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## **Abstracts**



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# Modelling the interaction between groundwater, surface water and unsaturated zone on the regional scale

Barthel, R.

Institute of Hydraulic Engineering (IWS), University of Stuttgart  
phone: +49 711 685-6601, [roland.barthel@iws.uni-stuttgart.de](mailto:roland.barthel@iws.uni-stuttgart.de)

## ABSTRACT

Today, sustainable management of water and land resources is widely understood as an integrative, cross-border task. Research activities such as the BMBF-GLOWA-Initiative ([www.glowa.org](http://www.glowa.org)) and the European Community financed RIVERTWIN project ([www.rivertwin.org](http://www.rivertwin.org)) take up this idea and link it to the investigation of the effects of Global Change on the hydrological cycle. Models are important tools that help to understand systems, to predict changes and to support decisions with far-ranging implications. Since groundwater is a major drinking water resource in many parts of the world, the groundwater system and its accurate representation play a major role in integrated modelling systems.

Within GLOWA-Danube a large scale three-dimensional numerical groundwater flow model has been developed for the Upper Danube Catchment, the greatest part of which lies in Germany and Austria (~80.000 km<sup>2</sup>). The model runs within the 'DANUBIA' decision support framework coupled to 15 other models. A second large scale groundwater flow model is has been developed for the Neckar catchment, Germany (~15.000 km<sup>2</sup>). It is part of the river basin management tool developed by the RIVERTWIN research cooperation. Both models are implemented using MODFLOW 2000 and are coupled in different ways to physically based surface water and soil water models or to conceptual hydrological models. Here it is shown, that in integrated systems a main challenge is the meaningful, scale-appropriate coupling of the groundwater and the surface water system (including the unsaturated zone).

After introducing the projects GLOWA-Danube and RIVERTWIN, the models and the coupling schemes used, an overview on the requirements and challenges of model coupling in Integrated Water Resources Management is given. Special attention is made to the role of 'groundwater recharge' and 'baseflow' in coupling groundwater models with hydrological models. The conclusions summarize the most relevant problems. This paper aims to point out that working on a large scale in an integrated context requires rethinking traditional disciplinary workflows and encouraging communication between the different disciplines involved.

# Quantitative aspects of stormwater infiltration

Coldewey, W.G.

University of Münster

## ABSTRACT

Near-natural stormwater infiltration can cause rising groundwater tables in urban areas. In order to assess these effects, the area-differentiated groundwater recharge in a real investigation area in Germany and their effects on the groundwater table are modelled using three different computer programs. The first program determines the natural area-differentiated groundwater recharge for the whole study area without considering the infiltration facilities. The second program is used to localise infiltration processes and it calculates the groundwater recharge below the infiltration facilities. The groundwater recharge rates calculated with these two programs are incorporated in the numerical groundwater model. It is used to simulate the groundwater surface level development. By varying the size of additional development areas, the degree of sealing, the infiltration rate and the precipitation different simulation scenarios were conducted. It was found that both the precipitation and the infiltration rate are the most influencing factors concerning the groundwater surface. Further, problems have to be expected especially in areas with low hydraulic conductivities. To ensure sustainable depths to groundwater table calculating the water budget can be recommended, as to name just one of the recommendations.

# **Infiltration of contaminated stormwater runoff through artificial barriers**

**Dierkes, C.**

HydroCon GmbH, Mendelstraße 11, D-48149 Münster, Germany

## **ABSTRACT**

Infiltration of stormwater is a proven sustainable alternative to classical drainage concepts in the urban area. Infiltration can help in returning the urban water cycle to its pre-urbanized state. It supports groundwater recharge in sealed areas, allows smaller diameters for sewers (resulting in cost reduction) and improves water quality of receiving waters because pollutants and high peak flow are effectively controlled.

Unfortunately urban runoff contains pollutants originating from domestic and industrial emissions and traffic. Sedimentary particles and pollutants from drained surfaces cause clogging and endanger soil and groundwater during long-term operation of those devices. German water authorities recommend to use infiltration devices with soil passages like swales or swale-trench-systems. Direct infiltration by underground situated facilities like pipes, trenches or sinks without pre-treatment of runoff often will not be admitted. Problems occur for metal roofs, traffic areas and industrial sites. But underground situated systems are often the only possible alternative, because shortage of space.

At first pollutant concentrations and loads had to be evaluated to design systems to treat urban stormwater at an adequate level. This step was done by an intensive literature study. In a second step water quality aims for seepage had to be defined.

To solve the problem of contaminated stormwater, artificial barriers can replace the soil passages. A pollution control manhole with hydrodynamic separator and multi-stage upstream filter elements was investigated, that treats runoff at source and protects soil and groundwater.

Sedimentary particles, hydrocarbons and heavy metals can be removed with efficiencies typically higher than 90 % from runoff. Specific filter elements were used to treat even high polluted stormwater from metal roofs and industrial sites. The cleaning process is based on sedimentation, filtration, adsorption and chemical precipitation. The sediments are trapped in a special chamber and can be removed easily. The pollutants are retarded in the filter element, which can be replaced. With the artificial barriers it is possible to infiltrate stormwater runoff directly without endangering soil and groundwater.

# Enhancing the potable water potential of tsunami-hit areas of NE Sumatra using high resolution airborne and ground geophysics

Eberle, D.

Federal Institute for Geosciences and Natural Resources (BGR), Germany

## ABSTRACT

The fresh water supply system had almost completely been demolished in coastal zones of NE Sumatra by the Tsunami event of December 26, 2004. Most of the shallow fresh water wells and part of the deeper wells had been flooded by saltwater.

As part of an aid programme funded by the CocaCola Foundation of Indonesia (CCFI), the Sigli-Pidie marshlands of the Sumatra NE coast were surveyed using the BGR helicopter-borne geophysical system whose principal component is a five frequency electromagnetic (EM) device. Survey results reveal that salinisation occurring parallel to the shore has not been produced by the Tsunami flooding, but is due to natural saltwater influx from the Andaman Sea and fishery ponds extending inland immediately behind the beach. In the hinterland, two major areas with increased apparent electric resistivity (25 – 50 Ohm\*m) were identified and are considered highly promising for larger, so far unknown fresh water aquifers. These are assumed to be suitable for sustainable fresh water provision of the local population.

Very low apparent electric resistivity values ( $< 5 \text{ Ohm}\cdot\text{m}$ ) constraining the depth of investigation of the helicopter-borne EM system were mapped along the whole of the Sigli coastal zone. This is why ground geophysical surveys - providing greater depth of investigation - were carried out in this particular and densely populated part of the survey area. Ground survey results reveal that fresh water can be expected in the coastal zone at depths greater than 50 to 150 m.

Airborne and ground geophysical survey results were assessed in the light of hydro-geological survey data. Suggestions where to drill for fresh water were made on request of some NGO's. Relevant drilling results will be discussed. The combination of airborne and ground geophysical surveys has proven to be highly effective in enhancing the fresh water potential of the Sigli-Pidie marshlands.

# **Sustainable groundwater management on the military training area Altmark**

**Ertl, C. & Maiwald, U.**

Federal Institute for Geosciences and Natural Resources (BGR), Germany

## **ABSTRACT**

The drinking water supply for about 800,000 inhabitants of Magdeburg, the main town of the federal German state of Saxony-Anhalt, and the neighbouring districts to the north is based exclusively upon the groundwater resources of the Colbitz Letzlingen heath.

This region stretches across an area of 600 square kilometres in the north of Magdeburg. Its main aquifer system is built up of a series of Quaternary, fluvio-glacial sand and gravel sequences over unconsolidated Tertiary formations of partly thick sticky clay or silty sand members. The groundwater flow pattern is controlled by the river Elbe and its tributaries, the small rivers Uchte, Tanger, Ohre and Milde, which are functioning as natural boundaries of the Colbitz Letzlingen heath.

The central part of the area was in military use since 1934 where the Deutsche Wehrmacht tested new weapons and practiced combats until 1945 and the Soviet army used the training area intensively since World War II until 1993. Subsequently, the German federal armed forces have taken over parts of the area. A modern centre for field exercises of the army was installed. The military use of the area led to a variety of soil contaminations related amongst others to shooting- and blasting grounds, car and tank washes, barracks, fuel dumps and testing plants. The possible influence of this soil contamination by heavy metals, hydrocarbons and the residues of blasting agents on the groundwater quality had to be observed, because big parts of the training area are situated in the catchment areas of the waterworks.

A number of smaller areas in the Colbitz Letzlingen heath are committed as nature reserves, others are provisionally reserved for future conservation.

The Federal Institute for Geosciences and Natural Resources (BGR) carried out a groundwater monitoring in this area since 1993. The knowledge of the geology, hydrogeological structure, hydrodynamics and hydrochemistry has been increased by intensive investigations.

# Quality of bank filtrated water in different wells locations

Górski, J. & Przybyłek, J.

Department of Hydrogeology and Water protection  
Institute of Geology Adam Mickiewicz University  
Makow Polnych Street 16, 61-606 Poznan

## ABSTRACT

This article presents the results of two year investigations of ground water quality drawn from the wells located at a different distance to a river. The big influence on ground water quality from a drainage well (with drains placed in the river bed) and the vertical wells located 70-80 m from a river has been found. This influence is in evidence in water contamination with bacteria and plankton as well as nitrates and micropollutants. In the wells located farther from a river (250-1100 m) these contaminants are almost not observed. However a gradual increase of organic matter has been noticed. Based on the carried research the distance of 150 – 250 m (travel time of approx. 0,5 year) as the best for the wells location to a river has been recommended. Nevertheless, more advantageous solution of river water exploitation through the infiltration would be an artificial recharge of ground water.

# Reactive modeling of river bank filtration

Horner, Ch.

Leibniz Institute of Freshwater ecology and Inland Fisheries,  
Müggelseedamm 310, 12587 Berlin,  
Phone ++49 (30) 64181668, e-mail: [horner@igb-berlin.de](mailto:horner@igb-berlin.de)

## ABSTRACT

During the years 2000-2003, the Kompetenzzentrum Wasser Berlin was managing the interdisciplinary NASRI project Natural and Artificial Systems for Recharge and Infiltration) with research groups from TU Berlin, FU Berlin, Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), and German Environmental Protection Agency (UBA), sponsored by Veolia Water and Berliner Wasserbetriebe (BWB). This project dealt with hydro geological, hydrochemical, biochemical and microbiological aspects during river bank filtration.

Most of the well fields of the Berliner Wasserbetriebe are situated along the rivers Havel and Spree (80 % of the groundwater well production are related to river bank filtration) so that a deeper understanding of these processes is necessary to ensure sufficient drink water quality for Berlin also towards the future. The Leibniz Institute of Freshwater Ecology and Inland Fisheries was responsible for the modelling part of the NASRI project. The main issue was the modelling of hydraulic and hydro geochemical processes during bank filtration at the Lake Tegel test site in Berlin. Based on hydro geological, geo- and hydro chemical investigations performed by the department of hydrogeology of the FU Berlin, numerical models were set up in order to understand the time-dependent and spatial distributed flow and transport regimes in the vicinity of well galleries taking into account the natural conditions and anthropogenic influences, e. g. pumping regimes. An interesting aspect of the interaction of surface water and ground water during river bank filtration is a redox zonation in the adjacent aquifer due to biogeochemical interaction with reactive organic carbon, ranging from oxic to anoxic redox conditions which was modelled using a reactive flow and transport model. Some results of the NASRI projects are published in the proceedings of the ISMAR5 conference, held in Berlin, 2005, and in different publications ( Greskowiak et al, 2005; Greskowiak et al, 2006; Holzbecher et al, 2006, and Horner et al, 2006).

As a first topic, the basics of reactive transport modelling are presented. As model software system, PHT3D (Prommer, 2002) was chosen, which is integrated (together with MODFLOW and MT3DMS) within the graphic user interface (GUI) PMWIN (Chiang, 2002). As reactive module, PHT3D performs an interface between the chemical software PHREEQC-2 (Parkhurst & Appelo, 1999) and MT3DMS ( Zheng & Wang, 1998) so that all features of PHREEQC-2 are available to model complex hydro chemical situations including biogeochemical issues. Using this way, a measured hydrochemical data set can be assigned to concentration initials as well as to all boundary conditions, such as groundwater recharge, leakage conditions along rivers and constant head conditions.

To model the hydrogeochemical features along the Lake Tegel test site, a reaction network was set up including different fractions of organic matter (DOC und particulate organic carbon), all possible electron acceptors (such as O<sub>2</sub>, NO<sub>3</sub>, iron and manganese oxides, and SO<sub>4</sub>) and the major ions like Ca, Mg, Na, K, Fe, Mn, Cl and HCO<sub>3</sub> as components. Biogeochemical degradation was formulated using an MONOD kinetics approach.

Further, the local hydro geological and hydro chemical situation along the Lake Tegel test site is presented. From the extensive NASRI database, a redox sequence ranging from oxic conditions to anoxic conditions ( Nitrate, Manganese and Iron zones) was derived.



Based on these data, a conceptual reactive transport model including the principal hydro geological stratification and variable pumping regime on two neighbored production wells was set up. Chemical input data were also available from the NASRI data base.

The reactive transport model verifies the observed spatial distribution of the redox zones on principle. From the simulation results the great impact of local flow and of the geologic pattern, such as variations in the leakance of the river bed or the local aquitard distribution, on the local hydro chemical groundwater composition is illustrated. Further, simulation results will be strongly influenced by the interplay of hydrodynamic transport, biodegradation kinetics, the extent of supply of reactive DOC by dissolution of particulate OC, and the spatial distribution of particulate Organic Carbon within the aquifer system. As an important application of the reactive transport modeling presented here, the stability of pharmaceutical trace compounds which were also investigated by the NASRI project can be assessed in terms of redox conditions.

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# **Coupled modeling of groundwater and surface water for renaturation planning in the National Park Lower Odra**

**Kaden, S. & Monninkhoff, B.**

WASY GmbH, Institute for Water Resources Planning and Systems Research  
12526 Berlin, Waltersdorfer Straße 105

## **ABSTRACT**

For the National Park Lower Odra a series of measures have been planned to improve the natural water system. Major parts of the park are controlled polder areas (inundation areas), which are flooded during the winter season. The planned measures include the prolongation of flooded periods for ecological reasons and the construction of a natural like river course parallel with the Odra River through the polder area.

Because in the study region surface water and groundwater are closely interrelated, the planned measures cause a number of conflicts, e. g. related to agriculture due to changing groundwater tables.

In order to analyze the impacts of the planned measures and to optimize those, WASY has been asked to develop and apply a coupled groundwater - surface water model.

With the recently developed IFM-Tool (FEFLOW Interface Manager) it is now possible to model the interaction surface water – groundwater effectively. The module IfmMIKE11 couples the WASY groundwater software FEFLOW with the DHI surface water software MIKE11.

Water levels of MIKE11 are imported to the boundary conditions of FEFLOW and discharges along the branches being calculated by FEFLOW are exported to the MIKE11 calculation points. A big advantage of the module is the fact that the assignment of the FEFLOW boundary points to the MIKE11 calculation points can be realised fully automatically. By use of observation point groups and reference distributions (both are options inside FEFLOW) this can be optimised. Further more, a comfortable GUI enables the user to check the assignment being made as well as to observe the interaction while simulating.

In the presentation the coupled model for the National Park Lower Odra will be explained and examples of its use for conflict analysis and planning of the water system in the park are given.

# **Modelling of attenuation processes for conservative components in the river catchment: a case study**

**Kania, J. & Witczak, S.**

AGH–University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, al. Mickiewicza 30, 30-059 Krakow, Poland  
[jkania@agh.edu.pl](mailto:jkania@agh.edu.pl)

## **ABSTRACT**

During mean low streamflow periods, rivers discharge mainly groundwater and wastewater. Therefore, quality of groundwater during base flow is the main factor responsible of river water quality. The conceptual model consists of two aquifers (Holocene-Pleistocene and Miocene) separated by an aquitard (Miocene clays), with various types of boundary conditions including the artificial lakes and rivers. Multi-variant simulations were performed using MODFLOW and MT3D codes with Processing Modflow interface (Chiang and Kinzelbach, 1998).

In the case of river's catchments with shallow open groundwater systems, the response of the system after changing the contaminant load has an exponential character, and is usually measured in tens of years. In such case, the flow geometry will have a small effect on base flow quality (Duffy and Lee, 1992). Typical response of the system was confirmed using modelling of the part of the Trzesniowka River catchment. Among a number of modelling solutions, so called zero option has been chosen to demonstrate the prediction of time and space quality changes in ground and surface water in the case of ceasing of all pollution sources, including the nonpoint source contamination. The response of the system after changing the contaminant load becomes very nearly exponential, and is measured in tens of years.

Exponential character of the response of the system after changing the contaminant load lead to the estimation of the half-time of attenuation for conservative components. Results of simulation indicate that for typical shallow river catchments, as Trzesniowka River basin, the process of contaminants attenuation will take tens of years after ceasing of all pollution sources. Half-time of contaminant attenuation seems to be a good indicator of the lag time in groundwater and surface water interaction, necessary for GWB status assessment.

The presented example indicates undoubtedly usefulness of groundwater flow and transport modelling for the evaluation of the interaction between ground and surface water systems.

# Application of the AISUWRS-Computer-Tools for the balancing of urban water and contaminant fluxes under special consideration of sewer defects

Klinger, J., Wolf, L. & Hötzl, H.

Department of Applied Geology, University of Karlsruhe  
Contact: [klinger@agk.uka.de](mailto:klinger@agk.uka.de); [wolf@agk.uka.de](mailto:wolf@agk.uka.de)

## ABSTRACT

**Introduction:** These days, groundwater in urban areas is gaining more and more attention as approx. 50 % of the world population and 80 % of the European population are living in urban areas. The resource is threatened by an increasing water demand and the resulting sewage volumina, the continuous deterioration of the sewer network, increased industrial activity and a higher traffic load. To tackle these questions sustainable water management systems including the urban aquifer are needed.

The overall scope of the AISURWS project is to Assess and to Improve the Sustainability of Urban Water Resources and Systems with the help of computer tools. The combination of the computer tools with Geographic Information System gives a detailed illustration of water and contaminant fluxes in an urban area and its effects on the underlying aquifer. The software suite which is called the AISUWRS model chain was developed within course of the project and consists of five different program codes which are linked with each other.

**Methodology:** The model chain starts with the **Urban Volume and Quality** model (UVQ), a conceptual, hydrological model that was developed to calculate the water and contaminant flows in the existing drinking water, waste water and storm water systems. As output, UVQ provides data on the quantity and quality of wastewater generated by land blocks together with volumes of storm water and irrigation water infiltrating through open spaces and gardens and of storm water produced in the residential quarters (named as neighborhoods) (Michtell and Diaper 2005; Diaper and Mitchell 2006). In the next step, the UVQ calculated volume and contaminant flows in the sewer system are transferred to the **Network Exfiltration and Infiltration Model** (NEIMO) that estimates the amount of exfiltrating sewage or infiltrating of groundwater accounting for the pipe properties, the spatial reference and the location relative to the groundwater level. The flexibility of NEIMO is given through the option of accounting either for real sewer defects deriving from CCTV protocols or for statistically determined defects.

For the representation of the flow and transport processes occurring in the unsaturated zone (decay, sorption, transformation) two approaches needed to be developed due to different boundary conditions (i.e. point sources and diffuse entries). The model **Sewer Leak Index** (SLeakI) calculates the residence times for the leaky water deriving from point sources (i.e. sewer defects). The **Public Open Space Index** (POSI) models the flow and contaminant transport below open space areas and is configured as a 1-D approach.

The **Decision Support System** (DSS) developed within AISUWRS project is the integrating software that supports the selection and comparison of predefined urban water scenarios. This is achieved by linking the individual models together to allow them to be run as one entity, rather than individual stand-alone models. The DSS provides the ability to track water and associated contaminants emanating from urban areas from the source until they reach the aquifer, enabling prediction of the impact of different scenarios on groundwater contamination and assessment of its implications for urban development (Burn et al. 2006). The output of the AISUWRS model chain provides spatial referenced water and contaminant fluxes to the groundwater deriving from free leakage below open space areas, leakage from supply pipes and the waste water network. The combination of the results gained through the

application of the model chain with the commercial GIS software ArcMap allows the quick spatial referenced illustration of the contaminant load distribution of natural and anthropogenic sources.

**Model set up:** In order to take a variety of geological, hydro-geological and climate boundary conditions, as well as different water supply and waste water management strategies into consideration, the AISUWRS model chain was set up at four case study cities: i.e. in Rastatt, Germany (Klinger et al. 2006), Doncaster, UK (Morris et al. 2006) and Ljubljana, Slovenia (Souvent et al. 2006) in Europe and in Mt.Gambier, Australia (Cook et al. 2006).

The **case study city Rastatt** is a middle-sized city of app. 45.000 inhabitants, located 20 km south of Karlsruhe, SW-Germany. Using the commercial ESRI code ArcMap the urban area of Rastatt (app. 1065 ha) was divided into 74 neighborhoods, which represent different areas of a homogeneous land use like residential, commercial or industrial areas. Demographic data (population density, data of water consumption, etc.) physical data (degree of sealing, properties of the sewer network, etc.) as well as the geological and hydro-geological information were fed into the model codes. The calibration of the models was performed quantitatively and qualitatively. The modeled water fluxes were adjusted to data sets recorded by installed flow meters. The substance fluxes were balanced by the comparison of quality data using marker substances gained through extensive field measurements (groundwater and sewage sampling campaigns) (Wolf et al. 2004; Klinger et al. 2005; Wolf 2006).

For the sustainability assessment of the water management practice in Rastatt a range of scenarios was set up: the actual state was represented in the baseline scenario. Additionally, a climate change scenario, a sewer rehabilitation scenario and an infiltration scenario were set up and evaluated.

## Acknowledgements

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*Further Results available at: [www.urbanwater.de](http://www.urbanwater.de)*

# **A 3D heat transport model for the sustainable use of thermal water in Hungary**

**König, Ch.**

delta h Ingenieurgesellschaft mbH  
Baroper Str. 239b, D-44227 Dortmund, Germany  
Tel.: +49 (0) 231 725154 0, Fax: +49 (0) 231 725154 20  
e-mail: [ck@delta-h.de](mailto:ck@delta-h.de), <http://www.delta-h.de>

## **ABSTRACT**

The Republic of Hungary is a landlocked country in central Europe. A great part of Hungary, is placed in the center of the Pannonian Basin (often referenced to as Carpathian Basin), which is of flat and hilly character without significant mountains. The precursor to the present plain was a shallow sea that reached its greatest extent during the Pliocene, when up to 4 km of sediments were deposited.

The earth's crust below the Pannonian Basin is thinner than the average and therefore the mantle's magma is closer to the surface. This leads to remarkably high geothermal gradient for a non-volcanic area in the interior of the Basin. Consequently, Hungary is a country with favourable geothermal conditions.

Currently the most significant field of utilization of geothermal energy in Hungary besides balneology is agriculture, where thermal water provides heating for greenhouses and animal farms. Besides that, thermal water is also used for domestic supply of hot water and heating. As waters of higher temperature can contain a higher level of dissolved substances, a great portion of the registered medicinal waters in Hungary, including spas, are thermal waters.

A problem attached to the usage of thermal water is the waste water treatment. Today used thermal water is usually discharged into draining channels or public sewers, which in turn lead into lakes or storage reservoirs. Thermal water that is discharged into surface waters can have various effects to the environment depending on the way of its release. The two primary causes which disturb the natural balance of the ecosystem are its remaining higher temperature in comparison to the environment, and the high concentration of geogenic chemical elements.

This paper concerns aspects of the geothermal conditions at the Bükk mountain range and the utilization and discharge of thermal groundwater at a 'test site' Mezőkövesd in the surface waters at the Pannonian Basin.

# **International cooperation between groundwater and surface water professionals**

**Nałęcz, T.**

Polish Geological Institute  
Warsaw

## **ABSTRACT**

The Water Framework Directive as well as preparation works concerning the Groundwater Directive created considerable build up of cooperation between surface and groundwater experts. Polish Geological Institute actively participates in implementation of WFD in Poland and also continues the international cooperation. The PGI with a group of European experts was an co-organizer of Groundwater modeling Workshop for employees of the Polish Regional Water Management Boards and Voivodship Inspectorates for Environmental Protection. The international water management cooperation with very well progresses and succeeds in the works of the Bilateral Commissions of Transboundary Waters. The PGI experts participate in those bodies cooperating there with professionals from neighboring countries. The future projects dealing with the integration of groundwater and surface water management should be the outcome of these works. All these operations will enable rational utilization of groundwater reserves which are essential for our future existence.



# Assessment of groundwater quality in the coastal regions of Aceh Province, North Sumatra

Plöthner, D., Klinge, H. & Boehme, J.

Federal Institute for Geosciences and Natural Resources (BGR), Germany

## ABSTRACT

This presentation will focus on the water quality assessment done along the west coast between Meulaboh and Calang.

On request of the Indonesian Government, BGR conducted airborne geophysical and hydrogeological surveys across three coastal areas of Aceh Province (Northern Sumatra, Indonesia) which has been heavily affected by the 26 December 2004 tsunami. The surveys were carried out from August to November 2005 in cooperation with the Geological Survey of Indonesia and intended to provide profound data for the rehabilitation and reconstruction of the seriously destructed drinking water supply infrastructure.

As a consequence of the seawater flooding caused by the tsunami, the majority of the dug wells – the traditional source for drinking water supply – were destroyed, salinised and polluted by waste and organic matter within a coastal strip, 2-3 km in width.

National and international rescue organisations and NGOs supported the villagers and urban population to clean, rehabilitate and reconstruct the dug wells and, in addition, to jet or to drill hundreds or even thousands of new small diameter wells to assure a rapid safe and fresh drinking water supply.

These new and the existing deep wells as well became the major target of the hydrogeological reconnaissance surveys. In total, approx. 60 water samples were taken for complete analysis of the major and trace inorganic constituents.

The majority of the wells sampled abstract fresh groundwater which is frequently depleted in dissolved oxygen; elevated concentrations of iron, manganese, ammonium, and nitrite give rise to concern. Based on UNICEF and BGR data, it is estimated that approx. 10% of the wells have groundwater with elevated arsenic concentrations of up to 50 µg/l with one hot spot south of Meulaboh (west coast) where arsenic rises up to 340 µg/l at relatively shallow depth.

It appears likely that this above described hydrochemical association is bound to swampy areas along the west coast (Meulaboh-Calang) or reclaimed swampy areas on the east coast (Sigli-Bireuen), whilst it is far less pronounced in the environ of Banda Aceh on the north coast where organic matter in sediments rarely occurs.

The technical cooperation project "Management of Georisks" being currently conducted by BGR in cooperation with the geological surveys of Indonesia and Aceh Province continues to execute hydrogeological surveys and to provide advice on well siting, well design, and water quality assessment. In this context, water quality of approx. 270 dug wells was analysed on request of German Agro Action. By this, it has become evident that shallow groundwater along the east coast (Sigli-Bireuen) has been still partly brackish and nitrate-polluted (up to 240 mg/l) and approx. 12% of the dug wells abstract groundwater with elevated concentrations of up to 25 µg/l with two hot spots where arsenic concentrations rise up to 90 µg/l.

# Contributions to the protection of water resources in Jordan

Schelkes, K.<sup>1</sup>, Margane, A.<sup>1</sup>, Schmidt, G.<sup>1</sup>, Khalifah, N.<sup>2</sup> & Subah, A.<sup>2</sup>

<sup>1</sup> Federal Institute for Geosciences and Natural Resources (BGR), Germany

<sup>2</sup> Ministry of Water and Irrigation (MWI), Jordan

## ABSTRACT

Groundwater is the major water resource in most of the arid and semi-arid regions of the Middle East. The sustainable use of this scarce water resource is a continuous challenge for an adequate groundwater management. Groundwater protection - as part of an integrated water management - is an important feature for the sustainable development.

Since several decades, the German Federal Institute for Geosciences and Natural Resources (BGR) supports the Ministry of Water and Irrigation (MWI) in Jordan in the groundwater sector. Whilst former projects pre-dominantly concentrated on assessment, exploration and use of groundwater resources, nowadays the main focus is directed at groundwater protection. Sustainable water and land use management in the Middle East refers to an improved knowledge of the processes and impacts, which might influence the groundwater regime and the quality of the groundwater.

To face the various problems in water management as overexploitation, dependencies on the highly variable rainfall pattern, growing water demand, and contamination by agricultural, industrial or domestic (waste, sewage water) pollution sources, there is an urgent need of countrywide regulations, including the establishment of sustainable groundwater production and protection schemes as an integrated part of the National Water Master Plan, as prepared by the MWI. An important component of the NWMP is a comprehensive countrywide numerical model that has been established in order to provide a tool for decision making related to groundwater resources management. The simulation model of the complex Jordanian groundwater system covers an area of about 100,000 km<sup>2</sup> and includes in the vertical direction the major hydrogeological formations, which are composed either of basalt, marl, limestone or sandstone. The model delivers figures about possible future changes in groundwater flow and quantity and provides water budgets in relation to any selected groundwater basin as well, thus providing the basis for future groundwater resources management in accordance to projections from the National Water Master Plan, respectively.

Since the mid 1990s and in cooperation with the BGR, the MWI has introduced a number of measures in order to minimize the pollution risks on groundwater and surface water resources. Providing the know-how and introducing modern methods, the project activities contributed to the preparation of groundwater-related guidelines and policies as part of an overall strategy for future groundwater resources management. Four groundwater vulnerability maps have been prepared for fast developing target areas in Jordan with the objective to improve the basis for land use planning decisions and to provide a better basis for groundwater resources management decisions, e.g. related to groundwater monitoring and wellhead protection programs.

Furthermore, thus far three groundwater protection zones have been established for important springs and wells. The Delineation of surface water protection zones for two major dams is in progress. As such protection zones must have a binding legal character, by-laws for the delineation of groundwater protection zones and of surface water protection zones have been drafted. Though these by-laws are still in the process to be enacted, some basic protection measures are already being implemented on a regular basis. The implementation process is supported by workshops and public awareness campaigns. Once fully implemented and accepted by the local population, these protection measures will contribute to a more sustainable use of the water resources.

# Removal capacity of slow sand filtration and riverbank filtration

Skark, C., Remmler, F., Schulte-Ebbert, U. & Zullei-Seibert, N.

Institut für Wasserforschung GmbH Dortmund,  
Zum Kellerbach 46, D-58239 Schwerte  
[skark@ifw-dortmund.de](mailto:skark@ifw-dortmund.de)

## ABSTRACT

Water treatment by riverbank filtration (RBF) and by artificial groundwater recharge via slow sand filtration (SSF) can be seen as near-natural purification processes which were practised since more than 100 years in order to produce drinking water from surface water.

Their intrinsic removal mechanisms are physical straining, microbial degradation, sorption, sedimentation, ion exchange and precipitation. As a result, bulk organic matter in terms of dissolved organic carbon (DOC) can be removed remarkably during the path from the surface water to the abstraction well. Observed DOC-elimination often exceeds 50 % of the surface water DOC-concentration. The main part of DOC can be seen as humic substances which were altered during the treatment process. Many man-made, hydrophobic trace compounds are eliminated due to sorption and microbial degradation. Polar organic micropollutants, however, may pass the filtration steps. Their degree of removal depends mainly on the local redox environment. The widely used, non selective herbicide glyphosate, for instance, is completely eliminated during the aerobic process of slow sand filtration and the subsequent underground passage whereas an excellent removal of the antiepileptic drug carbamazepine can only be observed under anaerobic conditions. The whole variety of micropollutants, however, either removed or not represents approximately less than 5 % of the bulk DOC in the surface water.

The reduction of microorganisms can be found in the magnitude of several log-units contributing to a high hygienic standard of the drinking water since long.

Water treatment by RBF and SSF represents a low-cost, energy efficient and sustainable technology which can be adjusted to local conditions. Particularly long subsurface residence times and long flow distances from the recharge area to the recovery wells will foster trace organics' elimination. As a module RBF and SSF can be combined with other purification processes. By their removal potential the additional use of expensive treatment chemicals and sophisticated technical devices can be avoided.

# **A long-term river flow data as the base of the catchment groundwater resources estimates**

**Smietanski, L.**

Polish Geological Institute

## **ABSTRACT**

In the long-term the groundwater runoff from the river catchment is balanced by the recharge generating this runoff. On the other hand this groundwater runoff can be approximated by the value of the river low flow, namely the mean low flow (MLQ) estimated from the long-term river flow data. So the MLQ can be considered to be the measure of the catchment recharge. A fraction of this recharge we can call the catchment disposable groundwater resources which can be used as the water supply source provided some conditions are met.

The presentation is aimed at introducing a method to calculate the magnitude and distribution of the disposable groundwater resources in a river catchment. To calculate the distribution of the catchment recharge and distribution of the disposable groundwater resources a Constant – Volume Transformation (CVT) algorithm was applied. This allowed to create the model based link between the groundwater resources and groundwater runoff assessed from the long-term river flow data.

The method was applied to estimate the disposable groundwater resources for the Łeba river catchment (1800 km<sup>2</sup>) in the northern Poland. The presentation shows the results of these calculations.

# Post tsunami helicopter borne electromagnetics in northern Sumatra

Steuer, A., Siemon, B., Meyer, U. & Rehli, H.-J.

Federal Institute for Geosciences and Natural Resources (BGR), Germany

## ABSTRACT

The earthquake and the tsunami event on December 26th, 2004, caused the loss of life of more than 120,000 people, the missing and injuring of more than 110,000 people and the destruction of about 80% of all private houses, basic infrastructure and public facilities in the coastal region in the Province of Aceh. The tsunami waves caused large scale coastal salt-water intrusions and destroyed thousands of shallow drinking water wells.

The HELP ACEH (HELicopter Project ACEH) project between the Indonesian and German governments is dedicated to re-install the public life and to secure the future health and wealth of the people that suffered from the consequences of the catastrophe. The focal point is the water assessment in coastal areas of Aceh about nine months after the tsunami.

The aim of the project HELP ACEH of the Federal Institute for Geosciences and Natural Resources (BGR) is to assist the Directorate General for Geology and Mineral Resources (DGGMR), the National Development Planning Agency (BAPPENAS) and the Executive Agency for the Rehabilitation and Reconstruction in Aceh and Nias (BRR) in their efforts to plan and realize a sustainable reconstruction of community infrastructure (like fresh-water supply) by providing geophysical, hydrogeological, geological and topographic data that will serve as a base for spatial planning.

The main activities comprise an airborne geophysical survey along the coastal areas of Banda Aceh, Calang-Meulaboh and Sigli conducted by the airborne group of the BGR from August to November 2005. The BGR helicopter-borne geophysical system includes five-frequency (387 to 133,200 Hz) electromagnetics, magnetics and gamma-ray spectrometry. The electromagnetic system provides information about the distribution of electrical conductivity in the earth down to a maximum depth of about 150 m. Based on the inversion of HEM data into the parameters of a layered half-space, resistivity maps and sections were produced.

One important task has been the mapping of the tsunami-affected contamination of shallow groundwater resources. That could successfully be realised by calculating and displaying the resistivities at shallow depths, e. g. at 5 m bgl. EC values measured by Planète Urgence and by BGR are in sufficient agreement with the airborne data. One of the further tasks of HELP ACEH has been to outline fresh-water resources. From the resistivity maps it is evident that there are only some shallow fresh-water resources within the coastal areas of the Krueng Aceh valley. Lateral and vertical extend of this fresh-water lens on top of saline water are clearly outlined by resistivity maps and sections, respectively. Several organisations are drilling water wells in order to provide the population of Banda Aceh with potable water. BGR received many enquiries for appropriate drilling sites or, if the site had already been chosen, for information about the lithology to be expected.

# Mathematical modeling of environmental isotopes data to estimate the catchments area of drinking water supply: Case study Lake Leis (Rhine valley)

Stichler, W.<sup>1</sup>, Maloszewski, P.<sup>1</sup>, Bertleff, B.<sup>2</sup> & Watzel, R.<sup>2</sup>

<sup>1</sup> GSF-Institute of Groundwater Ecology, Ingolstädter Landstr. 1, D-85764 Neuherberg, Germany

<sup>2</sup> Geological Survey Baden-Württemberg, Albertstr. 5, D-79104 Freiburg, Germany

## ABSTRACT

Lake – ground water interactions of a dredging lakes situated in a Quarternary gravel aquifer in the Rhine Valley were studied by means of stable isotope ( $^2\text{H}$  and  $^{18}\text{O}$ ) and by mathematical modelling techniques. The isotope composition of lake water is marked by evaporation and mixing processes. As a consequence lake water portions can be detected quantitatively in down gradient wells. The presented isotope studies demonstrate that continuous water exchange takes place between the lake and ground water. Applying mathematical model based on analytical solution to the transport equation to isotope data ( $^{18}\text{O}$ ) in wells using the isotope fluctuations in the lake as input function provides solid information about hydraulic aquifer parameters. Simultaneously, the tritium data measured in the observation well in the Rein Valley were used to estimate the water infiltration rates in the area under investigation. A numerical two-dimensional ground water flow model on a regional scale was developed to a transport model to simulate lake water portions in the aquifer. The transport simulations of isotope data allow reducing uncertainty of parameter distribution in the numerical flow model. The quantification of lake water portions in the surrounding aquifer is the basis for the evaluation of possible changes in ground water quality due to lake water influx. The lake studied represents a mass sink for the investigated dissolved solids in inflowing ground water.

The application of a mathematical model to stable isotope data of lake and ground water as well as environmental tritium measurements gave further information on the values of hydraulic parameters in the investigated area. It is shown that without those data the unique calibration of the numerical model of water flow in the surrounding of the Lake Leis was not possible.

# Behaviour of residues from municipal sewage during artificial recharge and bank filtration in a partly closed urban water cycle

Taute, T.<sup>\*\*\*</sup>, Fritz, B.<sup>\*</sup>, Grünheid, S.<sup>\*\*</sup>, Massmann, G.<sup>\*\*\*</sup>,  
Duennbier, U.<sup>\*\*\*\*</sup>, Pekdeger, A.<sup>\*\*\*</sup>, Jekel, M.<sup>\*\*</sup>

\* Kompetenzzentrum Wasser Berlin gGmbH, Cicerostr. 24, 10709 Berlin, Germany

\*\* Technical University Berlin, Strasse des 17. Juni 135, 10623 Berlin (wrh@tu-berlin.de)

\*\*\*Free University of Berlin, Malteserstr. 74-100, 12249 Berlin (pekdeger@zedat.fu-berlin.de)

\*\*\*\* Berliner Wasserbetriebe, Berlin Water Company, (Uwe.Duennbier@bwb.de)

## INTRODUCTION

The 3.4 million inhabitants of metropolitan Berlin rely on drinking water originating from local groundwater. Around 70 % of the abstracted groundwater originates from induced bank filtration and artificial groundwater recharge (Pekdeger and Sommer-von Jarmerstedt, 1998). The use of bank-filtered water for drinking water supply is very important due to the limited available quantity of natural groundwater. The fresh water aquifer in Berlin is very shallow and beneath an impermeable till layer a huge salty groundwater reservoir follows. The water works has to balance very carefully their pumping regime in order to avoid salt-water intrusion into the fresh water aquifer. This is one reason for using bank filtration and artificial recharge for drinking water supply. For drinking water treatment only simple techniques (aeration and filtration) are used. No disinfection is needed.

The surface water system is influenced intensively through advanced treated wastewater from the wastewater treatment plants with an additional impairment from the sewer system. Because the local waste water (WW) treatment plants discharge treated wastewater into the surface water while the natural discharge is low, the hydrological system can be considered a semi-closed water cycle relying partly on indirect WW reuse (see Figure 1). Therefore substances which are not eliminated during the WW treatment process are of major interest concerning their influence on the drinking water quality. Such substances are for example pharmaceutically active compounds (PhAC), antibiotics and other organic trace substances. Some PhAC such as clofibric acid, diclofenac, ibuprofen, phenazone, propy-phenazone,

primidone and carbamazepine are not eliminated completely during the WW treatment process and have been detected in the surface water (Heberer, 2002b).

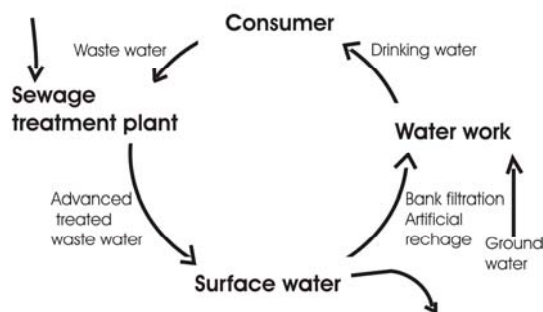


Fig. 1 Partly closed water cycle

## Methods

From November 2001 to August 2004, groundwater was sampled monthly at two bank filtration and one artificial recharge field site. The sampling was later intensified and done once or twice a week at the pond and the two sampled observation wells. Full water analysis was generally performed one day after sampling. Water levels and temperatures were recorded daily using data loggers. Anions and cations were measured by ion chromatography and atomic adsorption spectrometry, while DOC was measured photometrically. The analgesic and antipyretic pharmaceuticals and the antiepileptic drug carbamazepine were analysed among other high polar pharmaceutical residues. The determination of the PhACs was performed by the laboratory of the BWB (Berliner Wasserbetriebe) with a method based on a solid phase extraction of the analytes on RP-C18 materials using an automated extraction system (Zuehlke

et al., submitted, a). The trace organic compounds Iopromide, Sulfamethoxazole and the isomers of naphthalene-sulfonic acids were all extracted by different solid phase extractions (SPE) and measured with standard addition in high performance liquid chromatography with MS/MS- and FLD-detectors. Analysis of the organohalogens consists of coupled combustion and ion chromatography and is described in Oleksy-Frenzel et al. (2000).

## Results

Redox conditions are highly transient during artificial recharge in Berlin and depend on a number of factors out of which seasonal temperature changes and the performance of the well field are most dominant. In winter, at low temperatures, aerobic conditions prevail while in summer, O<sub>2</sub> is rapidly consumed and nitrate and manganese reduction commences. The same effect can be achieved with high water table fluctuations as a result of the well field performance. The removal of **phenazone** is not complete when anaerobic conditions are present i.e. under water-saturated conditions during summer. **AMDOPH** may be degradable under favorable conditions (i.e. when aerobic conditions prevail; temperatures are relatively high while recharge rates are low). However, this will need to be verified in the future, since other studies showed that AMDOPH behaves conservatively. **Carbamazepine** is thought to be a relatively persistent PhAC. Irrespective of the redox state, carbamazepine concentrations in the groundwater resembled those of the surface water. A removal during infiltration was not observed. Daughton (2001) points out that the fate of PhACs in groundwater is poorly understood. On the basis of current knowledge, more attention should be paid in future to the interrelation of PhACs' occurrence with the hydrochemical conditions, particularly the redox conditions, in a natural environment. A significant different removal between aerobic and anoxic/anaerobic soil passage was observed for AOX. **AOI and AOB<sub>r</sub>** were better degradable under anoxic/anaerobic conditions with removal rates of 64% and 81%, respectively. The **trace compound** Iopromide, an x-ray contrast agent achieved higher removal rates under oxic conditions. But there were strong indications that the removal was based on an aerobic metabolism and not on dehalogenation and mineralization. Sulfamethoxazole exhibited an efficient removal under anoxic/anaerobic conditions (97%). Oxic infiltration led for this compound to a reduction of 46%, which was increasing with higher retention times (2.8 month: 64%). For the isomers of the naphthalenesulfonic acid different removal efficiencies were observed. The 1,5-NSA was not degradable under all redox conditions, but the 1,7- and 2,7-NSA isomers were preferably removed aerobically.

## Conclusions

Redox conditions seems to be the most important factor for elimination of most organic trace substances as PhAC. Unfortunately, these favoured conditions differ from group to group. Any knowledge about preferential degradation conditions for problematic compounds might help to estimate the removal potential of a given field site. Within the limits the design parameters can be optimized to increase the removal of the problematic compound.

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# Groundwater – surface water interaction methods and case studies

Weise, S.

UFZ Centre for Environmental Research  
Department of Isotope Hydrology

## ABSTRACT

Interaction between groundwater and surface water such as rivers, lakes, and the sea, commonly affects issues e.g. of protection of water availability and quality and remediation techniques. Processes such as salinisation of sea-near groundwater reservoirs and penetration of anthropogenically polluted groundwater into surface water (or vice versa) have to be managed, and many methods are developed to parameterise them. With special focus on lake-groundwater interaction, a set of these methods will be presented that offers the analysis of interaction parameters at very different scales in space and time. At the micro scale the spectrum starts with biochemical sensors applied *in situ* by landers and ends at the regional scale with methods basing on environmental isotopes. The lakes presented as case studies result from gravel and lignite production, respectively.

# Mine water and the European Water Framework Directive

Wolkersdorfer, Ch.

TU Bergakademie Freiberg Lehrstuhl für Hydrogeologie  
Gustav-Zeuner-Str. 12; D-09596 Freiberg/Sachsen  
E-Mail: <mailto:c.wolke@tu-freiberg.de> -

## ABSTRACT

The European “Water Framework Directive” meant a significant change in the administration of many water catchment areas. That change also affected the administration of mine water discharges and in consequence the necessary measures of mine operators or regulatory authorities to manage those discharges. Due to the differences in the water and especially mine water legislation in the European countries the EU FW6 project ERMITE (Environmental Regulation of Mine Waters in the European Union) investigated those differences by addressing the many facets of Nations and disciplines involved.