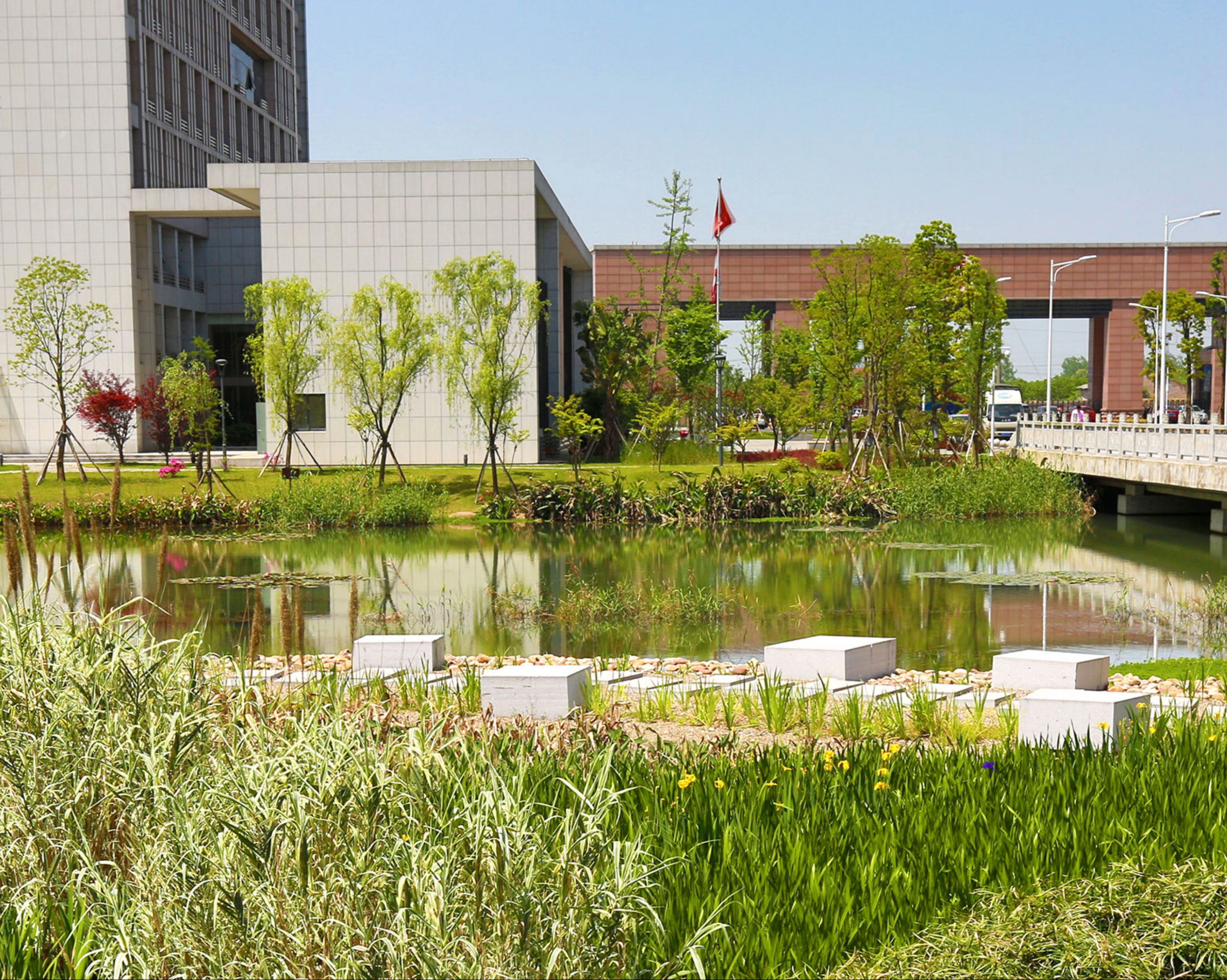

EVENT REPORT

Open Space Workshop | Hannover, June 19, 2019

Innovative ideas for boosting nature-based solutions for climate change adaptation

GRIPP GROUNDWATER SOLUTIONS INITIATIVE FOR POLICY AND PRACTICE

IWMI International Water Management Institute

BGR Bundesanstalt für Geowissenschaften und Rohstoffe GEOZENTRUM HANNOVER

itwh

TECHNISCHE UNIVERSITÄT DRESDEN

EVENT REPORT

Open Space Workshop

Innovative ideas for boosting nature-based solutions for climate change adaptation

10th Water Research Horizon Conference
Geozentrum Hannover, Germany
June 18-19, 2019

Moderator:
Dr. Catalin Stefan, Head of Research Group INOWAS, Technische Universität Dresden, Germany

Invited Speakers:
Dr. Lothar Fuchs[1], Dr. Karen G. Villholth[2], Dr. Maike Gröschke[3], M.Sc. Jana Glass[4]

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About this report

This document contains the report of the Open Space Workshop entitled "Innovative ideas for boosting nature-based solutions for climate change adaptation" organized during the Water Research Horizon Conference on "Water Security and Food Security" (WRHC2019) in Hannover, Germany, June 18-19, 2019.

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Photo cover

Nature-based solutions in Changde, China (Photo: Lothar Fuchs, itwh)

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(with contributions from invited speakers and workshop participants)

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Dresden, July 2019

CONTENT

Executive summary

Setting the stage

Nature-based solutions (NBS) have always contributed to the improved management of water resources. In the recent years, NBS received significant attention, culminating with the representation in the UN World Water Development Report 2018. Nevertheless, the total investment in NBS is still very low despite the obvious, proven benefits for climate change adaptation and mitigation. One of the reasons is the little understanding of the social, economic and environmental co-benefits and of the associated risks.

Strategic goals

To address these issues, an Open Space Workshop entitled "Innovative ideas boosting nature-based solutions for climate change adaptation" was organized within the premises of the 10th Water Research Horizon Conference on "Water Security and Food Security", which took place on 18-19 June 2019 at the Geozentrum Hannover, Germany. The conference was jointly organized by the Water Science Alliance e.V. (www.watersciencealliance.org) and the German Federal Institute for Geosciences and Natural Resources – BGR (www.bgr.bund.de).

Attended by 24 participants from academic and non-academic institutions from Germany and abroad, the workshop aimed to provide a platform for discussion and synthesis of ideas for boosting the use of nature-based solutions for water security and food security in the international context.

Workshop agenda

The workshop started with an **introduction** by Dr. Catalin Stefan from the Technische Universität Dresden who welcomed the participants and introduced the objectives and the agenda of the workshop. Dr. Stefan emphasized three key goals that summarize actual societal challenges and represented the thematic focus of the workshop: providing sufficient water quantity, enabling safe water quality and increasing the water value.

These objectives were addressed by four impulse **presentations** with examples from international practices collected at the interfaces between different components of the hydrological cycle: stormwater, groundwater, drinking water, and wastewater. The talks concentrated on three topics: a) enhancing the retention and subsurface storage of water, b) enabling effective nature-based water treatment, and c) enhancing and diversifying the environmental services and co-benefits of nature-based solutions.

The lessons learned (positive and negative) were discussed in an **interactive session**, with emphasis on the aspects related to the transition from linear to circular management of water resources. The active discussion revealed knowledge gaps and uncertainties in the long-term application of NBS for sustainable development.

Part 1 | Flash presentations

After the short introduction, the workshop continued with four impulse presentations given by invited guests from different countries. The aim of the talks was to initiate the discussion with the participants through examples of projects from various socio-economic contexts and under different implementation stages.
The session included the following talks:

Dr. LOTHAR FUCHS | Institute for Technical and Scientific Hydrology, Ltd. (itwh)
'Sponge Cities' in China – lessons learned for land-use planning and stormwater management practices

Dr. KAREN G. VILLHOLTH | International Water Management Institute (IWMI)
Groundwater-based natural infrastructure - a missing component of nature-based solutions

Dr. SARA VASSOLO | Federal Institute for Geosciences and Natural Resources (BGR)
Nature-based MAR solutions: Options for improving urban drinking water supply, example N'Djamena, Chad

Dr. CATALIN STEFAN | Technische Universität Dresden (TUD)
SMART-Control: smart framework for real-time monitoring and control of subsurface processes in managed aquifer recharge applications

‘Sponge Cities’ in China – lessons learned for land-use planning and stormwater management practices

The first impulse talk of the workshop given by Dr. Lothar Fuchs concentrated on “Sponge Cities” and best practices on land-use planning and stormwater management. Sponge cities are usually those cities that are equipped with the capability of integrating urban water management into the urban planning design. Their main characteristics are the ability to collect, retain and treat excess rainwater.

In 2013, the Chinese Government promoted the widespread of this concept in China with the main original goal to retain a significant share of precipitation (60-90%, depending on the region). In October 2014, the first Construction Guidelines for the implementation of the Sponge Cities in China were released, followed by the approval of a significant funding pipeline. One of the cities that qualified for this program is Changde, located in the south-eastern part of China. Changde can be described as a typical medium-size city in China with mean annual temperature of 17 °C and mean annual precipitation of 1,400 mm. Similar to most urban agglomerations in China, the city suffered from rapid urbanization in the past decade, which attracted significant pressure on the local water system: high ratio of impervious areas, high fragmentation without interconnections and water exchange, lots of concrete and no natural sources, rainwater inflow into the mostly open sewage water channels, many pumping stations for the drainage system (low terrain gradient) and severe domestic and industrial pollution.

As a consequence, the city required a step-by-step approach for the implementation of integrated rainwater management. After the division of the city into three main rings, the first step included the planning of decentralized solutions in the inner city, followed by centralized solutions in different creeks in rivers (mostly riverbank filtration) and, lastly, measures for water retention in available rivers. The planned measures were (theoretically) able to retain from 40 to 85% of the precipitation, which in average had to match the target of 21 mm rainfall. After impressive construction efforts that lasted three years, the plans were put in practice and the city image has been changed a lot. The theoretical retention values were physically measured by an independent board, with results obtained being 20 mm rainfall.

In conclusion, “sponge city” principles can lead to sustainable changes in urban land-use, even in short time, but several factors are crucial for success: substantial political will, wide problem understanding, combined efforts between engineers, architects, planners, and allocation of sufficient funds.

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Groundwater-based natural infrastructure - a missing component of nature-based solutions

Nature-based infrastructure is nowadays quite high on the political agenda but very often groundwater is completely missing from the debate. Dr. Karen Villholth from International Water Management Institute (IWMI) aimed in her talk at emphasizing the important role of groundwater in supporting nature-based solutions.

In response to the multiple pressures on groundwater, an independent consortium of 30 international partners has been created under the name Groundwater Solutions Initiative for Policy and Practice (GRIPP) - http://gripp.iwmi.org. The partnership aims to strengthen, expand and connect current groundwater initiatives with focus on both groundwater quantity and quality. One of the main lines of activity consists in sharing transferable solutions. For this, GRIPP with a host of partners assembled a portfolio of 20 cases on water storage, water retention, water quality improvement and environmental services. These cases specifically take advantage of the services that the subsurface and groundwater provide for nature-based solutions to enhance water security, resilience, and environmental protection (the portal can be accessed at: http://gripp.iwmi.org/natural-infrastructure/).

Several examples of best practices were given during the presentation from countries with different socio-economic and technological development. In Abu Dhabi, UAE, excess desalinated water is stored in the subsurface through an 'aquifer storage and recovery' (ASR) scheme as alternative to increasing the storage capacity of surface reservoirs. In the Netherlands, treated wastewater from processing of greenhouse agricultural products is stored in a coastal brackish aquifer with the aim of suppressing saltwater intrusion along the coast. Further, the implementation of a market mechanism for payment of ecosystem services demonstrated successful incentivization of managed aquifer recharge (MAR) in Japan. Since 2004, farmers from the Kumamoto prefecture are getting paid by the municipal water utilities and the private sector for allowing their rice fields to be flooded for one to three months per year. The examples continued with Bangladesh, where freshwater is collected from ponds and rooftops at community level, filtered through sand and infiltrated in the shallow brackish aquifers. The water is available for extraction using simple hand-pumps providing resilience of water supplies during long periods of droughts.

The multitude of examples demonstrates that groundwater-based natural infrastructure (GBNI) solutions are very attractive and innovative and can be applied in diverse contexts, also in conjunction with existing infrastructure. The GBNI solutions fit very well into the current political agenda on nature-based solutions, but further promotion is required for worldwide uptake and implementation.

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Nature-based MAR solutions: options for improving urban drinking water supply, example N'Djamena, Chad

Nature-based solutions for improving drinking water supply are currently investigated by the German Federal Institute for Geosciences and Natural Resources (BGR) in N'Djamena, Chad. Dr. Vassolo from BGR introduced the city's main challenges in providing a safe drinking water supply, and discussed how riverbank filtration and enhanced infiltration might help overcoming them.

N'Djamena, located in the southern Lake Chad Basin in the northern part of Africa, benefits of about 500 mm/a, which are distributed mostly between June and September. Groundwater from the shallow, unconsolidated Quaternary aquifer, which is essentially recharged by the floodplains of the rivers Chari and Logone, is the sole drinking water supply source for the city's 1.5 million inhabitants. The water is accessed through private wells (without treatment) or public wells with on-site chlorination. Because the city's wastewater system is poorly developed, the aquifer is subject to severe contamination from leaking septic tanks, soak pits and unlined sewage canals. During the rainy season, the water problems are aggravated by heavy storm water runoff that floods large areas of the city and poses another potential source of groundwater contamination.

To support the development of adapted water management solutions, BGR investigates the application of simple forms of managed aquifer recharge (MAR) in N'Djamena. One option to improve the public water supply scheme is the application of riverbank filtration (RBF) along the Chari. However, large seasonal variations in river discharge and water quality as well as the numerous clay lenses or layers in the Quaternary aquifer are potential challenges and might strongly constrain the technique. Starting by the installation of a monitoring system at a large public supply well, data on seasonal variations in river and groundwater quality, share of bank filtrate, travel times, etc. will be collected for assessing the possibilities and limitations of the RBF in N'Djamena and other cities of the Lake Chad Basin. While a successful RBF scheme generally benefits the users of the piped water supply, the application of controlled infiltration of stormwater through basins or trenches might be an option to improve the water quality of the shallow private wells and handpumps in low-income areas.

Considering the socio-economic situation of the country and the strong reservations against the implementation of high-tech solutions, the application of nature-based solutions can help improve the water supply situation. The two approaches aim at enhancing the water quality by purification through RBF or soil/aquifer treatment; the controlled infiltration of stormwater would moreover help improving the livelihood of local people by contributing with simple flood control measures.

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SMART-Control: smart framework for real-time monitoring and control of subsurface processes in managed aquifer recharge applications

Managed aquifer recharge (MAR) aims to contribute to the reduction of water-related risks caused by climate change, urbanization, mismanagement, poor governance, etc. But its implementation is sometimes hindered by the difficulty of assessing its own associated risks. Dr. Stefan from TU Dresden explains how a web-based, real-time monitoring and control framework can contribute to better understand and manage MAR associated risks.

In general, MAR can take various shapes and it can be implemented in different contexts, with or without integrating technical infrastructure. The Global MAR Portal (https://mar-portal.un-igrac.org) includes over 1200 examples of MAR schemes from over 60 countries, demonstrating the important contributions of MAR to agriculture, drinking water supply, ecology and also industrial applications. Nevertheless, one of the reasons that obstructs MAR development is the risks associated with operational challenges, such as unpredictable quality and quantity of the recharge and recovered water. Additionally, the absence of proper monitoring at some MAR facilities reduces the level of public trust, raises questions about the impact of MAR on the affected ecosystem and hinders the optimal operational management.

In the SMART-Control project (www.smart-control.inowas.com), the Research Group INOWAS at TU Dresden and its international partners are currently developing a cloud-based monitoring and modelling framework for real-time, web-based groundwater management where time series data collected from sensor networks installed at six selected MAR sites (pilot to full scale) in Germany, France, Cyprus and Brazil will be remotely transferred and automatically fed into real-time simulation algorithms. The proposed system is based on the existing INOWAS platform (www.inowas.com) and will include three main components: 1) in-situ real-time monitoring system; 2) web-based modelling and monitoring platform; and 3) a set of risk assessment and management tools to evaluate MAR-associated risks.

The new smart modelling framework for MAR aims to improve the management and operation of MAR facilities by allowing real-time control and risk assessment at any stage of development. The variety of case studies considered ensures that the SMART-Control framework can be applied to various environmental and operational conditions to improve the water resources management.

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Part 2 | Group discussion

An interactive session followed the flash presentations, in which all participants received the opportunity to contribute with ideas and comments. The moderated session started with questions from the audience and answers from the invited speakers but continued with an exchange of oppinions between participants. This section summarizes the outcomes of the discussion in four main thematic categories while a detailed transcript is included in Annex 1.

Identification of water-related societal challenges and corresponding nature-based solutions

Nowadays, we are facing a wide range of societal challenges that need to be addressed in a different way if we want to aim towards sustainable development. The objective of the workshop was to identify water-related societal challenges (marked in **bold text** below) and find suitable nature-based solutions (NBS) for addressing them. From the impulse presentations, several challenges and solutions were extracted and discussed with the participants.

From the example in Changde, China, it became obvious that the trigger for the NBS implementation was the **major pollution of runoff and receiving waters.** This increased significantly over the last decades together with the urban development, industrialization and increase in traffic, etc. In the past, when the urban areas were smaller, they could be drained out by quickly transporting the water out of the city using concrete canals. Nowadays, multifunctional solutions include the bioretention and natural treatment of waters within the city boundary and integrating them in the urban land use planning. This is linked to a generally **lower acceptability of highly-technological solutions,** partly rejected by poor communities (such as in N'Djamena, Chad) where the infrastructure is underdeveloped and cannot incorporate advanced technological solutions. Besides the expected increase of safe water availability, the creation of recreational areas brings a significant contribution to the acceptability, together with the incorporation of local knowledge and involvement of local leadership structures. Unfortunately, the successful NBS implementation can be hindered by **various water-related conflicting interests**. For example, the rise of groundwater tables caused by managed aquifer recharge can be very beneficial for ecological reasons but also strongly opposed by real estate developers who need a rather low groundwater level. In this case, understanding the entire context and co-participative involvement of different stakeholders from the earliest stage of the project ensures the representation of all interests. If some users are benefiting more from the system than others, market mechanisms for payment of ecosystem services can be installed, as successfully demonstrated in Kumamoto prefecture, Japan. Last but not least, **physical water scarcity** caused by the lack of natural resources and/or overexploitation of available resources can be addressed by properly tailored, fit-for-purpose water reuse solutions. While partial recovery of degraded groundwater-based ecosystems might be possible (i.e. gradual replenishment of a depleted aquifer), other issues such as land subsidence can be potentially slowed down or stopped, but hardly reversed.

Reducing the technical and operational limitations of nature-based solutions

Part of the discussion time was dedicated to technical and operational challenges associated with managed aquifer recharge (MAR) applications. From a quantitative point of view, MAR can only make sense if a **suitable water source** is available. Apparently, this is perceived as one major limiting factor in some countries lacking natural resources. In these cases (but not only), the use of treated wastewater has been proposed and several examples of successful implementation are available. For big-scale schemes, the effluent of municipal wastewater treatment plants can be used but also a decentralized approach has been discussed. A major reason of failure of MAR systems is the clogging of the infiltration units (in most cases either infiltration wells or recharge basins). So, the discussion evolved around different **maintenance requirements** for a good functioning of the system and the associated costs. Boosting the implementation of MAR can be related to the optimization of operational schemes in a way that maintenance costs can be reduced, including here the prevention and management of clogging. Other issues discussed referred to **technical limitations** regarding the amount of water that can be handled by the system. As this depends on the local hydrogeological conditions, it cannot be much influenced by the operational scheme. However, prefeasibility studies are usually done to identify a suitable aquifer, its storage potential, recovery efficiencies, etc.

Assessment and management of risks associated with nature-based solutions

A very important aspect is the **potential risk associated with NBS**, which is sometimes more difficult to assess in comparison to technology-based solutions. Being natural or very close-to-nature, the system can become more vulnerable to unpredicted events leading to its failure and posing a risk to human health and environment. In case of MAR, the final use of recovered water dictates the preventive measures to be taken, including operational conditions. For drinking water, the conditions are very strict and the post-treatment step is very important. In most cases, viruses and pathogens are of significant concern. This is usually addressed by considering a safe water residence time in the subsurface (in Germany this is 50 days) before the water can be extracted and further used. Although determined rather empirically, this time is considered sufficient to safeguard the microbiological removal. Australia benefits of the most advanced guidelines for MAR considering a risk-based approach. At the European level, discussions are under way to develop the first MAR regulations and include them in the European Groundwater Directive. But to assess and manage the associated risks, a detailed monitoring and control system is needed, often based on costly observation campaigns. The newly started project SMART-Control proposes an improved approach by developing a web-based and real-time monitoring and modelling framework of groundwater management applications (more info at the following link: www.smart-control.inowas.com).

Strategies for promoting and increasing the acceptability of nature-based solutions

During discussions, it was pointed out that **terminology is very important for the promotion and acceptability of NBS**. In China, the term *"sponge city"* found a high resonance among stakeholders and became a national initiative. For MAR, using the term *"nature-based solution"* seems to be a good idea and is well received. But looking more closely, it seems that MAR is not exclusively natural as it can also involve technology and 'grey infrastructure'. Even the term *"managed aquifer recharge"* is not very old, being coined for the first time in 2005 as replacement for the more widely used *"artificial groundwater recharge"* (still in use today, including in several languages). This was proposed since the word "artificial" had a rather negative connotation, being perceived as anything else than "natural". Moreover, the word "managed" has a broader meaning, referring to a controlled, purposeful approach, which also comprises monitoring. Other terms in circulation include *“water banking”*, which might facilitate better understanding of the concept. Nevertheless, for some, the term “banking” could be understood mostly as the (temporal) storage aspect, similar to the financial correspondent, while “managed” can comprehend the entire approach. In Chad for example, when the project was introduced as *“artificial recharge”* it was almost immediately rejected with the argument that it makes little sense to go for artificial recharge when even the natural recharge is completely unknown. However, the attitude changed completely when the term *“enhanced bank filtration”* was introduced, because this was easily understood.

Continuing the discussion on whether MAR can be regarded as NBS, it was pointed out that **replication and up scaling, or mainstreaming,** are important characteristics for the NBS definition. In the case of MAR, some maintenance seems to be necessary. MAR schemes are very site-specific and apparently they are not easily transferable everywhere. Nevertheless, successful examples from different countries evoke the application of MAR for ecological purposes, where no technology is involved and the system is self-maintained. In some cases, water is infiltrated through interconnected ponds and well-integrated into the urban landscape. From an even broader perspective, MAR should not be regarded as a magic to fix any problems, but rather as part of an integrated solution. MAR plays a significant role on the environmental flows and creates an important set of new ecosystem services. It has been recognized though that these best-practice examples are not very known, so more efforts should be put in collecting and disseminating evidence of successful projects, including clear description of their limitations.

Probably the most relevant aspect in promoting MAR (and NBS in general) is the sum of socio-economic benefits in comparison with other solutions. A **cost-benefit analysis** should demonstrate the feasibility of the project by taking into consideration the entire range of inter-sectorial co-benefits. Although the discussion during the workshop focused mostly on the technical benefits of MAR (especially for drinking water supply), further initiatives should discuss the wider pool of benefits that include components from other sectors such as agriculture and food production, ecology, etc.

Part 3 | Strategic opportunities

The keynote lectures initiated a debate on different aspects of nature-based solutions, including their technical limitations, associated risks, and strategies for increasing their acceptability in various socio-economic contexts. Based on the examples presented and the discussion that followed, a set of strategic opportunity areas have been identified, which are briefly presented in this section. Without being comprehensive, these ideas could represent the potential basis for further collaborative research initiatives.

The Open Space Workshop aimed to provide a platform for interdisciplinary exchange of ideas for boosting nature-based solutions for climate change adaptation. To set the stage for discussion, four impulse presentations were given with examples from different socio-economic contexts. It was expected that the lessons learned from these examples would serve as basis for further replication and enable the identification of knowledge gaps for the generation of further research initiatives.

Based on this, the following **strategic opportunity areas** were identified:

- ***Increasing the acceptability of nature-based solutions through proper terminology and evidence of scalable examples***

It has been demonstrated that terminology can have a big impact on the acceptability of water management approaches. Solutions based or inspired from nature tend to be easier accepted than those making heavy use of technology. The wording must be carefully chosen to consider the various social, economic and religious contexts, as to avoid misinterpretations and, eventually, mistrust. Bringing evidence of up-scalable examples and explaining the bigger picture further helps to increase their acceptability.

- ***Co-developing solutions that can solve different water-related conflicting interests***

Existing solutions tend to answer the needs of only one particular group of stakeholders (i.e. municipal water utilities operators, farmers, etc.). By comparison, nature-based solutions can have multifunctional roles, for example, reduce peak runoff values for urban drainage and increase groundwater recharge for drinking water supply. However, the challenge consists in addressing conflicting interests, e.g. when the benefits of one user become the detriment of another user.

- ***Making an inventory of the co-benefits of groundwater-based natural infrastructure and including them in site-specific costs-benefits analyses***

Nature-based solutions are originally developed to address specific challenges but they often achieve multiple benefits. The development of nature-based solutions should seek to maximize the environmental, social and economic co-benefits. One way to achieve this is to expand the costs-benefits analyses to cover the groundwater-based natural infrastructure, which is often neglected in the debate around nature-based solutions despite its demonstrated performance.

- ***Assessing the risks associated with nature-based solutions and developing tools and methodologies for risk assessment and management***

Being very close to nature and making use of natural components, the system can become more vulnerable to unpredicted events leading to its failure and posing a risk to human health and environment. The associated risks need to be evaluated and assessed through appropriate tools and methodologies.

Annexes |

This section contains annexes to the main report text, including the approximate transcript of the discussion in form of questions and answers (Annex 1), selected photographs taken during the event (Annex 2) and the list of participants (Annex 3).

Annex 1 | Questions and answers

The flash presentations were followed by a moderated session of questions and answers, which engaged the three speakers and the audience.

Q: The question is about the groundwater infiltration via basins, especially in Chad, in this case wetlands (it refers to the example 2 from the presentation). How does it work? How does the water infiltrate?

A: N'Djamena is an area with soils made of very fine materials so in some cases we need wells so that water can be infiltrated directly to the aquifer instead of flowing to the river, or being waterlogged on the ground surface. The advantage is that water can infiltrate quickly because at the end of the season the surface water is mixed with other types of water becoming some sorts of wastewater, practically unsuitable for infiltration. So, what we want to do is to enhance the natural infiltration.

Q: Regarding MAR with treated wastewater, do you use only the effluent from the municipal wastewater treatment plants or is it possible to use also other sources, at smaller scale, such as for example Sustainable Urban Drainage Systems - SuDS (i.e. for "micro-MAR projects")?

A: Decentralized wastewater treatment solutions that are not integrated in the municipal sewerage network are discharging their effluent in the nature. While we are interested in a 'safe' discharge, we are also looking into ways of capturing this effluent for groundwater recharge, although the volumes are very small. In general, the treatment step before infiltration can be of different types, such as small-scale wastewater treatment units, a simple sand filter, a wetland, etc. Often, the percolation through soil offers sufficient treatment, but the effectiveness must be properly addressed. Infiltration of treated wastewater would become paramount for countries such as Jordan for example, where the lack of rainfall and surface water sources is critical, so there are not many water sources to choose from. So far, MAR with treated wastewater is mostly for irrigation and not for drinking water supply, independent of the scale.

Q: I have limited experience in nature-based solutions, but I am learning and gaining a lot of information from this conference. The water management and food safety challenges are strongly interrelated so, in such solutions that you were presenting, is any data considered on unexpected events, hazards, etc., that could emerge and lead to failure of the system? That would be particularly important for microbiological hazards, especially if the water is used for food production.

A: Most such solutions aim at water conservation and regarding the quality, the type of use determine the measures taken, which are to be understood through risk assessment. For drinking water, the water that is pumped out of the system needs of course detailed analysis and characterization. If the MAR effluent is used for irrigation, the bacteria need to be considered and as preventive measure we have in Germany the 50-day rule. So, the risk assessment is linked to the final water use and not for the infiltration, especially for big scale schemes for drinking water supply (see for example the three-step risk-based guidelines on MAR from Australia). In Europe, discussions are under way to include provisions on MAR in the next update of European Groundwater Directive and the first draft text is already in preparation.

Q: I consider myself a big fan of managed aquifer recharge and I believe that this is the future for many countries. Unfortunately, in Jordan we don't have such applications due also to various constrains. What concerns me is the maintenance of these systems, how it is done and what is the lifetime of an infiltration system? And how about the long-time clogging?

A: First of all, maintenance depends on the technology. According to the Global MAR Portal, about half of the schemes are either infiltration wells or recharge basins. Maintenance of wells is usually more costly, based on backwashing, not easy to do properly and not always leading to 100% recovery, whereas basins are easier to maintain. Most clogging is due to accumulation of organic matter in the upper soil layers, which are usually either ploughed or removed for restoring the infiltration capacity. In most cases, the infiltration is done in several basins in alternating dry-wet cycles, so when one basin is clogged, it is emptied and let dry for some time while the others are in operation. Following this procedure, the basins can be operated for tens of years. In case of biological clogging, drying the basin helps in the oxidation of organic matter and the food supply for bacteria is stopped, therewith a stop in the bacterial development so the proper design of the wet-dry cycles can help in avoiding the problem.

Q: A serious problem linked to climate change is land subsidence, especially in urban areas. Is there any chance to overcome this by MAR, slowly recovering the levels?

A: There are two major aspects linked to this. One is trying to recover the aquifer and rise the groundwater levels and second is the land subsidence. In many cases, it might be difficult to find enough water to refill a depleted aquifer because the groundwater over-exploitation ran over a very long time. While this might be possible in some cases, it depends on the volume of water available for infiltration. The subsidence of land though is mostly irreversible due to changes in the internal soil matrix. So, the soil is not like a sponge that gets back to original shape but it rather remains compressed.

Q: What kind of societal problems did you experience in the cases you are working on? I am asking this because, for example, especially in the urban settlements, the question is what is the desired level of water table? Because usually there are different interests linked to this. I have in my mind an example from the Hessian Ried in central Germany where there was a debate between house owners, who wanted a lower water table, the ecologists, who wanted a higher water table, and also water suppliers, who were interested in storing water in the subsurface, etc. So, reconciling these different interests seems to be not straightforward.

A: In case of Chad, the most important societal problem we are facing is the acceptance. The local communities first thought that we are going to install thousands of wells for managed aquifer recharge and therefore they were reluctant at first. That's why we try to design simple schemes using local knowledge and simple approaches. But in our case there is no water so we start at a lower level. But once water is provided, we might face the problem of water sharing by different groups of interests. In China, the main societal problem was the "Black River" so the objective was to improve the quality of the runoff and of the receiving waters that was the only motivation. In the past, all the waters went to the river without any kind of treatment and this had to change. This followed a breakthrough in water management: for long time, the focus was on draining the city, so the water had to be evacuated fast, which was maybe possible because the city was small, the quality of the runoff was not so bad as it is today where there are more cars, more industry, etc. That's a major difference. Lately, the focus starts to shift into retaining and treating the water inside the city.

Q: What are the future research needs in case of sponge cities in China?

A: The bioretention of constructed wetlands works very well but, trying to think beyond that, I see an important potential in using them in conjunction with managed aquifer recharge. In case of Changde, this was not considered as the groundwater table is about 2 m below surface but it might be very relevant in other places.

Q: What was your experience, Mr. Fuchs, with the social acceptance for the project by the Changde citizens? And maybe the same question for Chad.

A: The people in Changde saw the benefits and eventually accepted the solutions proposed. They could see that the outflow from the constructed wetlands was obviously clean and the fact that new recreational areas were created also contributed to the acceptance. So littering the area also stopped. On the other side, the project received significant support from local politicians who engaged themselves a lot in the project implementation. And being designed by a German team ('made in Germany') seemed to ease the acceptance as well.

In Chad, littering is a problem and is probably going to be a problem also in the future. Right now, we have a major problem with the acceptance so that's why we focus on small-scale schemes in order to show that the proposed solution works. We are also integrating the local knowledge and blend our solution into the local water infrastructure. For example, the observation boreholes make use of local techniques (they are basically drilled by hand). There are also lots of people observing our work and they seem to be very interested. The involvement of local leaders (chefs) is extremely important and we need to have consultations with them for every step, even for measuring the water levels.

So reflecting on the social aspects, there are few issues that need to be considered depending on the scale of the area, etc. One of them is the source of water for the infiltration. In case of wastewater, there are probably no major conflicts, except perhaps the cases where farmers might want to use it directly for irrigation. But if the water is taken from a river, for example, then we need to consider who used that water before and for what purposes, so understanding the entire context is very important as some people may benefit more than the others. This can be seen in some catchments in India where local farmers installed many small-scale MAR schemes to capture the water and use it for irrigation. But this significantly reduced the flow downstream, generating local conflicts between different water users.

Q: What are the criteria for deciding about the implementation of a managed aquifer recharge project? For example the case presented from Abu Dhabi: are there technical limitations since this is interfering with the natural system? And where is the limit that decides the system's feasibility?

A: The deciding factor is the costs-benefit analysis. Technically, it is possible to inject water in very deep aquifers, about 300-400 m deep as in the case of Jordan, but the water needs to be also recovered, which is costly, so the question at the end is about the cost-benefit ratio. In most cases, pre-feasibility studies are done to identify a suitable aquifer, the recovery efficiency and so on. If the system is kept confined (the water injected doesn't get too far from the injection site), the recovery wells can be installed at the site so the entire system can be well controlled. But of course we can't inject infinite amounts and there are limits up to which the scheme is feasible. This needs to be analyzed on a case-by-case basis as there are no universal solutions available.

Q: If the water is injected by gravity and not by pumping, why shall we worry so much about the costs-benefits?

A: The costs are not only linked to the injection but mostly to drilling the wells and to pumping the water back to the surface. If the aquifer is very deep, these costs might become a significant part of the total budget. If this is maybe not very costly in some countries, in places like Chad this is expensive. And, if the groundwater drawdown is very high, i.e. 10 meters per year or more, most probably we won't find sufficient water to reverse this drawdown. Simply put, this would basically mean to inject back as much water as it was taken out of the system, and this by using a very big wellfield.

Q. Using the term "nature-based solution" for MAR seems to be a good idea for promoting it as this can inspire trust and coordinated and integrated approaches. But looking at it more closely it seems that MAR is not very natural as it also involves technology. Another term that I came across was "water banking" so maybe this is another perspective for managed aquifer recharge.

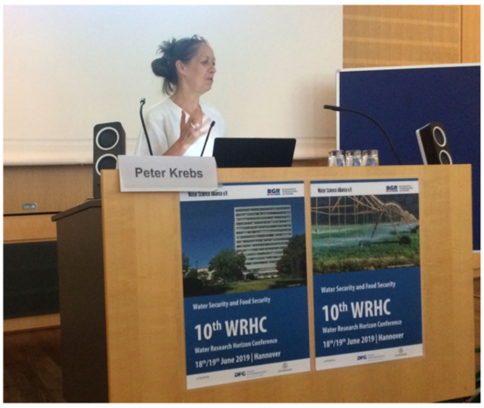
A: Sometimes, banks can also go bankrupt so for some people, the word "bank" is not necessarily very positive. But letting the joke aside, the terminology is surely very important for the acceptance. In the past, MAR was called (and in most languages it still is today) called "artificial groundwater recharge" in opposite to "natural groundwater recharge". This was partially perceived as bad, as "artificial" is sometimes not well accepted. So in 2005, if I am not wrong, the term "managed" was coined as to express not only the uncontrolled, unintended discharge of water underground but to emphasize the "managed", purposeful and controlled approach, which also involves monitoring. So for some, the term "banking" could refer only to the storage aspect, without the recovery, while "managed" might be understood as the entire approach.
In Chad for example, when the project was introduced as "artificial recharge" it was almost immediately rejected with the argument that it makes little sense for artificial recharge when even the natural recharge is completely unknown. But the attitude changed completely when the term "enhanced bank filtration" was introduced because this could be easily understood.

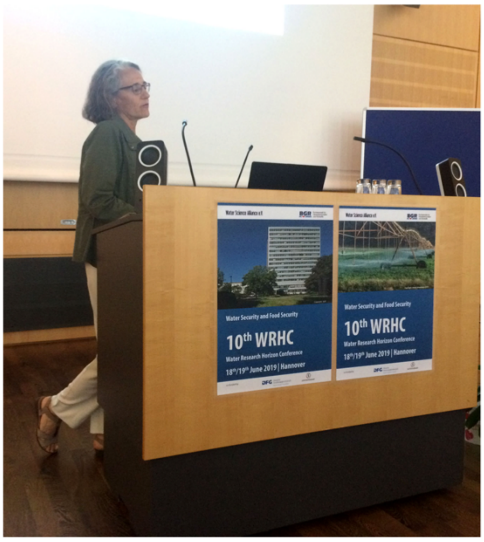
Q: Reflecting on the question whether MAR can qualify as a nature-based solution or not, it seems to me that nature-based solutions are those systems that can be replicated and upscaled everywhere in the world. In case of MAR, maintenance is needed so the MAR schemes might not be easily upscaled everywhere.

A: There are successful examples of MAR for ecological purposes where water is infiltrated through ponds and they can be very well upscaled and integrated into the land-use planning strategies. In case of infiltration wells, these are for sure technological solutions but the main principle is not very much different. As for the infiltration of treated wastewater in soil-aquifer-treatment (SAT) systems, most processes occur in the vadose zone and these are natural processes. Of course, the water needs to be pumped to the infiltration site (if gravitational flow is not possible) but the focus is on the natural-occurring processes.
From a general perspective, MAR should be regarded as part of an integrated solution because the concept is not only restricted to putting water into the ground and taking it out later. In a wider context, MAR can play a significant role on the environmental flows while creating an important set of new ecosystem services. So this is not only about drinking water supply or agriculture but it is often linked to recreational areas, tourism, bird habitats etc. So in the future we should perhaps look at this bigger image of integrating different cross-approaches for achieving environmental friendly solutions.

A final remark regarding the acceptance and terminology: this seems also strongly linked to some sort of water "identity". In Germany, most rivers receive treated wastewater and during summer, the portion of wastewater is significant. But the water in the rivers is always considered river water and never "reclaimed" water or wastewater. Moreover, the water is used by the next town downstream for riverbank filtration, where it is pumped from wells located very close to the riverbanks. So, the same water is now perceived as groundwater although it may contain a significant portion of the treated wastewater discharged upstream.

Annex 2 | Event photos





Photos: Greta Jäckel and Catalin Stefan

Annex 3 | List of participants

List of participants to the Open Space Workshop "Innovative ideas for boosting nature-based solutions for climate change adaptation" organized within the 10th Water Research Horizon Conference (WRHC2019), Hannover, Germany, June 18-19, 2019:

Name	Institution
Catalin Stefan	Technische Universität Dresden
Lothar Fuchs	Institut für technisch-wissenschaftliche Hydrologie GmbH
Christian Bernhofer	Technische Universität Dresden
Othman Almashaqbeh	Royal Scientific Society, Jordan
Romy Durst	Karlsruher Institut für Technologie
Anna Ender	Karlsruher Institut für Technologie
Juan Carlos Sanchez	n.a.
Michael Eichholz	Federal Institute for Geosciences and Natural Resources
Ramon Brentführer	Federal Institute for Geosciences and Natural Resources
Guido Hora	Fraunhofer IST
Imke Lorenz	Technische Universität Darmstadt
Joachim Went	Fraunhofer ISE
Dirk Osich	Umweltbundesamt / German Environment Agency
Insa Neuweiler	Leibniz Universität Hannover
Dima Faour-Klingbeil	Food Safety
Max Nölscher	Federal Institute for Geosciences and Natural Resources
Ahmed Ehteswan	n.a.
Kate Gibson	University of Nebraska
Afshin Sadeghikhah	Technische Universität Dresden
Susanne Dorasil	Federal Ministry of Economic Cooperation and Development
Julian Reyes	Technische Universität Dresden
Karen Villholth	International Water Management Institute
Franziska Wende	Federal Institute for Geosciences and Natural Resources
Leon Gorris	n.a.