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Combination of MAR and Adjusted Conventional Treatment Processes for an Integrated Water Resources Management

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Investigation of RBF potential in developing and newly industrializing countries: Lessons learnt from the Delhi case studies

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PREFACE

This report summarizes experiences from the TECHNEAU studies on Riverbank Filtration (RBF) for Managed Aquifer Recharge (MAR) in India. The aim of the report is, to provide information for other RBF projects, especially for the investigation of sites and the development of facilities in developing and newly industrialized countries.

The region of the Indian National Territory, had been chosen to perform exemplary studies on three field sites that provide a huge variety of environmental conditions. Geographical settings (alluvial sediments and a perennial river) seemed appropriate for inducing infiltration of surface water into the aquifer with appropriate RBF wells. Water scarcity, environmental pollution and increasing water demand in the area make it necessary to find new solutions for an integrated water resources management.

Previous TECHNEAU reports give detailed prescriptions of the study area and the setup and investigation of the field sites (D 5.2.1) and the results from the sampling campaigns for inorganic substances and physicochemical parameters (D 5.2.2) as well as microbial pathogens and organic trace compounds (D 5.2.6). A modelling tool for the simulation of RBF systems is described in D 5.2.5 and the vulnerability of bank filtration systems to climate change is discussed in D 5.2.3. Research papers about the potential for Riverbank Filtration in Delhi (Lorenzen et al., accepted on 04.01.2010) and about a multi tracer approach for the numerical quantification of surface-/groundwater interactions in central Delh (Sprenger et al., in review) have been submitted for publication to international scientific journals. Data analysis and preparation for further publications is in progress.

In a first step this report gives recommendations for the project preparation and management. The second part includes an overview on strategies and methods for the installation of field sites and their investigation and for the monitoring of relevant parameters. Examples from the experiences during the studies in Delhi demonstrate conditions and potential challenges in the context of the international cooperation project work.

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1. Introduction

According to the United Nations Human Development Report 2006 clean water and sanitation are today amongst the most powerful drivers for human development. Meanwhile water scarcity is increasing on a global scale. The lack of safe water threatens life, destroys livelihoods and causes conflicts on a devastating scale. Although shortages of water are obvious in many regions and the demand is rising, along with population growth, industrialisation and wealth, there is a growing recognition that inequalities and flawed water management policies exacerbate the scarcity (UNDP 2006).

The basic concept of the TECHNEAU project is to approach towards a "technology enabled universal access to safe water" by promoting research and development activities. Work package 5.2 aims to foster the international development of bank filtration as a managed aquifer recharge strategy with a main a focus on the situation in Delhi, India. Investigations have exemplified, that this low tech method has a high potential not only in Northern India but also in other developing and newly industrialising countries. Consequently, it is highly relevant to foster bank filtration and other MAR techniques internationally, with innovative projects accompanied by research, demonstration and training activities (Dillon 2005). For the planning of bank filtration facilities, however, hydrological and hydrogeological variables and controls must be investigated in detail, so field tests are irreplaceable and should be accompanied with laboratory investigations and model calculations (László & Literathy 2002, Hoehn 2002). The associated work requires not only a good understanding of the hydro(geo)logical processes and a broad knowledge of research methods but also a well organised management of the activities, a good infrastructure and a fruitful communication with project partners, end users, local authorities and other stakeholders.

The aim of this report is to summarize the experiences from the work in India and give a brief overview on crucial aspects that can be useful as an orientation for planning similar projects.

2. Project Preparation

The first steps for a project aiming for the implementation of managed aquifer recharge (i.e. RBF) should be to (i) built up a network with project partners, local authorities and end users, and other stakeholders, (ii) procure crucial information about the study area and (iii) work out a target-oriented strategy. The success of the project will not only depend on the environmental conditions but also on the capacities of all involved partners and a professional management.

In this chapter, minimum requirerements for a RBF site are specified and recommendations are given for the organisation of an international (research) project with the above mentioned target.

2.1. Definition of the study area: Minimum requirements for a RBF field site

RBF is a low-tech methods, that benefits from physical, chemical and biological processes in the environment. It can only be implemented successfully, if certain environmental conditions are given. It is therefore important to first invest in procuring and evaluating decisive information about the study area. Based on this a suitable site can be selected and research strategy can be developed before building up a field site and starting field tests. Possible sources of information are listed in Table 1, with a special focus on India.

Table 1: Sources of information for a first evaluation of a study area with reference to its suitability for the implementation of an RBF system.

Type of source	Recommended for information on	Examples and links (main focus on India)
TECHNEAU reports	- Bank Filtration, focus on semiarid and arid regions and developing and newly industrialized countries	TECHNEAU WP 5.2 reports (www.techneau.org)
Scientifical Publications	- all aspects	Via science search engines (http://apps.isiknowledge.com, http://scholar.google.de/)
Non-governmental Organizations (NGOs)	- Water resources management - Environmental problems	- Centre for Science and Environment (CSE): www.cseindia.org/
National or local public authorities	- Local environmental conditions (survey information and historical data, i.e. on geology, climate, water resources, land use) - Water resources management	-Central Groundwater Board of India (http://cgwb.gov.in/) - Indian Ministry of Water resources (http://wrmin.nic.in/) - Delhi Water Board (www.delhijalboard.nic.in)
Online providers of digital maps	- digital maps - satellite images - digital elevation models and GIS files	- www.geocomm.com/ - http://csi.cgiar.org - www.mapmyindia.com/
Libraries and local book shops	- local maps - textbooks, yearbooks, etc. with reference to the local situation	- i.e. www.jainbookdepot.com (New Delhi)
Others	- General information on Managed Aquifer recharge (MAR) and Riverbank Filtration (RBF)	- http://www.iah.org/recharge/ - http://www.bankfiltration.org/

Example: In India, national topographic maps have been elaborated by the Survey of India (SoI) but with a scale above 1:1000000 they are usually restricted for public sale. Even the purchase or export of geoscientific thematic maps on a scale of 1:25000 is prohibited, especially to foreigners. However, other sources od spatial information could be found, like high resolution satellite images, digital elevation models, US Army topographical maps (1955, TK India 250k) or detailed city maps of Delhi region (IMS0165-Eicher Delhi City Map). These and other sources were used to built up a Geographical Information System (GIS), which made the restricted SoI maps dispensable.

Available information like those mentioned in Table 1 can be used to pre-evaluate the feasibility of a site for RBF. Critical criteria concerning the quantity and quality of the source water the river/lake-sediment interface and the adjacent aquifer are listed in chapter 3. They should be taken into account for the selection of a RBF site.

2.2. Challenges of international projects

Cross cultural cooperation

In every major project, a professional management, good teamwork and constructive cooperation between all involved institutions is a key to success. All this depends a lot on a good communication between partners. This is an often underestimated but crucial aspect that requires much regard, especially in cross cultural projects when social and cultural standards diverge. Challenges begin, when individuals from different organizations, countries and value systems must share authority, responsibility, and decision-making (Shore & Cross 2004).

> *EXAMPLE: If two people from India and Germany work together, in a certain situation they may both behave 'normal' as a Indian or German would behave. When German `normality` deviates from what is considered `normal` in India, misinterpretations are likely to arise and may lead to all kinds of difficulties (Peringer 2006).*

Collaborative projects extending across national boundaries therefore introduce their own set of project management challenges (Shore & Cross 2004). Cross-cultural training, information about the other culture and simply the awareness of these dissimilarities between norms and values may help to develop cultural empathy and diplomatic skills to minimize these kinds of problems. For the German-Indian context for instance, Peringer (2006) explains cultural differences and explains "background, behaviour and practical guidelines for an assignment in India" from a European point of view. For international engagement in technical cooperation projects, useful guidelines for project preparation and management have been published by the GTZ (2004) or the European Commission (2009).

This aspects should however not detain from building international and cross cultural networks. It is very important to choose competent partners, define responabilities very clearly and not to underestimate the impact of cultural standards. Management may be challenging, but cooperation is the only way for successful international engagement and if it is based on mutual respect and a professional management, all available resources can be exploited for mutual benefit.

National rules and regulations

Another aspect, that should not be underestimated are additional organisational and bureaucratic work and efforts in intercontinental projects. For an effective project preparation, the following recommendations can be given:

Contacts: → Relying on existing networks or partnerships can help to establish contacts or evade bureaucratic hurdles. Official contacts exist for example between many European and Asian universities and other research institutes, or governmental agencies. A letter of intent or memorandum of understanding can be useful for instance to arrange funding, to get a Visa or working permission or importing/exporting equipment or samples.

Equipment: → If possible, local infrastructure, equipment and techniques should be used. Local partner can help to purchase or organise the instrumentation, local staff or sub contractors are skilled to handle them, spare parts can be found easily and alternative methods can be used without much effort or delay. If special equipment has to be imported, or samples have to be exported for analysis, it may result time consuming and costly.

EXAMPLE: In TECHNEAU work package 7.9, frozen water samples from India had to be sent to Europe for some highly sophisticated analysis. Several international courier services were asked for the shipping prices, rules and regulations and all of them confirmed, that no special permission would be necessary. The Indian branches of the same companies, however demanded special documents (material safety data sheet, laboratory report) before accepting the samples for shipment. Procuration of the documents implicated extra time and costs.

Rules and regulations → In other continents, rules and regulations can be very different from those in Europe. Project staff should be well informed and respect local regulations. In India for instance, the trespassing or photographing of some areas, or the purchase and export of some maps is restricted to foreigners (see above).

3. Feasibility study for potential RBF sites

After checking the minimum requirements for the potential new RBF site, it is recommended to carry out a feasibility study. The feasibility study includes investigations on source water quantity/quality, sediment properties, hydraulics and logistical aspects.

3.1. Source water quality/quantity

RBF water is always is mixture between different water sources. Within a feasibility study it is therefore necessary to know the chemical properties of the source waters: (i) surface water and (ii) the ambient groundwater. Moreover, ambient groundwater can differ significantly with depth. It is not unlikely that shallow groundwater carries contaminants derived from anthropogenic sources such as pesticides or pathogens. Whereas deep groundwater may carry geogenic contaminants such as Fluoride. In order to understand the chemical processes during the underground passage, it is necessary to know all participating water end-members.

The investigations in the Delhi have shown, that water quality parameters, especially in the surface water, can be subject to significant short-term fluctuations. Therefore, representative samples can be obtained by taking multiple samples, mixing them in equal proportions and analyzing the mixed sample. For instance, a sample for a specific day could be obtained by compositing samples of the previous and subsequent days as well. If short term fluctuations are expected, mixing samples from the morning, noon and evening would be more representative, than a single sample.

Surface water availability

The surface water (river, canal or lake) must have enough discharge or storage and the bottom sediment must be sufficiently permeable to allow the desired infiltration rates. The quantity of infiltration water must be of a certain magnitude to justify the cost and efforts for the installation, operation and maintenance of the bank filtration facilities. On the other hand, the seepage losses should not endanger the ecosystem stability or provoke conflicts with other stakeholders (i.e. neighbouring states).

Example: At the Najafgarh Drain field site in southwest Delhi, the discharge of the local drain is almost neglectable during the dry season. Consequently, RBF is only an option in monsoon and early post monsoon season, so it has to be assessed, whether the investment for RBF facilities is worth in the water scarce area, even though the wells would be operated only for some months a year.

Water suppliers have to satisfy a permanent demand and many of them have to cope with seasonal peaks, usually in warm and dry periods. Bank filtration systems have a certain buffer capacity and can compensate short term shortages in infiltration rates better than water supply facilities that extract the source water directly from a river or lake. Low water levels or dried up surface water bodies will, however, lead to a decrease in bank filtration share and simultaneously amplify the drawdown in groundwater. Fluctuations of water level and flow rate in a stream will also have an impact on the sedimentation-erosion dynamics of the channel. On the one hand, this may prevent the formation of riverbed clogging. On the other hand, erosion dynamics may be a risk to the riverbank stability.

The channel stability is another important aspect: Management of bank filtration systems at rivers that may shift their stream bed from year to year is for instance difficult to control. The distance from the well to the surface water is one of the controlling factors for the hydraulics of a bank filtration system. When the river channel migrates away from a well, the bank filtration share will decrease. Migration of a river towards a well, in contrast, may be a risk when decreased travel times reduce the attenuation capacity of the aquifer. In the worst case, it may even erode or flood the riverbank and damage or destroy the RBF well or other facilities. River dynamics at RBF sites in different geomorphological and geological environments are discussed in detail by Grischek & Ray 2009.

Example: Although the discharge of the River Yamuna is highly influenced by watershed management, there are pronounced seasonal differences. Heavy rainfall events during monsoon season regularly lead to flooding and migration of the riverbed. At the Palla field site, the existing well stations of the local water supplier are built upon columns, 2-5 meters above the ground, to protect them from flood events. However, at the field site the Yamuna regularly erodes parts of the scarp to the upper river terrace, where the wells are situated (at the field site, around 1 meter was eroded between 2007 and 2008). The supplier has to invest for measures like building protection damns or digging out existing channels to control riverbed migration, but still faces the risk of loosing wells during extreme events.

Surface water quality

One of the major benefits of RBF is the attenuation of many contaminants from the surface water during subsurface passage (i.e. Ray et al. [edts] 2002, Hiscock & Grischeck 2001). The removal of pathogens, for instance, is very effective, as well as the removal of algae toxins and many organic trace contaminants (compare Sprenger at al. 2008). Apart from this, other substances may occur that can seriously detoriate the quality of the pumped water so that further treatment is indispensable. Contaminants may not only arise from the surface water source (i.e. ammonia), but also be mobilised from the aquifer matrix during infiltration and aquifer passage (i.e. iron, manganese, arsenic) or originate from the ambient groundwater that mixes with the bank filtrate (i.e. dissolved salts). The existence and behaviour of these substances depends very much on site specific conditions (Lorenzen et al. 2008).

> *Example: At the Nizamuddin Bridge field site in central Delhi, highly degraded river water infiltrates into the aquifer. It leads to the dissolution of manganese, iron and arsenic from the aquifer matrix, but these substances could be treated with relatively low efforts. Much more critical are high contents of nitrogen species, mostly originating from untreated sewage. At RBF sites in Europe, where the surface water contains dissolved oxygen, nitrate is the dominant nitrogen species. During infiltration at RBF sites, it can get attenuated by natural denitrification in the anoxic aquifer. In central Delhi, in contrast, the Yamuna river water is already anoxic, so instead of nitrogen, ammonia is the dominant species. Consequently, there is no attenuation of total nitrogen it by denitrification at the anoxic river stretches (Lorenzen et al. accepted on 06.01.2010).*

In many cases, source water quality can roughly be pre-evaluated by studying the available sources (Table 1) or visiting a site. National geological surveys, water suppliers or local farmers, for instance often know about the occurrence of saline groundwater. Anoxic river sections with high loads of ammonia from untreated sewage will attract attention because of their smell, dirty appearance and breakdown of the ecosystem. Other contaminants, however, are more difficult to identify and have to be identified and monitored through field and laboratory investigations.

> *Example: Reports on the contamination status of the River Yamuna in Delhi have been published by governmental institutions (CPCB 2006), NGOs (CSE 2007) and research institutes (Zafar & Alappat 2004). Fluoride in groundwater has also been described as a common problem in Delhi (Datta et al. 1996, CGWB 2006), but arsenic has not yet been reported from wells in central Delhi. Samples from the Nizamuddin Bridge field site analysed during the TECHNEAU project , however, had shown that increased arsenic is a problem there, with concentrations clearly above the permissible limits in many wells (Lorenzen et al. 2008).*

Whether or not RBF is an appropriate solution, when further treatment is still necessary has to be clarified for each individual site in a cost benefit analysis.

Groundwater quality/quantity

Being located in the subsurface, groundwater is better protected from contamination than surface water and less prone to evaporation or warming. Nonetheless, groundwater contaminants may derive from numerous sources such as agriculture (e.g. nitrate, pesticides), landfills, industrial legacies, septic tanks (e.g. ammonia, pathogens, micropollutants) and damaged sewage system in urban areas. They can also be of geogenic (e.g. arsenic, fluoride) or marine origin (e.g. salinity).

Example: In the Najafgarh area in West Delhi, groundwater is often brackish or even saline. Water from a bank filtration well at the Najafgarh field site would therefore have increased salinity, because it would consist in a mixture of bank filtrated surface water and ambient groundwater. None the less, forcing surface water to infiltrate into the aquifer could make sense, because it would at least dilute the salt content in the groundwater and be free of some contaminants which are still present in the surface water (i.e. pathogens, turbidity). Although the water from RBF wells may still have a salty taste, it could be useful, depending on mixing proportions and further use (i.e. for desalinisation or irrigation).

The issue of groundwater contamination by pathogens is a more serious problem in cities of developing countries (Sprenger et al. 2008) where, generally, there are many densely populated and unsewered areas. Moreover, the sewage treatment plants in these countries are often ill-maintained or operating on low capacity (DWSSP 2004). Consequently, the untreated waste water is disposed in open drains or rivers and, as observed in Delhi, may infiltrate into the aquifer due to an over exploration of groundwater. In some cities, septic tanks and pit latrines are the only way to dispose sewage while groundwater is the main water drinking source. As a result, the worst contaminated groundwater in these cities is commonly found located in unconfined or semi-confined shallow aquifers.

Tracers

For the quantification of the interaction between physical (flow, transport) and geochemical (reactive) processes it is necessary to know the proportion of bankfiltrate in the abstraction water. Numerical models are often used to "understand" geochemical reactions or to describe the hydraulic conditions of the site. For the calibration of these models suitable tracer substances have to be found. A suitable tracer can be a substance which is conservative in its chemical behaviour (or at least predictable), occurs in concentrations well above the detection limit and is easy and cheap to measure. Possible trace substances are listed in Table 2. A clear seasonal signal of the tracer in the surface water makes it possible to observe the shifted and attenuated signal in the bankfiltrate. The knowledge about the behaviour of the potential tracer substance in surface water and groundwater throughout several seasons and the integration of the data is essential for a basic system understanding. Using tracer subbstances is often the only reliable way to calculate parameters like bank filtration share or travel time.

Table 2: Tracer substances and their application at RBF sites

Tracer:	Origin:	Useful for the interpretation of:	Difficulties:
stable isotopes (e.g. XXX)	surface water with seasonal variations	flow velocities, proportion of bankfiltrate, origin	water rock interactions
temperature	surface water with seasonal variations	flow velocities	retardation
Cl-	surface water with seasonal variations	flow velocities, proportion of bankfiltrate	only if influence of deep saline groundwater and anthropogenic impacts can be excluded
Cl-, Na+, B	saline deep aquifer	proportion of deep saline groundwater	determination of end-member

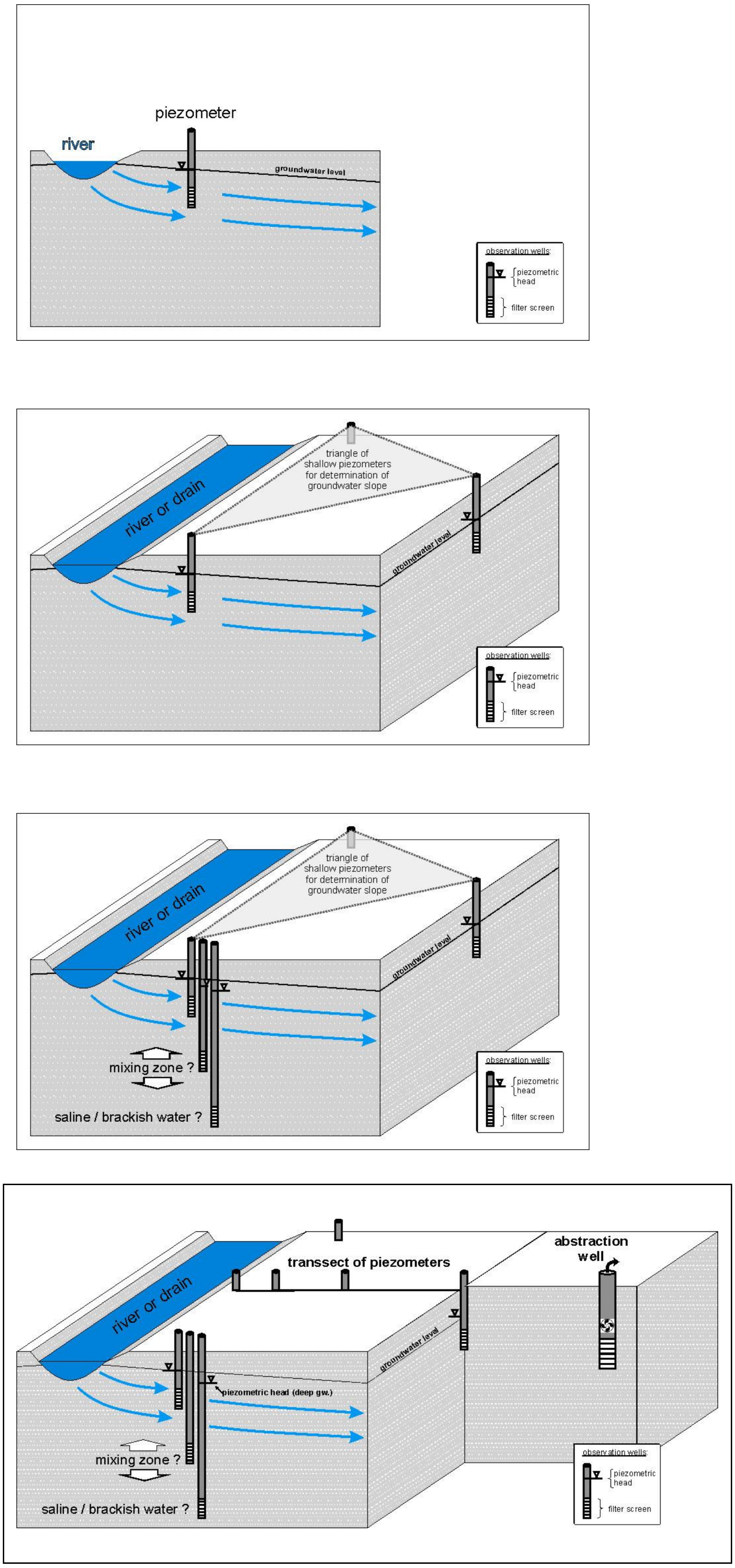
modified after: MASSMANN et. al. 2004

3.2. Setup and protection of RBF observation wells

For a more detailed investigation of the RBF site it is recommended to install a few observation wells. The optimal design depends on the local conditions, but setup shown in Figure 1 is suitable for many hydrogeological situations (e.g. up-coning of salt water, vertical and horizontal aquifer heterogeneities, tracer tests).

Example: Not only in India, but also in Germany the protection of observation wells against vandalism or thievery is a challenge, and there is no universal solution. A metal pipe with a lock will attract people since it appears to be valuable somehow. Indeed, the steel casing itself is valuable in countries where many people live in poverty. Therefore, we tried to protect our observation wells against thievery by using a heavy concrete base. This made it impossible to pull out the steel casing manually, but with enough manpower or even elephant power… . No Problem!

An alternative to the installation of steel casings for observation wells above the surface can be a observation well-head below ground level. This is only possible in areas without any agricultural activity, but has the advantage that nobody is attracted by the valuable steel or wants to satisfy their curiosity by dropping stones or rubbish into the observation well. The disadvantage is clearly that its hard to retrieve after a while.



(A) One observation well close to the surface water can be used to determine the hydraulic gradient (gaining river / loosing river). Groundwater can be sampled to get an impression of water chemistry or it can be used for tracer tests.

(B) A triangle of shallow piezometers will allow to determine the inclination of the groundwater surface. Several samples can be taken, to identify the scattering of different parameters or to estimate attenuation of contaminants during RBF with increasing distance and travel time.

(C) At least at one multi level monitoring point should be available, for being able to determine the vertical hydraulic gradient. It also allows to test whether the water properties change with depth. This is a crucial aspect in areas affected by groundwater salinity.

(D) Adding an abstraction well allows to investigate RBF under realistic operation conditions in real time. It can be further used for pumping tests. A transect of shallow observation wells between the river and the well can be used to investigate water quality changes during RBF, i.e. due to natural attenuation in the aquifer.

Figure 1: Exemplary design for the setup of a field site for investigations of RBF processes. For a first test, one shallow well can provide a lot of useful information (A). Developing a site with additional wells (B–D) will amplify the possibilities for groundwater monitoring and increase the accuracy of the investigation.

Hiding a data logger to protect it from unauthorised persons

Pressure-temperature–loggers are useful but relatively expensive tools for groundwater monitoring. Usually, they are hung on a wire rope which is fixed at the top of the well pipe. Groundwater observation wells can be equipped with a cap and a lock, but even with simple tools these locks can be removed violently. Consequently, the risk of the removal of a locker by unauthorised persons for different motives (curiosity, vandalism, theft) is high and leads to the loss of hardware and valuable data.

> *Example: For the investigations in Delhi, three field sites with at least five observation wells were built up. The PVC pipes were protected by a metal casing, and locker systems were installed (welded cap with a padlock). At the most remote site, all locks were broken and the metal caps were stolen after only one month, at another site the same happened within one year.*

To avoid this, a simple solution has been invented by FUB within the TECHNEAU Project, to hide lockers within the well and make them difficult to access without the knowledge of the method. The assembly is shown in Figure 2 and the installation is described in the following:

(1) The data-logger is fixed on the top of a short stick or pipe with a diameter much less than the well piping (i.e. 1m of a 1`` PVC pipe). The loggers are designed to be used hanging vertically in the water column.

(2) The stick with the programmed logger is fixed with a string and descended to the bottom of the observation well. The string should be sufficiently thick, semi-rigid and non-twisted, to avoid the formation of loops and knots.

(3) The string is cut above the top of the pipe and fixed to a small plastics bottle with a magnet inside. The bottle must be water proof, small enough to easily enter the piezometer, and contain enough air to keep floating on water. The magnet must be strong enough to lift the bottle with the string (neodymium magnets are recommended).

(4) The bottle is thrown into the piezometer, where it floats on the water surface and does not call the attention of unauthorised persons. Depending on the depth to water, it can hardly be seen and is difficult to remove without proper equipment. For it’s removal, another magnet can be used, which can be stored in a similar bottle, fixed to another string.

The method is recommended especially for shallow observation wells, with a non magnetic piping. The water level (depth to water) should always remain more than one arm length below the top of the pipe. A more detailed description of accessoires, setup instructions, limitations of the method and exemplary field data from the TECHNEAU bank filtration sites in Delhi was pulished by Lorenzen et al. (2010).

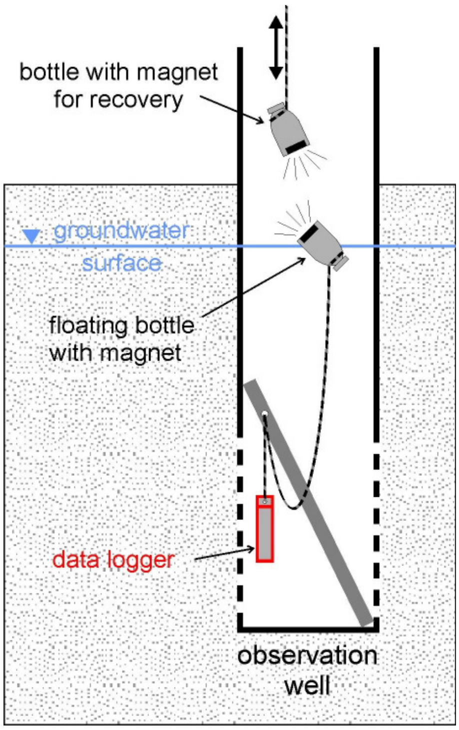


Figure 2: Secure installation of a pressure-temperature-logger in a shallow observation well [modified, from Lorenzen et al. 2010]. The logger is attached to a stick which is subdued to the bottom of the well. It is connected with a string to a bottle with a magnet inside. The bottle is hidden, floating on the water surface inside the piezometer and protected from unauthorised persons. A second bottle with a magnet can be used to lift the floating bottle and subsequently pull up the logger.

The method was invented within the studies for the TECHNEAU Project by Freie Universität Berlin (AB Hydrogeologie, G. Lorenzen) and successfully applied for monitoring shallow observation wells in Delhi.

3.3. Sediment analysis

During the feasibility study, it is strongly recommended to collect sediment samples of the aquifer. A simple but useful method is determination of the hydraulic conductivity by grain size analysis (Figure 3). Sieving and wet sieving of the grain size fraction < 0.063 mm is a straight forward method. Additional sediment analysis of fraction of organic carbon, cation exchange capacity or grain lithology are also recommended. For special aspects e.g. fate of arsenic during RBF it is useful to carry out sequential extraction, or sediment digestion with different solvents (e.g. aqua regia).

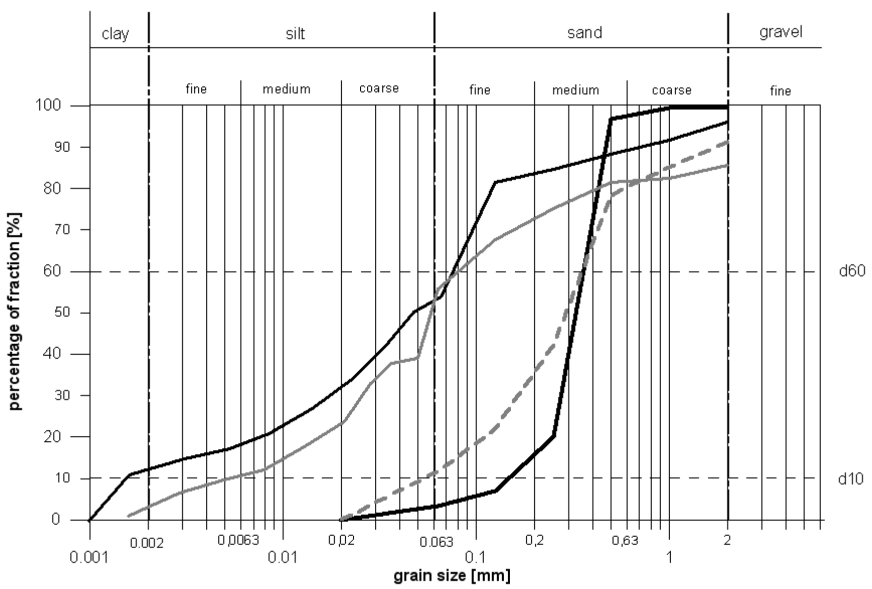


Figure 3: Grain size distribution of different samples from RBF sites in Delhi

4. Conclusions

- Projects for the development on RBF in developing and newly industrialized countries are very useful. If local conditions are suitable, the implementation of RBF facilities for managed aquifer recharge can help to progress towards a sustainable water resources management.
- Delhi is a dynamic Mega City, with a complex structure of municipal/national authority and bureaucracy. Hence, it cannot be expected that scientific outcomes of a research project get directly integrated into management practice. None the less, new insights are valuable and should be promoted, so that their thought-provoking impulse can stimulate changes in the long term.
- Knowledge of the local conditions in terms of good understanding of the socioeconimical and cultural background is as important as the technical expertise.
- A precise and comprehensive feasibility study under consideration of all technical aspects is essential, since only one mismatching parameter (e.g. high Ammonium, strong riverbed clogging) may impair RBF or even make it impossible.
- Patience, tolerance, diplomatic skills and cultural empathy are not neglectable in international cooperation projects.

We hope that the experiences gained from the TECHNEAU project in India, compiled in this report, may help for the planning of similar projects and to avoid unnecessary constraints.

References

CGWB (2006) Ground Water Year Book 2005-2006, National Capital Territory, Delhi. Central Ground Water Board, Gov. of India. New Delhi.

CPCB (2006): River quality status of river Yamuna (1999-2005). Central Pollution Control Board, Gov. of India. New Delhi.

CSE (2007): Sewage Canal - How to clean up the Yamuna. Centre for Science and Environment. New Delhi.

Datta , P.S., Deb, D.L. and Tyagi, S.K. (1996b) Stable isotope (180) investigations on the processes controlling fluoride contamination of groundwater. Journal of Contam Hydrol 24:85-96

Dillon, P. (2005) Future management of aquifer recharge. Hydrogeol Journal 13:313–316

DWSSP (2004) Delhi Water Supply and Sewerage Project. Project Preparation Study. Social Assessment Report submitted by Pricewaterhousecoopers in association with DHV Consultants, The Netherlands and TCE Consulting Engineers Ltd.

European Commission [Edt] (2009) Making Technical Cooperation More Effective. 156pp. Office for Official Publications of the European Communities, Luxembourg.

GTZ [Edt] (2004) Guidelines on the Preparation of TZ Projects and Programmes. Deutsche Gesellschaft für Technische Zusammenarbeit GmbH. Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung. Bonn.

Hiscock, K.M. and Grischek T (2001) Attenuation of groundwater pollution by bank filtration. J Hydrol 266:139-144.

Grischek, T. and Ray, C. (2009) Bank filtration as managed surface – groundwater

Interaction. International Journal of Water 5(2): 125 – 139.

Hoehn, E. (2002) Hydrogeological issues of riverbank filtration - a review. In: Ray C (ed) Riverbank filtration: understanding contaminant biogeochemistry and pathogen removal, Kluwer, Dordrecht

Ray, C., Melin, G. and Linsky, R.B. (eds) (2002) Riverbank Filtration: Improving source-water quality, Water Science and Technology Library 34. Kluwer, Dordrecht.

László, F. and Literathy, P. (2002) Laboratory and field studies of pollutant removal. In: Ray, C (ed) Riverbank filtration: understanding contaminant biogeochemistry and pathogen removal, Kluwer, Dordrecht.

Lorenzen, G., Sprenger, C. and Pekdeger, A. (2008) Preliminary report on data of all inorganic substances and physicochemical parameters listed in the Indian and German Drinking Water Standards from surface water and groundwater at the 3 (+1) field sites. TECHNEAU Integrated Project D 5.2.2. European Commission.

Lorenzen, G., Sprenger, C. and Pekdeger, A. (2010) A Simple Method to Hide Data Loggers Safely in Observation Wells. Ground Water: no. doi: 10.1111/j.1745-6584.2010.00771.x

Massmann G., Knappe A., Richter R., Pekdeger A. (2004) Investigating the Influence of Treated Sewage on Groundwater and Surface Water Using Wastewater Indicators in Berlin, Germany. Acta hydrochimica et hydrobiologica 32 (4-5): 336-350

Massmann G, Sültenfuß J, Dünnbier U, Knappe A, Taute T, Pekdeger A (2007) Investigation of groundwater residence times during bank filtration in Berlin: a multi-tracer approach. Hydrol Process 22: 788-801

Peringer, C. (2006) Cultural Differences between Germany and India – Background, behaviour and practical guidelines for an assignment in India. 132p. VDM, Saarbrücken.

Shore, B. and Cross, B. (2004) Exploring the role of national culture in the management of largescale international science projects. International Journal of Project Management 23 (2005) 55–64.

Sprenger, C., Lorenzen, G. and Pekdeger, A. (2008) Occurrence and fate of microbial pathogens and organic trace compounds at riverbank filtration sites in Delhi, India. TECHNEAU Integrated Project D 5.2.6. European Commission.

UNDP (2006) Beyond scarcity: Power, poverty and the global water crisis. Human Development Report 2006. United Nations Development Programme.

Zafar, M. and Alappat, B.J. (2004): Environmental mapping of water quality of the River Yamuna in Delhi with landfill locations. Manag of Environ Qual: 15(6): 608-621.