United for clean water resources – international co-operation

In its efforts to improve water supplies across the globe, the Federal Ministry of Education and Research (BMBF) supports a variety of research and development projects to devise technologies and concepts for the sustainable management of water resources. In the last funding period, these efforts focused primarily on Asia, the Middle East, Eastern Europe and Africa.

Technologies and procedures tried and tested in Germany generally require adaptation to regional, economic and social conditions. Another important factor is the training of local specialists. One of the main aims of the international water research projects is the transfer of knowledge to the relevant persons on site, thus enabling them to implement and pursue their own projects. German companies are contributing valuable expertise to these research and development initiatives. The BMBF-funded projects are thus also helping to establish new export markets for the German water industry – in areas that are likely to experience considerable growth over the coming decades.

Example of Indonesia. The southern coast of the island of Java is one of the poorest regions in Indonesia. The inhabitants suffer a severe lack of water, despite the relative abundance of this valuable resource underground. Previously, the water flowed straight into the sea via a complex underground water system comprising more than 1000 caves. As part of the project "Accessing and managing underground karst waters in Central Java, Indonesia", German and Indonesian scientists constructed a small underground hydroelectric power plant with which water can be transported to the surface to supply some 80,000 people (project 2.5.01).

Example of China. In the build-up to the Beijing 2008 Olympic Games, a water concept was devised for the 550 hectare Olympic Park with the Sino-German research project "Development of a sustainable water concept for the Olympic Park in Beijing, 2008". Research is also to be carried out to assess the transferability of the results to other regions of China as well as other states (project 2.5.02). The many hygienically relevant micro-organisms (viruses, bacteria, protozoa, worm eggs) present in the wastewater – even after biological cleaning – mean that adequate purification of the water is required before it can be reused. However, chlorination is generally accompanied by the formation of unwanted disinfection by-products. A comparison of various procedures has shown that alternatives exist to conventional wastewater treatment. The IWAR institute of the Technische Universität Darmstadt has tested four of these alternative procedures in China (project 2.5.08).

Example of Iran. Mashhad is the second largest city in Iran and is situated in an arid zone. To supply the population with low-nitrate drinking water, the BMBF worked with the Iranian Ministry of Energy on the project "Demonstration of different high-performance procedures developed in Germany for the removal of nitrate from drinking water and their adaptation to the treatment of groundwater with high concentrations of sodium nitrate and other salts using the example of drinking water purification in Mashhad, Iran" (project 2.5.03).

Example of Russia. At 3500 kilometres, the Volga is Europe's longest river. Massive intervention has altered the waterway on an almost unprecedented scale – with complex consequences for people and the environment. As part of a German-Russian project, sustainable solutions were developed for the economic and ecological management of the Volga and its feeder streams (project 2.5.04).

Example of Vietnam. Black coal is an important energy source in Vietnam, but mining efforts cause significant damage to the environment. The aim of the German-Vietnamese project "RAME (Research Association Mining and Environment)" in the Quang Ningh province is to transfer remediation technologies from the German coal mining industry to its Vietnamese counterpart (project 2.5.05).

Example of Israel. Scientists from Germany and Israel have worked together to develop new measuring procedures to serve as the basis for continuous monitoring of the pollutant content of drinking water sources in Israel (project 2.5.06). In another project detailed in this brochure, German and Israeli scientists are using cloud seeding in an attempt to counter desiccation of the land (project 2.5.07).

Adapted technology – an underground hydro-power plant on Java

The southern coast of the island of Java is one of the poorest regions in Indonesia. Water is in short supply, despite the relative abundance of this valuable resource beneath the ground; however, the water flows directly into the sea via a complex underground water system comprising well over 1000 caves. Scientists in Germany and Indonesia have found a simple solution for one region on Java: a small underground power plant that transports enough water to the surface to supply some 80,000 people.

The approx. 1400 square metre karst landscape◄ in Java's Gunung Sewu region is littered with hundreds of interconnected caves and underground streams. Although there is plenty of water beneath the earth, the region's inhabitants suffer extreme water shortages during the dry seasons due to an absence of appropriate storage facilities – the limited rainfall simply seeps into the karstic ground. Previously, diesel-powered pumps were used to transport the water from the caves up to the surface. Not only does this system use a great deal of energy and carry significant operating and maintenance costs, but the water volume conveyed is not enough to cover the water requirements of private households, local industry and the region's agriculture.

Cave water

A feasibility study commissioned by the BMBF concluded that it would be technically possible to transport the cave water using hydraulic energy. On this basis, the German-Indonesian pilot project **"Accessing and managing underground karst waters in Central Java, Indonesia"** was launched in 2002, with the aim of constructing a demonstration hydro-power plant in Gunung Sewu. The project was overseen by the Institute for Water and River Basin Management (IWG) of the Karlsruhe Institute of Technology (KIT) and involved seven institutes from different specialist disciplines as well as industrial partners from the fields of tunnelling, pump and control technology.

Following intensive on-site research, the specialists decided on the (Gua) Bribin cave. It has a capacity of some 300,000 cubic metres and a water flow rate of over 1000 litres per second, even in dry seasons. The project participants decided to construct a barrage in the cave to dam the continuous flow of water, a part of which was to be transported along a 100 metre riser pipe by means of a small hydro-power plant; this would then supply some 80,000 people in the surrounding shanty towns with

Drill site in the karst area

water. During research and development, a conscious effort was made to employ easily manageable techniques adapted to the needs of the local people and the environment.

To determine the potential water levels and storage volumes, large portions of the cave were measured using state-of-the-art laser technology and the resulting data compiled to form a high-resolution, three-dimensional model. The rock porosity and mineralogical composition was determined through macroscopic and microscopic analyses of samples. This provided the scientists with the means to predict potential water losses and signs of corrosion, thus allowing them to assess the long-term stability of the system. A monitoring network was then installed to enable continuous recording of the water quality as well as hydrological, hydraulic and hydrogeological conditions.

Upon completion of necessary preparations at the project site, the Department of Public Works, Yogyakarta, drilled a first sounding hole (103 m) on the basis of the measurements obtained by the IWG. Following an additional drilling and detailed analysis of the drill samples, work on the access shaft began in 2004; for this purpose, Herrenknecht AG developed a vertical tunnelling machine tailored to local conditions and excavated a shaft around 100 metres deep with a diameter of 2.5 metres. The tunnelling from the surface through to the cave was completed in December 2004.

Exploration of the cave system

Construction work in the cave

Pumps instead of turbines

For the construction of the dam with its integrated hydropower plant, a number of different building, material and design variations were examined. As well as focussing on functionality, safety and availability, the project participants were conscious of the fact that the technology employed for the small power plant would have to be adapted to the abilities and expertise of local technical personnel, specifically with regard to control, repairs and maintenance. For this reason, inversely operated pumps developed jointly by the IWG and KSB AG were used instead of turbines. These pumps are affordable, highly robust and easy to maintain.

Work interrupted by earthquake

Upon completion of the planning work, construction of the underground barrage began in April 2005. At the end of 2005, work ceased due to the early onset of the rainy season; shortly after construction resumed in May 2006, the region was struck by a severe earthquake measuring 6.3 on the Richter scale, the epicentre of which was just 30 kilometres from the project site. The site itself escaped relatively unscathed, but the water level rose by approx. two metres following the quake, thus rendering any further work impossible. Professional divers from Germany discovered that the increased water level was caused by fallen rubble after the downstream siphon: over 1000 cubic metres were blocking the flow cross-section at this virtually inaccessible location. At the end of 2006, German and Indonesian specialists blasted a path through the rubble – work then resumed in June 2007.

Following successful completion of the dam and installation of the first pump module, the first test of the system was performed in August 2008 amid great public interest. Based on saturation processes in the surrounding mountains, it was estimated that it would take one to two weeks to fill the man-made reservoir – in actual fact, the targeted water level of 16 metres was reached after just two days. The first filling of the reservoir was also accompanied by a test of the first pump module, during which the scientists measures a delivery rate of 20 litres per second at the end of the 100 metre vertical pipe – the results were thus in line with expectations. A further four pump modules were then installed, along with an electric system to control the plant.

In March 2010, the project partners were able to hand over the finished system to the responsible Indonesian authority, the employees of which had already received the necessary training to operate the plant. To assess the behaviour of the system in continuous operation and assist with any problems that may occur, the KIT continues to offer its support as part of the follow-up project "Integrated water resource management (IWRM) in Gunung Kidul, Java, Indonesia" (see project 1.3.05).

Project website ► **www.iwrm-indonesien.de**

Karlsruhe Institute of Technology (KIT)
Institute for Water and River Basin Management (IWG)
Prof. Dr.-Ing. Dr. h. c. mult. Franz Nestmann
Dr.-Ing. Peter Oberle
Dr.-Ing. Muhammad Ikhwan
Kaiserstraße 12
76131 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08 63 88
Fax: +49 (0) 7 21/60 60 46
E-mail: peter.oberle@kit.edu
Funding reference: 02WT0424

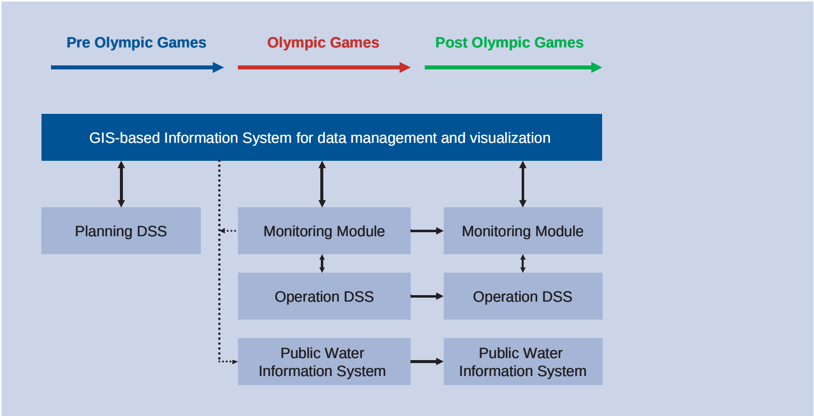
2008 Olympics in Beijing – a water use concept

Having won the honour of hosting the 2008 Olympic Summer Games, the Chinese government was anxious to improve the environmental situation in the region around the capital and host city, Beijing. A Sino-German research project was therefore tasked with devising an exemplary water concept for the 550 hectare Olympic Park constructed in the north of the metropolis. The concept was built around a large artificial lake as well as an artificial river within the park.

The environmental situation in the Beijing megalopolis is extremely challenging. In addition to air pollution, the city is also encountering problems with its water supply: water requirements are rising constantly while groundwater levels are falling by one to two metres per year and water quality is also declining. For the 2008 Olympic Games – dubbed the "Green Olympics" by the organisers – a functional and reliable water management system was required for the Olympic Park, which was home to some 18,000 athletes and officials. After the Games, the park became a green recreation area between the city and its surroundings. In addition to extensive forestation measures, an approx. 60 hectare lake was created in the north of the park. A small river was also formed in the central area of the Olympic Park. The latter was filled with water of the highest quality (reverse osmosis◄) and the lake to the north with municipal wastewater treated with microfiltration◄.

Public and private partners

The bilateral joint venture **"Development of a sustainable water concept for the Olympic Park in Beijing, 2008"** was to contribute to the sustainable management of the limited water resource for 2008 and beyond – with the additional aim of transferring findings and experiences to other regions of the country as well as different states. Funded by the Ministry of Science and Technology (MOST) of the People's Republic of China as well as the BMBF, the project involved both the University of Duisburg-Essen and the Technische Universität Berlin (TUB – Berlin Technical University) as well as a number of midsized companies: WASY Gesellschaft für wasserwirtschaftliche Planung und Systemforschung mbH from Berlin (now known as DHI-Wasy GmbH), Institut für angewandte Gewässerökologie GmbH, GeoTerra GmbH and the consulting firm Obermeyer from Munich. The Chinese project participants were the Tsinghua University of Beijing and the Beijing Water Authority. As well as perform-



OWIS – Olympic Water Information System

ing a detailed appraisal of the planning basis, the project examined the use of domestic water-saving technology in the Olympic Village, modern techniques for wastewater and stormwater treatment as well as the waterway construction in the Olympic Park. One of the outcomes of the project was the creation of a decision maker's handbook for sustainable water management in cities.

Among other things, the research project focussed on the selection of suitable technologies for the treatment and reuse of wastewater in the Olympic Park, particularly for the water bodies. The recycling concept involved the management of hygiene, algae and odour problems through regulated nutrient concentrations. Hygiene was ensured by means of a multi-barrier system (dual low-pressure membrane procedure◄, soil filtration), which allowed the treated water to be used as process water for toilet flushing, fountains and street cleaning.

Combined process technology

On the grounds of the Beixiaohe purification plant in the north of Beijing, water specialists from the Technische Universität Berlin worked with representatives of Tsinghua University and the Beijing Drainage Group (BDG) to construct a pilot system for all planned water recycling procedures. Combined, modern process technologies were used: membrane bioreactors (MBR), fixed beds, phosphate adsorption materials and ultrafiltration◄ with near-natural treatment processes such as artificial bank filtration. The MBRs separated the biomass and germs, thus ensuring particle-free water flow. Since orthophosphate serves as a fertiliser for algae and plants in the lake, thus potentially upsetting the ecological bal-

Part of the pilot system at the BeiXiaoHe purification plant

ance of the water, the orthophosphate was removed in an adsorptive stage. The suitability of the systems with regard to the required water quality was successfully verified during prior testing (2005). In the test lake of the purification plant, mesotrophic◄ conditions were maintained throughout, while excellent process water quality was achieved following artificial bank filtration in the test lake and subsequent processing with ultra-filtration membranes. The results from the pilot system and test lake were established during the first phase of the project (2004 – 2008). However, the recommendations of the project partners BDG and TUB were only partially implemented in the Olympic Park as the authorities only wanted to use reverse osmosis water in the central area. Here the partners had recommended a combination of bio- and ultra-filtration.

Electronic information and monitoring system

In conjunction with Tsinghua University, employees of WASY GmbH developed the "Olympic Water Information System" (OWIS) for the planners, organisers and operators of the Olympic Park. This database included new information and research results established over the course of the project as well as existing data provided by the Chinese project partners. OWIS enables continuous monitoring of the water system in the Olympic Park and features an integrated alarm module. OWIS can also be used to assess the consequences of potential decisions or events for the water system and compare different courses of action – for example, which measures would need to be taken in the case of a sudden dramatic worsening of the water quality in the Olympic lake.

Map of the Olympic Park
(source: www.strategy4.china.com)

DHI-WASY GmbH
Prof. Dr. Stefan Kaden (Managing Director)
Waltersdorfer Straße 105
12526 Berlin, Germany
Tel.: +49 (0) 30/67 99 98-0
Fax: +49 (0) 30/67 99 98-99
E-mail: s.kaden@dhi-wasy.de
Internet: www.dhi-wasy.de
Funding reference: 02WA0526

Nitrate reduction in Iran – knowledge export improves drinking water quality

Across the globe, agricultural deposition and untreated household wastewater are causing high nitrate concentrations in the groundwater. Without appropriate treatment, the resulting drinking water can be harmful to health. To reduce this risk for the inhabitants of the Iranian city Mashhad, a German-Iranian project has tested four different methods for removing nitrate from groundwater. The results will help to decide whether and with which technology drinking water treatment plants will be built in Iran in the future.

Nitrate is a nitrogen compound, low concentrations of which are naturally contained in most water sources. However, for many years now nitrate concentrations have been on the rise in numerous regions across the globe – a fact that is frequently attributed to nitrogen depositions from the agricultural sector. Groundwater is also affected by untreated household wastewater seeping into the ground. When drinking water is sourced from nitrate-containing groundwater – without sufficient treatment – the nitrate content remains in the end product. Excessive nitrate concentrations are damaging to health.

Significantly raised nitrate levels

With a population of over two million, Mashhad is Iran's second largest city and is located in an arid zone in the north-east of the country. Untreated groundwater accounts for around 85% of the city's water supply. The summer months in particular are characterised by severe water shortages. Over the past few years, the nitrate concentration in many of Mashhad's wells has risen significantly – up to values of 150 mg/l (in some cases even exceeding 250 mg/l). By way of comparison: the guide value stipulated by the World Health Organisation (WHO) is 50 milligrams of nitrate per litre of drinking water. These high values are likely to be caused by untreated domestic wastewater seeping into the ground, thus causing high nitrogen deposition in the aquifer◄. Although the wastewater situation in Mashhad has greatly improved in recent years, the nitrate concentrations in the water resources are unlikely to diminish in the short or medium term.

To supply the population with low-nitrate drinking water in the future, the Iranian Ministry of Energy and the BMBF had agreed a joint venture in 2002; the project was entitled **"Demonstration of different high-performance**

Erection of test systems on the grounds of the well pump station in Mashhad

procedures developed in Germany for the removal of nitrate from drinking water and their adaptation to the treatment of groundwater with high concentrations of sodium nitrate and other salts using the example of drinking water purification in Mashhad, Iran". The parties involved in the project were the IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung), VA TECH Wabag Deutschland GmbH, Forschungszentrum Karlsruhe (Karlsruhe Research Centre, now part of the Karlsruhe Institute of Technology (KIT)), the WETECH – Institute for Water and Environmental Protection Technology as well as the local water supplier Mashhad Water & Wastewater.

Combined processes

The aim of the project was the first ever parallel application of four different methods for removing nitrate from drinking water; the processes employed were ion exchange◄, reverse osmosis◄, electrodialysis◄ and biological denitrification◄. As these procedures were developed in Germany and had never been used with such heavily polluted groundwater, they needed to be adapted to the specific conditions in Iran – not least to ensure reliable nitrate removal in the face of similarly high sulphate concentrations. The test systems with throughputs of around three cubic metres per hour were constructed in Germany in modular format and installed in Mashhad in October 2004. A German-Iranian team (IWW, Mashhad

Water & Wastewater Co.) was responsible for the operation and optimisation of the systems and performed extensive scientific research between 2004 and 2007.

Upon completion of the project at the end of May 2008, it had been established that the four procedures could be successfully applied to the situation in Mashhad. All test systems worked reliably and reduced the nitrate concentrations in drinking water to levels below the WHO guidelines. However, the project partners identified significant differences between the individual procedures – e.g. with regard to the specific wastewater volume and required resources (energy, chemicals, personnel) as well as the ecological and economic consequences. These aspects were recorded for all four processes and assessed in the form of a cost/benefit analysis. Taking the situation in Iran into account (e.g. the extremely low energy prices), biological denitrification and reverse osmosis were identified as the most suitable means of achieving the targeted water quality in Mashhad. However, these findings may be different if the boundary conditions were to change (e.g. due to increased energy prices).

Transferable results

The experiences gained over the course of this project are also relevant for new water works in Mashhad and other cities in the region, since they provide an ideal basis for Iranian experts to decide whether and with which procedures future nitrate removal plants are to be built Another important outcome of this research initiative is the new contact established between German and Iranian water experts.

The project partners have already presented their findings at numerous international conferences and trade fairs as well as in international publications. The final report entitled "Demonstration of high-performance procedures developed in Germany for the removal of nitrate from drinking water in Iran" is available online via the German National Library of Science and Technology (TIB) Hanover (http://edok01.tib.uni-hannover.de/edoks/e01fb09/590090909.pdf; 7.4 MB).

Reactor for biological nitrate removal (denitrification)

IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung)
Water Technology division
Dr.-Ing. Stefan Panglisch
Dipl.-Ing. Oliver Dördelmann
Moritzstraße 26
45476 Mülheim an der Ruhr, Germany
Tel.: +49 (0) 2 08/4 03 03-243, -321
Fax: +49 (0) 2 08/4 03 03-82
E-mail: s.panglisch@iww-online.de
o.doerdelmann@iww-online.de
Internet: www.iww-online.de
Funding reference: 02WT0393

Sustainable water management on the Volga – safeguarding the future of Europe's longest river

At 3,500 kilometres, the Volga is Europe's longest river. Massive intervention has altered the waterway on an almost unprecedented scale – with complex consequences for man and nature in the river basin. As part of a German-Russian project, sustainable solutions were developed for the economic and ecological management of the Volga and its feeder streams. The initiative focussed on water quality, water management and the safety of hydraulic structures.

Nizhegorodskaya hydroelectric power station near Nizhny Novgorod (source: RusHydro)

The basin◄ of the Volga with its approx. 200 feeder streams is the economic and cultural centre of the Russian federation and is home to around 40% of the population. Thanks to its water and resulting energy resources, the river offers enormous economic potential, which Russia has been exploiting for decades: as early as the mid 1930s, eleven large dams were constructed on the Volga and its largest tributary stream, the Kama. These structures (collectively known as the "Volga-Kama Cascade") now generate a total output of 11 gigawatts. However, these massive interventions in the region's ecosystem have resulted in far-reaching risks and conflicts.

The minimisation of these risks was the objective of the **"Volga-Rhine project: a German-Russian joint venture for water quality and resource management on the Volga and Rhine"** (period of study: 2004 to 2006). Funded by the BMBF and the Russian Research Ministry, the project involved a number of different parties: the Institute for Water and River Basin Management (IWG), the Engler-Bunte Institute (EBI), department of Water Chemistry, and the Institute of Concrete Structures and Building Materials (IfMB) of the Karlsruhe Institute of Technology (KIT), the Institute for Environmental Geochemistry of Heidelberg University and the Soil Physics department of the Helmholtz Centre for Environmental Research (UFZ) as well as the companies Voith Siemens Hydro (Heidenheim), MC-Bauchemie (Bottrop) and RusHydro (formerly RAO EES), Russia's largest energy supplier. The project was co-ordinated by the IWG and EBI institutes of the KIT.

Precipitation and outflows analysed

Of particular significance are the statistical analyses and simulations of the precipitation/outflow behaviour in the Volga basin: how often and intensively does it rain? How does rainfall affect the natural outflow of the Volga? The relationship between precipitation and outflow is of central significance to the entire river system: only when modelled on the basis of precise data, can accurate statements be made regarding the solute transport and high-water levels of the river.

To be able to analyse the flood zones, water depths and outflow during flooding, the scientists developed digital terrain models of five important barrages on the Volga. While the Russian contributors recorded and processed the available data, their German partners simulated the hydraulic conditions of the Volga using hydrodynamic numerical models. They also developed the program "Volga decision support system" to analyse different outflow scenarios. This program enables computer-based simulation of the entire Volga system and reservoirs, thus allowing the scientists to identify the most energy-efficient and ecologically sound management strategy for each barrage. To satisfy the various usage requirements for reservoir management, fundamental principles were devised for the simulation of barrage chains including automation functions for improved management.

Structures and water quality assessed

One of the main prerequisites for economical and environmentally friendly management of the Volga is the functionality and operational safety of the existing hydraulic structures. At the Volgograd hydroelectric station, scientists and engineers examined the condition of the structure and its individual components (weir overflows and pillars, concrete walls). The results of these on-site inspections and laboratory analyses then formed the basis for a restoration concept, the implementation of which was supported by the project partners with their combined technical expertise.
Although the former Soviet Union initiated extensive efforts to control its water quality in the mid 1940s, the results have never been published. Following the dissolution of the Soviet Union, these initiatives ground to a halt

Extraction and analysis of samples in the research area

due to lacking materials and personnel. As a result, little is known about the current condition of the Russian waterways – despite the role of the Volga and other rivers as important sources of drinking water. The project thus also involved analyses of the pollutant content of Volga water and sediments. In the examined area of Nizhny Novgorod, the water quality was surprisingly good; introduced pollutants are greatly diluted by the massive water volumes transported by the river and contaminant levels reduced by self-cleaning processes.

Eutrophic reservoirs and their consequences

However, the nutrients in the water are leading to critical levels of eutrophication◄, particularly in reservoirs; this is caused by the introduction of phosphorous compounds from household wastewater (e.g. detergents) and nutrient inputs from the agricultural industry. In the summer months, this eutrophication is causing massive algae growth in reservoirs in particular; this in turn results in a reduced oxygen content of the water and the release of toxins. These effects are exacerbated by the relatively high concentrations of natural organic substances. The consequence: anaerobic◄ zones are appearing at many locations, which in turn leads to decomposition processes. Therefore, one of the main aims of the research project was to put the results to use, as a means of improving preventative measures and removing sources of pollution – for example, by practising ecological agriculture in the river basin.

Longitudinal section of the Volga and Kama barrage chain

Area 1: water resource management
Karlsruhe Institute of Technology (KIT)
Institute for Water and River Basin Management
Prof. Dr. Dr. h.c. mult. Franz Nestmann
Prof. Dr. Rolf Krohmer
Kaiserstraße 12
76128 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08 21 94
Fax: +49 (0) 7 21/60 60 46
E-mail: iwg@iwg.uka.de
rolf.krohmer@kit.edu
Internet: www.iwg.uni-karlsruhe.de
Funding reference: 02WT0484

Area 2: water quality
Karlsruhe Institute of Technology (KIT)
Engler-Bunte Institute and DVGW Research Centre
– Department of Water Chemistry
Prof. Dr. Fritz H. Frimmel
Dr. Gudrun Abbt-Braun
Engler-Bunte-Ring 1
76128 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08 25 80
Fax: +49 (0) 7 21/69 91 54
E-mail: fritz.frimmel@kit.edu
Internet: www.wasserchemie.uni-karlsruhe.de
Funding reference: 02WT0480

Protecting the world heritage site Ha Long Bay – German expertise supports mine rehabilitation

Black coal is an important energy source in Vietnam, but mining efforts are causing significant damage to the environment. In a joint venture, technologies and experiences from the German coal mining industry are being employed to make Vietnamese mining more environmentally compatible. Scientists and engineers from both countries are working on site to determine which techniques and procedures can be adapted to local requirements.

Some 95% (45 million t/a) of Vietnam's coal extraction occurs in the Quang Ninh province in the north-east of the country. Yet the province is not only home to Vietnam's most important coal field, but also to the unique natural landscape that is the Ha Long Bay. The Bay, with its countless limestone karsts and small islands, became a UNESCO World Heritage Site in 1994 and is a very popular tourist destination. The Vietnamese government wishes to develop the tourist appeal of Ha Long and further increase the number of visitors. But the country has also massively increased its mining efforts in recent times – and thus also the level of environmental damage to the area. The lack of vegetation on spoil tips and abandoned mining areas, combined with the transport of coal to harbours and power stations in open-bed trucks, have caused a high level of dust pollution – many villages and entire stretches of land are covered in grey dust.

Mine and seepage water entering the Bay

The mine and seepage water from the spoil tips is contaminating the streams and rivers in the mining areas; it flows into the Ha Long Bay, where it endangers or damages the unique and highly sensitive coastal and marine fauna and flora. Large-scale erosion of the unvegetated mining areas exacerbates the situation by transporting carbonaceous fines into the Bay. Another problem is the lacking space for spoil tips: to save space, the tips are usually built up very steeply and in direct proximity of nearby villages; this can lead to landslides posing a significant risk to the residents.

To eliminate or at least reduce the negative consequences and risks of Vietnam's coal mining to man and nature, rehabilitation measures are urgently required. But how can German expertise in mine rehabilitation be adapted to specific Vietnamese requirements? This question is being addressed by the BMBF-funded, German-Vietnamese research programme "RAME (Research Association Mining and Environment) in Vietnam, Quang Ninh

Ha Long Bay is a recognised world heritage site

province". The project is being overseen by the Chair of Environmental Engineering and Ecology of the Ruhr University Bochum (Prof. Dr. Harro Stolpe), with a study period of 2007 to 2012. The project participants are RWTH Aachen University (Chair of Mining Engineering I), the Helmholtz Centre for Environmental Research (UFZ), CBM GmbH – Gesellschaft für Consulting, Business und Management mbH (Aachen), Brenk Systemplanung GmbH (Aachen), LMBV International GmbH, eta AG engineering (Cottbus), GFI Grundwasserforschungsinstitut GmbH (Dresden), BioPlanta GmbH (Leipzig) and DHI-WASI GmbH (Berlin). Work is being performed in close co-operation with the Vietnam National Coal-Mineral Industries Holding Cooperation Limited (VINACOMIN), which has provided the research team with an office at its Hanoi headquarters. The German partners are developing the technical concepts to be implemented by VINACOMIN at the example locations in the form of pilot projects.

During the first project phase (2005 to 2007), the aim was to identify, isolate and describe the specific problems as well as to find suitable example locations to perform analyses for the adaptation of German technologies (topic: mining and the environment in Vietnam, problem analysis and solution strategies). Since 2007, the project partners have been developing concepts for selected locations: the Chinh Bac Nui Beo spoil pit (stabilisation and recultivation), the mining location Vang Danh (wastewater treatment) as well as the mining areas Dong Trieu (treatment of mining-impacted water in a passive water purification system) and Hon Gai (environmental management).

Pilot system and experiments

After establishing the ecological consequences of mining during the first phase, the project team – in collaboration with VINACOMIN – designed an adapted mine water purification system that would remove both the fine carbon particles as well as the high iron and manganese content. Extensive field experiments were conducted on the selected spoil tip, e.g. relating to the pouring technology After selection of suitable local species, plant experiments for the recultivation efforts were also introduced on this tip and are currently examined on a regular basis. Based on the data recorded for Hon Gai, an environmental information system is being implemented that will facilitate the environmental management and reporting of VINACOMIN. Furthermore, a handbook for Vietnamese environmental engineers is to be created by the end of the project on the basis of knowledge acquired from the pilot systems and various experiments.

Vietnamese experts trained

An important aspect if the project is the cultivation of contact with Vietnamese research institutes, ministries, authorities and companies. In this regard, an excellent working relationship has already been established with scientists of the Vietnam Academy of Science and Technology (VAST) and the Hanoi University of Mining and Geology (HUMG). This scientific collaboration is also paving the way for later economic co-operation between German and Vietnamese companies.
The capacity building◄ measures of the joint venture are another important aspect of the technology transfer conducted in this project. A number of one to three-week courses were held for VINACOMIN employees in Vietnam; these were taught by German mining experts and covered

A village in front of a spoil tip in Quang Ninh

Acacia seedlings planted by VINACOMIN

topics such as dust, spoil tip design and mine water. In addition, technical excursions to Germany were organised to show the decision-makers of VINACOMIN examples of mining locations with effective rehabilitation◄ and recultivation measures.

Project website ► **www.vinacomin.vn**

Ruhr University Bochum
Environmental Engineering and Ecology
Prof. Dr. Harro Stolpe
Universitätsstraße 150
44780 Bochum, Germany
Tel.: +49 (0) 2 34/32-2 79 95
Fax: +49 (0) 2 34/32-1 47 01
E-mail: harro.stolpe@ruhr-uni-bochum.de
Internet: www.ruhr-uni-bochum.de/siwawi/

Research Association Mining and Environment in Vietnam (RAME)
Vietnam National Coal & Mineral Industries Group (VINACOMIN)
Dr.-Ing. Katrin Brömme (CEO)
226 Le Duan
Ha Noi, Viet Nam
Tel.: 00 84/4 35 18 83 07
Fax: 00 84/4 35 18 83 41
E-mail: katrin.broemme@rub.de
Internet: www.rame.vn

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Water quality monitoring – new measuring procedures developed

Drinking water sources require continuous monitoring of their contaminant content – a time-consuming and expensive process. Yet monitoring is particularly important in crisis regions, where there is a risk of terrorist attacks – for example, poisoning of drinking water sources. Scientists from Germany and Israel have worked together to develop new measuring procedures, which can serve as the basis for early warning systems. These processes are based on the infrared absorption spectrum◄ of substances.

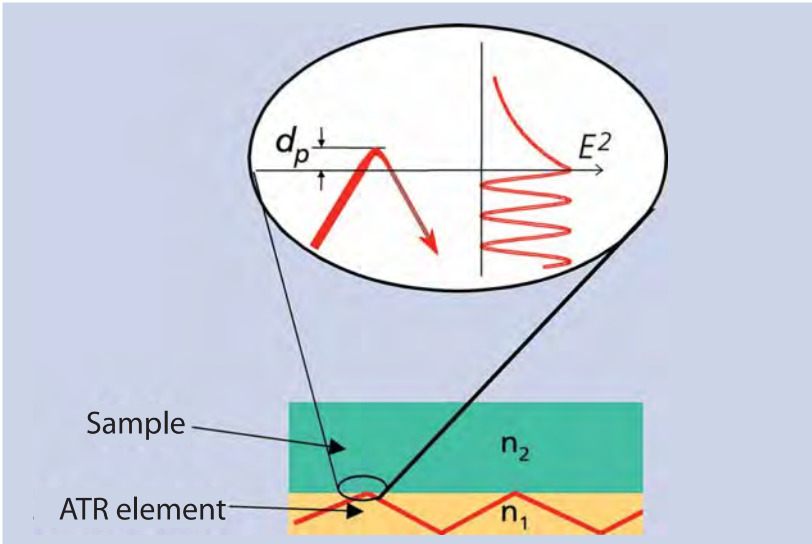
Continuous monitoring is essential to the reliable and timely detection of pollutants and contaminants in drinking water sources. In politically sensitive regions such as Israel, there is also a risk of targeted poisoning of water sources (chemo-terrorism). As a result, there is great demand for measuring procedures that can provide continuously reliable information on water quality.

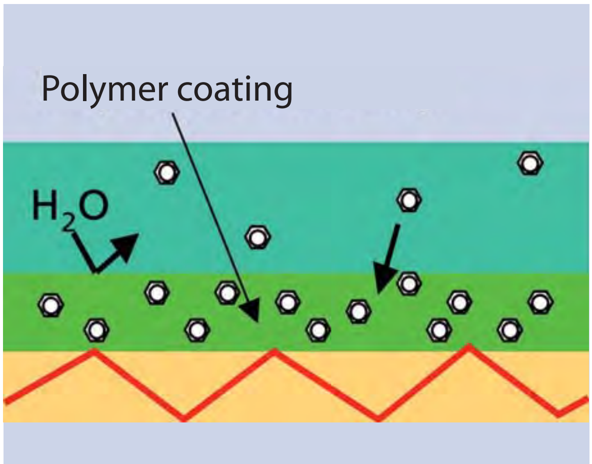
German-Israeli co-operation

Previously, groundwater testing in Israel primarily took the form of laboratory analyses. The samples had to be taken from the measurement locations before being transported to the lab for processing – a time-consuming, expensive and error-prone process. Funded by the BMBF as part of the German-Israeli scientific co-operation, the project **"Compact fibre-optic infrared system for online monitoring of pesticides and other pollutants in water"** was set up to develop a measurement system that would enable continuous, reliable monitoring of the water quality in real-time and across great distances. The research was conducted by the School of Physics and Astronomy of Tel Aviv University and the Fraunhofer Institute for Physical Measurement Techniques (IPM).

Analysis of radiation spectrum

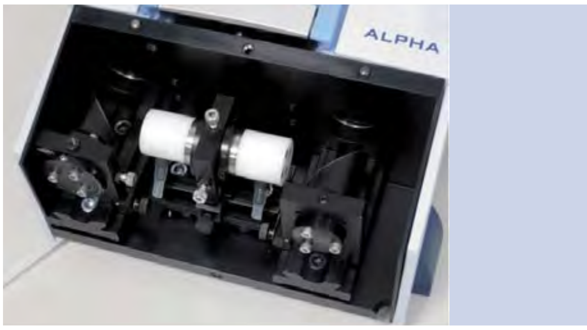
The IPM had already laid the technical foundation in the form of a wide-band spectrometer, which was originally developed to monitor landfill and seepage water online as well as to control industrial processes. The analytical device is programmed to detect different organic molecules (e.g. pesticides). The measuring process is based on the property of all substances to absorb infrared radiation in a specific spectrum. Infrared spectroscopy◄, a technical analysis method, can be used to identify substances via their infrared absorption spectrum. The researchers employed the technique of attenuated total reflectance (ATR) spectroscopy◄, which is based on an optical system. The analytical radiation spectrum provides information on the presence and concentration of contaminants. This enables identification of water contamination by most harmful chemicals and immediate radio transmission of the data to a central monitoring station.





Schematic representation of ATR technology

The measurement system of the wide-band spectrometer consists of three modules: a light source, a sensor element and an infrared spectrometer. The radiated light of a miniaturised emitter is directed into the ATR sensor element where it passes through the measuring path and is recorded by the spectrometer. The individual substances in the water, and their concentrations, are then determined in the subsequent spectrum analysis.



An ATR measurement module for recording infrared absorption spectra (the sensor fibre is located on the cylindrical measuring cell, through which the water sample flows via the two water connections.)

Detection of minimal contaminant concentrations

ATR technology is based on the fact that the field of a light wave passing through a transparent medium partially extends into the surrounding medium. This so-called evanescent field is ideal for performing absorption measurements. A sensitive fibre serves as the sensor: when it is coated with a suitable polymer, the targeted molecule is enriched, thus amplifying the measured signal up to a thousandfold. The water-resistant polymer also offers protection against water, which would otherwise greatly interfere with the measurement. A movable grid allows the spectrometer to measure wavelengths between 8 and 12.5 micrometres. Other wavelength bands can be analysed by replacing the grid. Absorption measurements in the mid-infrared range enable detection of organic molecules with concentrations of less than 1 ppm◄.

Two measurement systems developed

Over the course of the project, which started in 2003 and was concluded in June 2006, the German-Israeli team developed two different measurement systems based on ATR technology: a large device with higher sensitivity – but which was also more expensive and not suitable for field use – as well as a handy and more cost-effective model with lower detection sensitivity. In a follow-up project, advances in the miniaturisation of commercial Fourier transform infrared (FTIR) spectrometers was utilised to create a measurement system offering virtually the same detection sensitivity as the expensive counterpart (see photo). These projects have formed the basis for the development of compact, reliable and user-friendly measurement systems. The devices have been subjected to initial field tests and are at a high stage of development. Additional field use in Germany and Israel is planned.

Fraunhofer Institute for Physical Measurement Techniques (IPM)
Dr. Werner Konz
Heidenhofstraße 8
79110 Freiburg, Germany
Tel.: +49 (0) 7 61/88 57-2 89
Fax: +49 (0) 7 61/88 57-2 24
E-mail: werner.konz@ipm.fraunhofer.de
Internet: www.ipm.fraunhofer.de
Funding reference: 02WU0268

Tel Aviv University
School of Physics and Astronomy
Prof. Abraham Katzir
Ramat Aviv
PO Box 39040
69978 Tel Aviv, Israel
Tel.: 00 97 23/6 40 83 01
Fax: 00 97 23/6 41 58 50
E-mail: katzir@post.tau.ac.il
Internet: www.tau.ac.il
Funding reference: FZK0201

The rainmakers of Israel – cloud seeding increases rainfall

Despite many years of research across the globe, attempts to increase rainfall in arid regions through human intervention have enjoyed little success. However, significant progress has now been made in a joint research venture between German and Israeli scientists: their simulations show that precipitation increases when clouds are seeded with suitable minute particles.

Israel is one of the world's driest countries, yet water is a key economic factor for the state: Israel has a highly productive agricultural industry and exports both fruit and vegetables. Around 70% of the fresh water consumed by the country is used for agricultural irrigation, but high water requirements have caused a continuing decline of groundwater levels. The river Jordan is gradually being reduced to a trickle since 85% of its water is used to supply the population and agricultural areas. This in turn has had a direct impact on the water level of the Dead Sea (into which the Jordan empties), which has fallen by more than 20 metres over the last 70 years – a trend that is showing no sign of abating.

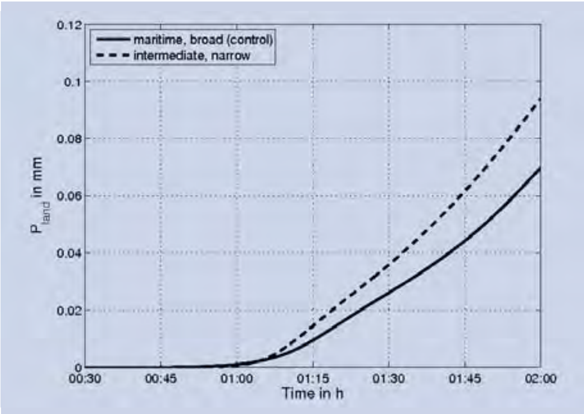
Satellite image of the region (source: visibleearth.nasa.gov)

German-Israeli water technology co-operation

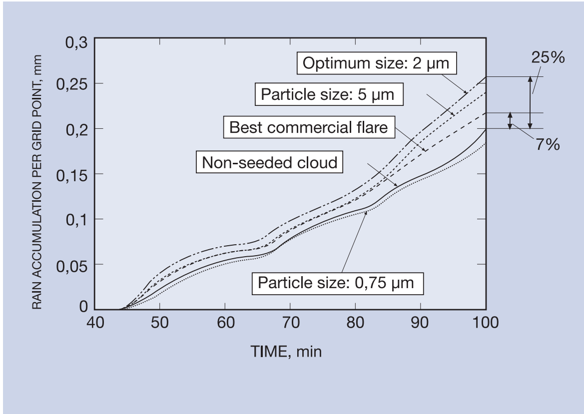
Israel – and the rest of the Eastern Mediterranean – would benefit greatly from increased rainfall, and this is exactly what scientists are working on. Supported by the BMBF, the Institute of Earth Sciences of the Hebrew University in Jerusalem and the Institute of Meteorology and Climate Research (IMK) of the Karlsruhe Institute of Technology (KIT) have given the "rainmakers" a significant boost in the form of their joint research project entitled **"Numerical investigations on the effect of aerosol particles on the precipitation dynamics of clouds in the Israeli coastal region"** (period of study: 2004 to 2008), which was conducted as part of the German-Israeli water technology co-operation. Computer-simulated calculations have shown that artificial "cloud seeding" off the Israeli coast delays rainfall such that inland precipitation is increased in the event of a westerly wind. Optimum results are achieved when (sea/table) salt particles of a specific size are dispersed into the clouds.

The focus of the project was on aerosol particles◄. These tiny suspended particles are everywhere in the air and are required for the formation of cloud droplets and the production of rain: when air is oversaturated with water vapour, the aerosol particles act as condensation nuclei to which the water vapour attaches, thus creating drops. The number and size of the drops depends on the composition of the condensation nuclei. For example, the air in coastal areas contains few but very large salt particles – large drops thus form in the clouds in small numbers. The air over the mainland, on the other hand, contains many aerosol particles and the cloud droplets are relatively small.

The project team discovered that manually released aerosols also have a significant influence on the temporal development, spatial distribution and volume of the resulting precipitation. For may years, researchers have been observing a decline in the rainfall over the Judean Highlands. Their calculations suggest that this development can be attributed to an increase in man-made suspended particles (e.g. soot, dust).



Calculated temporal development of total inland rainfall after seeding with hygroscopic particles. Solid line: control calculation without seeding; dashed line: simulation with seeding using medium-sized particles



Calculated temporal development of total rainfall with seeding of deep convective clouds using hygroscopic particles of optimum size

Simulation models employed

To determine the impact of the aerosol effect on precipitation formation, the scientists utilised two different numerical simulation models: the complex computer model "Spectral Bin Cloud Microphysical Module" (SBM) of the Hebrew University and the enhanced program "Two-Moment Parameterization" (TMP) of the Karlsruhe IMK. The latter represents a rough (yet still sufficiently accurate) means of reducing the overall computing time. The German-Israeli team started by testing the ability of the two models to predict natural weather processes – both functioned very well and provided similar results. They then calculated means of actively influencing rainfall. The results showed that artificial seeding of the clouds forming off the coast successfully delays the formation of precipitation. The rate of rain development is slowed and the clouds blown east by the westerly wind then rain over the mainland, generally near the coast (though sometimes up to 50 km inland).

Particle size decisive

The size of the particles is of central importance to the precipitation development. Large hygroscopic particles◄ accelerate the formation of rain, while smaller particles slow the development and often reduce the volume. The scientists used computer simulations to establish the particle size that would most effectively raise the level of rainfall achieved with cloud seeding: the optimum size – depending on cloud height and other meteorological parameters – is between 1.8 and 2.5 micrometres. Using hygroscopic particles of this size, the inland precipitation volume can be increased by 20 to 25%, while overall rainfall is marginally reduced.

To compare the model calculations with the actual natural effects of cloud seeding, a number of practical tests were performed in Israel, whereby aircraft were used to disperse salt particles of the calculated optimum size into the clouds; the observed results largely matched the theoretical calculations.

Karlsruhe Institute of Technology (KIT)
Institute of Meteorology and Climate Research (IMK)
Prof. Dr. Klaus Dieter Beheng
Kaiserstraße 12
76128 Karlsruhe, Germany
Tel.: +49 (0) 7 21/6 08-4 35 95
Fax: +49 (0) 7 21/6 08-4 61 02
E-mail: klaus.beheng@kit.edu
Internet: www.imk-tro.kit.edu
Funding reference: 02WT0536

Four methods, one goal – wastewater disinfection in China

A comparison of disinfection procedures in the effluent discharge of Chinese wastewater treatment plants has highlighted the existence of alternatives to conventional chlorination. As part of a joint research project funded by the BMBF, the IWAR institute of the Technische Universität Darmstadt (Darmstadt Technical University) tested four different procedures in conjunction with the Tongji University in Shanghai (period of study: August 2006 – March 2011).

The many hygienically relevant micro-organisms (viruses, bacteria, protozoa, worm eggs) present in the wastewater – even after biological cleaning – necessitate adequate purification of the water before it can be introduced to sensitive surface waters (especially prior to reuse). While wastewater disinfection is a legal requirement in the People's Republic of China, this process is frequently omitted for cost and operating safety reasons (Xin, 2004).

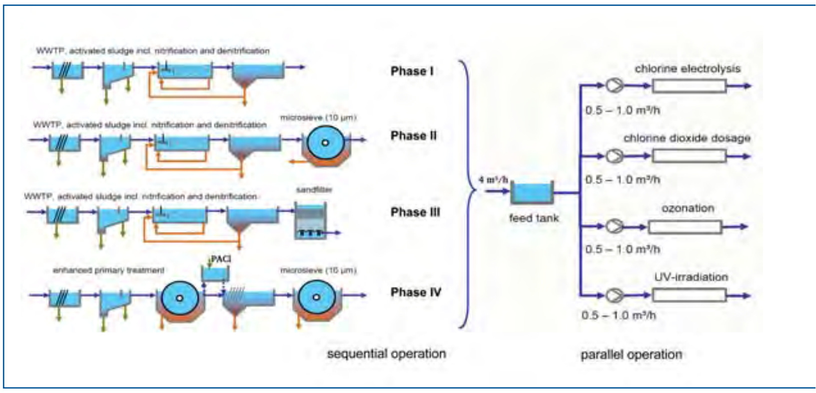
An alternative to conventional disinfection methods is required for a number of reasons. The most common procedure, chlorination, is generally accompanied by the formation of unwanted disinfection by-products. Other disadvantages of chlorine and its compounds are the ever-present concerns regarding operating safety and the limited effectiveness against chlorine-resistant organisms. Therefore, the aims of the joint research project are to:

- Improve the hygienic water quality in the effluent of municipal treatment plants to protect against water-borne diseases
- Provide a scientifically verified contribution to the issue of cost-effective application of effective, innovative wastewater disinfection processes
- Avoid new risks by minimising the formation of disinfection by-products

Employed methods

Relevant factors influencing the choice of disinfection method include effectiveness, operational safety, investment and operating costs, practicality (transport, storage, production etc.) and the creation of unwanted by-products. Having been selected during a pre-project literature study, the processes tested over the course of the project were as follows:

UV radiation: UV rays with a wavelength of 245 – 265 nanometres alter the nucleic acid in the cell nucleus, thus resulting in the irreversible loss of the cell's multiplication



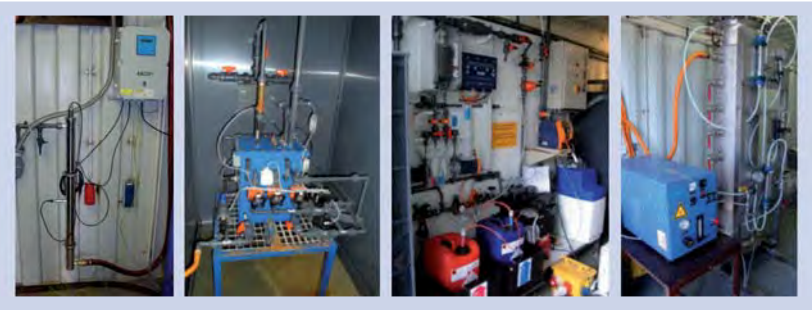
Pilot disinfection systems (right) with various wastewater treatment stages (left); intake = untreated communal wastewater

capacity and subsequent inactivation of the cell when its regenerative ability is exceeded. No addition of disinfectants remaining in the water occurs with this disinfection method. As a result, negative environmental and health impacts can be largely eliminated, though a potential depot effect in the discharge water is also excluded. The UV system features two replaceable UV lamps with outputs of 80 and 120 watt. The desired radiation dose can be set via a control unit (from 80 – 800 J/m).

Electrochlorination: The electrochlorination system produces gaseous chlorine (Cl) and other electrochemical oxidants from table salt, water and electric current on site, thus eliminating the transport and storage of chlorine (gas). Chlorine causes the oxidative destruction of the cell wall of micro-organisms. The maximum dosage is 20 mg Cl_2/l.

Chlorine dioxide: The disinfectant properties of chlorine dioxide can be mainly attributed to its high oxidation potential (approx. 2.5 times higher than that of chlorine gas). When wastewater is disinfected with chlorine dioxide rather than chlorine (gas), the potential for formation of ecologically damaging compounds is lower, since no trihalomethanes (THM), chlorophenols or reaction products with ammonium and amino compounds are produced. The dosage of chlorine dioxide is between 1 and 20 mg ClO_2/l. Chlorine dioxide (ClO_2) is created on site from hydrochloric acid and sodium chlorite by means of the chlorite/acid process.

Ozone: Ozone (O_3) is one of the most effective disinfectants. Ozone attacks the cell membrane directly or permeates the wall to enter the cell interior, where it attacks the DNA, RNA or other cell components, this inactivating the



Pilot system for wastewater disinfection (from left): UV radiation, electrochlorination, chlorine dioxide, ozone

cell. Wastewater ozonation can also be used to remove pharmaceutical residues, endocrine disruptors as well as odourants and colourants (Schuhmacher, 2006). Ozone generators are used to create ozone on site by means of electrical discharges from industrially produced oxygen. Ozone dosage varies between 2 and 20 mg O_3/l.

All of the above procedures (with the exception of ozonation, which was only tested in Germany) were operated and examined over the course of the project using identical semi-industrial test systems at a communal treatment plant in Darmstadt-Eberstadt and in Shanghai.

In addition to the choice of disinfection process, the manner in which the water is pre-treated is also of decisive importance – both with regard to the success of disinfection and the potential for by-product formation. In many cases, the overall performance of a disinfection system and the potential health risks are greatly determined by the shadowing and inclusion of micro-organisms in wastewater particles. In this project, disinfection capacity was assessed by using standard methods for microbiological cultivation to quantify the indicator organisms E. coli, total coliforms, enterococci and somatic coliphages.

Achieved results

Both micro-screening and sand filtration can reduce COD concentrations◄ by around 30%, UV absorption (at 254 nm) by approx. 10% and turbidity by some 80%. During test phases I to III (see figure), all four disinfection processes were able to reduce the level of indicator organisms below the detection threshold or by up to four orders of magnitude (Bischoff, 2009). An increased toxicity◄ of the wastewater, measured as the effect on the luminescence of Vibrio fischeri organisms, was not significant in this case (order of toxicity rise: Cl_2>O_3>ClO_2; UV radiation: no increase).

In addition to the disinfectant dosage and the organic substances contained in the wastewater, the water temperature was also found to have a significant impact on the success of the disinfection process. Phase IV was terminated after four weeks, as stable operation of the disinfection system was rendered impossible after two weeks by the increasing biofilm growth◄. As a result, a critical assessment was made of wastewater disinfection procedures in which no biological treatment methods are employed. Depending on the employed dosage, the examined disinfection methods with prior biological wastewater treatment◄ produced environmentally sound water that could be introduced even to sensitive surface waters and is perfectly suitable for a range of reuse scenarios. A more detailed assessment of the test results can be found in the final project report.

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Technische Universität Darmstadt
IWAR Institute
Department of Wastewater Technology
Prof. Prof. Martin Wagner
M.Sc. Astrid Bischoff
Petersenstraße 13
64287 Darmstadt, Germany
Tel.: +49 (0) 61 51/16-37 59
Fax: +49 (0) 61 51/16–37 58
E-mail: m.wagner@iwar.tu-darmstadt.de
a.bischoff@iwar.tu-darmstadt.de
Internet: www.iwar.bauing.tu-darmstadt.de
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