Antibody Screening with Whole Cell Microarrays** The antibody screening presented here is part of our project to develop a rapid online monitoring system for human pathogens. Our microarray-based approach to rapid online detection uses immunomagnetic separation (IMS) for pre-selection and pre-concentration of indicator pathogens: Super-paramagnetic nanoparticles labeled with group-specific antibodies bind to relevant microorganisms, which can be subsequently pre-selected and thousandfold concentrated alive on a magnetic column.




Screening experiments are necessary to meet the demand for fast identification of suitable antibodies. An optimized group specific Enterobacteriaceae antibody recognizes a common enterobacterial antigen at the lipopolysaccharide cell wall structure, which has to be accessible on the living cell. At the same time, interactions with mere LPS fragments and cell debris, as well as cross-reactivity with other antibodies, must be minimized in order to eliminate false-positive results.

Different bacterial cells, as well as cell fragments, were covalently immobilized on a chip by microcontact printing on epoxy-activated PEG surfaces. The immobilized cells simulate the in vivo presentation of surface antigens. Cells were inactivated by treatment with heat, ethanol, and trifluoroacetic acid. Detection antibodies bind to spotted enterobacterial cells; labeled secondary antibodies then bind to the detection antibodies. Enzyme and substrates for an enhanced chemiluminecence reaction are added, and the generated signal is detected with a microarray readout device. The microarray patterns of individual antibodies allow for specific differentiation of antigen recognition. After placing the microarray into the microfluidic device, the reaction steps can be automatically executed with valves and pumps.

About 20 different antibodies have been tested. The majority of the antibodies bound to a variety of different antigens, while some antibodies selectively recognized only one antigen. As a consequence, our strategy for IMS is to apply a suitable

mixture of different antibodies, which covers the full spectrum of relevant bacteria. The indicator bacteria for our project include *E. coli* O157:H7, *Salmonella typhimurium*, *Legionella pneumophila*, and *Campylobacter jejuni*.

**DNA Microarray** In the AQUASens project DNA quantification should be achieved using a CMOS-based DNA chip. The DNA probes immobilized on the chip have to be designed and evaluated. The IWC develops a chemiluminescence DNA chip as a reference method and as a test system for the designed DNA probes.

DNA detection using hybridization based techniques is sensitive to varying reaction temperatures. For this reason a new temperature regulated setup was designed. The temperature of the flow-cell can be controlled and thus reproducible reaction conditions are achieved. Another feature of the new setup is the possibility to run one sample several times through the flow cell increasing the sensitivity of the assay.

Oligonucleotides are spotted on a chip. The complementary biotinylated DNA strands bind to these probes. Streptavidin-coupled horseradish peroxidase (HRP) generates the chemiluminescence detection signal. It is possible to detect DNA of microorganisms in a dynamic range of 9 decades and a limit of detection of 100 fmol/L. By combination of microfiltration, IMS and nucleic acid amplification strategies such as PCR (Polymerase Chain Reaction) as pre-enrichment steps 100 to 1000 cells should be detected in 10 L water samples. A chip has multiple different detection areas, which allows for the parallel monitoring of several pathogens of interest in drinking water, such as *E. coli* O157:H7, *Salmonella typhimurium*, *Legionella pneumophila*, and *Campylobacter jejuni* as well as indicator bacteria (e.g. *E. coli*, Coliforms, and Enterococci).
(*G. Pappert, S. Donhauser, M. Seidel*)

# 2 Publications of Present Members of the IWC

## 2.1 Journal articles (reviewed)


Belmont A.-S., S. Jaeger, D. Knopp, R. Niessner, G. Gauglitz and K. Haupt; Molecularly Imprinted Polymer Films for Reflectometric Interference Spectroscopic Sensors. Biosensors & Bioelectronics 22 (2007) 3267-3272

Cervino C., M. Weller, D. Knopp and R. Niessner; Novel Aflatoxin Protein Conjugates for Generation of Aflatoxin Specific Antibodies. Molecules 12 (2007) 641-653

Cervino C., W. Weber, D. Knopp and R. Niessner; Comparison of Hybridoma Screening Methods for the Efficient Detection of High-affinity Hapten-specific Monoclonal Antibodies. J. Immunol. 329 (2007) 184-193

Goryacheva I.Y., S.A. Eremin, E.A. Shutaleva, M. Suchanek, R. Niessner, D. Knopp; Development of a Fluorescence Polarization Immunoassay for Polycyclic Aromatic Hydrocarbons. Anal. Letters 40 (2007) 1445-1460

Haisch C. and R. Niessner; Visualisation of Transient Processes in Biofilms by Optical Coherence Tomography. Water Research 41 (2007) 2467-2472

Haisch C., K. Zell, J. Sperl, M. Vogel and R. Niessner (2007); Acoustical Properties of Selected Tissue Phantom Materials for Ultrasound Imaging. Physics in Medicine and Biology 52, N 475- N 484

Haisch C., K. Zell, J. Sperl, S. Ketzer, M. Vogel, P. Menzenbach and R. Niessner; Optoacoustic Imaging as Add-on for an Commerial Ultrasound System: Potential for Improved Breast Cancer Diagnostics. Proc. SPIE Vol. 6631, 663105 (Jul. 17, 2007)

Han D., X. Yang, D. Knopp, R. Niessner, M. Wu, C. Pun and M.Y.A. Deng; Development of a Highly Sensitive and Specific Enzyme-linked Immunosorbent Assay or Detection of Sudan I in Food Samples, J. Agric. Food Chem. 55 (2007) 6424-6430

Held A., R. Niessner, F. Bosveld, T. Wrzesinsky and O. Klemm; Evaluation and Application of an Electrical Low Pressure Impactor in Disjunct Eddy Covariance Aerosol Flux Measurements. Aerosol Sci. Technol. 41 (2007) 510-519

Helmbrecht C., R. Niessner and C. Haisch; Photophoretic Velocimetry for Colloid Characterization and Separation in a Cross-flow Setup. Anal. Chem. 79 (2007) 7097- 7103

Ivleva N., A. Messerer, X. Yang, R. Niessner and U. Pöschl; Raman Microspectroscopic Analysis of Changes in the Structure and Reactivity of Soot in a Diesel Exhaust Aftertreatment Model System. Environ. Sci. Technol. 41 (2007) 3702-3707

Ivleva N., U. McKeon, R. Niessner and U. Pöschl; Raman Microspectroscopy Analysis of Size-resolved Atmospheric Aerosol Particle Samples collected with an Electrical Low Pressure Impactor: Soot, Humic-like Substances, and Inorganic Compounds. Aerosol Sci. Technol. 41 (2007) 655-671

Klump S., R. Kipfer, Y. Tomonaga, P. Kienzler, W. Kinzelbach, T. Baumann, and D. M. Imboden, Field Experiments Yield New Insights Into Gas Exchange and Excess Air Formation in Natural Quasi-Saturated Porous Media, Geochim. Cosmochim. Acta 71, 1385-1397 (2007).

Lai J., M. Yang, R. Niessner and D. Knopp; Molecularly Imprinted Microspheres and Nanospheres for Di(2-ethylhexyl)phthalate Prepared by Precipitation Polymerization. Analytical and Bioanalytical Chemistry 389 (2007) 405-412

Messerer A., V. Schmatloch, U. Pöschl and R. Niessner; Combined Particle Emission Reduction and Heat Recovery from Combustion Exhaust – A Novel Approach for Small Wood-fired Appliances. Biomass & Bioenergy 31 (2007) 512-521

Wolter A., R. Niessner and M. Seidel; Preparation and Characterization of Functional PEG Surfaces for the Use of Antibody Microarrays. Anal. Chem. 79 (2007) 4529-4537

## 2.2 Monographs

Baumann T., Colloid transport processes: Experimental evidence from the pore scale to the field scale, In: F. H. Frimmel, F. von der Kammer & H.-C. Flemming, Colloidal transport in porous media, 55-86, Springer, Berlin (2007).

Knopp D., A. Deng, M. Letzel, M. Taggart, M. Himmelsbach, Q.-Z. Zhu, I. Peröbner, B. Kudlak, S. Frey, M. Sengl, W. Buchberger, C. Hutchinson, A. Cunningham, D. Pain, R. Cuthbert, A. Raab, A. MJharg, G. Swan, Y. Jhala, V. Prakash, A. Rahmani, M. Quevedo and R. Niessner; In: Rational Environmental Management of Agrochemicals: Risk Assessment, Monitoring, and Remedial Action. ACS Symposium Series, ACS Washington 966 (2007) 203-226

Miller J. N., R. Niessner and D. Knopp; Enzyme and Immunoassays. Ullmann's Biotechnology and Biochemical Engineering 2 (2007) 585-612

## 2.3 Conference Presentations

### 2.3.1 Oral Presentations

Baumann T.: Trinkwassererschliessung und -schutz, Leibniz Kolleg, 1.3.2007, Tübingen (invited)

Haisch C., P. Menzenbach and R. Niessner, Measurements Instruments for Optical Absorption Spectra of Aerosols by Photoacoustic Spectroscopy, European Aerosol Conference 2007, 09.-14.09.2007, Salzburg, Austria.

R. Niessner, Protein Chip Technologies for Fast Monitoring Purposes 46. Tutzing Symposium (DECHEMA) "Sensorsysteme - Praxisanforderungen und Forschungstrends", Tutzing, 27.2.2007 (invited)

R. Niessner, Biosensoren und ihre Potentiale für die Lebensmittelindustrie 65. FEI Jahrestagung, Weihenstephan, 6.9.2007 (invited)

R. Niessner, Photophoretic Velocimetry for the Characterization of Aerosols AAAR Annual Conference, Reno (USA), 25.9.2007

R. Niessner, Ruß-Aerosole – Eine harte Nuß als Nanoteilchen Österreichische Akademie der Wissenschaften, Wien, 15.6.2007 (invited)

R. Niessner, Ruß-Aerosole – Eine harte Nuß als Nanoteilchen GDCh Wissenschaftsforum 2007, Ulm, 17.9.2007 (invited)

R. Niessner, Microarray-based Biosensors: Their Potential for Food Quality Monitoring Tsing Hua University, Dept. of Chemistry, Peking, 18.10.2007 (invited)

R. Niessner, Selective Analysis by Antibodies and Photons – Status and Trends 12th Beijing Conference and Exhibition on Instrumental Analysis, Peking, 19.10.2007 (invited)

Seidel M.: Biochiptechnologie zur Mikroorganismenerkennung. fms/Dechema Gemeinschaftsausschuss “Sensoren und Sensorsysteme”, 16. Januar 2007, Frankfurt (invited).

Seidel M., A. Wolter, C. Peskoller, K. Kloth, A. Didier, D. Dietrich, E. Märtlbauer, M. Weller, R. Niessner: Einsatz von Antikörper-basierten Testsystemen im Microarray-Format zur Detektion von Antibiotika in Milch und Mikroorganismen in Trinkwasser. ANAKON, 27.-30. März 2007, Jena.

Seidel M.: Protein-Mikroarrays als Plattform für die Quantifizierung von Mikroorganismen und Antibiotika. 5. Deutsches Biosensorsymposium 18-21. März 2007, Bochum.

### 2.3.2 Poster Presentations

Baumann T., Transport of reactive particles - the pore scale perspective, EGU General Assembly, 23.-27.4.2007, Vienna.

Cervino C., D. Knopp, M.G. Weller, and R. Niessner, ELISA with in-situ analyte conversion for determination of the total aflatoxin content, ANAKON ’07, 27.-30.3.2007, Jena

Donhauser S., G. Pappert, R. Niessner, and M. Seidel: Rapid automated chemiluminescence oligonucleotide microarray for the detection of human pathogens in liquids, e.g. drinking water, Biological Medical Defense Conference 2007, 17.-18.Oktober 2007, München.

Ivleva N., U. Mckeon, U. Pöschl and R. Niessner, Analysis of size-resolved atmospheric aerosol particle samples by Raman Microscopy, European Aerosol Conference 2007, 09.-14.09.2007, Salzburg, Austria

Kloth K., A. Wolter, C. Peskoller, S. Donhauser, G. Pappert, Cervino C., J.C. Sauceda, D. Knopp, M. Seidel, and R. Niessner: Automatisiertes Chemilumineszenz-Mikroarray-Auslesegerät (MCR 3) in der Lebensmittelanalytik, FEI Jahrestagung 6.9.2007, Freising.

Kloth K., A. Wolter, M. Seidel, A. Didier, and R. Dietrich, E. Märtlbauer, M. Weller, R. Niessner: Development of a regenerable immunosensor array for the rapid parallel detection of antibiotics in milk, Statusseminar Chiptechnologien 2007,1.-2. Februar 2007, Frankfurt.

Kloth K., M. Seidel, and R. Niessner: Development of a regenerable immunosensor array for the rapid detection of antibiotics in milk, ANAKON ’07, 27.-30.3.2007, Jena.

Kloth K., M. Seidel, and R. Niessner: Regenerierbarer Hapten Mikroarray zur parallelen Detektion von Antibiotika in Rohmilch, FEI Jahrestagung 6.9.2007, Freising.

Knauer M., M. Carrara, R. Niessner and N. Ivleva, Raman microscopic analysis of changes in structure and reactivity of soot undergoing oxidation and gasification by oxygen, European Aerosol Conference 2007, 09.-14.09.2007, Salzburg, Austria

Kykal C., R. Niessner and C. Haisch, Photophoretic Migration of Aerosols, European Aerosol Conference 2007, 09.-14.09.2007, Salzburg, Austria

Maiolini E., E.N. Ferri, B. Luca, S. Eremin, R. Niessner, D. Knopp, and S. Girotti; Sviluppo di saffio chemiluminescente per la determinazione dei BTEX in acqua e suolo, XX Congresso Nazionale di Chimica Analitica, 16.-20.09.2007, Viterbo, Italy.

Peskoller C., M. Seidel, and R. Niessner: Enrichment of microorganisms in drinking water with crossflow microfiltration, Biological Medical Defense Conference 2007, 17.-18.Oktober 2007, München.

Peskoller C., M. Seidel, and R. Niessner: Voranreicherung von Mikroorganismen im Trinkwasser durch Querstromfiltration, ANAKON '07, 27.-30.3.2007, Jena.

Seidel M., K. Kloth, A. Wolter, C. Peskoller, S. Donhauser, G. Pappert, C. Cervino, J.C. Sauceda, D. Knopp, and R. Niessner: Rapid multiplexed analysis of microorganisms and pharmaceuticals with an automated chemiluminescence microarry chip reader (MCR3), Technologieforum Diagnostik 11.-12.12.2007, Frankfurt.

Stolper P., D. Knopp, M.G. Weller, and R. Niessner, Effect-directed analysis with online biodetection and chemical analysis, Workshop Sino–German Cooperation Research Group, 08.03.2007, München.

Stolper P., D. Knopp, M.G. Weller, and R. Niessner, Identification of toxicants in complex environmental samples using HPLC combined online with toxicity testing, ANAKON '07, 27.-30.3.2007, Jena

Stolper P., D. Knopp, M.G.Weller, and R. Niessner, Online-Toxizitätstests von wässrigen Proben–Kopplung von HPLC und Biodetektion, Wasser 2007, 14.-16.5.2007, Passau.

Toops L., R. Niessner, and T. Baumann, Quantification of colloid dispersion using particle image velocimetry, Wasser 2007, 14.-16.5.2007, Passau.

Wolter A., C. Peskoller, M. Seidel, and R. Niessner: A new concept for quantification of microorganisms in drinking water, Wasser 2007, 14.-16.5.2007, Passau.

Wolter A., M. Seidel, and R. Niessner: Protein Microarrays for the quantification of microorganisms in drinking water, ANAKON '07, 27.-30.3.2007, Jena.

Wolter A., M. Seidel, and R. Niessner: Protein Microarrays for the quantification of microorganisms in drinking water, Statusseminar Chiptechnologien 2007,1.-2. Februar 2007, Frankfurt.

Wolter A., M. Seidel, and R. Niessner: Protein microarrays for the detection of microorganisms in drinking water, Biological Medical Defense Conference 2007, 17.-18.Oktober 2007, München.

### 2.3.3 Organisation of Scientific Meetings

Baumann T.: EGU General Assembly, 23.-27.4.2007, Vienna(Convener)

R. Niessner: EUROANALYSIS, Merck-Symposium, 10.-14.9.2007, Antwerpen (International Advisory Board)

## 2.4 Hydrogeological Consulting

*Mineralisation control analyses* Bad Abbach, Bayreuth, Bad Birnbach, Bad Endorf, Bad Füssing, Bad Griesbach, Bad Gögging, Bad Rodach, Sybillenbad, Bad Staffelstein, Straubing, Utting, Bad Wiessee, Bad Wimpfen

*Hydrogeological and hydrochemical expertises (mineral water, spa water)* Bad Aibling, Bad Gögging, Hölle, Kondrau Sibyllenbad, Bad Tölz, Obernsees

*Deep Hydrogeothermal Energy Exploration* Bad Birnbach, Pullach

## 2.5 Bachelor Theses

Cedrik Schöne

## 2.6 MSc and Diploma Theses

Cand.chem.ing. Michael Dopfer: Untersuchung des Betriebsverhaltens neuer und beladener Luftfilter bei Nebel und oberflächiger Eisbildung

Cand.geol. Marian Damyanov: Untersuchung der hydraulischen und hydrochemischen Verhältnisse im Höllental

Cand.geol. Rolf Hentschel: Hydrochemische Verhältnisse im Malmaquifer in Oberbayern

Cand.Sci.Technol.Environ. Matteo Carrara: Experimental Study of the Oxidation Readiness of Soot by Raman Microscopy, Thermogravimetric Oxidation Analysis and FTIR Spectroscopy

## 2.7 PhD Theses

Dipl.-Chem. Susanne Fabel: Online Enzyminhibitionsdetektor für die wirkungsbezogene Analyse von Toxinen

Dipl.-Chem. T. Fehrenbach: Analyse von Aminosäuren, Proteinen und Nitroderivaten in atmosphärischen Aerosolen und in Straßenstaub

Dipl.-Biol. Roman Radykewicz: Wirkung ultrafeiner Modellpartikel auf das isolierte Langendorff-Herz von Meerschweinchen

Leb.-Chem. Isabel Schaupt: Entwicklung von immunanalytischen Methoden (ELISA und Affinitätsanreicherung) für die Bestimmung von Microcystinen auf der Basis von monoklonalen Antikörpern

# 3 Teaching, Colloquia, and Other Activities

## 3.1 Classes

### 3.1.1 Chemistry (B.Sc. and M.Sc.)

- Analytical Chemistry - Physical and Chemical Separation Methods (Analytische Chemie - Physikalisch-chemische Trennmethoden); Niessner
- Bioanalytics I: Immunological Procedures; Sensor Technologies (Bioanalytik I: Immunologische Verfahren; Sensortechniken); Knopp
- Biochemical and Molecular Biological Methods for Environmental Analysis (Biochemische und molekularbiologische Verfahren in der Umweltanalytik); Knopp

- Biochemical and Molecular Biological Procedures for Envrionmental Analysis II - Enzymatic Methods, DNA Probes (Biochemische und molekularbiologische Verfahren in der Umweltanalytik II - enzymatische Verfahren, DNA-Sonden); Knopp
- Hydrogeological, Hydrochemical and Environmental Analytics Seminar (Hydrogeologisches, Hydrochemisches und Umweltanalytisches Seminar); Niessner, Baumann
- Graduate Course in Analytical Chemistry: Organic Trace Analysis Lecture (Vertiefungsfach Analytische Chemie: Vorlesung Organische Spurenanalytik); Niessner
- Graduate Course in Analytical Chemistry: Organic Trace Analysis Lab (Vertiefungsfach Analytische Chemie: Praktikum Organische Spurenanalytik); Niessner, Seidel
- Trace Analysis Techniques (Spurenanalytische Techniken); Niessner
- Water Chemistry Lab II (Wasserchemisches Praktikum II); Niessner, Haisch, Knopp, Seidel

### 3.1.2 Chemical Engineering (Diplom)

- Aerosol Characterisation (Aerosolcharakterisierung); Niessner
- Environmental Measurement Technologies Lab (Praktikum Umweltmesstechik); Niessner, Haisch, Seidel
- Gas Measurement Technologies/Chemical Sensors (Gasmesstechnik/Chemische Sensoren); Niessner

### 3.1.3 Geosciences (B.Sc. and M.Sc.)

- Analytical Chemistry I: Instrumental Analysis for Geoscientists (Analytische Chemie I: Instrumentelle Analytik für Geowissenschaftler); Niessner
- Analytical Chemistry II - Organic Trace Analysis for Geoscientists (Chemische Analytik II - Organische Spurenanalytik für Geowissenschaftler); Niessner
- Introduction to Hydrogeology (Ringvorlesung Geowissenschaften); Baumann
- Applied Hydrogeology (Angewandte Hydrogeologie); Baumann
- Contaminant Hydrogeology (Transport von Schadstoffen im Grundwasser); Baumann
- Remediation Design (Erkundung und Sanierung von Grundwasserschadensfällen); Baumann
- Technical Hydrogeology (Technische Hydrogeologie); Baumann
- Regional Hydrogeology (Regionale Hydrogeologie); Baumann
- Fluidflow in Porous Media Lab (Hydrogeologisches Laborpraktikum); Baumann, Haisch, Niessner

- Numerical Methods Lab (Hydrogeologische Modellierung II); Baumann
- Hydrogeological Field Lab (Hydrogeologische Feldmethoden); Baumann, Haisch
- Hydrogeological Mapping (Hydrogeologische Kartierung); Baumann, Haisch
- Hydrogeological, Hydrochemical and Environmental Analytics Seminar (Hydrogeologisches, Hydrochemisches und Umweltanalytisches Seminar); Baumann, Niessner
- Hydrogeological and Hydrochemical Field Trips (Hydrogeologische und Hydrochemische Exkursion); Baumann, Niessner
- Water Chemistry I (Wasserchemie I); Niessner
- Water Chemistry II - Hydrocolloids, Micellar Systems and Photochemical Transformations (Wasserchemie II - Hydrokolloide, micellare Systeme und photochemische Umsetzung); Niessner
- Hydrochemical Lab (Hydrochemisches Praktikum); Knopp, Baumann

### 3.1.4 Biosciences (B.Sc. and M.Sc.)

- Biochemical Analysis (Biochemische Analytik); Görg, Gierl, Knopp, Nitz, Parlar, Schwab, Seidel
- Analytical Chemistry - Separation Techniques, Chemical and Biochemical Sensors (Analytische Chemie - Trenntechniken, chemische und biochemische Sensoren); Knopp

## 3.2 Institute Colloquia

PD Dr. Michael Kumke, Institut für Chemie (Physikalische Chemie), Univ. Potsdam: Analytical Applications of Time-Resolved Luminescence (31.01.2007)

Dr. Monika Möder, Analytische Chemie, UFZ Leipzig: Spurenbestimmung von bioaktiven Verbindungen in der Umwelt: Eine analytische Herausforderung (22.2.2007)

Prof. Dr. Markus Flury, Dept. of Crop and Soil Sciences, Center for Multiphase Environmental Research, Washington State University: Colloid Transport in Unsaturated Porous Media: On the Role of the Liquid-gas Interface (17.4.2007)

Dr. Irina Goryacheva, Saratov State University, Saratov: Clean-up Tandem Immunoassay for Mycotoxin Detection (19.4.2007)

Prof. Dr. Harald Lesch, Institut für Astronomie und Astrophysik, LMU München: The Origin of Water (20.4.2007)

Prof. Dr. Siegfried Stapf, Technische Universität Ilmenau, Fakultät für Mathematik und Naturwissenschaften, FG Technische Physik: NMR Imaging for Chemical Engineering Applications - flow in structured media (30.4.2007)

Prof. Dr. Martin Sauter, Geowiss. Zentrum, Univ. Göttingen: Geothermal Reservoir Spiking: Some Experiences (1.6.2007)

Prof. Dr. Jürgen Popp, Institut für Physikalische Chemie, Friedrich-Schiller-Universität Jena: Raman Spectroscopy - an Essential and Powerful Tool in Life Science Research (6.6.2007)

Dr. Kerstin Leopold, Arbeitskreis Analytische Chemie, TU München: Flow injection system for ultra trace analysis of mercury species by AFS (28.6.2007)

Prof. Dr. Michael Keusgen, Fachbereich Pharmazie, Phillips-Universität Marburg: Biosensors - New Instruments for Drug Screening (10.7.2007)

Dr. Jens Ducree, HSG-IMIT, Villingen-Schwenningen: Lab-on-a-Disk - Principles and Applications of Centrifugal Microfluidic Technologies (4.9.2007)

Dr. Olga Popovicheva, Institute of Nuclear Physics, Moscow State University: Water/Soot Particle Interaction in Atmosphere (7.9.2007)

Prof. Dr. Hans Lehrach, Max-Planck-Institut für Molekulare Genetik, Berlin: From Functional Genomics to Systems Biology (20.9.2007)

Prof. Dr. Hans Puxbaum, Technische Universität Wien: Source Apportionment of Wood Smoke by Tracer Analysis (16.10.2007)

Dr. Martin Gerlach, Bayer Technology Service GmbH, Leverkusen: Online Analytics for Process-Control (30.10.2007)

Dr. Frank Stahl, Institut für Technische Chemie, Universität Hannover: Aptamers: Microarray and Downstream Applications (5.11.2007)

Prof. Dr. Siegfried Scherer, LS für Mikrobielle Ökologie, TU München: Identification of Microorganisms by FTIR-Spectroscopy (12.11.2007)

## 3.3 External Tasks and Memberships

### Prof. Dr. Reinhard Niessner

| | |
|---|---|
| Bayer. Fachausschuß für Kurorte, Erholungsorte und Heilbrunnen | Member |
| DECHEMA Commission “Chemische Grundlagen und Anwendungen der Sensortechnik” | Member |
| DFG-Senatskommission für Wasserforschung | Member |
| Heinrich-Emanuel-Merck-Award Committee | Jury Head |
| Smoluchowski-Aerosol-Award Committee | Jury Head (until 5/2007) |
| Bayer. Institut für Abfallforschung, Augsburg | Advisory Board Member (until 7/2007) |
| Analytical Chemistry | Associated Editor |
| Analytical and Bioanalytical Chemistry | Advisory Board Member |
| Microchimica Acta | Advisory Board Member |
| Fresenius’ Environmental Bulletin | Advisory Board Member |
| Analytical Sciences | Advisory Board Member |
| Analyst | Advisory Board Member |

**PD Dr. Thomas Baumann**

| | |
|---|---|
| Bayer. Fachausschuß für Kurorte, Erholungsorte und Heilbrunnen | Member |
| VBGW AK Grundwasserschutz | Member |
| Taskforce “pHOENIX” in the International Waste Working Group | Member |
| DIN NA 119-01-02-05 UA Leaching | Member |

**Prof. Dr. Dietmar Knopp**

| | |
|---|---|
| Ecotoxicology and Environmental Safety | Editorial Board Member |
| Chromatographia | Editorial Board Member |

**Dr. Michael Seidel**

| | |
|---|---|
| KRdL-3/7/04, ”Luftgetragene Mikroorganismen und Viren”, im VDI/DIN | Member |

# 4 Equipment

## 4.1 Hydrogeology

Two pilot scale tanks with flow lengths of up to 10 m allow transport experiments in a controlled environment while preserving almost natural conditions. Apart from studies on the transport behaviour of contaminants and colloids, these facilities are used for testing sensor prototypes and serve as a test bed for numerical models.

Additionally three landfill monitoring sites, one municipal solid waste landfill, one MSWI bottom ash landfill, and one mixed waste landfill are run by the institute.

## 4.2 Environmental Analytical Chemistry

### 4.2.1 Laser

3 He/Ne-laser
6 Nd-YAG-laser
1 $CO_2$-laser
3 Dye-laser (tuneable with frequency doubler)
5 $N_2$-laser
8 Diode-lasers (600-1670 nm; up to 2 W CW)
1 Laser-diode-array with 10 diodes (0.8 $\mu$m - 1.8 $\mu$m)
1 Laserdiode with external resonator
1 Optical parameter oscillator (410 nm - 2.1 $\mu$m)

### 4.2.2 Optoelectronics/Spectrometer

1 Rowland spectrometer
2 Echelle spectrometer
1 FTIR-Spectrometer, Perkin Elmer 1600
1 Fluorescence spectrometer, Perkin Elmer LS-50
1 Fluorescence spectrometer, Shimadzu RF 540
1 UV/VIS spectrometer, Beckman DU 650
1 Boxcar integrator
4 Digital storage oscilloscopes (400 MHz, 500 MHz)
3 Optical multichannel analysators with monochromators, time-resolving
3 Intensified CCD cameras

1 Wavemeter

### 4.2.3 Chromatography

7 GCs with FID, NPD, ECD, TEA and AED
1 GC/MS, block-injection and autosampler
1 High-resolution GC/MS, VG Autospec
1 LC-Orthogonal-ESI-TOF-MS, Micromass
1 Lyophilizer
1 Asymmetrical Field-flow-fractionation system
1 SFE-System with modifier, Suprex
2 Concentrators for dynamic headspace analysis
1 High-speed counter-current-distribution chromatographie system
3 HPLC, UV/VIS array detector, programmable fluorescence detector
2 HPLC
1 Capillary electrophoresis system
1 Ion chromatograph, Dionex 4500 i
1 Ion chromatograph, Dionex BioLC (Photodiode Array Detector, Electrochemical Detector)
1 AMD system for HPDC with UV, VIS and fluorescence scanner
1 LC system, ECONO
1 Preparative HPLC

### 4.2.4 Dioxin Laboratory

3 High security labs with locks,
separate activated carbon filter and high-performance particle filter systems

### 4.2.5 Bioanalytics

2 Fluorescence reader systems, time-resolving
3 Photometric reader systems
1 Chip spotter system, GeSIM
1 384-channel washer, Biotek

### 4.2.6 Element Analytics

1 TXRF, Atomika EXTRA II a
1 Flame-Photometer, Eppendorf ELEX 6361
2 AAS systems with flame atomization, electrothermal atomization, hydrid system,
Perkin-Elmer PE 3300, ELAN 4100
1 ICP-MS, Perkin-Elmer ELAN 6100

### 4.2.7 SEM/Microscopy/Colloid Sizer

1 SEM/EDX system
1 Polarisation microscope for phase analysis
1 Fluorescence microscope
1 Image analysis software for automated image processing
1 Inert gas glovebox
1 Laser Raman microscope, Renishaw (514 nm, 633 nm, 780 nm)
1 Zetaphoremeter, SEPHY

### 4.2.8 Sum Parameters

2 Coulostat for C quantification, Coulomat 702
1 DOC analysator, UNOR 6 N
1 TOC analysator, TOCOR 2
1 AOX/TOX, Sigma

### 4.2.9 Aerosol Research

1 Aerosol chamber (1 $m^3$)
1 Aerosol flow tube (10 L)
1 Ozone analyzer (UV absorption)
1 $NO/NO_2$ analyser (Chemiluminescence)
2 Aerodynamic particle sizers (0.5-25 $\mu$m)
1 Berner impactor (9 stages, 50 nm - 16 $\mu$m)
1 Electrical low-pressure impactor (12 stages, 30 nm - 10 $\mu$m)
2 Low-Volume filter samplers (PM 10, PM2.5)
1 High-Volume filter sampler (PM 2.5)
2 Differential mobility particle sizer systems (10-1000 nm)
2 Diffusion batteries (5-300 nm)
5 Condensation nucleus counters
3 Electrostatic classifiers (10-1000 nm)
2 Spark-discharge soot aerosol generators (polydisperse ultrafine carbon aerosol)
1 Berglund-Liu aerosol generator (monodisperse aerosols, 0.8-50 $\mu$m)
1 Floating bed aerosol generator (powder dispersion)
1 Rotating brush aerosol generator (powder dispersion)

### 4.2.10 Microbiology

Bioseparation:
Crossflow Filter (Inge AG)
Crossflow Filter (Spectrum Laboratories, Inc)
Pressure and Flowrate controlled Crossflow Filtration System (IWC)
Molecular Biology:
1 Real-time PCR (Light Cycler 480, Roche) Microarray Technology:
3 Chemiluminescence Microarray Reader (PASA, IWC)
1 Chemiluminescence Microarray Reader (MCR 3, IWC)
1 Ink-Jet Microdispenser (Nanoplotter, GeSim)
1 Contact Microarrayer (BioOdyssee Caligrapher, BioRad)
Microbiology:
1 Flow Cytometer (Cell Lab Quanta SC, Beckman Coulter)
1 Water Microbiology (Colilert-18 and Quanti-Tray 2000, IDEXX)
1 Clean bench (Haerasafe KS, Kendro)
1 Microbiological Incubator (BD 53, Binder)
1 Autoclave (Century 2100, Prestige Medical)
1 Refrigerated Incubator Shaker (C24 KC, New Brunswick Scientific)
Standard Lab Equipment:
1 Ultra Low Freezer (B35-85,Thermo Electron Cooperation)
1 Lyophilizer (Alpha 1-4 LSC, Christ)
1 Washer Disinfector (DS 500 Lab, International Steel CO.SPA)
1 Ultrapure Water System (Direct-Q 3 UV, Millipore)
1 Refrigerated Centrifuge (Universal 320R, Hettich)

# 5 Staff 2007

Univ.-Prof. Dr. Reinhard Niessner

PD Dr. Thomas Baumann
Dr. Christoph Haisch
Dr. Natalia Ivleva
Prof. Dr. Dietmar Knopp
Dr. Michael Seidel

Birgit Apel
Christine Beese
Julius El Masry (from 9/07)
Roswitha Glunz
Joachim Langer
Susanne Mahler
Christine Sternkopf
Christa Stopp
Sebastian Wiesemann

Hatice Hazir
Mira Kolar

## PhD Students

MSc Chem. Matteo Carrara (from 8/07)
Dipl.-Chem. Christian Cervino
MSc Chem. Simon Donhauser (from 4/07)
Dipl.-Ing.FH Clemens Helmbrecht
Dipl.-Chem. Katrin Kloth
Dipl.-Chem. Markus Knauer
Dipl.-Met. Carsten Kykal
MSc Maxime Loussouarn (from 8/07)
Dipl.-Biotechn. Gerhard Pappert (from 5/07)
Dipl.-Chem. Caroline Peskoller
MSc Chem. Jimena Sauceda (from 8/07)
Dipl.-Chem. Philipp Stolper
Dipl.-Chem. Zhe Sun
MSc Laura Toops
Dipl.-Chem. Anne Wolter
Dipl.-Phys. Karin Zell

## External PhD Students

Apotheker Alexander Buhl (Klin. re. d. Isar)
Dipl.-Biol. Melanie Maier (GSF)
Dipl.-Phys. Peter Menzenbach (INNOLAS, Krailling)
Dipl.-Biol. Roman Radykewicz (GSF, until 11/07)
Staatl.gepr.Leb.-Chem. Michael Rampfl (IBP Holzkirchen)
Dipl.-Chem. Tobias Roßteuscher (z.Zt. Prof. Kitamori, Tokyo University)

## Diploma Students/MSc Students

Susanne Heinrich (from 8/07)
Steffen Lauber (from 10/07)
Christina Mayr (from 5/07)
Claudia Muhr (from 10/07)
Maria Rye-Johnsen (from 11/07)
Natascha Torres (from 7/07)

## External Diploma Students

Michael Dopfer, (Fa. Gore, Putzbrunn, until 10/07)

## Bachelor Students

Cédrik Schöne (Chemistry)

## Student Assistants

Zhang Ning (until 3/07)
Okroy Andrea (until 4/07)
Schöne Cédrik (from 9/07)
Wolter Wolfgang