Proven technologies in use abroad – progress through a global transfer of knowledge

The implementation of environmentally-conscious, high-tech and hygienic requirements for treating drinking water and cleaning wastewater comes with additional challenges in developing and emerging countries in particular. They begin with the question as to which procedures and technologies are suitable for the varying conditions and extend to reliable operation and maintaining facilities.

One of the government's key concerns is to build up specialist knowledge in developing and emerging countries. This means taking procedures established in Germany for treating water and cleaning wastewater and adapting them to the respective local conditions. The Federal Ministry of Education and Research (BMBF) has funded several projects in recent years that have shown how procedures and technologies that have proven themselves in Germany can be developed further and adapted to local conditions.

Example: drinking water supply

A joint research project funded by the BMBF has documented results of German water research and developed them to suit other conditions. For this purpose, reference values were determined for the size and operation of water treatment and distribution plants while taking extreme untreated water properties as well as deviating climatic and social conditions into account. Treatment methods tried and tested in Germany are assessed as to their applicability under amended conditions or when improved performance is to be expected (project 2.4.03). The project looking into long-term water resource management in connection with this is called "Abwasserbehandlung bei der Papierherstellung mit Stroh als Rohstoff zur Zellstoffherstellung am Beispiel der Shandong Provinz (Volksrepublik China)" (wastewater treatment for paper manufacturing using straw as a raw material for pulp production using the Shandong Province (PRC) as an example). One objective of the research project is to feed treated wastewater back into paper production as process water in order to reduce water consumption (project 2.4.06).

Example: bank filtration

Bank filtration is a well-established drinking water treatment procedure in Germany: waterworks use the natural cleaning power of the soil to improve the quality of the untreated water without the use of any energy or chemicals. Scientists examined the prerequisites for this in a project called "Determination of the potential purification performance of bank filtration/underground passage with regard to the elimination of organic contaminants under site-specific boundary conditions" (project 2.4.01).

Example: slow filtration

Slow filtration has become a well-established procedure for biological drinking water purification. The systems usually consist of an infiltration pond filled with different filter and support layers. However, uniform and well cleaned filter sand is not widely available. Several institutes have been investigating how the procedure can be adapted to local conditions as part of the slow sand filtration project. The cleaning performance of recycled glass granulate and coconut fibres among other things was analysed to serve as an example (project 2.4.02).

Example: wastewater technologies

Germany is a world leader in the field of water technology. However, some knowledge gaps still exist – the objective of the joint venture "Export-oriented research and development in the field of water supply and wastewater treatment part II: Wastewater technologies in other countries" was therefore to adapt technologies for communal wastewater treatment tried and tested in Germany to different climate zones. The project included investigations into the state of communal wastewater treatment in twelve nations (project 2.4.04).

Example: database for water management systems

Reliable information is essential for successful water management. The water authority of the megalopolis Beijing needs to be able to monitor the supply and consumption of water accurately due – among other things – to the region's climate causing significant fluctuations in available water levels. A computer program addressing this need has now been developed as part of a Sino-German joint venture – in the face of highly challenging conditions. The results of the project are also important to other megacities in Asia, where application is also possible (project 2.4.05).

A natural water filter – bank filtration

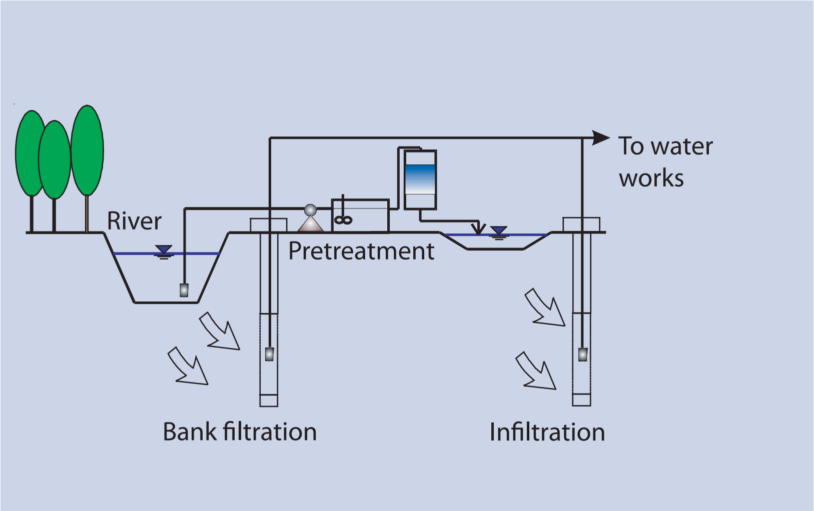
Bank filtration is a well-established and cost-effective drinking water treatment procedure in Germany: waterworks use the natural cleaning power of the soil to improve the quality of the untreated water without the use of any energy or chemicals. A research project was set up to investigate the ability of bank filtration to remove or at the very least reduce organic contamination under fluctuating conditions, the ultimate objective being to create planning and operating guides to enable this procedure to be used worldwide.

Depending on the wastewater discharge from industry, households and farming, surface water in industrialised and urban areas often contains many organic trace elements◄ or substances produced from their degradation: pesticides, mineral oils and chemicals with hormonal effects or active pharmaceutical agents can be detected in the water. These substances must be effectively removed if the surface water is a source of drinking water.

Bank filtration involves wells being established directly by the river used to supply drinking water, which artificially lowers the groundwater level. The result is a hydraulic slope between the riverbed and wells, and the surface water trickles over the bed or the bank to get underground: dirt and contaminants are filtered out and degraded by means of natural physical, chemical and biological processes. Depending on the geological conditions, the distance between the wells and the bank and the level of the river, this can take just a few days or as much as six months.

Fluctuating conditions on site

So to what extent is bank filtration suitable for removing organic compounds when these compounds have a whole host of different chemical-physical properties? Scientists examined this question in a project called **"Determination of the potential purification performance of bank filtration/underground passage with regard to the elimination of organic contaminants under site-specific boundary conditions"**, which ran from 2001 to 2005. They also wanted to discover the prerequisites a site must meet for bank filtration to be a success. This is because, alongside the range of contamination and the respective concentrations in the water, hydrogeological conditions also have a major role to play – especially the composition, permeability and sorption capability◄ of the soil, as well as climate factors such as water temperature.



How bank filtration works

Other aspects of bank filtration were examined by the Institute for Water Research, Dortmund (overall co-ordination of the "bank filtration" project), the Karlsruhe Research Centre and TU Berlin, TU Dresden and TU Hamburg-Harburg (guidelines: Kühn, W.; Müller, U. (editor) (2006): Export-oriented R&D in the field of water supply and wastewater treatment – part I: Drinking water. Volume 2. Guidelines. Water Technology Centre, Karlsruhe, ISBN 3-00-015478-7).

With the aim of creating planning and operating guides for using bank filtration in other climate zones, the project partners collated existing research results and experience gained in Germany and other countries and conducted an analysis. They filled any gaps in information – e.g. in relation to more extreme climatic conditions – with the results of true-to-life field and lab tests.

Clear improvement in water quality

The tests performed during the project showed that bank filtration can remove most (around 80%) of the organic trace elements found in the surface water, with a reduction in concentration observed at the very least in the remaining substances. Nevertheless, the behaviour of innovative substances is not 100% predictable in bank filtration as chemically similar substances occasionally react in very different ways. The project confirmed that the removal of organic compounds is attributed to sorption processes and biological and chemical degradation processes underground. This means the bulk of the reduction in contamination takes place in the "infiltration zone", directly after the water gets into the soil. The conclusion from this is that removing the wells (20 to 400 metres) does not have a major impact on cleaning performance. Even so, the increased flow course/water retention time underground is significant as it ensures optimum effect. The project team therefore observed that many substances were eliminated to a much higher degree when the water spent longer underground.

Oxygen supply is crucial

The trace elements that are degraded and the extent to which this occurs depend heavily on the oxygen-reduction environment◄ in the soil, or in other words, the micro-organism oxygen supply. For example, some trace elements are removed more effectively in an aerobic◄ environment, and others in an anaerobic◄ one. This means that locations suitable for bank filtration are those where the water can spend a while in both aerobic and anaerobic areas of soil.

Regardless of the oxygen-reduction conditions, bank filtration is suitable for removing organic trace elements such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls◄ (PCB) and many insecticides. Odours, tastes and substances affecting hormones are also degraded to a great extent. One key consideration for bank filtration in warmer climates: rising temperatures lead to increased metabolism and thus a higher conversion rate in most cases.

A well of the vertical well gallery in Düsseldorf

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Adapted slow filtration – versatile and cost-effective

Slow filtration is a near-natural, simple and cost-effective means of water treatment; in Germany, it is usually combined with other processes. It can also be performed using alternative, locally available filter materials. A number of research projects have looked at ways in which slow filtration could be technically improved and adapted to the specific conditions at locations outside Central Europe.

Slow filtration has become a well-established procedure for biological drinking water purification. The systems usually consist of an infiltration pond◄ filled with different filter and support layers. A drainage and support layer comprising stones, gravel and coarse sand is followed by an (approx.) one metre high filter layer. The primary filter material employed in Central Europe is sand (slow sand filtration); generally speaking, the longer the water remains in the sand filter, the greater the level of purification.

However, uniform and well cleaned filter sand is not widely available. Attempts to proliferate this procedure (particularly in developing and emerging countries) requires adaptation to local circumstances – for example, the use of locally available and cost-effective filter materials. This matter has been closely examined by the IWW Water Centre (Rheinisch-Westfälisches Institut für Wasserforschung) in Mülheim an der Ruhr (overall co-ordination of “slow sand filtration” projects) and the Institute for Water Research (IfW – Institut für Wasserforschung) in Schwerte (period of study: 2002 to 2005).

Sand alternatives examined

The scientists compared the cleaning performance of sand to that of recycled glass granulate and coconut fibres – employing a range of methods at varying temperatures and filter speeds. Another sub-project addressed the question of whether the effectiveness of slow filtration is improved by adding gravel, pumice or coconut fibres to the sand filter layer.

Extreme pollutant concentrations simulated

The research was performed in laboratories and semi-industrial test facilities. To establish the procedure’s effectiveness in the face of extreme pollutant concentrations in the unprocessed water, tests were partially conducted using contaminated surface water with raised DOC and ammonium content◄. The researchers also employed the outflow of a sewage plant as untreated water◄ in the test

Column experiment system in a climatic chamber

Recycled glass granulate

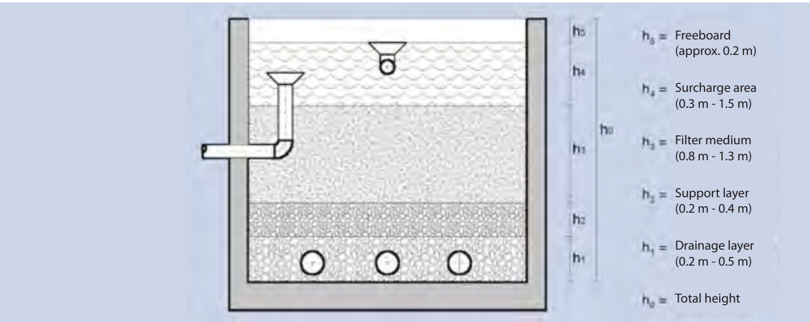
facilities; this was done to determine whether slow filtration is also suitable for the treatment of water in rivers that are greatly affected by wastewater discharge but still possess some assimilative capacity.

Another area of research was the nature of microbial colonisation in slow sand filters. To optimise system performance, the Water Technology Centre (TZW) of the Deutsche Vereinigung des Gas- und Wasserfachs (DVGW – German Technical and Scientific Association for Gas and Water) developed a module for the practical mathematical simulation of slow sand filtration under different environmental conditions.

Finally, the objective of the projects **“Boundary conditions for slow sand filtration, suggestions for technical modification and adaptation to regional conditions”** and **“Optimisation of slow sand filters by means of special protection layers and operating methods”** was to combine existing slow filtration data with current results in order to create guidelines for the planning and operation of slow filtration systems (Kühn, W.; Müller, U. (eds.): Export-oriented R&D in the field of water supply and wastewater treatment – part I: Drinking water. volume 2; Karlsruhe; at www.tzw.de).

Recycled glass granulate and coconut fibres as alternatives

The research showed that both recycled glass granulate and coconut fibres represent viable alternatives to sand as slow filtration materials. Under test conditions, however, the cleaning performance of these substances was not of a sufficient level to produce drinking water in all circumstances. The experiments highlighted specific strengths and weakness of the different filter materials, which are to be taken into account in practice and potentially



Schematic representation of slow sand filtration (section) according to DIN 19605, from DVGW work sheet W213-4

compensated by means of technical modifications (e.g. pre-separation or aeration).

The purification performance of slow filtration greatly depends on the temperature: the biodegradation processes become significantly slower at temperatures below 10°C, in some cases even coming to a complete standstill. At high temperatures and with a high concentration of biodegradable substances, the degradation processes result in significant oxygen consumption. Column experiments in an air-conditioned room showed that, in the selected operating conditions (filter layer thickness, operating method, filter speed etc.) and at 5 to 10°C, none of the filter materials was able to process the untreated water (high DOC and ammonium content) such that it met the drinking water regulations of the World Health Organisation (WHO) in terms of the examined chemical parameters. At 20°C, only the filtrate treated with recycled glass granulate exceeded the thresholds, while all filtrates met the WHO limits at 30°C. In these experiments, the sand-filtered water actually complied with the values stipulated by the even stricter German Drinking Water Ordinance.

Protective layer

The experiments showed that a 20 cm protective layer consisting of gravel, pumice or coconut fibres greatly increases the filtering time. Furthermore, a large portion of the particles contained in the water was retained in this layer, thus protecting the sand filter layer below and minimising agglutination. If the filtered particles are organic rather than mineral substances, they are already biodegraded in the protective layer. The disadvantage of this is the lack of oxygen further down, which – without additional aeration – has a negative impact on subsequent aerobic biodegradation processes◄, e.g. ammonium oxidation.

The scientists assessed the ability of slow sand filters to retain degradation-resistant trace elements◄ in a separate test system featuring an activated carbon layer below the sand layer. The result: layers of sorptive materials such as activated carbon◄ are highly effective in retaining organic trace elements from pesticides and pharmaceuticals. As this "sandwich" method entails high construction and maintenance costs, large-scale application is not currently a realistic option. Therefore, if slow filtration alone does not provide the desired water quality, a better option would be to integrate the procedure in a system of suitable pre- and post-treatment techniques adapted to the relevant location.

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Export-oriented research & development – transfer to other countries

A joint research project funded by the Federal Ministry of Education and Research (BMBF) has documented results of German water research and developed them to suit other conditions. For this purpose, reference values were determined for the size and operation of water treatment and distribution plants while taking extreme untreated water properties as well as other climatic and social conditions into account. Ten institutes and universities participated in the project.

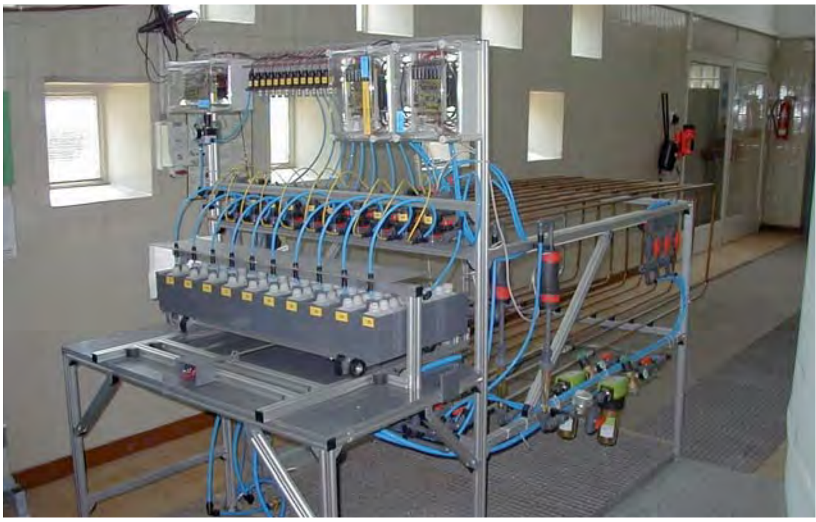
In the following, treatment methods tried and tested in Germany are assessed as to their applicability under special boundary conditions or when improved performance is to be expected.

Slow filters◄ with closed bottoms and infiltration ponds◄ with subsequent groundwater recharge represent possible alternatives for small systems in rural areas and cities of developing and emerging countries. It should be noted that slow filtration without pre-treatment should only be used to process low-turbidity◄ water with minimal microbiological contamination.

Wealth of experience in bank filtration

Since bank filtration has been used in Germany for over 100 years, the country has a wealth of experience in this area. This knowledge can be employed for targeted application in other nations – despite the existence of different climatic and hydrogeological conditions. To support this transfer of knowledge, the project participants developed a range of engineering aids and provided detailed descriptions in the form of user guidelines (see references at end of article).

A combination of flocculation◄, sedimentation and filtration is the standard procedure employed by many countries for the treatment of surface water. Important considerations during project planning are optimum hydraulic and technical conception with regard to the addition of processing agents for flocculation, the minimisation of flushing water requirements, optimised sludge water discharge as well as the use of measurement and control technology adapted to local standards.



Transportable test rig for assessing the influence of water quality on corrosion on site

Micro- and ultra-filtration – an alternative to conventional water treatment

In addition to conventional water treatment by means of flocculation and filtration, micro-◄ or ultra-filtration◄ represents a possible alternative for turbidity removal purposes. These processes can be used to purify either low-turbidity untreated water without pre-processing or high-turbidity untreated water following conventional pre-processing. Micro- and ultra-filtration is also a suitable means of processing eutrophic water◄. Sustainable use of these techniques requires an appropriate infrastructure for maintenance and operation.

The removal of heavy metals using ion exchangers◄ is particularly suitable for low-turbidity water; the capacity of the ion exchangers is barely reduced. In the case of water containing heavy metals, ion exchange can be an alternative to treatment via flocculation, for example.

Particularly when used with waters containing unknown compositions of water-based substances, the by-product generation connected with oxidation processes and removal of residual content must be taken into account. The combination of hydrogen peroxide and UV radiation has proven to be a very energy-intensive process; pre-oxidation with potassium permanganate◄ is not an effective means of enhancing the turbidity removal capacity of flocculation. Important planning criteria are the

Procedure	Sub-procedure	IC	EC	DC
Bank filtration		++	++	+++
Slow filtration	Slow filter infiltration	+	++	+++
Flocculation, sedimentation		+++	+++	+++
Filtration	Rapid filtration	+++	+++	+++
	Biofiltration	++	++	+++
	Micro-/ultra-filtration	+++	++	+
Ion exchange		+++	+	+
Oxidation	Atmospheric oxygen	+++	+++	+++
	Ozone	+++	+	+
	H_2O_2/Fe	+	+	+
Adsorption	Granular activated carbon	+++	++	+
	Powdered activated carbon	++	++	+++
Disinfection	With residual concentration	+	+++	+++
	Without residual concentration	++	Generally not used	

Suitability of treatment processes in industrialised (IC), emerging (EC) and developing countries (DC)
+++ Minimal expenditure or state of the art
++ Moderate expenditure or not yet widely used
+ Higher expenditure or availability only in specific cases

operational reliability of the process and the necessary qualification of the relevant personnel. The deficiencies of biological ammonium oxidation in cold water can be countered by a number of means. However, at water temperatures under 5°C, extremely long treatment periods (weeks to months) are required to eliminate high ammonium loads, which could effectively outweigh the benefits offered by the procedure.

Activated carbon◄ should, in principle, only be loaded with low-turbidity water (e.g. < 0.2 NTU, Nephelometric Turbidity Units). The effect of the water temperature on the adsorption◄ of natural, organic substances in water is relatively minor. High DOC concentrations◄ in untreated water can limit the activated carbon's adsorption capacity for trace elements◄, which should therefore be minimised as much as possible by other means prior to the adsorption. Although granulated iron hydroxide is very effective in the removal of arsenic, its ability to eliminate dissolved organic substances is quite limited.

Drinking water disinfection is the most important and frequently employed treatment process throughout the world. As a rule, drinking water purification outside Germany stipulates the disinfection of the water and its subsequent introduction to the distribution network with free disinfectant; this is often a necessity given the fact that conditions in the distribution network are frequently less than ideal. Since a residual chlorine level is desired at the water tap, appropriate disinfectants with a lasting depot effect are still required as a final safety step following the optimisation of the water treatment process. However, care must be taken to avoid overdosage due to the potential for disinfectant by-product formation and negative reactions on the part of consumers.

Component	Cost type	Factor for development standard IC	EC	DC
Structures	Frequently constructed by regional companies	1,0	0.6	0.4
Mechanical engineering equipment, Electrotechnology/measurement and control technology	Local/regional production	1,0	0.8	0.6
	Imported equipment		1.5-1.7	1.5-1.7

Cost factors in industrialised, emerging and developing countries (Gieb, 2005)

Water quality and corrosion in pipe networks

Outside Germany, the impact of water quality on pipe corrosion cannot be adequately assessed by the common-practice method of establishing the corrosion probability on the basis of ion ratios. More concrete information can be gained by conducting additional experiments with a special test rig (see photo) under the applicable specific conditions.

When assessing the basic applicability of the various procedures from a technical perspective, the country-specific conditions regarding infrastructure, availability etc. must be taken into account (see table). Provided that any climatic differences are taken into account, transferring these procedures to other industrialised countries does not represent a problem, since a virtually identical technological standard can be assumed. However, this does not apply to developing and emerging countries (or only to a limited extent).

The results of the joint project have been published in the form of guidelines, while an accompanying CD documents the final reports of the sub-projects: "Export-oriented R&D in the field of water supply and wastewater treatment.
Part I: Drinking water, volume 2: Guidelines, in-house publication of DVGW Water Technology Centre Karlsruhe (2006),
ISBN: 3-00-015478-7" (out of print)

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Adapted wastewater technologies – knowledge gaps filled

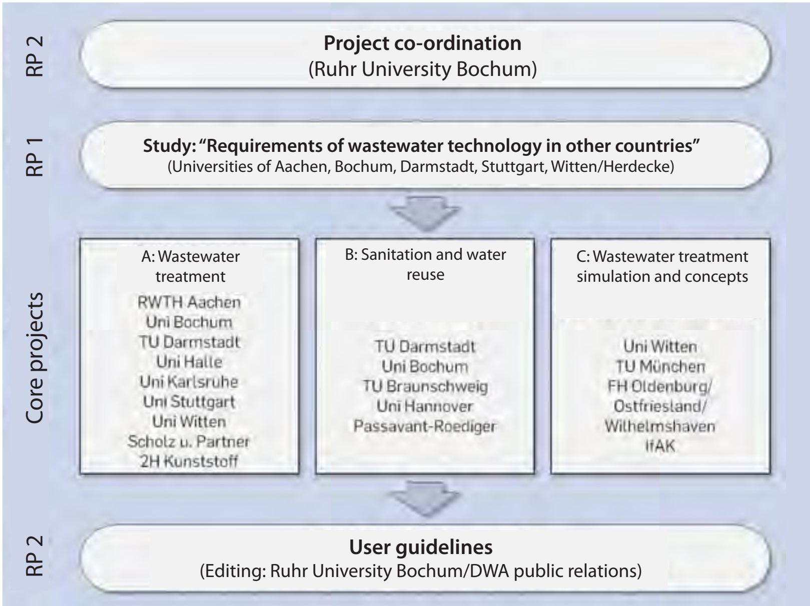
Germany is a world leader in the field of water technology. However, some knowledge gaps still exist – one example being the adaptation of wastewater technologies to altered conditions, such as the climate in different countries. These gaps have been successfully closed by a joint research project.

These altered conditions include extreme wastewater temperatures, low concentrations of easily degradable compounds, raised salt content or intensive algae growth in sewage ponds◄ due to high insolation levels. The objective of the joint venture **"Export-oriented research and development in the field of water supply and wastewater treatment – part II: Wastewater technologies outside Germany"** was to adapt technologies for communal wastewater treatment tried and tested in Germany to different climate zones and boundary conditions. A further objective was to place greater emphasis on the subjects of recycling and planning methods. The research project thus helped to raise the quality and efficiency of wastewater treatment while ensuring improved and more sustainable use of the resource water.

During the first project phase, investigations were performed of the special conditions of communal wastewater treatment in the following twelve nations, which were selected as being representative of different world regions and development levels: Egypt, Brazil, China, Indonesia, Iran, Jordan, Morocco, Russia, South Africa, Thailand, USA and Vietnam. This general survey was accompanied by 24 individual research and development projects, which were conducted by 11 different universities as well as numerous companies and focussed on three core areas.

Core area A: wastewater treatment

Core area A looked mainly at procedures that are standard in Germany and throughout the world: activated sludge processes◄, trickling filters◄, rotating biological contactors◄, submerged fixed beds◄ and sewage ponds. German water technology can provide a wealth of experience in this area, which must be adapted to the relevant conditions. The focus is on the composition of the waste water, the temperature of the waste water and ambient air as well as the specific requirements for the purification plant process or treatment stages (mechanical, biological, nutrient elimination).



Project structure

Core area B: disinfection and water reuse

The sub-projects of the second core area focussed on water recycling possibilities as well as the analysis, demonstration and enhancement of selected wastewater treatment procedures. One particular area of research was the different requirements of wastewater treatment plants – varying by time of year (summer, winter) or users – for the generation of irrigation water. In addition, the scientists examined the use of anaerobic processes for the treatment of wastewater. Examinations of sewage sludge treatment and utilisation were also part of the project.

Core area C: wastewater treatment simulation and concepts

Core area C comprised the projects in which locally adapted aids were devised for the planning of wastewater treatment plants outside Germany. These aids include adapted economic methods for variant evaluation, models for purification plant simulations, stepwise expansion concepts for adaptation to growing treatment requirements or rising pollution as well as working aids ("ExpoTool", available from ifak e.V., Magdeburg) for project assessment, which provide quantitative evaluations and visual

Demonstration system at the Yamuna Vihar treatment plant in New Delhi, India

representations of the various treatment plant alternatives. With these aids, available alternatives can be described and presented – e.g. to ordering or contracting bodies – in a clear and meaningful manner.

Extensive documentation

The project documentation produced by the research initiative provides a wide range of tools and information to support the adaptation of treatment plant technologies to the specific conditions in different countries. For the first time, quantitative recommendations can be made for a range of known qualitative phenomena. In this context, the impact of the water temperature is of primary importance: in all projects involving measurement and assessment, the water temperature is the most important parameter in terms of the adaptation of wastewater purification and sewage sludge treatment processes to different climatic conditions. One of the most significant observations in this regard is that higher wastewater temperatures may greatly increase performance, but can also result in operational problems (e.g. siltation, insufficient oxygen supply) without the implementation of suitable countermeasures.

As well as being the subject of scientific publications and presentations, the results of the research project are summarised in the three reports "Requirements of wastewater technology outside Germany", "Cross-project closing report" and "Guidelines for wastewater technology outside Germany". The reports are available from the Ruhr University Bochum via the address specified below.

Final clarification and digester of the Fujairah treatment plant, United Arab Emirates (provided by Passavant-Roediger GmbH)

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Water management in megacities – the role of the database

The water authority of the megalopolis Beijing knows all too well that correct decisions cannot be made without reliable information: since the region's climate causes significant fluctuations in available water levels, accurate data is required to control and monitor the supply and consumption of water. A computer program addressing this need has now been developed as part of a Sino-German joint venture – in the face of highly challenging conditions. The results of the project may also prove extremely useful to other megacities in Asia.

The sustainable management of water resources in semi-arid areas is an extremely complex task. As of a specific size (supply area, population) optimum management of multiple resources is required – both from a temporal and geographical perspective – whereby wastewater is also considered a resource in semi-arid areas. For megacities such as Beijing, with its 16 to 17 million inhabitants, this is a particularly challenging task.

Extreme situations

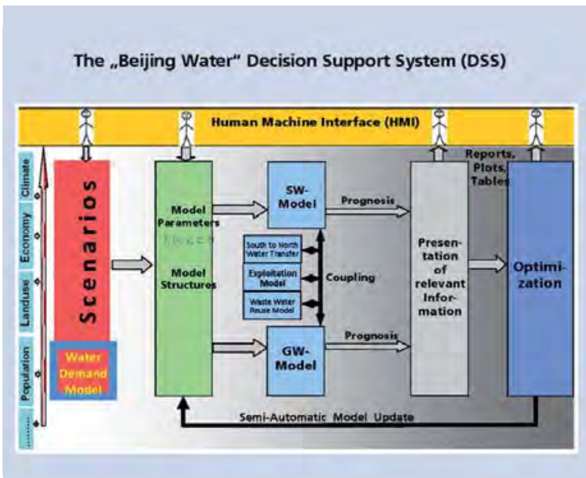
Due to its geographical situation at the northern edge of the North China Plain, Beijing has a semi-arid and intermittent semi-humid climate. Virtually the entire annual rainfall occurs over just two months (including flood events), while the area remains mostly dry for ten months of the year. The city's water authority is therefore required to manage two very different, yet equally extreme situations.

The most water is required for agricultural purposes in the areas surrounding the metropolis, whereby demand is largely covered by the 40,000 to 50,000 local groundwater wells. Drinking water is currently obtained from surface water (predominantly water reservoirs) as well as from groundwater – both sources are overused. The water carried by the two major rivers in the region (Yongding and Chaobai) has been seasonally or geographically restricted for years. In addition, groundwater levels are dropping by one to metres every year.

To ensure continued water supply in the face of ever growing consumption, plans were made in 2007 to channel water into the Beijing region from the South-North water transfer. The link-up has been delayed, however, and is currently scheduled for 2012/2013. The transfer is to convey an annual water volume of 1.4 billion cubic metres into the metropolis, but suitable reservoirs to store the water are still required.

Example of a dry river bed in the area under examination

These multifaceted tasks can only be addressed with the aid of a computer program tailored to these specific requirements. The creation of such an information system for the Beijing area was the remit of a Sino-German venture, which reached its conclusion in November 2009 with the delivery of the software system to the Beijing Water Authority (BWA). The project, which was supported by the Federal Ministry of Education and Research (BMBF), was overseen by the Fraunhofer Institute for Optronics, System Technology and Image Exploitation (IOSB).



Structure and functions of the information system developed for Beijing

Dried out littoral zone of Kunming Lake at the Summer Palace in Beijing

Multilayered program

The resulting "Beijing Water Decision Support System" (DSS◄) collates data and information of varying quality, quantity and controllability (see figure). The information ranges from easily measurable data (e.g. water abstraction from a specific source) to uncertain estimates (e.g. consumer behaviour, groundwater recharge rate). The system maps all resources onto mathematical models on the basis of balance equations: this allows the BWA to simulate various scenarios to support its decision-making.

As was to be expected, significant problems were encountered with the creation of a comprehensive information base as well as with the derivation of representative model structures with spatial and temporal parameters. Data is generally held by different institutions and authorities, and is therefore fragmented, inaccurate, inconsistent and occasionally even contradictory – something which greatly hinders efforts to implement the required modelling detail. Another exacerbating factor was that many model parameters (or model input quantities) were to be determined as functions of location and time – i.e. in the form of charts – but the available measurement data was severely lacking.

Creation of water balance system

The project partners tackled this problem by creating a coherent, multilayered system for water balances: it can be used, for example, to balance the water levels of different sources, groundwater recharge and untreated water abstraction, water consumption as well as the treatment and disposal of wastewater. The results can be used to identify and correct implausible data and close any gaps. The system also enables automated multi-criteria optimisation, in which simulations of pre-defined parameter variations are used to identify the specific scenario representing the best possible water supply solution under given conditions. Due to the high complexity of this process, the system always checks the consistency, plausibility and completeness of user entries.

The work performed on the Beijing Water Decision Support System gave rise to new methodical approaches for high-resolution modelling of water resources with meso-level analysis areas of over a thousand square kilometres (and larger), as well as for the determination of parameters on the basis of incomplete, inconsistent or contradictory raw data (as is usually the case with the water supplies of Asian or South American megacities). The success of these approaches was underlined by the high level of concordance between calculated and measured results as part of the verification of data from the period between 1995 and 2000.

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Transferable solutions for special wastewater problems – paper manufacture at the Yellow River

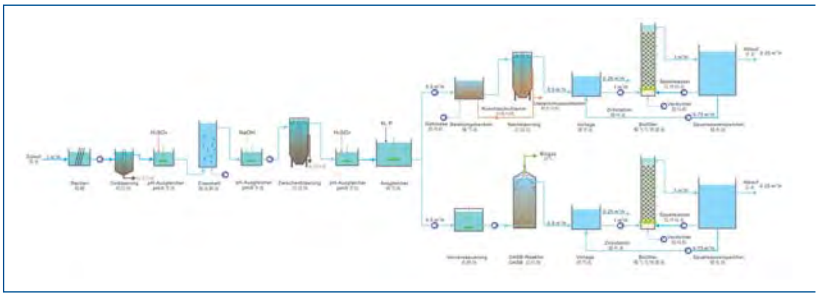
Paper factories are of great economic importance to the Chinese province of Shandong. However, the wastewater production of these factories is extremely high. A new research project supported by the BMBF has examined ways of making China's paper production more environmentally sustainable.

The Shandong province in the east of the People's Republic of China accounts for the second highest GDP of all Chinese provinces – and most of this can be attributed to the industrial operations based in the region. These primarily include paper manufacture, distilleries, dye industry and monosodium glutamate production.
The Shandong province has long suffered problems with its drinking water supply. In 2003, more than two million people did not have an adequate supply of drinking water. According to the annual report of the Shandong Ministry of Water Resources, more than six million people were without a short-term supply of drinking water, despite the relatively high level of precipitation experienced in 2003. As a result, the problems with the province's drinking water supply are likely to increase in the coming years.

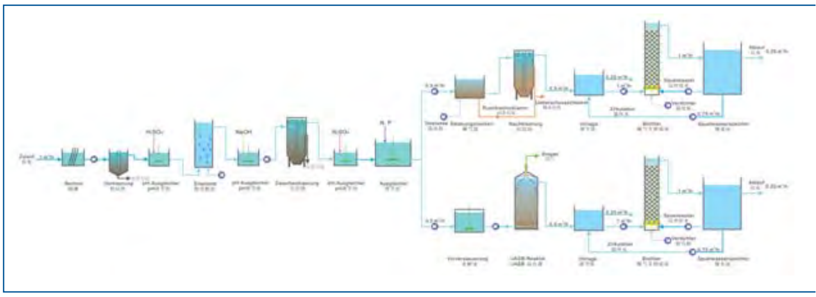
China's second largest river – the Yellow River – flows through the Shandong province. Water is channelled from the Yellow River into the "south-north transfer", particularly to supply the Beijing region with untreated water◄ for drinking water production. In this context, the establishment of sustainable water resource management in the basin◄ of the Yellow River and the transfer is a very important topic. Consequently, a large number of projects have been initiated to tackle this matter. The focus of these initiatives is on the cleaning of industrial wastewater from, for example, distilleries, textile dye works and paper factories in particular.

In 2005, 38 paper factories in Shandong were using straw as a raw material. The wastewater produced by these factories – 416 million cubic metres in 2000 alone – is extremely damaging to the province's waterways. A production output of some three million tons of paper in 2000 equates to 138 litres of wastewater per single kilogram of paper – by way of comparison, German paper factories produced a mere tenth of this.

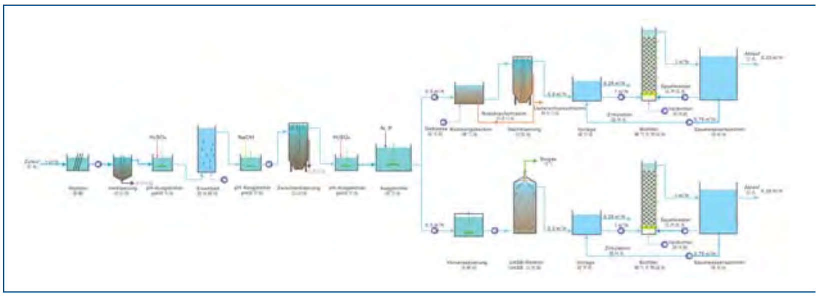
To ease the conflict between economic growth and environmental protection and gradually achieve all environmental goals, both the central government in Beijing and local government of the Shandong province issued stricter regulations concerning industrial wastewater disposal. As of 1 January 2011, wastewater fed directly into the receiving waters must not exceed a concentration of 100 mg COD◄/l ("Integrated Wastewater Discharge Standard in Shandong Peninsula Basin"). This discharge limit is lower than its European counterparts. This made it all the more impossible for the wastewater treatment plants in the Shandong paper factories to meet these requirements, both with regard to the polluting load and the pollutant concentration. It was therefore necessary to develop processes that would allow the factories to comply with the stipulated discharge loads and concentrations in a reliable and cost-effective manner.



Pre-treatment stage – micro-electrolysis procedure



Aerobic–aerobic treatment stage



Anaerobic–aerobic biological treatment stage

Iron bed (foreground), intermediate treatment and final clarification (background)

The overall aim of the commissioned research project was to identify purification solutions for the special paper wastewater of the Shandong province and to make initial improvements to general wastewater treatment. Another long-term goal was to optimise process water recirculation to reduce the overall water consumption in Shandong's factories. The project was also to assess the transferability of the examined procedures to other paper factories in the Shandong province and throughout China.

The initiative can be split into two main steps: in the first part of the project (project phase A), the micro-electrolysis procedure was examined on a laboratory scale at the Technische Universität Darmstadt (Darmstadt Technical University) in order to optimise the biodegradability of wastewater from paper production. The aim was to achieve significant BOD_5◂ and COD reduction and improve biodegradability in subsequent stages. This step supported the later research in the semi-industrial test facility (project phase B), which had been constructed in Shandong's Qufu factory as part of the Sino-German joint venture.

In the semi-industrial test facility, the paper wastewater was processed in a pre-treatment stage based on the micro-electrolysis procedure and a two-stage biological cleaning process (anaerobic◂/ aerobic◂ or aerobic/aerobic). The micro-electrolysis was used to pre-treat the wastewater, particularly to eliminate lignin compounds, degradation of which is very difficult. In a first basin, the wastewater was then processed in a highly concentrated activated sludge procedure◂ and a subsequent biofilter stage. In the second basin, the wastewater was subjected to anaerobic pre-treatment with a UASB reactor◂ and subsequent aerobic post-treatment using a biofilter. In addition to the semi-industrial test facility, project phase B also involved additional laboratory experiments with a modified treatment stage, in which the various treatment steps were processed in the following sequence: micro-electrolysis, UASB, activated sludge basin and biofilter.

In their tests with the semi-industrial facility, researchers were able to meet the 120 mg COD/l threshold applicable from 1 January 2010, but not the more stringent emission standards that would take effect in 2011. However, the additional laboratory experiments succeeded in reaching these future requirements (less than 100 mg COD/l).

The conducted research showed that it was possible to optimise the wastewater treatment in China's paper factories by affordable means; however, meeting the required pollutant limits would require the adaptation of procedures to the special wastewater streams and polluting loads. With regard to the transfer of results to other factories, researchers are currently still working on a water balance for the paper factory specified above However, the general assumption is that the employed procedures will be suitable for factories using straw as a raw material. In order to assess suitability for the paper wastewater treatment of factories using other raw materials, consideration and possible further examination of the specific conditions and wastewater composition is required.

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