CAWR
Center for Advanced Water Research

ChinaConcept 2016 –
Inventory of demands, activities and interests in environmental research

HELMHOLTZ
CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

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ENVIRONMENTAL
RESEARCH – UFZ

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Preamble

This document combines two efforts in identifying most relevant joint strategic research topics with Chinese research institutions and stakeholders for future cooperation in environmental science, technology and education.

- CAWR#China Concept: The joint ”Centre for Advanced Water Research” (CAWR) of UFZ and TU Dresden focusses on strategic cooperation in the field of water research, education and training as well as transfer of research with the overall mission ”safe water for humans and environment”.
- UFZ#China Concept: This strategy covers a broader spectrum of interdisciplinary environmental sciences highly relevant for tackling environmental challenges in China. While the topic water is thoroughly covered by the CAWR#China Concept, it considers issues such as land use in a bio-based economy vs. protection of biodiversity as well as maintaining ecosystems services or risks posed by chemicals in the environment.

Both strategic efforts together form an excellent basis and roadmap for future cooperation in environmental research described in the following document.

Purpose of this document is to:

- Describe the current situation (Chapter 1) as well as challenges and research demands for future cooperation (Chapter 2),
- Present selected highlights of existing cooperation projects (Chapter 3),
- Define topics and a research agenda for future collaboration (Chapter 4),
- Provide (statistical) information on previous activities and existing cooperation (Appendices 5).

The present document serves also as a ”handbook for collaboration” and will be updated on an annual basis.

Greeting words

From the Editorial Team

The idea to write a more general strategic paper on how to foster the Sino-German cooperation in environmental sciences arose a few years ago when organizing an "open space" workshop at the Water Research Horizon Conference WRHC 2014 in Berlin and a first opinion paper was drawn with a priori like–minded colleagues and partners. At the beginning of 2016, we started the idea to develop an inventory-taking and institutional concept. We soon realized that this was a complex project and required a coordinated effort.

On the one hand, as an indication of great interest, various scientists and institutions volunteered to contribute to this exercise. While on the other hand, this process needed professional organization including several workshops in Leipzig and Dresden, which was then followed by extensive writing and editing work until the end of 2016.

With the printed result in hand, it is impressive to see the large variety of bilateral initiatives already started by German and Chinese scientists [1]. Yet, the intention of this ChinaConcept is to provide the basis for future efforts towards cutting-edge initiatives and larger research units, such as centers of excellence, focal research networks, and comprehensive educational concepts. Aimed at solving complex environmental problems, the Sino-German collaboration can only stand out by organizing it in an integrated and sustainable way.

Figure 1: Cooperation modules

This requires strategic approaches and focused joint activities on carefully selected research targets. The left figures shows some ingredients for such integrated collaboration (1) excellence of science will be a decisive criteria for building stronger networks, (2) research results must be applied and transferred into technologies, (3) joint education concepts will guarantee long-term networks, (4) capacity development is required also for successful and stable networking including sufficient fund raising.

To sum up, integrated networking is essential for leveraging the quality of collaboration, which also requires novel organizational frameworks for cooperation beyond the classic bilateral schemes.

[1] Chen, C., Börnick, H., Cai, Q., Dai, X., Jähnig, S.C., Kong, Y., Krebs, P., Kuenzer, C., Kunstmann, H., Liu, Y., Nixdorf, E., Pang, Z., Rode, M., Schueth, C., Song, Y., Yue, T., Zhou, K., Zhang, J., Kolditz, O., (2015): Challenges and opportunities of German-Chinese cooperation in water science and technology. Environ. Earth Sci. 73 (8), 4861 - 4871

Finally we would like to use this opportunity to thank the engaged scientists for contributing to the present ChinaConcept (list of contributors can be found at the end). Even though this first version is written from an institutional perspective, we would encourage the German and Chinese colleagues to build similar structures and to combine these institutional efforts to stronger research units, in order to tackle the grand challenges in environmental science, technology and education. The message to the young scientists from both countries is – start networking as early as possible, this will strengthen your own scientific work, broaden your perspective and sharpen your view on solving complex problems. Environmental challenges are global, and can only be tackled with excellent science and technology resulting from international collaboration.

Olaf Kolditz, Mareike Braeckevelt, Cui Chen, Eike Dusi, Greta Jäckel, Ursula Schmitz, Chengzi Zhou (Editorial Team)
Leipzig/Dresden, 22.04.2017

Executive Summary - Rationale

The intention of the present version of the ChinaConcept is to provide a detailed overview of past and ongoing scientific collaboration activities between the Helmholtz Center for Environmental Research - UFZ[2], the Center for Advanced Water Research (CAWR)[3] and their Chinese partners from various institutions as well as to offer concerted opportunities for future collaboration. Based on the research portfolio of UFZ and CAWR a strategic cooperation concept can than be developed which meets the demand and challenges in analyzing and developing solutions for environmental problems in China particularly concerning sustainable use of natural resources, waste management and circular economy. Chinese society can benefit from the long-term experience of Germany in solving environmental problems e.g. especially after the reunification in 1989. The Helmholtz Center for Environmental Research - UFZ was particularly placed into the former industry-mining area of Central Germany in order to initiate and support environmental remediation projects towards the restructuring into an environmental friendly, green economy. Today UFZ acts on international level and addresses global problems. Examples of recent related strategic efforts by UFZ and CAWR include initiating the Helmholtz Water Network[4], World Water Quality Assessment[5], or IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). TU Dresden[6] belongs to one of the Universities of Excellence in Germany; the Faculty of Environmental Sciences is engaged in both research and education (e.g. UNEP) cooperation with Chinese Universities.

In 2015, a general framework of Chinas strategic development goals was formulated in "Made in China 2025"[a] - an ambitious concept concerning technology development based on innovation, quality, and efficiency principles.

[a] http://english.gov.cn/2016special/madeinchina2025/

Towards these long-term goals, China currently is implementing the strategic process of the 13^{th} Five-Year-Plan, where "Major Programs" are important instruments for realization. In 2016, the "Major Science and Technology Program for Water Pollution Control and Treatment" and several related environmental acts (e.g. water, soil, air, see Chapter 1) were launched in order to significantly improve water environments in focus regions in China.

Recognizing the importance and opportunities of Sino-German bilateral research cooperation, the Federal Ministry of Education and Research (BMBF)

[2] www.ufz.de
[3] www.ufz.de/cawr
[4] www.ufz.de/helmholtz-wassernetzwerk
[5] https://www.ufz.de/index.php?en=40082
[6] https://tu-dresden.de

published a "China-Strategy of BMBF" in October 2015[7]. Main areas for strategic cooperation are "Key Technologies", "Life Sciences", "Strengthening Social Sciences", and "Ecological Challenges".

During the 1st Sino-German Conference "Major Water Program" in December 2016 in Shanghai organized by the Ministry of Science and Technology of China (MoST) and BMBF current progress of the joint activities within the BMBF-CLIENT and the "Major Water" Programs were elaborated and planned. The efficiency of a structured cooperation has been improved by establishing the Innovation-Cluster "Major Water"[a].

[a] http://sino-german-major-water.net/de/

Future successful cooperation needs further joint strategic efforts combining research, education and knowledge transfer portfolios of both Chinese and German partners with societal demands.

The present report reflects the "BMBF China-Strategy" introducing the portfolio of UFZ and CAWR in environmental sciences.

Challenges, past and ongoing activities

Figure 2: Research portfolio of UFZ and CAWR for cooperation in environmental science, technology and education

Chapter 2 addresses challenges and demands for cooperation in environmental science, technology and education. Best practice examples are briefly presented to highlight successful cooperation projects in the past (3). The current structure of the research portfolio is depicted in Figure 2. Main areas concern environmental resources and waste management – linked by the concept of

[7] https://www.bmbf.de/de/china-strategie-des-bundesministeriums-fuer-bildung-und-forschung-2015-2020-1882.html

cycle economy. The use of natural resources (e.g. water, land use, mineral and energy resources) is also related to waste production (e.g. waste water, municipal solid waste, emissions to the atmosphere), which needs to be minimized and treated. At the same time "anthropogenic" waste becomes an important resource again – which is the fundamental idea of cycle economy. Due to its complexity, appropriate management and governance concepts tailored to the specific national demands are of essential importance. This includes the availability of mature IT–based planning and monitoring instruments. This document also contains a description of particular expertise and a compilation of ongoing cooperation activities between German and Chinese partners (with statistical material in the Appendices).

Opportunities for Future Cooperation

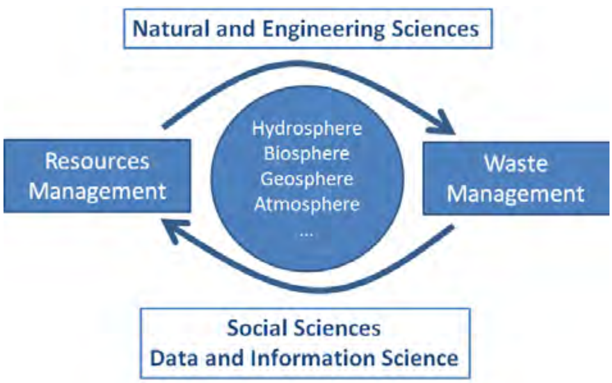

Figure 3: Structuring major areas for cooperation in environmental science, technology and education

Based on existing expertise and challenges, Chapter 4 indicates major interest for future cooperation. The research interests are related to all spheres of terrestrial environmental systems (Figure 3). The comprehensive portfolio contains basic and applied approaches (natural and engineering sciences) including social as well as information sciences. The suggested cooperation concept – driven by the most pressing societal challenges – follows the general idea of cycle economy and life-cycle perspective of natural resources and waste conversion. The major criteria for cooperation are: (1) Excellent science, (2) Knowledge and technology transfer (ready for implementation), (3) Education, (4) Capacity building (Figure 1). The present concept from the perspective of UFZ and CAWR is an invitation to our Chinese partners and German colleagues for participation - in order to build an even more intensive and successful collaboration in environmental science, technology and education.

Contents

Chapter 1

Relevance and strategic framework

Rapid economic development and population growth in China go hand-in-hand with industrialization, increasing demand for energy and resources, intensified agriculture and increasing urbanization, involving growing megacities. These developments have caused and continue to cause severe pressures and risks to natural resources and the long-term provision of highly required goods and services based on natural resources. Pollution containing hazardous substances for environmental and human health, depletion and deterioration of water resources as a result of overexploitation and contamination, soil degradation and air pollution in mega-metropoles (such as Jing-Jin-Ji[1], Taihu area) are increasing at an alarming rate. At the same time the long time neglected development of rural areas has to be tackled with corresponding environmental friendly master plans.

Consequently, to stop negative trends jeopardizing the economic and societal development in China, protection, remediation and productive management strategies as well as sustainable planning need to be developed and implemented for China's natural resources in a highly diverse, complex and dynamic environment. This offers most important opportunities for international collaboration in environmental science, technology and education.

The Chinese government recognized the importance and complexity of the water situation and has initiated a program entitled "Major Water Program of Science and Technology for Water Pollution and Governance" (2006-2020). While shortages resulting from regional resource depletion have led to projects of large-scale water transport from distant water-rich areas of China (Water Diversion Project), the water quantity and quality problems in other areas require efficient, flexible, and site-specific solutions and overall management concepts.

[1] The national capital region of China (Beijing-Tianjin-Hebei)

In April 2015, the Action Plan for Water Pollution Prevention (Clean Water Action Plan)[2] was published by the State Council of the People's Republic of China. It requires that by 2020, China's water environment quality will gradually improve; the percentage of severely polluted water bodies will be greatly reduced and the quality of drinking water will be improved. The plan seeks to protect surface water in seven river basins: Yangtze, Yellow, Pearl, Songhua, Huai, Hai and Liao River. It sets urgent, strict targets for water scarce regions such as Beijing-Tianjin-Hebei, Yangtze River Delta, and the Pearl River Delta.

In September 2013, China has formulated and implemented an in-depth Action Plan for the Prevention and Control of Air Pollution (Clean Air Action Plan)[3] in order to set up an evaluation system focusing on improving air quality and assessment results will be used for performance evaluation of the local leaders.

On 31st May 2016, China launched a new action plan to tackle soil pollution (Clean Soil Action Plan)[4]and China aims to curb worsening soil pollution by 2020 and stabilize and improve soil quality by 2030. These plans highlight the determination to control pollution, improve environmental quality, and protect the people's health[5].

The Chinese Government released its 13th Five-Year Plan (2016 -2020)[6] on 17th March 2016. It promotes a cleaner and greener economy, with strong commitments to environmental management and protection, clean energy and emission control, ecological protection and security, and the development of green industries. Specific objectives for environmental protection in the 13th Five Year Plan period include: reduction of water consumption by 35% by 2020 as compared to 2013; estimated total consumption of primary energy in 2020 of less than 5 billion tons of standard coal; energy consumption per unit of GDP to be reduced by 15% in 2020 (compared to 2015); reduction of carbon dioxide emissions per unit of GDP by 40-45% by 2020 (compared to 2015 which is consistent with China's Plan for Addressing Climate Change (2014-2020)). On 3rd September 2016, the presidents of China, Xi Jinping, and the USA, Barack Obama, announced the ratification of the Paris Agreement (of the 2015 United Nations Climate Change Conference) by their countries, respectively.

On 08th August 2016, Chinese government released its 13th Five-Year National Science and Technology Innovation Plan[7]. China will continue to support the national science and technology major projects, which include the major project in water pollution control and treatment. The targets are: A number of key technologies shall be developed in terms of water circulation system restoration, water pollution control, drinking water safety, ecological service

[2]http://www.mep.gov.cn/gkml/hbb/qt/201504/t20150416_299173.htm
[3]http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm
[4]http://www.gov.cn/zhengce/content/2016-05/31/content_5078377.htm
[5]http://www.mep.gov.cn/
[6]http://www.gov.cn/xinwen/2016-03/17/content_5054992.htm
[7]http://www.gov.cn/zhengce/content/2016-08/08/content_5098072.htm

functions restorations well as long-term management mechanisms. The comprehensive demonstration will be carried out in the region "Beijing-Tianjin-Hebei" and Taihu lake area. Comprehensive environmental information systems for on water pollution control, environmental management and drinking water safety shall be established in order to set up the big-data based platform for water environment monitoring and observation.

German-Chinese Governmental Consultations are taking place on a regular basis, enabling discussion on recent topics for collaboration between the two countries at highest level. The first German-Chinese governmental consultations were held on 28 June 2011 in Berlin and provided the framework for the German-Chinese Forum for Economic and Technological Cooperation. During this first consultation, a joint declaration on the establishment of the bilateral "Research and Innovation Programme Clean Water" was signed. The second consultations between the two governments took place in August 2012 in Beijing, the third on 10 October 2014 in Berlin. The fourth consultations were held in June 2016. The major topic was how to link "made in China 2025" and "German Industry 4.0".

Recognizing the importance, opportunities and strength of Chinese-German bilateral research cooperation, the Federal Ministry of Education and Research published their "China-Strategy of the BMBF" in October 2015, a strategic framework for the cooperation with China in research, science and education[a]. The BMBF China-Strategy is dedicated to further improve the framework conditions for cooperation between Germany and China in science and research, networking and education. The main areas for cooperation are "Key Technologies", "Life Science", "Strengthening Social Sciences" and coping "Ecological Challenges".

[a] https://www.bmbf.de/de/china-strategie-des-bundesministeriums-fuer-bildung-und-forschung-2015-2020-1882.html

Within the latter area the topics "Sustainable water management", "Urbanization", "Renewable Energies", and "Geosciences" are directly related to the research portfolio of the UFZ.

HELMHOLTZ ASSOCIATION

Already 13 years ago, the Helmholtz Association established a permanent office in Beijing, acknowledging the importance of scientific and technological cooperation with Chinese research institutions.

Regular visits of the Helmholtz president to China emphasize the continuous interest. In 2012, the Helmholtz Association launched a joint funding program together with the Chinese Academy of Sciences (CAS) aimed at supporting Helmholtz-CAS Joint Research Groups. Meanwhile, five projects passed thorough Chinese-German evaluation procedures and are being implemented, one of these dedicated to a specific aspect of marine environmental and energy research (gas hydrates).

Even more importantly, the Helmholtz Association devoted one of only two Helmholtz International Research Networks to fostering cooperation with China in environmental sciences: RCEIS, the Helmholtz-CAS Research Centre for Environmental Information Science. RCEIS started in 2014 and already succeeded in linking important Chinese-German cooperation projects in environmental sciences, mainly on water and soil, thus forming the basis for the development of environmental information systems. This approach shall be enlarged to include data from remote sensing and earth observation. RCEIS will become a Sino-German competence center and research platform for Earth systems observation and prediction by combining expertise in the fields of environmental and information sciences using modern information technology.

Research in Germany is at the forefront worldwide in tackling complex environmental problems and is involved in the development of management approaches and technologies, in order to solve complex environmental problems in the past and present. The Helmholtz Centre for Environmental Research – UFZ and jointly in cooperation with the TU Dresden as the "Center for Advanced Water Research" (CAWR) - have the competences and interest to join in and cooperate with their Chinese colleagues in addressing the challenges posed to environmental research in China. In order to face these challenges, systemic and integrative approaches are necessary.

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Research at the Helmholtz Centre for Environmental Research – UFZ aims at demonstrating ways in which a sustainable use of our natural resource base is possible for the benefit of both mankind and the environment.

Therefore, UFZ investigates the complex interactions between mankind and nature under the influence of global change. Biodiversity, functioning ecosystems, clean water and intact soils all make up our natural resource base. In the face of global change, UFZ has the goal of demonstrating ways to combine societal and economic development with a healthy environment. In dealing with complex environmental issues, the disciplinary borders between the natural-, engineering- and social sciences need to be overcome. The UFZ has extensive competences in interdisciplinary and integrated environmental research and develops systemic solutions.

The Center for Advanced Water Research focuses its work on the fields of research, education & training and transfer regarding its mission “Safe Water for the people and the environment”, incorporating the fields of water quality, waste-water management, water and food supply, soil and land use as well as human health. Consequently, research at CAWR is taking into account the entire water cycle including chemical, bio-geo-chemical, evolutionary and ecological processes as well as their socio-economic conditions and implications.

The CAWR scientists focus on the following thematic priorities:

- They analyse interdependencies in natural and anthropogenically impacted hydrosystems, particularly regulation mechanisms and the impact of human activities,
- They develop status targets and management strategies for the sustainable use of anthropogenically impacted hydrosystems, and determine risks and indicators for critical trends,
- Faced with processes of change, uncertainties and high complexity they make use of projections and scenarios in order to better understand and control hydrosystems,
- In order to analyse complex hydrosystems and optimize decision making processes, they develop tools such as models, visualization techniques and innovative monitoring concepts.

The promotion of young scientists as students/PhD-students/PostDocs with tools for the research-related education and training is another priority topic of the CAWR. Tools like the UNEP/UNESCO/BMUB supported Centre for International Postgraduate Studies of Environmental Management (CIPSEM), an e-learning module with the focus on Integrated Water Resources Management (IWRM), international master programs, Workshops for Human Capacity Development (HCD) are setting the basis for close (bilateral) successful cooperations in the field of water research. The strategic cooperation between the Free State of Saxony and the Hubei Province (capitol is Wuhan) can provide a common ground for UFZ and CAWR to intensify their research activities in Hubei Province in future.

Chapter 2

Challenges and demands

The following challenges and related research areas are presented and discussed in detail in this document as important areas for focused cooperation in environmental science, technology and education (Fig. 2.1).

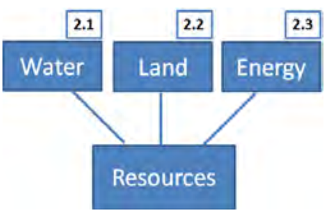
Figure 2.1: Focus areas for Sino-German cooperation in environmental science, technology and education

The major themes of cooperation are the management of resources and waste. Both are linked by cycle economy. The use of resources – e.g. water, land use, energy conversion - is still producing waste which needs to be minimized, e.g. wastewater, municipal solid waste, or emissions of carbon dioxide and various substances to the atmosphere resulting in partly tremendous air pollution. At the same time waste can be turned into resources again (e.g. reuse of treated wastewater, recovery of raw materials) - which is the fundamental idea of cycle economy.

The description of the cooperation topics is structured according to Fig. 2.1 as follows:

- Integrated water resources management (section 2.1),
- Sustainable soil, land use, biodiversity (section 2.2) and
- Development of renewable energy utilization to substitute fossil resources (section 2.3),
- Wastewater treatment as basic demand to ensure healthy life in urban and rural areas (section 2.4),
- Appropriate handling and disposal of municipal solid waste (section 2.5),
- Mitigation of air pollution and related health effects (section 2.6).
- Appropriate information systems and management concepts and tools (section 2.7) crucial for the implementation and public acceptance of novel approaches to resources and waste management and
- Governance for effective and efficient resource use (section 2.8).

Environmental education is an inherent part of the cooperation concept between Germany and China.



Resources – water, soil, land, renewable energies: Natural resources and the services they provide are prerequisite to a sustainable economic and social development. High attention has to be given to their maintenance and sustainable use.

2.1 Water Resources

China's annual average total freshwater resources are about 2800 billion cubic meter[1]. However, because of its large population, the per capita availability of renewable freshwater, at 2.3×10^3 m^3/year is only 25% of the world's average. Moreover, water shortages are aggravated by the uneven temporal and spatial distributions of water resources. Water resources are not well matched with land resources and population. North China has 60 percent of the national cropped area and 40 percent of the population, but only 20 percent of the nation's water resources.

Water pollution and degradation of aquatic ecosystems have produced massive damage to the function and integrity of water systems (Yu, 2014). Industrialization led to pollution of surface and ground water with persistent organic

[1]MWR, 2011b, China Water Statistical Yearbook 2011. China WaterPower Press, Beijing, China

pollutants and heavy metals from anthropogenic sources. Industrialized agriculture activities like biomass combustion, application of pesticides and crop fertilization (Wang et al., 2012) also caused massive input of toxic compounds with hazards for human health. Hazardous secondary effects consists of the development of toxic cyanobacteria blooms, the increased tendency of hypoxia and water fouling in surface waters (black blooms) and bioaccumulation of toxicants within the aquatic food web (Qin et al. 2015).

The MEP 2013 exemplified the pollution situation for river water quality: as of 2011, among 469 major rivers in China only 61.0% met Grade I-III of national water quality standard and could be used to make drinking water, 25.3% met Grade IV-V and were just suitable to be used for industrial and agricultural purposes, and 13.7% failed to meet Grade V and were therefore unsuitable for any use. 55% of 4,727 monitored sites in 200 cities had poor to very poor water quality.

The demands on water management are manifold comprising the provision of water for industry, agriculture and the provision of drinking water for the Chinese society in sufficient quantity and quality while protecting aquatic ecosystems against further overexploitation and pollution.

According to a new policy called "Action planning to prevent and control water pollution" (promulgated by the State Council of People's Republic of China on 2nd April 2015[2]), one of the main tasks in the next few years by 2020 is the control of proportion of black-odor water body below to 10%. By 2030, the black-odor water body should be eliminated in the city area. Although numbers of techniques such as biological oxidation in sediment or artificial wetland have been employed to repair the polluted water, it is necessary to screen the main organic pollutants caused the black-odor problems and their sources in order to control the pollution.

It is of highest relevance to safeguard the supply of drinking water for Chinese people in the next years from both surface water resources (mainly in Middle and South China) and groundwater (in Northern and Western China).

2.1.1 Safeguarding surface and drinking water quality

A recent national water quality survey showed that only 58.3% of rivers, 49.7% of lakes, 79.5% of reservoirs, and 38.7% of groundwater produced from wells met quality criteria for source water supplies. Lakes and reservoirs are highly relevant for drinking water supply in the densely populated areas of China. In recent years, tremendous efforts have been focused on restoring the water quality of three of the most seriously polluted lakes: Taihu Lake, located in the Yangtze River Delta, Chaohu Lake in Anhui Province, and Dianchi Lake in Yunan Province (e.g.(Yu, 2014)).

Lakes and reservoirs suffer from intense eutrophication and pollution from or-

[2] http://www.gov.cn/zhengce/content/2015-04/16/content_9613.htm

ganic and inorganic pollutants. Food production and urban wastewaters go along with extremely high nutrient inputs to the surface water. Additionally, there is the increasing problem of mass development of cyanobacteria associated with the formation of hazardous and odor compounds. At the same time, a rising demand for recreational purposes is noticeable in many lake areas. These multiple purposes create severe risks to aquatic resources and require early warning systems for drinking water supply as well as sustainable management concepts and tools. Monitoring and modelling techniques need to be improved, in order to implement safe water quality management systems.

Monitoring, assessment and abatement of the complex mixtures of organic toxicants and metals are an increasing issue in China with respect to drinking water production but also other ecosystems services such as fishery and recreation.

Similarly to Europe, surface and drinking water guidelines in China focus currently on predefined threshold values for a couple of substances, which are quantified by time consuming and often expensive chemical analysis. However, the vast number of contaminants in the aquatic environment requires an integrated approach to ensure a continuous monitoring of the water quality. Effect-based monitoring tools including *in vitro* and *in vivo* biotests detect all chemicals (knowns and unknowns) with a similar mode of action or impacting on the same selected test organism and provide a first, more holistic measure for water contamination. In Europe, as well as in China, the following scientific and policy-directed requirements need to be met.

1. Appropriate test batteries need to be established to safeguard non-toxic water resources and protect biodiversity and vital ecosystems functions and services.

2. Effect-based trigger values are required indicating the quality status and thus the priority of abatement measures and

3. strategies and tools need to be developed that help to identify the chemicals causing effects if the trigger values are exceeded.

The latter include effect-directed analysis and target- and non-target chemical analytical approaches. For the protection of drinking water on-line biomonitoring, with effect-based tools is particularly helpful however requiring the development of a suitable online environment information system including conceptual models, big data management and modern computer technologies. Furthermore, the microbial quality of drinking water can be tested by community analytics which is already routinely done in Switzerland (Kötzsch et al., 2012)(Hammes et al., 2008). The application could be further developed and implemented in China.

Risks posed by riverbank filtration for drinking water abstraction also need to be considered. According to recent estimates, nowadays there are over

300 riverbank filtration facilities existing in China (Hu et al., 2016). However knowledge on the removal of the organic micropollutants and pathogens during the bank infiltration process seems to be scarce. As well a systematic assessment of alluvial systems along major Chinese rivers concerning the suitability of riverbank filtration is lacking so far. Such contaminants may travel along a water cycle from wastewater to raw water used for drinking water thus posing a significant problem to water quality, especially if they are resistant against chemical or biological degradation.

Finally, in Chinese rural areas 60-70% of drinking water relies on direct abstraction from wells without the effective control of water quality, which causes increasing concerns for the drinking water safety and is one of the reasons why China's groundwater resources require thorough attention.

2.1.2 Safeguarding and managing groundwater resources

The annual report[3] from the Ministry of Water Resources (MWR) of China said that in 2014, nearly half of 2,071 monitored wells had "quite poor" water quality, and an additional 36 percent had "extremely poor" quality. 32.9 percent of wells tested across areas mostly in Northern and Central China had Grade 4 quality water, an additional 47.3 percent of wells were even worse, Grade 5. China grades its water quality in six levels, from Grade I to Grade VI, with Grade VI being the most polluted. Thus, understanding and sustainable management of groundwater resources need to be improved.

Managed aquifer recharge (MAR) is a technology for restoration of groundwater resources. The history of managed aquifer recharge (MAR) in China goes back to 1000-2000 B.C. when canals and wells were used to infiltrate river water into the underground as excavations show (Wang et al., 2010). In the past century, starting in 1965, industrial cooling water was used for restoration of strongly depleted aquifers. Soon after, MAR was extended also to rural areas in Northern China to cope with the lack of water resources caused by climatic conditions and high water demand of the irrigation-intense agriculture. Overexploitation of aquifers also led to massive ecological problems in other, densely populated areas, including increase of seawater intrusion. As countermeasure, subsurface reservoirs were built along coastal areas but their number and total capacity was rather insufficient. Further trials included using treated municipal sewage but for various reasons, the preliminary tests were not continued by full-scale MAR schemes. A survey conducted recently by the Junior Research Group "Innovative web-based decision support system for water sustainability under a changing climate" INOWAS[4] at TU Dresden identified about 140 MAR case studies throughout China, with almost half of them located in Shandong province (25%) and Beijing (21%). In contrast to earlier practices (using industrial cooling water for infiltration), almost half

[3] http://www.mwr.gov.cn/zwzc/hygb/szygb/qgszygb/
[4] https://tu-dresden.de/bu/umwelt/hydro/inowas

of the case studies use nowadays mostly water from the perennial streams for infiltration into alluvial-fluvial deposits and karstic carbonate aquifers (40%), followed by rainwater (25%) and river water (13.5%).

The alarming extent of groundwater contamination requires increasing attention and even remediation measures in specific regions. The sources for groundwater pollution are manifold, spills from industrial activities, leaking sewage systems, non-point pollution from intensified agriculture, secondary pollution from contaminated surface waters (microscystines from eutrophication entering subsurface aquatic systems) etc. National scale risk assessments of groundwater resources shall be further developed and appropriate remediation strategies need to be developed. Research and development in the field of contaminated site management, revitalization of brownfields in urban areas of remediation technologies is aimed on the reduction of environmental risks, revitalization of brownfields and water resources and thereby contributes to a successful implementation of China's environmental policy goals and public health aspects, since many former industrial sites are transformed in housing areas.

Concerning novel technologies for in-situ groundwater remediation at contaminated sites novel methods based on environmental catalysis and nanoremediation are promising concepts. Multiple contaminations at sites of former industrial use require development of tailored treatment train concepts for achieving remediation goals within reasonable time scales as well as cost- and resource efficiency.

2.1.3 Coastal Aquifer Systems

Groundwater systems in coastal areas represent a fundamentally important component of the water cycle, while being subject to strong impacts from various origins. Coastal aquifer systems bridge onshore freshwater aquifers, with their potential as long-term stable and sustainable drinking water sources, and marine water bodies, as the receiving compartment in the water cycle for natural and anthropogenic contaminations. Meanwhile, these subsurface water bodies which reside in a labile equilibrium between marine salt and recharge-borne inland freshwater, are compromised by external stressors through impacts of e.g. urban (drinking water wells, sewage systems, heat usage) or agricultural (irrigation water, fertilizers, pesticides) origins. Additionally, due to the nature of this subsurface system, uncertainty and inaccuracy in data acquirement pose large challenges that pass to the system's assessment through numerical models and their necessary parameterization.

2.2 Land use, soil and biodiversity

2.2.1 Agriculture

The rural areas of China are facing several challenges in sustainable land use resources management. Intensive agricultural use causes soil losses by erosion, losses of soil organic matter, non-point nitrogen and phosphorus pollution of water resources. From April 2005 to December 2013, the Ministry of Environmental Protection and Ministry of Land and Resources jointly conducted the first national survey of soil quality. The report[5] from the first national survey on soil quality which was released in 2014, showed the gravity of soil pollution. More than 16 percent of the samples taken nationwide were contaminated. Moreover, contaminants were discovered in 19.4 percent of surveyed farmland, 10 percent of forests and 10.4 percent of grassland. The new action plan requires that 90 percent of contaminated farmland be made safe by 2020, with an increase to 95 percent by 2030. To implement the plan fully would be extremely costly, at more than 7 trillion yuan (US$1.06 trillion) according to one estimate. To put that into perspective, the Chinese government's investment in soil remediation this year is around 9 billion yuan (Yang, 2016).

Concerning agriculture, China is the largest rice producing country with around 160 million hectares of lowland rice fields accounting for about 28% of global rice production in 2013[6]. It is well known, that this rice production is responsible for the emission of large amounts of greenhouse gases but also for deteriorating water quality by nutrients and residues of pesticides. Improving water management to reduce the environmental footprint of rice cultivation becomes even more important taking the warming effects of reducing air pollution into account (Li et al., 2016).

A particular problem of rice cultivation is the fact that rice (*Oryza sativa*) is a main source of human exposure to inorganic arsenic (As) in Asia, and mitigation measures are needed to decrease As accumulation in this staple crop. Contamination of irrigation water is the main source of this contamination. The potential of reducing As uptake of rice crops by altering As speciation in the soil or by silicon (Si) fertilization has been recognized. However, systematic research on the processes at the soil-root interface of anaerobic paddy systems is required for understanding chemical speciation in the rice rhizosphere for a better crop quality by linking biology (root development, microbial community) with small-scale soil solution dynamics and solid-state chemistry.

2.2.2 Land management under climate change

Rural areas in China which are vulnerable due to adverse climate conditions or land management and/or are critical for the supply of water resources of

[5] http://www.mlr.gov.cn/xwdt/jrxw/201404/t20140417_1312998.htm

[6] FAO, 2014. FAO Statistical Databases. FAO, Rome. http://faostat.fao.org.

the metropolitan areas shall be in the focus of future research activities. In this connection first successful cooperation between German and Chinese research teams have been made during the BMBF sponsored research project Development and implementation of a scientific based management system for non-point source pollution control in the Miyun basin near Beijing / China" (Fkz: 02WM1047, 2009-2012). The Miyun reservoir is the main drinking water source for Beijing. For a variety of reasons such as over-fertilization, monocultures, intensive livestock production, uncontrolled waste disposal and lack of wastewater treatment it suffers from an ever decreasing water quality. This is exacerbated by excessive water withdrawal and declining precipitation. Over the past 20 years the reservoir water level has declined by 10 m. Intensive agriculture is now practiced on the former lake bed. To secure the water supply of the Beijing agglomeration an integrated management of the resources in the Miyun catchment area is called for. The first step to reach this goal is an analysis of the water and solute pathways in the catchment with a particular focus on non-point pollution sources from agricultural areas and settlements. This was supported through the installation of a hydrological monitoring network (equipped with lysimeters, tensiometers, soil moisture probes and stream gauges) at different scales (from plot via field to subcatchemt) and representative areas to measure key hydrologic parameters. The data thus obtained have been used to identify pollution sources and to quantify important elements of the hydrologic balance in the study area. In combination with the meso-scale, web-GIS-based model STOFFBILANZ a management system to reduce input of contaminants into the Miyun-reservoir has been developed and delivered to the Chinese partners. Future research shall result in sustainable soil management considering organic matter turnover, nutrient and pesticides management, reduction of soil erosion and flood formation e.g. by afforestation without decreasing water yields and woody/non-woody biomass production for renewable energy, as well as rice production systems with lower water consumption and lower emissions of greenhouse gases, nutrients and pollutants.

2.2.3 Soil erosion

Soil erosion is a major threat in China and the country is actually running one of the most ambitious reforestation programs worldwide. Despite China harbors a much higher diversity of forest trees than Europe, this potential is not considered enough in actual reforestation programs that mainly use only a few commercial species. First assessments reveal that simple reforestation such as monospecific plantation mostly fails to be fully sustainable in terms of not only erosion avoidance, but also of closing nutrient cycling, enhancing soil carbon storage and general soil fertility (Wang et al., 2014). This opens a new research field coupling research on biodiversity and ecosystem functions and services in forests.

Droughts, low water quality, and loss of fertile soil are among the most important problems to overcome. In erosion sensitive regions such as the loess plateau in NW China countermeasures to mitigate one problem may worsen the other as measures to decrease soil erosion (i.e. by large-scale afforestation) result in decreasing water recharge from restored soils in the upland part of larger basins. This situation causes water scarcity in downstream areas, notably with respect to the high water demand for agricultural irrigation (Wang et al., 2012).

2.2.4 Biodiversity

China is placed in several biogeographic zones (Metzger et al., 2013) and harbours a very diverse biodiversity, which generally is little investigated and understood. Only in recent years have biodiversity monitoring efforts been increased to lead to a SINO biodiversity observation network covering large parts of China, but showing taxonomic, temporal and spatial gaps (Schmeller et al., 2017). Our understanding of Chinas biodiversity is also hampered by scattered data, inaccessibility of data (data format, language, access rights) and lack of data in regions logistically difficult to access (e.g. mountains). Generally, biodiversity is threatened by urbanization, habitat fragmentation, climate change, and pollution. Due to the lack of data, the combined extent of those threats is difficult to be assessed at the current moment.

Due to the strong economic link between Germany, Europe and China, Asia, many natural products are shipped between the countries, with a bias from China to Germany. This has led to several introductions of invasive species to Germany and Europe with devastating effects on e.g. bees (Roques et al., 2009). Further, introductions of pathogens have been reported, which may lead to the extinction of such emblematic species such as the European Fire Salamander (Martel et al., 2014) and may be responsible for tree diseases as well. Such studies show the importance and need to better understand Chinese Biodiversity to prevent detrimental effects.

China has made a considerable reforestation effort since 65 years to stabilize soils against erosion and degradation (Zhang and Song, 2006). However, most of the time reforestation in China consists of monospecific plantation of commercial timber species, with proven reduced ecosystem services compared to natural secondary forests(Zheng et al., 2008). The world largest biodiversity and ecosystem services experiment in forest is settled in a biodiversity hot spot in south China and has established nursery procedures to enlarge the spectrum of local tree species for afforestation; experimental plantation enable to tackle the link between biodiversity and soil protection (Bruelheide et al., 2014).

2.3 Renewable Energy Resources

China has an enormous and increasing energy demand. Today China's total energy consumption is still mainly based on coal (66% in 2012). China's installed coal-based electrical capacity was 77% of the total electrical capacity in 2014[7]. In order to decrease the coal consumption (being the most serious reason for air pollution) China is developing shale gas exploration and exploitation strategies (Hou et al., 2015). In addition to bridging technology such as unconventional gas resources China is developing renewable energy resources mainly from hydro and wind power (378 GW in 2013[8]). Even though China is the world's largest manufacturer of solar photovoltaic technology the own use is still limited. China has a substantial potential of geothermal energy resources, high-temperature resources in the Himalayan (for electricity production) and middle-low temperature resources in sedimentary basins (for domestic heating) (Kong et al., 2014). Near surface geothermal systems (ground-source-heat pumps GSHP) are particularly suited for combined heating-cooling purposes in urban areas – a promising technology also for mitigating air pollution by substituting coal-fired heating.

2.3.1 Geoenergy

Research on system understanding of both shallow and deep geothermal reservoirs is required for exploiting geothermal energy as one important source to cover Chinese energy demands. A Sino-German Geothermal Research Centre has already been established focusing on the quantification of coupled Thermal (T), Hydraulic (H), Mechanic (M) and Chemical (C) processes in the subsurface, which covers all underlying physics of geothermal reservoirs.

Research demand exists for all types of geothermal systems:

- Shallow Geothermal Systems. In Chinese cities, large living complexes / commercial and public buildings can be supplied by ground source heat pump (GSHP) systems, which are coupled with several hundreds to thousands of borehole heat exchangers (BHE) for heating and cooling purposes. Therefore, it is necessary to develop analysis methods, monitoring concepts and tools for both consideration of thermodynamic and economic efficiency. It is also important to assess environmental risks regarding the exploitation of large-scale shallow geothermal resources, which is not recognized as an issue in China yet.
- Hydrothermal Systems. A comparison of karst geothermal reservoirs and their operation modes between China and Germany will give insight to the functioning of low-to-middle temperature hydrothermal systems, with particular focus on the sustainable operation of reinjection technologies. Long-term aspects of hydrothermal karst systems utilization need to be investigated.
- Enhanced Geothermal Systems (EGS) are still the most unreliable geothermal systems due to the lack of basic understanding of deep geothermal

[7] https://en.wikipedia.org/wiki/Coal_in_China
[8] https://en.wikipedia.org/wiki/Renewable_energy_in_China

systems and underlying thermo-hydro-mechanical-chemical (THMC) processes triggered during reservoir exploitation. To this purpose basic research has to be continued as well as the exchange of exploration and operational experiences learned from site studies worldwide.

2.3.2 Bioenergy

In addition to geothermal energy resources, biomass energy is also of high interest for cooperation in order to reduce the coal extent used for energy production, e.g. through biogas or biofuel generation by controlled anaerobic bioprocesses. Recent estimations say that China plans to increase the proportion of biomass energy to an installed capacity of biomass power generation to 30 GW by 2030 [9]. The majority, however, is still used directly for heat production by burning. But e.g. urban waste was estimated to be 210 million tons by 2015 which is a resource not yet efficiently used for biogas production [10]. It is stated that biogas is of high interest for China's national energy-mix. Besides the huge number of 42 million already existing household digesters 16.000 middle- and large scale biogas plants are planned to be implemented until 2020. But research specific to technology assessment and process stability and control is still required (Oos and Martin, 2014). To conform to increasing demands of a circular economy, digesters can also be part of wastewater treatment plants to make optimal use of the capacity of microbial meta-communities by combining the water purification process with biogas production. Sludge from wastewater treatment plant (WWTP) reactors or from solid biodegradable waste can be used for methane production in digesters. An innovative approach for controlling the efficiency of digester communities is microbial community analytics (Günher et al., 2016). This approach aims for the development of new control strategies for bio-based biotechnological processes (Koch et al., 2014) in the frame of Germans Industry 4.0 initiative.

The behavior of microbial communities under changing environmental conditions is often non-linear and still unpredictable despite applications of modern omics-technologies. An overarching theory as thermodynamics has in principle the potential to increase the pre-dictability of such complex systems. For that reasons, biothermodynamic theories, methods, tools etc. need to be developed and assessed concerning their predictive power. Calorimet-ric sensors have to be developed to monitor changes. Application of thermodynamics and calorimetry to more complex ecological networks shall be in the focus of future cooperation. The developed sensors and methods are relevant to energy research and can be applied to optimize and control anaerobic bioprocesses during e.g. biogas generation and production of biofuels, but can also be used for treatment of contaminations.

[9] http://www.bioenergyconsult.com/biomass-energy-china/

[10] LiuEtAl:2014

Pollution and Waste: The following three research topics are dealing with various aspects of pollution and waste management in urban and rural areas including wastewater, municipal solid waste and air pollution, which is of particular importance for Chinese cities.

2.4 Wastewater Management and Treatment

The total discharged wastewater in China has increased by 65% from 41.5 billion m^3 in 2000 to 68.5 billion m^3 in 2012. Recent projections estimate further increase of water consumption (Hou et al., 2015) that might result in a wastewater production of more than 90 billion m^3 in 2030. In response to water shortages and the severe pollution of water resources, China is already investing in the improvement of wastewater infrastructure, supporting the development of new technological solutions and adapting wastewater regulation. From 2000 to 2014, the total number of wastewater treatment plants in cities increased from 481 to 3,717 with a total treatment capacity of 1.48 $\times 10^8$ m^3/d (Zhang et al., 2016). In 2013, two pilot projects started to transform the Chinese wastewater market by implementing cutting edge technologies for building up a circular economy that closes loops by resource recovery from wastewater such as drinking water, energy, platform chemicals and nutrients[11]. In 2015 the National Action Plan for Water Pollution Prevention and Control was adopted that lays out 240 actions among those regulations for factories in the ten worst water-polluting industries.[12] Thus, the development of improved treatment technologies for industrial wastewaters has a high relevance and offers also market chances for the German water industry. Elimination of hardly biodegradable contaminants, for example, requires innovative physical-chemical methods with improved cost- and energy-efficiency. Novel functional materials can provide new opportunities for treatment of industrial wastewaters here, combining principles of nanotechnology and heterogeneous catalysis.

However, the causes for severe pollution of many Chinese water bodies are not only the lacking capacity of water treatment for domestic and industrial wastewater and intense agricultural activities, but also the lack of integrated plans for resilient environmental engineering for urban and rural areas. The protection of aquatic ecosystems and the security of drinking water provision are ever-growing economic challenges in water management, especially in metropolitan areas. Thus, there is an urgent need for the development and

[11] Workman (2016) China's new strategy to transform its wastewater market. http://www.thesourcemagazine.org/chinas-new-strategy-to-transform-its-wastewater-market/

[12] The State Council of the People's Republic of China (2015) China announces action plan to tackle water pollution. http://english.gov.cn/policies/latest_releases/2015/04/16/content_281475090170164.htm

implementation of innovative system solutions for sustainable water quality improvement by means of Urban Water Resources Management (UWRM). The UWRM concept relies on a holistic view of the urban water network (storm water and wastewater management and treatment, drinking water supply) and all levels of the aquatic system according to the principle of emissions (source of pollution) / immissions (contamination), thus not only evaluating emission loads and intensities, but also effects and concentrations in the receiving water. The main aim of UWRM is to provide efficient sanitary systems in urban and rural areas and to preserve natural aquatic ecosystems as ecological and economic resources and as drinking water sources.

A specific challenge encountered in urbanized areas worldwide is the emergence of diffuse urban pollution contributing to the contamination of receiving aquatic ecosystems. Pollutants such as heavy metals, PAK and PCB are washed off urban watersheds, producing urban runoff high in metals and organic pollutants which is transported through sewers or directly into the receiving water. Monitoring and modelling of pollutant built-up in and leaching from road-deposited sediments (RDS) is essential to assess the potential adverse effects of RDS on the storm water quality and the performance of an integrated storm water pollution management (Zhang et al., 2015).

Urban flooding and flash floods, involving health and environmental risks due to polluted storm water, are the result of a lack of proper urban rainwater management in China. Intensified monitoring efforts to obtain highly resolved precipitation data are therefore needed to enable thorough rainfall-runoff and flood modelling, early warning for urban flooding and the focusing of prevention and reduction measures on affected areas.

Also in many rural areas of China, wastewater treatment is still deficient. In such remote areas with moderate population density, the implementation of centralized wastewater infrastructure is difficult or even impossible due to high investment costs. Therefore, China has a huge demand on cost-efficient and low maintenance treatment processes (decentralized wastewater treatment).

Main primary nonpoint sources of pollution in rural catchments are: (i) Direct discharges of untreated domestic wastewater from rural households or settlements, (ii) waste emissions from livestock production, and (iii) agricultural runoff (fertilizer residues).

Decentralized wastewater management schemes offer several advantages: (i) a reduced technical complexity, (ii) shorter depreciation times and often (iii) much lower investment costs because an expensive sewerage network is usually not or only partly necessary (Afferden et al., 2015). Furthermore decentralized systems have the advantage of being highly flexible and can be easily adapted to changing conditions and demands such as population growth.

The research demand and cooperation opportunities are ranging from specific technology developments and transfers to comprehensive systemic approaches, including:

- Using inherent microbial communities as sensors for WWTP reactor states, (Günher et al., 2011)
- Improving the efficiency of water purification, energy production, and raw material recovery from sludge treatment treatment (see also the SEMIZENTRAL project in Qingdao), (Koch et al., 2014)
- Biogenic waste treatment by Hydrothermal Carbonization (HTC), conversion of sewage sludge into biochars,
- Adapted technologies for decentralized treatment and reuse of wastewaters in rural areas, e.g. using constructed wetlands and integrative multi-technological management schemes for wastewaters generated by households, livestock and agricultural runoff,
- Introduction of innovative and cost efficient hybrid technologies for hygienization and pollutant removal in small-scale treatment plant to improve water quality of receiving water and for various possibilities of water reuse
- System solutions for N, P and energy recovery for closing resource loops at local level,
- Implementation of UWRM approaches with integrated storm water (pollution) management,
- Early warning systems for urban flooding relying on monitoring networks and rainfall run-off / flood modelling,
- Industrial and domestic wastewater as a substrate for innovative wastewater treatment technologies (yeasts, algae) for the production of platform chemicals in the frame of bio-economy,
- Novel functional materials for efficient catalytic degradation of hardly biodegradable contaminants in industrial effluents,
- GIS - decision support tools for implementing integrated wastewater management concepts at micro-catchment scale,
- Life cycle (cost) assessment for individual technologies and technology combinations in the frame of circular economy
- Treatment of wastewater and surface-runoff water in watersheds of tributaries in rural areas and informal settlements by using riparian treatment zones,
- Measures to increase the fertilizer use efficiencies in rural areas,
- Treatment of pesticide contaminated waters using artificial wetlands.

More details of research approaches and cooperation opportunities can be found in section 3.4.

2.5 Municipal Solid Waste Management

Today's governments face increasing problems by quick growing volumes and forms of solid and hazardous wastes due to continuous economic improvement, industrialization, and urbanization. Inappropriate handling of waste leads to threats for the environment, such as greenhouse gas emission, land degradation, water and resource pollutions etc. Waste disposal and resource depletion are two main urgent problems for the human society, and waste reduction and recycling are two promising solutions.

China is one of the fastest growing countries in the world and has, as a result, a growing waste management problem. Chinese MSWM is dominated by 60.16 % landfilling, whereas incineration, untreated discharge, and other treatments are 29.84, 8.21, and 1.79 %, respectively. In 2014, a total of 604 sanitary landfills, 188 incineration plants, and 26 other units were used for MSWM (Mian et al., 2016). The fast urbanization and population growth in China has led to remarkable increase for municipal solid waste (MSW) generation volumes. According to China Statistic Yearbook 2009, the average annual growth rate for MSW from 1979 to 2009 is approximately 7%. The amount of MSW in China increases greatly with the ambitious urbanization targets and the improvement of the living standards. There are about 660 cities in China that produce about 190 million tons of solid waste annually and account for 29% of the world's MSW each year.

Developing a circular economy and building green societies are global consensus. As the two leading countries in their regions in this field, both China and Germany want to reduce the environmental impacts of waste, and have accumulated many experiences on waste reduction and gradient utilization of waste. "Pay As You Throw", "Green Dot" system, and "trade in policy (the new for old policy)" are all have proven to lead to higher recycling rates and minimization of waste in the past 30-40 years.

2.6 Air Pollution

Recent years have seen incidents in which the air pollution level in many Chinese Mega-Cities was quite literally off the charts. Beijing and Shanghai also have had incidents far beyond "severe" and the current guidelines are exceeded in many other locations in China as well. Increased manufacturing powered by coal, rising numbers of cars and motorbikes, and a disregard for environmental laws contribute to the situation. The black soot particles at the root of the problem are not only toxic to humans, but also are a factor in climate change. According to a study on air quality in 74 major cities and key regions in November 2013, 47.7% of days failed to meet standard air quality (MEP, 2014). The Chinese Academy for Environmental Planning estimated that tackling country? dirty air will cost about 210 billion Euro between 2013 and 2017 (The Guardian, 2013). The Chinese government has initiated a pilot carbon cap and the Airborne Pollution Prevention and Control Action Plan in 2013[13] which aims to reduce air pollution in northern China 25% by 2017.

In the 13^{th} Five-Year Plan, Chinese government has proposed the following key measure to reduce the smog and air pollution: coal-fired plant reform using low emission control technology, elimination of outdated industrial equipment and processes, improved monitoring of industrial pollution sources, and increased supervision of compliance by motor vehicles and vessels with environmental protection standards.

The air quality in large cities has deteriorated due to nitrous oxides (NOx), carbon monoxide (CO), photochemical smog (such as ozone), volatile organic compounds (VOC), and (ultrafine) particulate matter (PM1, PM2.5, PM10), which are typical for vehicle pollution. Some cities now have a mixture of these and often the visibility in urban areas continues to deteriorate.

Ambient particulate air pollution is a challenging problem. Facing the environmental and health hazards of the enormous air pollution in many Chinese cities, several preventive measures are necessary to reduce mortality and morbidity of the inhabitants of the polluted areas. Particulate air pollution has been consistently associated with daily mortality and morbidity around the world. At present, PM10 and PM2.5 (particles $< 10\ \mu m$ or $2.5\ \mu m$ aerodynamic diameter) are the most frequently used particle fractions in epidemiological investigations. In addition, some newer findings suggest that ultrafine particles (particles $< 0.1\ \mu m$) may be of special importance for human health. Particulate air pollution is estimated to be responsible for about one million premature deaths per year in China ((Florig, 1997), (Florig et al., 2002))

Future research cooperation shall elucidate the respiratory (and cardiovascular) health effects of airborne exposure of the mega-city population (i.e. Beijing). The research will focus on soot particles as an important detrimental constituent of the combined air pollution. Simultaneous analysis of air quality and land use change shall illuminate their interrelations, help mitigating further deterioration of air quality and support sustainable urban development. Integrating urban climate and air quality modelling with smart sensors and Information Technology will serve improved models, prediction and warning tools for environmental and human health in cities.

[13] http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm

Environmental information, governance, regulation and management: Fundamental to successful implementation of scientific approaches and environmental technologies are appropriate environmental management concepts including governance and law, education as well as advanced management concepts e.g. from environmental information science.

2.7 Information science for environmental management

Our environment is very complex due to interfering natural and anthropogenic imposed processes. An essential prerequisite for a better understanding and finally sustainable management of complex socio-environmental processes is the availability of adequate information about the actual environmental situation. The "simple" formula is: collecting data, understanding by analysis and knowledge – planning – acting and controlling. The complexity of environmental problems requires adequate analysis, planning and management tools for problem identification and developing system solutions.

Environmental Information Science is providing concepts and tools to build the above "value chain" for a comprehensive approach to solving environmental problems. Currently, advanced tools exist for specific purposes such as for infrastructure planning of cities (energy, water supply, traffic, waste management etc.) but mainly separated. How those complex infrastructure measures – in particular their interaction - affect our environment is not properly investigated mainly because of missing concepts, tools and governance. This is where Environmental Information Science comes into play in order to combine specific purpose approaches and to develop systems solutions.

An important basis for building Environmental Information Systems (EIS) as a product of Environmental Information Science are Geographic Information Systems (GIS) for providing the real geographic context. EIS development steps can be organized and generally structured as follows:

1. Step 1: Based on the availability of data and information about the environmental system the status-quo is defined. The data base should compile "all" available data from monitoring stations, remote sensing, surveys and historical records etc.

2. Step 2: This data base should be embedded into so called Virtual Geographic Environments (VGE) for providing all information into the real geographic context – but using Virtual Reality methods and tools. This allows a holistic view to the environmental system from different perspectives (authorities, stakeholder, public etc.). At this stage, EIS already provides a useful tool for any kind of planning processes – as mentioned from various viewpoints based on best engineering practices.

3. Step 3: When modeling tools are invoked, the information system achieves predictive power. Future consequences of planning processes can be assessed based on best scientific knowledge and practices. This includes operational aspects, e.g. how sewage systems can be built optimally depending on urban planning concepts as well as long-term trends, i.e. how surface and groundwater quality will develop when water pollution control measures have been implemented. Furthermore, only a combination of monitoring and modelling platforms through information systems can generate knowledge based on observed data in a comprehensive way and enable the development of management scenarios which can be used meaningful by corresponding authorities.

The development of Environmental Information Systems and particularly their implementation is a complex and long-term challenge for science, technology and the society. In order to tackle this challenge the Helmholtz Association together with the Chinese Academy of Sciences launched the "Research Centre for Environmental Information Science – RCEIS" [14].

2.8 Environmental governance, law and management

On 1 January 2015, a new environmental protection law (EPL) took effect in China. It is the nation's first attempt to harmonize economic and social development with environmental protection (Zhang and Cao, 2015). China's latest five-year plan shifts its environmental law away from a pollution-control system and towards one that manages environmental quality (Cyranoski, 2016). Under the plan, Chinese provincial environmental-protection departments will be responsible for unifying local monitoring and inspection programs and for eliminating protectionism in local governments.

This general ambition can only be successfully achieved if China overcomes governance deficiencies like, e.g., lack of stringent environmental laws, incoherent regulatory instruments, unclear and overlapping competencies, ineffective organization, lack of polluter responsibilities, poor monitoring-schemes, lack of information disclosure, public participation, enforcement and judicial

[14] www.ufz.de/rceis

review. Thus, China will only succeed in solving its environmental problems if it develops effective governance approaches. Chinese officials are, today, very much aware of these governance challenges and considerable steps have already been undertaken. In particular, national environmental laws have been revised and tightened in the past decade, with strong reference to US and European standards and with intensive involvement of scholars from both China and abroad. However, it is obvious, that China has still far ways to go in developing a governance system that not only provides ambitious environmental objectives but also the instruments and administrative arrangements needed to effectively implement these objectives. This is what still needs to be developed now in most fields of environmental protection, where China can still strongly benefit from the German and European cooperation. Scientific cooperation appears to be particular promising in this field due to the fact that the Chinese national government relies heavily on scholarly advice in drafting its legislation and policy programs.

The development of a sound environmental management in China is crucial in tackling the problems caused by pollution. Environmental accounting and management control is increasingly needed in Chinese companies (OECD, -2007; Chen, Zhang, Yang, & Zhang, 2011). The Chinese government has required companies to report air pollution, wastewater, and heavy metals to environmental regulators and encouraged them to make real-time disclosures (The Economist, 2014). While companies in developed countries like Germany are already accustomed to environmental accounting, Chinese companies are still at the beginning of the process since it was not considered in accounting law and environmental regulations (Sun & Sun, 2003; Xiao, 2006). Several concepts of environmental accounting and management control need to be further developed and tested for China.

Furthermore, the impact of cultural differences in environmental management and control systems in China and Germany has to be investigated when developing such systems for China.

Important fields for future cooperation on governance are: Water management, climate change, sustainable urban development and planning and green energy transition, as well as general requirements of environmental governance.

Specific challenges in need of improved regulation and management shall be tackled:

Urbanization: The tremendous economic and population growth in Chinese cities caused large urban transformations. One transformation field refers to land as a resource with respect to the expansion of urban land in its rural and agricultural hinterlands. Former rural population has become citizens and has undergone socio-demographic and socio-economic changes. Both, land use dynamics and demographic development, are central drivers and influence the Chinese urban environment by putting pressure on environmental resources and destabilize the urban quality of life. The velocity in which urbanization takes place and the lack of sensitivity for a sustainable land management have led to broad array of socio-demographic and pollution problems with negative impacts on human well-being.

So far, China has a number of projects dedicated to a more sustainable urban development labeled “Eco City”, e.g. Lingang New City or Dongtan Eco City, or “Turenscape”. The respective masterplans consider ecological, social and economic targets such as CO2 neutral energy supply, public transport or a large amount of green spaces and resilience against natural hazards. Such environmental-friendly cities thus make an effort to guarantee sufficient quality of life and attractive living conditions, but are still singularities. It is essential to study approaches, experiences, state of the art to understand the specifics of these projects in comparison to other approaches worldwide. On the long run the goal must be to develop recommendations for a resource-efficient and resilient land management towards a sustainable urban development in China (for research details see chapter 4.2.1. Urban land use and multifunctional Green Infrastructure)

Scientific support and recommendations for land use policy based on international standards of indicator sets, strategies and land management tools shall help fostering an adequate urban quality of life and environmental justice in Chinese cities.

Carbon emissions: Carbon emissions as major source of climate change and global warming are also recognized by the Chinese government and society. In 2011, 26.4% of worldwide emissions were emitted from China with an increase of 9.4% compared to 2010. The National Development and Reform Commission (NDRC) of Chinese government issued ”The Notification on Piloting Carbon Emission Trading” in October 2011 to approve the launch of carbon emission trading schemes in five cities (Beijing, Shanghai, Tianjin, Shenzhen, Chongqing) and two provinces (Guangdong, Hubei). Due to the increasing interest in scope 3 emissions, containing carbon emissions from suppliers, Chinese companies started to see carbon reporting, accounting and control as a business case. In 2009, Foxconn announced that they want to invest US$100 million to $200 million in the GreenCert project, which allows the measurement and certification of carbon emissions at a facility. Furthermore, the company stated that they also want to use the software itself and become a showcase for its industry (PCWorld, 2009). Nevertheless, carbon cutting measures are still not consequently implemented and require further improvement.

Climate change and extreme events: China’s cities face the risks posed by a changing climate and the need to implement adaptation strategies (Li, 2013). This includes more extreme temperatures and rainfall and more frequent cyclones. In 2007, China started to develop a national policy framework to address climate change challenges, which has included adaptation policies to help people cope with the impacts. Effectiveness and efficiency of these measures need to be analyzed.

Water footprints: Besides pollution, the consumption of water is becoming increasingly important for transnational supply chains. For the calculation of product water footprints, the consumption of water in Chinese production sites is relevant for companies all over the world.

Chapter 3

Past and ongoing activities

In this section, a brief portrayal of past and ongoing activities is being provided to exemplary highlight progress for research topics. A more complete and detailed list can be found in the Appendix. Figure 3.1 depicts geographic overview of major research activities of UFZ in China.

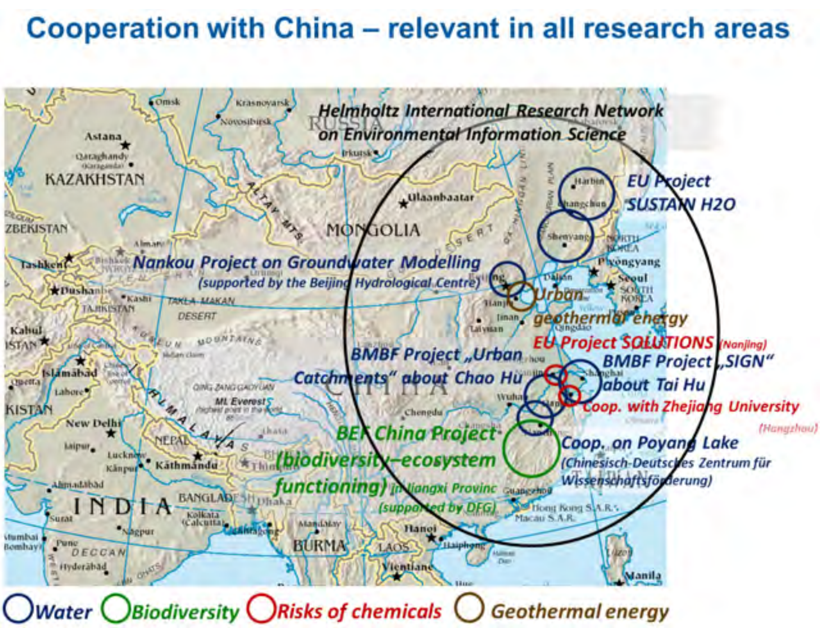


Figure 3.1: Examples of cooperation activity areas in China concerning research in water resources, biodiversity, chemicals in the environment and renewable energy resources

3.1 Water resources

3.1.1 Safeguarding drinking water quality/supply

Among the freshwater resources, the protection and restoration of drinking water resources such as lakes and dams have received the highest priority. A typical example is Lake Chaohu, located in the Chinese province of Anhui. The Lake Chaohu is the fifth largest freshwater lake in China (766 km^2) and is the major drinking water supply for the 5 million people living in the cities and towns of its catchment. Lake Chao is the most important source of drinking water in the area, and this severe human health hazard presents an urgent need for action towards improving the water quality and is therefore a focus area of the "Major Water Program" of the Chinese Government. The causes are not only the lacking capacity of water treatment used in industry and intense regional agriculture, but also the lack of integrated plans for resilient environmental engineering for urban and rural areas. Many scientific studies have examined the most prevalent pollutants—lake and river sediments contain sometimes high levels of heavy metals, alkylbenzene, and pesticides—but research on technical solutions to improve the water quality has not been substantial. Summer algal blooms in Lake Chao are regular occurrences due to extremely high phosphorus imports, which then results in high levels of cyanotoxins (microcystins). The BMBF-CLIENT project "Managing Water Resources for Urban Catchments"[1] is dedicated to the development and implementation of an early warning system for drinking water supply for the City of Chaohu. An Environmental Information System (EIS) for water management aspects is developed for Chaohu City jointly by Chinese and German scientists, SMEs in close cooperation with the authorities of Chaohu.

The figure shows the EIS for a part of the urban catchment of Chaohu including the city, suburban areas and the lake. The emphasis is status-quo and future planning of waste water infrastructure by numerical modeling shown in a Virtual Geographic Environment[a]. The EIS for water management can be extended for any kind of urban infrastructures.

[a]Rink et al. (2016): Virtual Geographic Environments (VGEs) for Water Pollution Control. J Digital Earth, submitted

"Urban Catchments" partners are AMC, BBE Moldaenke, ITWH, OpenGeoSys e.V., TU Dresden, UFZ and WISUTEC.

[1]www.ufz.de/urbancatchments

"Urban Catchments" is part of the BMBF-CLIENT Initiative "Innovation Cluster – Major Water"[2], (Dohmann et al., 2016).

3.1.2 Safeguarding groundwater resources

Several projects have been successfully completed concerning groundwater resources Northern China, e.g. the "Nankou" project dealing with nitrate pollution of Beijings groundwater resources (Sun et al., 2012). The figure shows a visualization of the "pump-and-treat" technology for the contaminated groundwater.

The EU project "SUSTAIN H2O" dedicated to pollution control and water quality improvement in the Songhuajiang-Liaohe river basin [3] with corresponding training courses (OGS Tutorial)[4]. INOWAS is a new Junior Research Group at TU Dresden aiming at providing stakeholders with a scientifically based decision support system (DSS) for planning, design and management of applications in the water sector [5].

3.2 Land use, soil and biodiversity

3.2.1 Influence of 2000 years of rice cultivation on the greenhouse gas CO_2

Rice cultivation is usually believed to favour sequestration of carbon in the soil, leading to a net removal of the greenhouse gas CO2 from the atmosphere. However, this paradigm is overturned by a joint German-Chinese study funded by DFG with a leading role of Prof. Kalbitz from TUD (Kalbitz et al., 2013) In a unique investigation of soils under continuous rice cultivation for up to 2000 years, it has been shown that processes in the deeper soil layers may completely offset carbon sequestration in the topsoil.

Soils store more carbon in the form of soil organic carbon than the standing vegetation and the atmosphere combined. This enormous carbon stock forms a crucial part of the global carbon cycle and directly influences atmospheric concentrations of the greenhouse gas CO2. On the one hand, plants remove CO2 from the atmosphere through photosynthesis, part of which is subsequently stored as soil organic carbon when dead plant material enters the soil. On the other hand, microorganisms in the soil degrade soil organic carbon into CO2 that returns to the atmosphere again. Whether or not a soil under a certain

[2] www.ufz.de/urbancatchments
[3] http://www.craes.cn/cn/SUSTIANH2O/home.html
[4] http://www.springer.com/de/book/9783319528083
[5] https://tu-dresden.de/bu/umwelt/hydro/inowas

land management serves as a net sink or source of CO2 depends on the balance between these two processes.

Soils used for rice production are mostly managed under submerged conditions (paddy soils). Through the lack of oxygen, such conditions reduce microbial degradation of soil organic carbon. Therefore, until now rice paddy soils were generally thought to function as net sinks of CO2. However, a large international study led by Prof. Karsten Kalbitz and Prof. Ingrid Kögel-Knabner (Technische Universität München) shows that this may not be true.

In their investigation, the research team assessed carbon stocks in paddy soils used for 50, 100, 300, 700, and 2000 years as well as in adjacent soils with non-paddy management in the Yangtze delta, China. They found that all paddy rice soils have indeed been continuously accumulating soil organic carbon for up to 2000 years in the upper soil layers. However, this was offset by an increased removal of organic carbon in the deeper soil layers. In addition, weathering of naturally present carbonates increased, which might contribute to the release of CO2 as well. When the shallow and deep layers of the soil were considered together, in some cases the soils turned out to be net sources instead of sinks of CO2.

The results have far reaching implications. We are still struggling to understand the role of soils in climate change. Differences between the upper and deeper soil layers are hardly considered in our current climate models. In fact, carbon credits are given for the first 20 years of paddy rice cultivation, meaning that you can use it to compensate CO2 emissions from other sources, such a coal fired power plants. Our study shows that such schemes are no longer justified, and that we may have to completely rethink the way our land management practices affect the global carbon cycle. Especially when you realize that CO2 is not the only greenhouse gas influenced by land management, but that the release of methane gas also plays an important role, especially in rice paddy soils.

3.2.2 The role of tree and shrub diversity for production, erosion control, element cycling, and species conservation in Chinese subtropical forest ecosystems (BEF-China)

Forests are known to protect soils from erosion, and China has started and intensive reforestation program to fight against important erosion problems. However despite China harbors a high diversity of forest trees, mostly a few commercial timber species are used in for reforestation programs, in which plantation of non-native species such as Eucalypts of exotic pines tend to dominate. Under these auspices Sino-German-Swiss cooperation was stated more

Figure 3.2: Look to side A of BEF-China (Photo: Stefan Michalski, UFZ), www.bef-china.de, www.idiv.de

than 10 years ago. In China it includes scientists from several universities (in particular Bejing University), who under the coordination of Prof. Keping Ma (Chinese Academy of Science, Botanical Institute, Bejing) were successful in acquiring four two years grants from the National Science Foundation China (NSFC). From the German-Swiss side, Prof. Helge Bruelheide (Martin Luther University Halle) and Prof. Bernhard Schmid (Zürich University) coordinated the Research Unit (FOR 891) BEF China that has been granted in three phases for a total duration of eight years by the German Science Foundation (DFG). UFZ has been permanently represented in that frame with two subprojects hosted at the soil ecology departments and one from the community ecology department. In addition four trilateral meetings were granted by the Sino-German Centre of Bejing, including international summer schools.

BEF China stays for Biodiversity and Ecosystem Functions. The program is settled in the Chinese subtropics, a transition zone between deciduous and evergreen forests, which harbors a remarkable tree biodiversity. On the one hand, the Chinese and European team performed common monitoring in the Gutianshan National Nature Reserve (Zhejiang, China), where they compared 26 forest plots of different ages, elevation and distances, and considered a number of below and above ground parameters to tackle the rules of community assembly and succession in natural multi-diverse forests (Bruelheide et al., 2011). On the other hand the two teams planted more of 250,000 trees on two plots with a total surface of more than 50 ha in Xingangshan (Jiangxi Province). The trees belong to more than 40 species and are planted on more than 600 plots with different levels of species richness (1-24). Apart the effects of tree diversity of diversity of other trophic levels (e.g. herbivores or soil microorganisms) many ecosystem functions such as productivity, of impact of soil erosion are measured (Bruelheide et al., 2014). The particular topography of the plots with step slops is adequate to integrate the results not only at the plot level but also at the scale of landscapes.

Figure 3.3: Installation of the borehole heat exchanger array for the geothermal heating/cooling system

Geothermal energy systems are an important ingredient of renewable Energies in particular in the context of domestic heating and cooling in China (Huenges et al., 2013), (Kong et al., 2014). The UFZ working group "Geothermal Systems Analysis" (led by JProf. Haibing Shao) conducts research on system understanding of both shallow and deep geothermal reservoirs.

Actually, almost 100 scientific articles with both Chinese and European authors have been published in the frame[6]. To mention here is a study showing that variation of diversity with growing geographic distance is not similar between different taxa groups such as trees, herbivore insects of soil microorganisms, which brings new perspectives for delimiting optimal size of protected areas (Schuldt et al., 2015). In particular to mention is also a series of bilateral publications between Chinese and German Colleagues in the field of soil microbial ecology (Gao et al., 2013). Actually the group is applying for an international graduate school by DFG and NSFC on the one hand, and on the other hand a new research Unit is being prepared from the German side. Apart the purely scientific activities, this program was the occasion to develop procedures to germinate and produce seedlings of native Chinese trees, which can now be used in nurseries for reforestation with increased biodiversity and use of local species (Gao et al., 2015).

3.3 Energy resources

The research focuses on the quantification of coupled Thermal (T), Hydraulic (H), Mechanic (M) and Chemical (C) processes in the subsurface, which covers all underlying physics of geothermal reservoirs. The work group by JProf. Shao is supported by the Chinese Scholarship Council and the National Science Foundation of China (Scholarships for Yonghui Huang and Renchao Lu, NSFC PostDoc Exchange Program for Prof. Yanlong Kong). In order to foster the joint research activities, the Sino-German Geothermal Research Centre was established in October 2015 during the Sino-German Symposium on "Sustainable Utilization of Geothermal Energy Resources" in Beijing. The center will

[6] http://www.bef-china.de/index.php/en/publications

Figure 3.4: Impression of rural water systems in suburban areas

In 2010, a total of about 400 million m^3 of wastewater from point sources was discharged into Lake Chaohu. Additionally agricultural pollution makes up for about 68 % of the total discharged phosphorus and for about 74 % of the total discharged nitrogen within the lake. In 2006, the Anhui Environmental Protection Department estimated that the total discharges exceeded the assimilative capacity of the lake by 305 % for COD; by 1,730 % for TN; and by 606 % for TP.

support joint research and education activities in all fields of geothermal energies, shallow and deep resources (www.ufz.de/sg-grc). Currently the work group is involved in two large geothermal energy projects in Jinan (Province Shandong, Fig. left shows the implementation of 2000 borehole heat exchanger (BHE) module for a new administrative building). For a new New City Administration Center (CAC) in Beijing (Tongzhou district) the heating/cooling concept is based on geothermal energy systems, more than 10000 BHE modules are planned by modeling.

3.4 Wastewater management and treatment

The main problem in the catchment of the Lake Chaohu (see 3.1.1) is eutrophication caused by nitrogen and phosphorus (Hong et al., 2007).

For this reason, the Asian Development Bank supported the Anhui Chaohu Lake Environmental Rehabilitation Project by introducing even more integrated approaches for municipal wastewater treatment and management of nonpoint source pollution. Household domestic wastes in rural areas have been identified as the main source of organic (COD) and phosphorus pollutions. Centralized collection and treatment facilities do not exist in rural areas, and public sanitation conditions can be poor. As much as 62 % of all rural household wastewater is released directly into the environment[7]. In addition, tons of anthropogenic silver nanoparticles (over 1,000 tons in 2015 worldwide) are released into the environment due to their use in many consumer products. Silver nanoparticles are known to be toxic towards microorganisms and thus may harm their specific functions in ecosystems such as wastewater communities. Actually UBZ is partner of the BMBF funded research project "Urban

[7] Asian Development Bank (2015) Reviving lakes and wetlands in the People's Republic of China, Volume 2: Lessons learned on integrated water pollution control from Chao lake basin

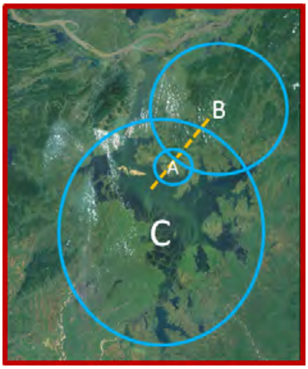


Figure 3.5: Poyang lake investigation area

The Sino-German Cooperation Group "Modeling platform prototype for environmental system dynamics" is funded by the German Research Foundation (DFG) and National Science Foundations of China (NSFC). The general goal for this initiative is to build a research network by leading Chinese and German experts in the field of environmental informatics, hydrology, climatology and remote sensing (satellite born earth observation). This initiative will form the basis for intensive exchange of research methods and knowledge, and is intended to the development of bilateral research project proposals.

Catchment". The ongoing activities are related to the development of decentralized wastewater management concepts for Lake Chaohu.

Research towards this topic is conducted by a PhD student coming from CRAES at UMB, UFZ (Yuting Guo, funded by SMWK/SAB, Nr. 100148808). The CSC is funding a related project at UMB, UFZ (Zishu Liu, University Harbin, Nr. 201306120044) where ecosystems tools are implemented to calculate and predict structural and functional evolutions of microbial wastewater communities.

3.5 Environmental information science

RCEIS Research Centre for Environmental Information Science

The Sino-German Research Centre for Environmental Information Science (RCEIS) was established in March 2014 (www.ufz.de/rceis).

It shall become a Sino-German competence centre and research platform for Earth systems observation and prediction by combining expertise in the fields of environmental and information sciences using modern information technology. The Centre is coordinated by Helmholtz Centre for Environmental Research in Leipzig and Institute for Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences in Beijing.

The Poyang Lake (PL) is an appropriate and prominent investigation area, which is well suited for the interdisciplinary eco-hydrology research concept in this project. The first workshop has been conducted in September, 2015. During the workshop, the participants successfully developed a proposal concept dealing with the System: Lake -Poyang. The envisaged project is dedicated to gain a better understanding of the system lake including the analysis of multiple (natural and anthropogenic) stresses on aquatic ecosystems.

3.6 Outreach and community activities

Publication activities cover both research and strategic papers. Numerous papers have been published since 2013 dealing with joint Sino-German research in environmental sciences. Since 2014 several Thematic Issues have been published in Environmental Earth Sciences (EES) dedicated to the results of the Chinese Major-Water program in river and lake basins (Liaohe (Song et al., 2015), Dianchi, Erhai (Wang et al., 2015), Poyang (Yue et al., 2015), Taihu (Xi et al., 2015) Three Gorges) as well as unconventional (Hou et al., 2015) and renewable energy research (Kolditz et al., 2015).

Chapter 4

Major interests for future cooperation

This chapter describes the major interests for future cooperation of UFZ and CAWR (more focused on water research) compiled during a series of workshops. The research interests are related to all spheres of the terrestrial environment, hydrosphere, biosphere, pedosphere, geosphere as well as the atmosphere. The researchers represent basic as well as applied sciences involving social sciences as well as data and information science. The activities are driven by the most pressing societal challenges - the sustainable and environmentally management of resources and waste, pollution control and restoration of natural resources of all related spheres. The suggested research structure also follows the general idea of circle economy and life-cycle perspective of natural resources, i.e. resources will be converted into waste – being considered as a resource itself[1].

More specifically, the research interests address water resources (above and below surface) and waste water management, land use and soil, renewable energy resources, municipal solid waste management, air pollution and urban climate. More general concepts of urbanization processes, biodiversity and ecosystem services, environmental information science as well as environmental management and governance complete the research portfolio offered by UFZ and CAWR researchers – which will be updated and further completed by dialogue with our Chinese partners in an open process. Existing partnerships are compiled in "cooperation matrices" for each section – which should be considered open for further extensions of interested researchers from both German and Chinese sides.

[1] http://www.eea.europa.eu/soer/

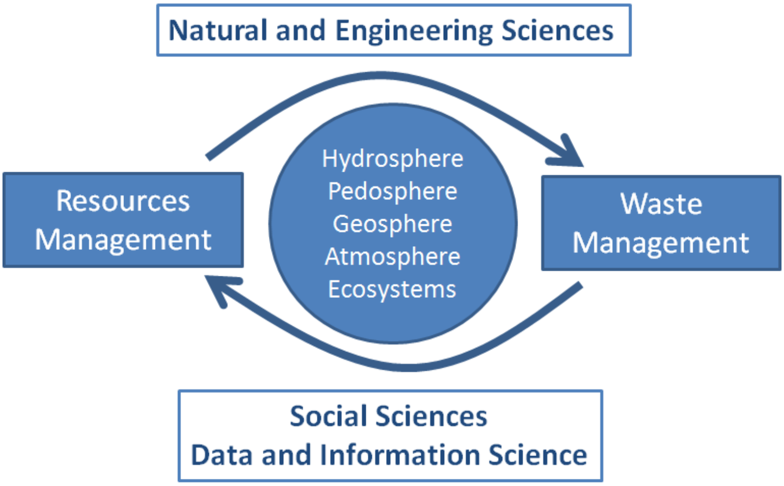


Figure 4.1: Structuring major interests for future cooperation

4.1 Water resources

Environmental impacts of Chinas large water infrastructure projects

A pressing issue in Chinese water management is the full integration of water quantity and water quality management into one coherent framework for sustainable water resources availability. Given the tremendous changes in the water cycle induced by man-made transformations and large scale engineering, the long-term perspective of aquatic ecosystems, the services provided by them, as well as the general development of water quality remain elusive. First-level examples of anthropogenic perturbations of the water cycle are the south-to-north-water-diversion-project (SNWDP) or the rapidly progressing construction of large dams. As these large scale projects are entirely motivated by resource-oriented planning (flood control, drinking water availability, irrigation water, hydropower generation, etc.), their environmental impacts over time and spatial scales are not yet thoroughly assessed and appropriate mitigation strategies are hardly considered.

Innovative monitoring and management concepts (best practice) for toxicant pollution

The development of safe but cost-efficient monitoring strategies integrating effect-based and chemical analytical tools for the protection and sustainable use of water resources is one of the common major interests for future cooperation. This includes the advancement and standardization of classical in-vitro and in-vivo bioassays and related trigger values but also cutting edge multi-endpoint and genetic tools together with innovative chemical analytical approaches for toxicant identification.

Common projects are also required in the field of data interpretation and translation into management measures. The demonstration and validation of the new tools in European and Chinese case studies will help to increase the common understanding in assessment and abatement. Future projects on non-toxic and sustainable water resources can build on the existing experience (e.g. SOLUTIONS).

4.1.1 Surface water quality

Nutrient transport and retention in agricultural subtropical watersheds in China

Agricultural land use and fertilizer application has strongly increased in Chinese subtropical watersheds. This led to serious eutrophication problems of surface waters and endangered drinking water resources. Although large amounts of the agricultural nutrient surplus is retained in the subsurface and in surface waters there is a strong knowledge gap on quantifying these retention processes, their controlling factors and their possible change in time. Therefore research will focus on determining nutrient losses from land to water and evaluate retention capacities of terrestrial and river network systems. We will investigate nutrient retention using a combined experimental and modelling approach at agricultural subtropical watersheds of different scale within important drinking water reservoirs in south east China. Based on these experimental investigations integrated terrestrial and in-stream nutrient loading and retention processes will be explored and modelled with suitable water quality watershed models. State-of-the-art continues water quality monitoring will support model verification. Integrated watershed modelling can be used to evaluate the importance of subsurface and in stream nutrient retention processes.

Research questions:

- How current land use and changes of land use management practices may alter nutrient loads?

Nitrogen-centered management of lake water quality under the constraint of climate change

Eutrophication is a major threat to water resources being closely linked to global change in several ways. First and foremost, nutrient emissions to surface waters are positively correlated with population density as well as with the development of the industrial and agricultural sector. The undesired consequences of increased nutrient levels such as algal blooms and hypoxia are stimulated by the general rise in water temperatures and, in a site-specific way, by anthropogenic alteration of hydraulics. While eutrophication control strategies traditionally focused on Phosphorus, Nitrogen (N) limitation of algae is controversially debated by scientists and receives increasing attention by water managers. Chinese-German collaborative research is proposed to elucidate the possible effect of reduced N loads on the blooms of blue-green algae in shallow lakes under the constraint of climate change. Experiments at the lab- and pond-scale shall be complemented with process-based computer models to identify and resolve gaps in mechanistic understanding.

Research questions:

- What is the quantitative contribution of N-fixation to a shallow lake's nitrogen budget, compared to external input and the recycling of settled organic matter?
- Does the contribution of fixation to the total N-pool increase over time? If so, is this due to adaption at the organisms' or ecosystem level?
- What are the direct and indirect effects of increased water temperature on N-fixation?
- How can controlled, small-scale experiments help to predict the ultimate effects of reduced N loading on the ecological state (e. g. the algal community) of shallow lakes?

Increasing the significance of biological indicators in water quality assessment

Chinese monitoring programs for water quality assessment are currently based on defined limit values of certain physical and chemical water parameters, whereas biological indicator systems are not implemented. However, the complex pollution of surface and subsurface waters cannot be captured using only these physical and chemical characteristics. Additionally, an integrative approach as provided by biotic tests is necessary, but this approach is not yet prevalent in China. Within the scientific community of China, the idea of biological tests and indicators arises constantly and a few studies have started to establish those indicator systems using e.g. fish or macroinvertebrates. However, the spatial dimension of China and the respective number of differing eco-regions with unique biotic communities impede the development and implementation of biomonitoring. Germany has excellent experience and expertise with biomonitoring induced by the requirements of the European Water Framework Directive the cooperation interest focuses on (i) the support in developing a general appreciation of biomonitoring e.g. by establishing a functional index for the sediment as key compartment for water quality in China; (ii) the development of generalized data acquisition formats for online databases for the context-specific biomonitoring data, to ease data management and analysis on public authority level; (iii) to enhance the promotion of technical biomonitoring for online determination of surface water quality.

Research questions:

- Which species are suitable bioindicators for a good water quality?
- What are suitable reference sites in China of healthy aquatic ecosystem?
- Which species can be used for sediment toxicity tests?

Antibiotic resistance affecting public health in China

China is a country where large parts of the population live close to a water body, that is used to extract water, food, and for recreational purposes. Research published in recent years indicates that waterways are heavily impacted by inflow of antibiotic resistance determinants from anthropogenic sources (wastewater treatment plants, industrial production, etc.). This poses a severe risk for public health due to an increase in infections and decreasing treatment options. There are Chinese laboratories that study antibiotic resistance in the environment, but the results from different studies and different research groups are difficult to compare. TUD-IHB is part of the Europe wide collaboration (NORMAN) working on normalizing the antibiotic resistance analysis from a wastewater treatment so that results from different laboratories can be compared. A further collaboration of TUD-IHB (STARE) investigates the impact of different treatment processes on antibiotic resistance determinants.

Research questions:

- Are there seasonal changes of antibiotic resistance in waste water treatment plants (WWTP) and in the receiving environment?
- Are there any other sources impacting the resistome in natural water bodies?
- What risk does this have on the inhabitants?

Water quality monitoring and modelling for lakes and reservoirs and its integration into water resources planning and management

China requires a sustainable basis for its water resources, which are currently suffering from nutrient and toxicant pollution, unsustainable water abstraction, as well as structural degradation. Besides large scale and country-wide management frameworks and appropriate technical solutions, adapted management plans are required for individual water bodies and their catchments. For balancing anthropogenic needs (e.g. water abstraction, agricultural intensification, waste water disposal) against environmental risks (e.g. eutrophication, pollution, biodiversity loss) aquatic ecosystem models often serve as state-of-the-art approach. At best, these modelling activities go hand in hand with adaptive water quality monitoring efforts in order to improve and validate the existing models or for providing real-time information on the ecosystem's state. UFZ and CAWR have a broad expertise in various water quality monitoring and modelling concepts. It holds a series of mobile infrastructures for water quality monitoring, is engaged in the development of new technologies (remote sensing, biomonitoring, real-time monitoring) and actively runs and develops different aquatic ecosystem models (e.g. 1D or 3D hydrodynamics & ecological models).

Longitudinally (Lagrangian) continuous monitoring of rivers

A boat based monitoring system is currently developed in the BMBF funded project BOOT-Monitoring, coordinated by TUD-ISW. The approach allows for the high resolution de-termination of longitudinal matter and discharge profiles as well as the identification of input sources and process rates. The technology raised the interest of potential cooperation partners from Nanjing Institute of Limnology and Geography (NIGLAS). Currently funding potentials are evaluated for a joint project and the adaptation of the technology to Chinese river conditions.

4.1.2 Safeguarding and managing groundwater resources

Catchment hydrology

Catchment hydrology addresses extreme events in the short and long term in catchment areas. This includes short-term events such as flood events due to rising pluvial, fluvial or coastal impacts and long-term events such water scarcity accrued from droughts and overexploitation. The main cause of scarcity is the disjunctive temporal and spatial distribution of China's water resources, followed by the combination of low water quantity with insufficient water quality. Water scarcity assessment can be done in warm arid areas (North-East China) and cold arid areas (West China) and addresses geogenic or anthropogenic contaminations in the catchment area. Geogenic contamination can be examinated by salinity via total dissolved solids analysis, which occurs in coastal areas and inland saline geological formations. Chemical monitoring and further flow modelling of water resources are important to understand and separate freshwater resources. Anthropogenic influences of the resource occur mainly through urban and industrial wastewater and agriculture return flows. The contamination in arid catchments can intrude into vulnerable groundwater resources and determine the future water-food nexus.

Scientific questions:

- Understanding the changing spatio-temporal patterns and processes of hydrological extremes at catchment scale,
- Reliable predictions of water resources' quantity and quality to develop

management strategies tackling the water-food-energy nexus in water scarce regions,

- Assessment of the capacity and chemical composition of a saline geogenic contaminated water body for the preparation of further water, and salt mixture uses.

Managed aquifer recharge (MAR)

Despite obvious achievements, China still faces important challenges in coping with the in-creasing water demand (e.g. South-to-North-Water-Diversion Project). With regard to Managed Aquifer Recharge (MAR) these can be related to several factors: a) in-sufficient understanding of the ecological impact of MAR (especially when using treated sewage effluent in coastal areas as protective barrier against seawater intrusion), b) lack of technical and scientific expertise on processes occurring during aquifer re-charge, c) lack of instruments and experience in predicting the efficiency of MAR systems (e.g. simulation tools etc.), and d) lack of technical and scientific criteria for planning, construction and management of MAR schemes. In addition, more efforts need to be invested in the development of new methodologies for quick, cost-effective MAR implementation, thus reducing overall costs while maintaining the system's efficiency.

Research topics:

- Site and technology assessment: Identification of appropriate MAR sites (existing and future) and corresponding groundwater recharge technologies; assessment of usefulness of small-diameter wells drilled by direct-push; development / expansion of corresponding site inventory.

- Design and optimization of facilities: Optimal hydraulic and hydrochemical performance (high infiltration rates, low clogging potential, minimum losses from the MAR region via natural groundwater flow) of facilities has to be aligned with economic considerations (investment costs, running costs). Design and optimization of facilities can be most efficiently done by using numerical modelling and corresponding optimization algorithms. Controlling variables that need to be triggered to get the optimal hydro-economic behavior are, for instance, position, number, and time of abandonment / new construction of small-diameter wells.

- Recommendations / capacity building: Development of guidelines for the design and operation of small-diameter well fields in MAR regions, knowledge transfer to authorities and consulting companies.

River bank filtration (RBF)

In China, the existing river bank filtration (RBF) sites are mainly in the north. Among the present 300 RBF facilities, more than 50 RBF sites are located along the Yellow River. Five provinces along the Yellow river have developed RBF into supply water for urban drinking in various degrees(Hu et al., 2016). The studies of RBF in China on water quality improvement (e.g. removal of NH^{4+}; removal of pathogens, surrogates and indicators; removal of COD)(Wang et al., 2007)(Wu et al., 2007) the interaction between groundwater and surface water and biogeochemical process are available. Unfortunately the research on the removal of micro-pollutants is still deficient.

Research topics:

- Aim at the existing sites, a research in terms of micro-pollutant removal process could be developed, which is helpful to understand the characteristics of river side groundwater source, to assess sustainability of RBF and to put forward feasible suggestion for RBF systems management.

- To develop the new RBF sites: The most existing locations of RBF facilities are in arid or semi-arid regions, because the application of RBF is turned out to be an effective solution of the shortage of water resource and maintaining the sustainable development and utilization of groundwater. However nowadays it seems that it is necessary to explore and to construct the RBF sites in the Yangtze River delta as well (including Jiangsu province, Zhejiang Province and Shanghai) because in this region there is a very high population and industry density. Although there is enough water supply in the Yangtze River delta, however severely water pollution due to the fast economic growth has already affected the safety of drinking water.

Coastal aquifer systems

A secure and reliable drinking water supply is of highest relevance for Chinese people, which concurrently requires a healthy and sustainable status of the natural environment. This can only be achieved with a profound understanding of the natural system's structure and processes and requires the consideration and use of coastal aquifers. Besides external connections to adjacent water cycle compartments that affect the system's status, internal processes include – in contrast to most conventional groundwater systems – coupling of flow and transport processes due to density and viscosity dependence from solutes and temperature. The latter relationship results in a highly non-linear behavior which requires special consideration for the assessment of coastal aquifer systems. Research demands are abundantly evident in the fields of process understanding (level of process and system complexity), model robustness (data reliability and sensitivity analysis), and long-term scenario development (simulation and strategic decision making) in the framework of coastal aquifers and external stressors from their neighboring system components.

Groundwater remediation

The extent and complexity of groundwater contamination occurring especially at sites of former intensive industrial use in China, many of them subject of transformation into housing areas requires the development of novel site characterization, risk assessment and remediation strategies. Innovative in-situ-methods allow for less invasive and cost efficient remediation rather than conventional ex-situ-treatment. Treatment train concepts for in- situ-remediation combining measures for source and plume treatment and multiple process steps tailored to the contaminant spectrum and specific site requirements need to be developed. In this respect, nano-remediation with fitted injectable particles for contaminant adsorption, degradation or enhanced bioremediation has the potential of a key technology.

Research questions:

- Which novel materials and technologies provide a step change towards cost-efficient remediation?
- What are optimal treatment train concepts for multiple contaminations at large sites?

Isotope forensics for analyzing sources and sinks of organic contaminates at catchment scale

The stable isotope composition (^{2}H, ^{13}C, ^{15}N, ^{18}O, ^{34}S) of organic chemicals provided a unique fingerprint for analysis the sources and sinks of organic contaminants. In collaboration with CAS institutes and universities we are exploring the potential of isotope forensics to identify the sources and contaminants as well as to identify their major degradation pathway in soils, aquifers and surface water bodies. With the CAS Institute of Urban Environment we intent to develop concepts for reactive transport processes of long distance transport using microbiological, ecological, biochemical and isotope information. In 2018 a Sino-German Symposium is intended to ”Isotope Forensics”.

4.1.3 Urban flooding mitigation

Effect of low impact development on urban flooding reduction

Urban flooding is a serious and growing development challenge, which causes widespread devastation, economic damages and loss of human lives. The occurrence of floods is the most frequent among all natural disasters globally, which is mainly due to the climate change induced extended periods of high-intensity rainfall and rapid urbanization induced changes of watershed hydrology. Except for the global phenomenon of extreme rainfall event, considerable concern has be addressed to the increased proportional area under impervious surface which is the primary agent responsible for the catchment hydrologic changes associated with the urbanization process. The increase in impervious surface cause a decrease in the infiltration of stormwater and an increase in the production of surface runoff which has indirect effects on downstream flooding. Gray infrastructure is regarded as a typical approach to drain surface runoff from urban areas. Increasing drainage capacity of gray infrastructures relies on expanding and upgrading the existing systems. However, due to the pressures of climate change and urbanization, mere expansion of capacity of gray infrastructures has been increasingly proven to be unsustainable, costly and even impractical, especially for a developed urban area. As an alternative to the traditional gray infrastructure, green infrastructure, also known as low impact development (LID), sustainable urban drainage systems (SUDS), water balance methodology (WBM), and water-sensitive urban design (WSUD), includes a variety of practices such as Green Roof, Bio-Retention Cell, Rain Barrel/Cistern, Vegetative Swale and Permeable Pavements (here they are operationally itemised as LID practices) to reduce runoff, minimize pollutant discharges, decrease erosion, and maintain base flows of receiving streams.

According to the Chinese national requirement that cities in China will collect and utilize 70 percent of the rainwater, with 20 percent of urban areas meeting the target by 2020, and the proportion will increase to 80 percent by 2030 [2]. Therefore, it is necessary to integrate LID into the redeveloped construction to meet the national permit requirement. Therefore, evaluating the potential LID transition is essential to assist and develop the best strategies. This potential cooperation aims to simulate the effect of low impact development on urban flooding reduction.

A decision making support system

Given the techniques available, the possible selection of green infrastructure practices are numerous at watershed scales because of complicated watershed features. In order to evaluate strategies which are effective and support decision-maker to optimally implement transitioning plan of drainage infrastructures, a systematic assessment of the possible strategy is necessary. First of all, the optimum drainage solution must be sufficiently resilient to handle urban flooding; secondly it must be also cost-effective. It has been reported that some LID practices can achieve stormwater management goals at a lower initial cost than conventional systems, since they require less pipe and underground infrastructure. Certainly, these are other parameters need to be considered when a final decision has to make. Therefore, a decision making support framework for as-

[2] State Council, www.english.gov.cn, accessed May 2016

sessing which design alternative (LID or conventional) fulfils the performance requirements of a municipal land development project is essential. This potential cooperation aims to install such a system to support the local city plan of the redeveloping construction with the consideration of LID practices.

4.2 Land use, soil and biodiversity

Effects of changes in land use on soil erosion and export of nutrients to surface water in the Loess plateau

Land use and agricultural management systems have been changed dramatically and will further change in future. Preventing soil erosion and surface water pollutions has become increasing awareness resulting e.g. in afforestation programs. However, the importance of cash crops as kiwi has increased as well resulting in huge inputs of inorganic fertilizers as nitrogen (up to 900 kg N ha^{-1} yr^{-1}) and changes in soil erosion. In this area, the proportion of kiwi orchards has increased substantially. Cropping of maize and wheat is less important any more but is now practised at the steeper slopes. These changes in land use are representative for the southern parts of the Loess plateau and might result in increasing soil erosion and nutrient export to surface waters. Therefore, we want to study changes in soil erosion, deposition of nutrients and in the turnover of organic matter in a small catchment close to Yangling. Besides sampling of soils and the small stream in this catchment and GIS based erosion modeling using RUSLE we can make use of soil cores to be collected at a reservoir at the outlet of the catchment to get an integrative signal for the whole catchment related to changes in erosion rates and nutrient exports from 1957 (building of the dam). This project will be a joint effort of the College of Natural Resources and Environment, Northwest A&F University in Yangling and the Institute of Soil Science and Site Ecology of TU Dresden to improve the scientific base for stainable soil and nutrient management in rural watersheds.

Phosphorus and nitrogen exports and transfer effects from various land use types in the Miyun reservoir, Beijing region

Even though afforestation is highly effective in reducing soil erosion and related N and P exports the water yields clearly decrease after increasing the forest percentage in the watershed. Reduced water fluxes from afforested land may cause severe water scarcity and increase of concentrations of contaminants and nutrients originating from other land uses, i.e. cropland agriculture and settlements. Therefore, forest-/agroforestry related soil and water conservation measures have to be carefully planned in terms of design (species, density), placement, and subsequent management. TUD-IBS will address these questions together with partners in the Chinese Academy of Forestry and Beijing Capital Normal University by a combination of event-based water sampling from streams draining defined land-use systems and implementation of GIS-based watershed-models (e.g. SWAT) for various land-use and climate change scenarios.

Soil organic matter formation and carbon storage capacities

To date, the majority of studies on investigating ecosystem carbon (C) storage response triggered by climate change have been focused dominantly on the role of above-ground plant tissue chemistry and biomass production, the general dynamics of total soil organic carbon turnover, and only recently in identifying microbial mass turnover and eco-physiological concepts. Although it is well recognized that the dynamics of the terrestrial C pools are dominantly driven by living soil microorganisms, the incorporation of carbon into microbial biomass and resulting necromass residues in stable soil organic matter have received much less attentions. However, understanding the details of the underlying processes is of crucial importance for understanding of the carbon storage processes in soil organic matter and the resultant the nutrient use efficiency potentials of plants.

In this field we established a multi-functional collaboration with the CAS Institute of Applied Ecology in Shenyang, Prof. Xudong Zhang and Prof. Shao Liang in the field of microbial carbon (and nitrogen) use efficiency (CUE) and the contribution of microbial necromass to the formation of soil organic matter.

We plan to study microbial residue stabilization of soil carbon plus nitrogen and its response under long-term environmental change. Amino sugar biomarkers, which are constituent of fungal or bacterial cell walls, will be used to represent microbial residues for addressing whether global change drivers accelerate or slow the accumulation of microbial-derived C. Compound specific stable isotope signatures of different microbial amino sugars will provide a detailed view on C utilization and microbial residue patterns as well as long-term changes of microbial functional potentials.

The collaboration also led to the approval of a Humboldt Fellowship for Prof. Chao Liang at the UFZ starting in March 2017. This collaboration will lead to intensive exchange of Chinese PhD students and the set-up of common experiments as well as mutual use of complementary analytical facilities.

Research questions:

- How do bacteria and fungi contribute to the formation of stable soil organic matter?
- How can different amino sugars be used as group specific biomass (necromass) biomarker for comparative analyses of different soils?
- Can amino sugars used as proxy for the quantitative assessment of the non-equilibrium steady state turnover of soil organic matter?

Antibiotic resistance affecting public health in China

In a cooperation of the UFZ-department ISOBIO and the CAS institute Environmental Sciences, Institute of Urban Environment (Environmental Soil Science & Biogeochemistry) in Xiamen the distribution and spreading of antibiotics resistance genes in soil fertilized by manure is investigated. Key aspects are the fate of antibiotics in manure from animal farming used for fertilization of agricultural land which may support the development of antimicrobial resistance in soils.

Soil remediation

The implementation of new techniques for monitoring of contaminated site and implementation natural attenuation strategies is a current subject of collaboration with the University of Science and Technology Beijing (USTB) and China University of Geosciences (CUGB). We are in the process to build up a center of competence for stable isotope analysis at both universities in Beijing and train staff in CSIA at the UFZ. Due to the large extent of contaminated sites, a future focus should be laid onto the investigation of metabolic processes leading to microbial degradation of contaminants in soils and aquifers.

Research questions:

- Which microbial processes, which novel materials and which technologies provide advancement with respect to cost-efficient remediation?
- What are optimal treatment concepts for multiple contaminations at large sites?
- How to quantify natural attenuation processes in soils?

Biodiversity

Socio-ecological drivers of change, operating at various administrative and temporal scales in an interactive pattern, determine the directionality and intensity of anthropogenic processes and their impacts on biodiversity and ecosystems. Anthropogenic processes may therefore also directly or indirectly impact on ecosystem resilience, the ability of a system to return to its original state after a disturbance. Mountain ecosystems are seen as particularly sensitive to global change because they are influenced not only by altered average environ- mental conditions but also by climate extremes. Globally, the negative impacts of current and future global change on mountain ecosystems, and especially mountain freshwater habitats and their biota and the surrounding terrestrial environment, are expected to greatly outweigh potential benefits. It is therefore important to understand the impact of global change on microbes, plankton, invertebrates, vertebrates, and pathogen emergence in aquatic and terrestrial mountain habitats. Such information is necessary to evaluate the global change risks in mountain ecosystem for stakeholders and for human well-being and will develop and inform the concept of mountains as sentinels of change.

In China, we will focus on mountain ecosystems, as they and the services they provide to society face multiple threats arising from global change and its interactions with socio-cultural, economic and political developments. In particular, high-altitude mountain ecosystems have been, and will continue to be, severely impacted globally by climate and land use change, since they are influenced not only by altered average environmental conditions but also are sensitive to climate extremes (Millennium Ecosystem Assessment 2005)(Assessment, 2000). However, currently mountain research is limited to only a few critical zone observatories in North America and Europe, despite the importance of research that relates eco-geochemical processes in mountain watersheds to biodiversity change. These processes could have important impacts even in remote environments where they are rarely studied. The accumulation of persistent organic pollutants (POPs) in pristine areas in organic soils in marshes, forests and wetlands (Bacardit et al., 2012) at high latitudes is a well-known phenomenon, but its consequences are elusive. As a result of "global distillation", which is the long-range atmospheric transport and subsequent deposition in colder environments (Wania and Mackay, 1993), remote arctic environments are highly contaminated with POPs posing a severe risk for ecosystems and human health (Macdonald et al., 2000). Depending on their physico-chemical properties, POPs are deposited associated to particles or accumulate in particulate organic matter (POM) after deposition in the lakes (Arellano et al., 2014). The deposition of pollutants varies depending on topography, wind patterns and vegetation type. In addition to long range transport, other processes can contribute to pollution of mountain lakes. While transport processes of POPs towards mountain lakes have experienced substantial investigation, the impact on lake ecosystems and particularly on sensitive mountain amphibians (Davidson, 2004) and other fauna (Dachs et al., 1999),(Blais et al., 2003) Blais et al. 2003) has not received much attention.

As internationally visible case study on biodiversity and ecosystems services, BEF China (www.bef-china.de), the largest experimental manipulation of forest tree biodiversity worldwide looks back on 8 years of fruitful collaboration between German Groups (including two from UFZ) and Chinese teams from universities and the China Academy of Science, with a grant support of a Research Unit by the German Science Foundation (DFG) and several grants from the Chinese National Science Foundation (NSFC) and the Sino-German Center (Bruelheide et al., 2014). Actually an International Graduate School program is under application by DFG and NSFC, the German part of which will be settled in Leipzig at the German Center for Integrative Biodiversity Research (iDiv) Halle– Jena–Leipzig (https://www.idiv.de). In addition several UFZ departments are involved in preparing a new Research Unit. Recent results of biodiversity ecosystem function experiments have shown that high biodiversities at several levels of food webs are necessary to warrant and preserve multifunctionality of ecosystems (Soliveres et al., 2016). This however poses research challenges as for example the scale to consider in biodiversity analyses in the field differs between plants, insects and soil microorganisms (Schuldt et al., 2015) . Therefore, a focus in the follow up projects of BEF China will be in investigating co-occurrence and interaction networks of different organism categories in forest of diverse tree diversity levels, but also to analyze neighborhood diversity effects.

Another focus in biodiversity research is its interplay with climate and land use intensity. Here the UFZ has implemented a research platform, the Global Change Experimental Facilities (GCEF, www.ufz.de/gcef) in which climate and land use scenarios are co-manipulated. Another large facility is the Biodiversity Exploratorie granted by the German Science Foundation (DFG) within its priority program SPP 1374(www.biodiversity-exploratories.de). Here 300 forest and grassland plots across Germany are intensively analyzed by 40 German teams and several of them are from UFZ in particular in the frame of the coordinating core projects. These research platforms gains growing international visibility, and several PhD students of Post Docs from China have recently applied for grant within the Sino-German (CSC-DAAD and CAS-DAAD) frame to join the two platforms and perform studies on soil biodiversity and connect it to studies on plots in China (Gossner et al., 2016)

4.3 Renewable energy resources

4.3.1 Geothermal energy

Utilization of **shallow geothermal energy** resources is of increasing interest for domestic heating and cooling systems for urban areas in China. Large ground-source-heat-pump (GSHP) systems are under development for entire districts. Those GSHP can easily exceed thousands of Borehole-Heat-Exchanger (BHE) modules. Even though GSHP systems are state-of-art technology, there is no long-term experience with those large systems which may massively modify the subsurface heat system. Failure of BHE is a critical issue. The German cooperation interest consists (i) in the development and provision of system analysis tools for better process understanding of sustainable (urban) subsurface heat management and corresponding planning tools and in (ii) innovative model-based exploration and monitoring concepts. German industry partners are interested in contributing IT developments for online monitoring systems.

Research questions:

- How to build economically feasible complementary heating # cooling systems for a sustainable subsurface heat management (thermodynamic equilibrium and even remediation of heat islands)?
- What long-term environmental impacts may be related to massive GHSP utilization (process understanding)?
- How to control and prevent BHE failures?

Engineered geothermal systems (EGS) are under development worldwide for electricity generation from deep geothermal reservoirs. For this purpose artificial circulation systems have to be created via wellbore doublets at 3-5 km depth. China provides unique field laboratories for a variety of geothermal conditions for scientific research.

Research questions:

- Basic understanding has to be built for coupled physico-chemical processes in hot geothermal reservoirs and approved by field experiments in different geological settings.
- What long-term environmental impacts may be related to EGS operation (process understanding)?

4.3.2 Energy from biomass

The energy of biomass is of high interest in order to reduce the usage of fossil recourses. The energy can be used either for the production of energy carriers (e.g. biogas, methane, butanol) or for the synthesis of bulk chemicals.

The use of microbial communities for product syntheses from biomass is well established in numerous applications, however, the control of such processes, if at all, is realized based on operator experience or by means of basic models that use simple process bulk parameters. Research specific to this drawback is thus mandatory. In addition, circular economy requires the use of waste biomass in digesters thus producing conditions for microbial communities that are constantly changing. The benefit coming from of the huge metabolic capacity of microbial communities needs to be better exploited by expanding the knowledge on the organisms' structural and functional relationships. Biotechnologically relevant microbial communities have the advantage that they can use cheap waste substrates, they do not need sterile process operation and they have complementary competences for product synthesis which obliterates genetically engineered pure strains in various applications (Koch et al., 2014). However, control of such biotechnological processes requires new concepts. An innovative approach for controlling the efficiency of digester communities is single cell community analytics(Günher et al., 2016). The new tools should allow for monitoring of stability properties of natural communities in managed systems, either post-hoc or ad-line, and thus contribute to both process control and understanding of community behavior.

A promising approach to control any kind of biotechnological processes using renewable energy sources in real time is the direct monitoring of the metabolic activity of the microbial catalyst in combination with so-called soft sensors. Soft sensors process several measurements together with models in order to get a holistic picture about the actual state of the bioprocess and the respond on control actions. Calorimetry as a direct measure of the metabolic activity will be developed at different scales (from lab-on-chip to megacalorimetry), combined with other modern sensors (e.g. impedance), metabolic and thermodynamic models in order to get a direct access to the performance of the microbial catalysts (Günher et al., 2016),(Maskow and Paufler, 2015). The goal is to overcome the main weakness of biocatalysts compared to conventional catalysts; the often non-linear and still unpredictable behavior. In addition, product conversions can be controlled by the new approach with high space-time yields, which are otherwise difficult to control (Rohde et al., 2016) Calorespirometric Feeding Control Enhances Bioproduction from Toxic Feedstocks – Demonstration for Biopolymer Production out of Methanol. Biotechnology and Bioengineering 113(10): 2113-2121. A further major advantage of our approach is the applicability to different renewable sources of energy (biomass, sunlight and electricity (Korth et al., 2016), any biocatalyst (strains of bacteria, algae and fungi but also microbial communities), and any product.

4.4 Waste water management (treatment and recycling)

4.4.1 Decentralized concepts and technologies

Decentralized treatment and reuse of waste water

Innovative cost-efficient hybrid technologies for disinfection, denitrification and (micro-) pollutant removal in small-scale treatment plants to improve water quality of receiving water and for different water reuse applications.

Decision support tools for implementing clusters of decentralized wastewater technologies

In remote rural areas with moderate population density, the implementation of centralized wastewater infrastructure is challenged due to high per capita investment costs and spatially exclusive wastewater management and operation schemes.

These problems might be overcome by implementing decentralized wastewater management schemes that feature a) reduced technical complexity and robustness, b) shorter depreciation times and c) lower per capita investment costs due to reduced or sewerage requirements (Afferden et al., 2015). Decentralized systems are highly flexible and easily tailored to changing conditions and demands such as population growth.

Efficient planning and decision-making for infrastructure requires reliable data. Wastewater and natural environment related data is usually very scarce, incorrect or incomplete. Decision-making based on insufficient data entails incorrect planning and leads either to failure of the infrastructure investment or ex-post amendments for which financial budgets have not been allocated.

Research topics:

- Developing GIS-based decision support and planning tool tailored to implementing integrated wastewater management concepts at micro-catchment scale in China. This tool tackles data scarcity via combining geographical, physical and socio-economic data and proxies to build real-life scenarios for wastewater management solutions (decentralized and centralized) that can be assessed in terms of their economic efficiency.

Integrated wastewater treatment and reuse system for urban areas

Commonly used decentralized wastewater treatment systems include eco-technologies (for e.g. constructed wetlands), biofilm technologies, sequencing batch reactors (SBRs), membrane bioreactors, anaerobic technologies etc. Among these technology types, constructed wetlands represent an innovative, simple to operate, robust, and cost-effective technology for sewage treatment. It is able to eliminate a variety of wastewater components and to generate treated effluent for reuse. Recently, aerated wetlands have gained popularity due to their superior treatment performance. Furthermore, constructed wetlands can be enhanced with a planted cover layer and be integrated into public areas, e.g. parks, in an urban or suburban context. Such a ”wetland park” concept can be defined as a combined subsurface wastewater treatment with aboveground reuse area.

Research questions:

- How to design a vegetated surface cover layer on a vertical aerated wetland system that can be integrated into a public park in urban areas and up to which extent this cover layer impacts on treatment performance?

Decentralized treatment and reuse of waste water

Innovative cost-efficient hybrid technologies for hygienization and pollutant removal in small-scale treatment plant to improve water quality of receiving water and for various possibilities of water reuse.

4.4.2 Monitoring concepts

Microbial community monitoring in wastewater to increase efficiency in water purification, biogas production and phosphorus recovery

In a circular economy wastewater treatment plants do not only purify water but produce biogas or/and recover phosphorus. These different tasks are performed by microbial communities of different compositions and functionality and at different reactor localities in a WWTP. All bioreactors in a WWTP are interconnected. A steady inflow of microorganisms with the incoming wastewater, the constantly changing wastewater characteristics and weather events impact the efficiency of all these processes. Frequently, operators have to deal with reactor failures. Currently, such processes are operated based on experience and by using models that reduce the activity of microbial communities to generalized biomass values (e.g. ADM1 (Batstone et al., 2002), ASM3 (Henze et al., 2000). New tools were developed at UFZ using individual-based monitoring of microbial communities and new bioinformatics evaluation tools that allow for efficient reactor specific process control. Partner from CREAS showed interest in using the technology for monitoring and controlling of microbial communities in highly contaminated pharmaceutical wastewater from a pharmaceutical company in Shenyang.

New metabolic activity sensors for control of sanitation and wastewater cleaning

The cleaning performance of sewage treatment plants is essentially provided by microorganisms. The simplest and most robust way to monitor there metabolic activities is the direct recording of the metabolic heat by means of calorimetry. For that purpose new calorimetric techniques and sensors will be developed and tested which are applicable under field conditions. A further future application of calorimetric sensors is the control of sanitation. For that purpose highly sensitive calorimetric sensor will be developed in order to monitor rapidly bacterial contaminations in water for domestic use, tap water, process water in food industry, heating-circuit water etc.

4.4.3 Innovative waste water treatment technologies

Novel functional materials for efficient catalytic degradation of hardly biodegradable contaminants in industrial effluents

For elimination of hardly biodegradable contaminants there is a high demand for physical-chemical methods with improved cost- and energy-efficiency. Novel functional materials which combine principles of nanotechnology and environmental catalysis are in the focus of current research and offer an interesting research field for Chinese-German cooperation. Depending on wastewater composition, catalysts can be designed for either selective removal of specific target contaminants (e.g. reductive dehalogenation of halogenated organics) or unselective broad-range attack of contaminants (e.g. radical-driven advanced oxidation processes). Materials which allow combining adsorption and wet-chemical degradation, such as functionalized carbon materials or zeolites, are suitable for on-site regeneration and can replace conventional activated carbon adsorption which requires frequent replacement and disposal or energy-intensive thermal regeneration after transport to specialized facilities.

Research questions:

- Which reagents, adsorbents and catalysts can lead to significantly improved water treatment technologies for removal of recalcitrant pollutants?
- How can recent developments in nanotechnology be efficiently implemented in water treatment?
- How can we achieve reactive adsorbents with optimal synergy of adsorptive enrichment and chemical reaction by rational design?

Near natural treatment approaches for agricultural surface water runoff and waste water in informal settlements

Although the Water Framework Directive has led to a reasonably acceptable chemical status of freshwater systems in Europe, the ecological quality of many habitats is still decreasing in the EU and worldwide due to effects of so-called micropollutants such as pesticides, flame retardants, pharmaceuticals, and laundry detergents products. However, this kind of contaminants are actually no "micro-pollutants" in many areas of China, they are just 'pollutants?and thus need to be treated due to ecotoxicological and human health care reasons. Conventional activated-sludge wastewater treatment systems are too much effort and are insufficient for a significant cleaning of such contaminated waters, in particular if their hydraulic regime is not continuous and coordinated by sewers. Therefore, near-natural treatment approaches, for example using constructed wetlands or slow sand filters are needed for a general treatment of such waters.

In addition, since water for irrigation is an increasingly scarce good the pressure to reuse surface waters and even waste water for irrigation purposes is raising. Farmers, and in particular small family farmers in China, are not interested in having treated pure clean water; instead they are keen on the nutrients (N and P) inside of the waters but not on the other contaminants and the potential pathogen load. Therefore, any approach for lowering contaminations while keeping the nutrients is welcome. In this field a long lasting collaboration already exists which is reflected by several common publications, for details see Appendix.

Research questions:

- Do wetland plants stimulate removal/degradation of organic pollutants?
- Which microorganisms are responsible for the degradation of pollutants?
- Is the formation of reactive oxygen species increased in aerated systems in the presence of certain organic pollutants?
- Do antibiotic resistance genes transfer more easily in aerated wetlands?

4.4.4 Drinking water quality - disinfection

Effect of pre-oxidation of chlorine dioxide on Microcystis aeruginosa

The frequent occurrence of algal blooms in drinking water reservoirs causes problems to water supply. Pre-oxidation, especially with potassium permanganate, chlorine or ozone, is deemed effective in promoting the coagulation of cyanobacterial cells and their organic matters. Chlorine dioxide (ClO2) is another emerging water treatment oxidant due to its stronger oxidizing capacity than chlorine. To date, the information about the effect of ClO2 on algae removal rate and toxin release laws remains unclear. This potential cooperation aims to study the pre-oxidation effect on Microcystis aeruginosa (the most widely occurring blue-green algae) under different chlorine dioxide dosages, pH values, temperatures and time to the algae survival rate toxin degradation.

Changes of algae cells, EOM and IOM after disinfection by chlorine dioxide

The release of algal organic matter, including extracellular organic matter (EOM) and intra-cellular organic matter (IOM), in high concentrations to water sources can causes problems to water supply. EOM has been known to be mainly comprised of proteins and polysaccharides and to possess distinct features like high molecular weight (MW) and strong hydrophilicity. The aims of potential cooperation are to characterize the algal organic matter variation in algal cells, EOM and IOM produced from Microcystis aeruginosa after chlorine dioxide disinfection using Excitation–emission matrix (EEM) fluorescence and TOC analyzer.

Formation rule of disinfection byproduct of organic chlorine dioxide disinfection

ClO2 has been proved that it does not produce harmful trihalomethanes (THMs) in the reaction with natural organic matters (NOMs) and can reduce the formation of other halogenated organic by-products. However, the application of ClO2 can produce inorganic by-products such aschlorite (ClO2−) and chlorate (ClO3−). The aims of potential cooperation are to evaluate the effects of different chlorine dioxide dosage, algae concentration, disinfection time on disinfection byproducts (DBPs) formation.

Attenuation and end-products of algae organic matter after chlorine dioxide disinfection in the water treatment plant

When the water contains high concentration of algae and their extracellular secretions, it will affect the removal efficiency of coagulation process. Without removal of algae in the coagulation process will continue to grow and block or penetrate the filter layer to impact of water production rate. The overall objectives of this potential cooperation are to study the attenuation and the final product of the algae organic matter in the conventional water purification process after chlorine dioxide disinfection through the pilot plant.

4.4.5 Recycling (wastewater in a circular economy)

Water and material recovery and reuse combined with sustainable wastewater treatment should be considered as the core of an integrated water management approach to save costs, provide raw materials, fertilizer, platform chemicals and demonstrate environmental sustainability. This requires changing the focus from treating wastewater and bio-solids to be ready for disposal, but rather to provide water fit for purpose and yielding revenues from recovered resources. Innovative wastewater treatment units can lead to the development of new products and business opportunities contributing to a circular flow economy.

Wastewater reuse (Fit for purpose)

Reusing treated effluent for irrigation must take into account agronomic aspects, surface water, soil and groundwater protection as well as the protection of public health. These complex interactions and potential risks associated with reuse of treated water have led to international regulations (limits) for wastewater reuse under the zero risk scenario, meaning for avoiding all potential risks very low limit concentrations have been defined for an unrestricted reuse of treated wastewater. Compliance with such limits requires complex technologies for tertiary and quaternary wastewater treatment with denitrification and disinfection and correspondingly implies high investment and O&M costs. Furthermore such regulations represent an obstacle for investments in the water sector and might completely prevent reuse for fresh water substitution.

The aim of potential cooperation is the development of wastewater technologies that produce specific wastewater qualities on demand depending on the intended use and taking into account the related potential risks. Such treatment systems could include: Aerated wetland technologies that allow switching "on or off" tertiary treatment steps such as denitrification and disinfection, depending on the required use of such waters for fertilization or suitable irrigation systems.

Nutrient recovery and bio-chars

The new EU-Fertilizer Regulation will widen the scope of "fertilizers" to include inorganic, organo-mineral and organic fertilizers, organic soil amendments, liming products, growing media, plant bio-stimulant and agronomic fertilizer additives. This will considerably facilitate the placing on the market organic products containing recycled nutrients (e.g. processed biosolids, digestates, composts, bio-coal) and recovered phosphate products (e.g. struvite, phosphates recovered from sewage sludge or similar, incineration ash).

The aim of potential cooperation is the development of combined sludge treatment technologies that allow recovery and concentration of nutrients such as phosphor and the conversion of the organic sludge matrix to soil amendments with a neutral CO_2 balance.

Production of platform chemicals

Carboxylic acids are organic acids, which are widely used in various end-use industries such as consumer goods, food and beverage, pharmaceuticals, and chemicals. The rapid industrialization, primarily in the emerging economies, is one of the major factors driving the demand for carboxylic acid at the global level. Alone in the EU there is a current citric acid consumption of 530,000 tonnes/y and an import requirement of about 200,000 tones covered mainly by Chinese producers.

Organic acids are produced either from petroleum-based feedstocks through chemical synthesis or from carbohydrates via fermentation. With the increasing oil price, concerns about oil supplies and environmental pollution caused by petrochemical processes, and consumer demand for recycling, there has been a high level of interest in producing carboxylic acids from renewable resources. This can be accomplished by using bioprocesses such as yeast bioprocesses utilizing organic compounds from wastewater streams as substrate. On the one hand, the economic efficiency of the wastewater treatment chain will be increased by establishing integrated, added-value bioprocessing units; on the other hand, significant potentials in terms of sustainability and closed cycle management will be opened up, particularly with regard to the establishment of yeast bioprocessing units at sites where concentrated, carbon-rich wastewater is produced.

The aim of potential cooperation is the development of sustainable and cost-effective bioprocesses for organic platform chemicals production from wastewater using non-conventional yeast strains.

4.5 Municipal solid waste management

Developing a circular economy and building green societies are global issues and consensus. Today's governments face increasing problems by growing volumes of and different modes of solid and hazardous wastes due to continuous economic development and urbanization. Inappropriate handling of waste leads to threats for the environment, such as greenhouse gas emission, land degradation, water and resource pollution. Waste disposal and shortage of resources are urgent problems for the human society. Waste reduction, recycling and incineration of waste are promising solutions to overcome these shortcomings.

Source separation as a basic step for efficient recycling could even help to turn climate impacts of waste management into positive effects. Recycling has the biggest effect on preventing GHG-emissions. Incineration reduces the waste amount and the environmental impact of waste.

The joint research activities include the development of the waste incineration sector and the implementation and improvement of biogas technology as well the increasing of recycling and the reduction of waste.

Introduction of separate waste collection systems

The big challenge in China is the segregation of wet waste (bio-waste) streams out of mixed municipal solid wastes. On the one hand valuable composts scan be generated out of the bio waste and second the incineration and recycling properties of the mixed waste are increasing. Establishing modern waste management system with high collection and recycling rates is still in the rural areas of china a big problem and subject to several research activities.

Optimization of anaerobic digestion of biowaste for CH_4-rich biogas generation

Anaerobic digestion on waste biomass facilitates the energy recovery and extends the utilization range of the biomass source, which could include tertiary waste biomass, such as sewage sludge, food waste, and by-products of processed biomass. The key research questions addressed are which co-substances could be the best option for anaerobic digestion from the list of the biogenic waste/residues? Further which pre-treatment process will be the suitable one to accelerate the carbon release in the anaerobic digestion process? What's the big barrier for the traditional anaerobic digestion process? And which risks may originate from a shift towards bio-chemicals and bio-energy in anaerobic digestion and what is the public perception on this. The aim is to increase CH_4 rich biogas yields from low-value biogenic waste/residues through an anaerobic digestion system.

Two streams are formed with a liquid stream and an organic solids rich stream.

The liquid stream with the dominant fraction of VFA can be proposed to convert to the bio-chemical products with different additives, after the co-substances will be firstly agitated into wet slurry. The solid stream can be developed and applied to generate the CH_4 rich biogas, and CO_2 sequestration by rumen microorganisms is also investigated in a cost-effective way simultaneously. In order to formulate a sustainable biomass utilization system and GHG mitigation from biogenic waste/residues disposal, an overall evaluation of the technically, economically and socially acceptable integrated biomass management system need to be investigated and assessed using LCA in the end.

Improvement of waste incineration

In 2013 already 166 waste incineration plans where in operation treating app. 30% of Chinas municipal solid waste (Zhang et al., 2015). In the next three years the Chinese government plans on building 300 waste-to-energy plants additionally. Waste incineration has many advantages over using landfills, such as effecting significant volume reductions (approximately 90%), complete disinfection, and energy recovery. It is becoming an important means of waste disposal in big cities, where space for landfills may be limited. In most of these cities, it is still difficult to fully incinerate waste and control secondary pollutants, because of the waste's high moisture content, high inorganic composition, high degree of heterogeneity, and the low heat value of household waste; therefore, improving the quality of the waste that is fed into furnaces is crucial to achieving safe incineration. A problem is still the utilization of the generated energy. Most of the plants generate electrical power and the net efficiencies are only around 20%. With recovery of heat for district heating the net efficiency can be increased to 70%. Here a solution for the public opposition to waste incineration has to be found to build the plants closer to towns to have connections to heating networks.

4.6 Air pollution and urban climate

The growing Chinese economy has been associated with a variety of urban air pollution problems in recent decades (see subsection "Urbanization"). The air quality in large cities has deteriorated due to nitrous oxides (NOx), carbon monoxide (CO), photochemical smog (such as ozone), volatile organic compounds (VOC), and (ultrafine) particulate matter (PM1, PM2.5, PM10), which are typical of vehicle pollution. Some cities now have a mixture of these and often the visibility in urban areas continues to deteriorate. In addition, China's cities face the risks posed by a changing climate and the need to implement adaptation strategies (Li, 2013). This includes more extreme temperatures and rainfall and more frequent cyclones. Urban climate and air pollution influences both the health of citizens and the development of cities. In 2007, China started to develop a national policy framework to address climate change challenges, which has included adaptation policies to help people cope with the impacts.

On the basis of cooperation with the Department of Land Management (Zhejiang University, Hangzhou) the future research will be focused on

- Integrating urban climate and air quality modelling with smart sensors and IT technology for environmental and human health. Recently, numerous low-cost smart environmental sensors are commercially available. The combination of multiple environmental factors recorded by many sensors with the results of model simulation is a promising novel field of urban environmental research (Reis et al., 2015).
- Analysis of air quality and land use change both in Hangzhou and Shanghai on the basis of data gathered for two periods (1997-2005, 2006-2020) from land-use planning, including land use types during study periods, such as Farmland, Forestland, Grassland, Water body, construction land, as well as the land use/cover classification maps from Landsat data with the spatial resolution of 10 meters.
- Development of scientific support and suggestions for land use policy and environment policy based on an inter-comparison of urban environments in different megacities around the world.

Outdoor air pollution influences the entire urban population. In contrast to waterborne and soil pollutions, there is no effective individual strategy for residents to avoid the intake of outdoor airborne pollutants. Outdoor air pollution also contributes to indoor air pollution. While the link between air pollution and adverse health effects is well established, it is not fully investigated and understood which components of the complex air pollution might be responsible for the health effects, especially in polluted mega-city areas.

Research questions:

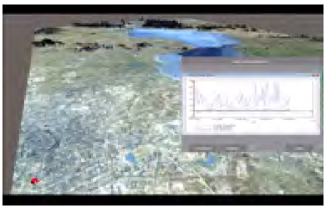
- Which pollutants mainly contribute to air pollution in Chinese megacities and which size distributions characterize the particulates as an important toxic component of air pollution?
- Which impacts have various components of air pollution on cardiovascular and respiratory morbidity?
- Which impacts have various components of air pollution on cardiovascular and respiratory mortality?
- Are there any mixtures with higher detrimental health impacts than has to be assumed with respect to the mixture components?
- Which air pollutants and mixtures of air pollutants have to be addressed as a priority for mitigation measures?

Approach:

The following air pollutants will be considered: NO_X, CO, SO_2, O_3, PM10, PM2.5, UFP (size distributions of airborne particulates). Additionally, meteorological data and on waves of influence has to be considered in the epidemiological studies. In dependence on data availability both, longitudinal and transversal study designs will be included. The design of sub-studies has to be adjusted in dependence on data availability. Following medical endpoints should be included into research on morbidity: Cardiovascular diseases (ICD-10), Respiratory diseases ICD-10). Mortality studies will include total mortality (except accidents and homicides) as well as cardiorespiratory, cardiovascular and respiratory death cases. If data will be available, specific disease groups will also be taken into account.

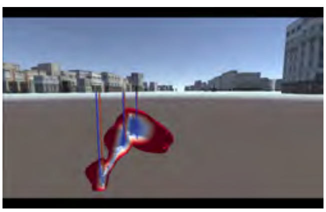
4.7 Environmental information science

The complexity of human – environment interactions requires novel scientific - disruptive approaches. Environmental Information Science is of increasing importance for a variety of those applications towards e.g. future urban water and energy infrastructures etc. In addition to related planning aspects – long-term environmental impacts need to be assessed. The concept is illustrated based on the urban catchment prototype Chaohu (China).



Future water infrastructures: Urban water streams, sewage networks, waste water treatments plants build a complex urban water infrastructure. Integrated management concepts require the access to all related data. EIS provide this information in an interactive, virtual reality context.

Future urban infrastructures: The above depicted approach can be extended step-by-step urban until addressing complete urban infrastructures such as energy and heat supply, communication networks as well as comprehensive waste management concepts.



Energy infrastructures: EIS are particularly suited to include "hidden" parts of infrastructures such as the urban subsurface. Urban heat management includes energy supply (for heating and cooling) as well assessing related possible environmental impacts (e.g. for geothermal energy supply).

Urban catchments presentation:
`https://www.youtube.com/watch?v=kjVold9M6yM`

4.8 Environmental management and governance, urbanization

4.8.1 Water governance

Policy, Regulation and Economics are obviously playing a decisive role in the quest for more sustainable management of catchments and urban water systems, and UFZ has been involved in collaborative research and consultation on water governance issues as described in section 2.1. On the basis of these experiences further collaboration is envisaged on seminal issues of water governance, in particular:

- **Institutional framework for water sensitive urban development**: It is obvious that integrated planning and coordination instruments are needed in order to enable sound and synergistic development of grey and green water infrastructures (see 4.1.3). However, both urban planning and infrastructure planning are institutionally less developed in China and coordination is hampered by a diversity of involved competences / agencies and government levels. Development of modern public planning (lawI) instruments is thus an important development and research issue for further cooperation.

- **Water quality objectives and implementation framework**: The Chinese system of water quality criteria presents an opaque mixture of usage/function oriented zoning criteria, actual quality indicators and quality objectives. There is no nationwide criteria for ecological water quality and ecological quality objectives are currently being developed for some selected lakes. In this context there is great interest on the Chinese side to learn about the European system of quality criteria and objectives. On the European side, however, we are recently witnessing a substantial failure of the quality concept of the EU Water Framework Directive as Member States are largely failing to implement the ecological and chemical quality standards. Therefore, we wish to conduct a mutual discourse on the design of long and mid-termed water quality objectives and implementation frameworks. Of course, this needs to be done in due consideration of the different ecological, economic and political conditions. However, there are yet very similar governance challenges to solve in designing adequate water quality regimes and in determining the right level of ecological ambition in the different time scales. A bilateral research project on this crucial governance issue shall be launched in 2018 preferably at the occasion of the envisaged NSFC-DFG call.

- **Waste water standards**: UFZ is currently consulting CRAES on the ongoing re-form of the Chinese system of waste water standards. In this regard, too, it is important to define an ambitious but also realistic set of standards and time lines and to find efficient solutions for important details like the handling of industrial parks.

- **Water stewardship**: Water stewardship is an emerging topic both for the Chinese government to protect human health, but also for Chinese companies as there competitive advantage is influenced by the quantity and quality of water resources. An investigation of the companies' understanding of water related risks and the actual availability of regional water resources is needed in order to develop and implement appropriate sustainability strategies.

- **Water accounting**: Water accounting is gaining importance as it allows to trace both water resources and waste water emissions throughout the whole life cycle. How established accounting approaches have to be adapted so that they can be successfully implemented in Chinese companies would be an interesting research question.

- **Monetary evaluation**: The monetary evaluation of environmental impacts from wastewater emissions and use of water resources is gaining importance for companies and will be even standardized in two ISO standards (14008 and 14007). An evaluation of different industries at different locations would be interesting in order to explore the true site-dependent and industry-specific costs.

- **Emissions trading scheme**: For selected river basins an emissions trading scheme should be developed similar to the carbon emission trading scheme.

4.8.2 Urbanization and land-use

Urban land-use changes

Urban land-use changes serve as basic indicator for urban transformations. The high dynamics of urbanization processes in China signify an urban transformation path. We define urban transformations as fundamental, multi-dimensional changes in urban land-use and land-consumption patterns, population developments and infrastructure provision, governance regimes as well as established values, and norms. In urbanization processes, land is a scarce and contested resource, so land-use changes must be geared in a resource-efficient and resilient way towards a sustainable urban development. For a German – Chinese research we focus on urban land consumption, where its use is of highest value for multiple functional options. Pressures constantly exist on urban land; a resource-efficient and resilient urban development ensures appropriate quality of life to urban dwellers. Likewise, resilience strives for taking precautions in land use to cope with environmental hazards. Both approaches endeavour to develop urban areas in a sustainable way.

Green infrastructure

The European working group named 'Science for Environment Policy' [3] has proposed the Green Infrastructure (GI) policy, which has the potential to offer win-win, or "no-regret" solutions and could also promote integrated spatial planning by identifying multi-functional zones and incorporate habitat restoration measures into land use plans and policies [4]. The scope and span of GI means it can perform several functions at several scales, whilst taking into account the multiple connections and interactions which are so essential in nature.

GI is set in a scientific framework and firmly based on knowledge about the impacts of fragmentation, land use change, and pollution (see sub-section 4.6 air pollution). A feasible conceptual framework for a sustainable GI requires the identification of its functions and objectives so that the GI can be assessed in its performance of its multi-functionality.

Chinese urbanization

As for China, the Green infrastructure (GI) is still in the stage of theoretical analysis, and the related guide and regulations are too general to guide an effective GI development. For example, on 16th March 2014, China released new-type urbanization plan for 2014-2020 period in an effort to steer the Chinese urbanization onto a human-centered and environmentally friendly path. A starting point on GI mapping was elaborated by Yu (1995, 2006) when he developed Turenscape. This approach was first realized in Taizhou city, where his "water town" planning concept integrates a man-made bifurcation to recover the ecological and social functions of rivers in this city.

Research questions:

- How is the European framework of Environmental quality goals and standards in the city realized as a baseline for multifunctional urban GI in China?
- Are there environmental quality goals for Chinese New-type Urbanization? For what spatial scale? What is considered and how to address multi-functionality in China with respect to the urban green infrastructure (GI)? What are the differences between the concepts of Leipzig and the one of a Chinese city?
- Which indicator system can be applied to a Chinese city to support a multifunctional GI? How can we derive recommendations for city planners and stakeholders to achieve a more sustainable city?

[3] European Commission 2013
[4] EEA, 2011a

Approach:

- Quantitative approach (spatially explicit knowledge):
  - Monitoring techniques: esp. remote sensing techniques,
  - Spatial statistics: esp. population statistics based on various administrative boundaries,
  - Modelling tools: esp. spatial dynamics in GIS.
- Qualitative approach (individual and subjective evaluation):
  - Surveys and questionnaires (reflect public viewpoints),
  - Expert knowledge (deepen understanding for urban planning),
  - Smartphone App's (mapping toolset that serve at local level with a global multiplier).

Keywords: urban land-use changes, Green Infrastructure (GI), remote sensing, GIS, governance

Chapter 5

Appendices

5.1 Contributions and acknowledgements

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Contributing scientists (alphabetically):

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Editorial team:

Olaf Kolditz, Cui Chen, Greta Jäckel, Ursula Schmitz, Chengzi Zhou

5.2 Cooperation matrices

The cooperation matrices compile existing and requested collaborations between German and Chinese partners according to the focus areas of research (Figure 2.1).

5.2.1 Water resources

Topic	Content	German partners	Chinese partners
General topics			
	Environmental impacts of Chinas large water infrastructure projects	UFZ-SEEFO UFZ-ENVINF	Chinese cooperation partners
	Innovative monitoring and management concepts (best practice) for toxicant pollution	UFZ-WANA SOLUTIONS consortium	University of Nanjing, State Key Laboratory of Lake Science and Environment, National Engineering Centre for Pollution Control and Resource Reuse
	Water scarcity	UFZ-CATHYD	CAREERI UCAS (Centre for Water System Security & College of Resources and Environment)
	Microbial potentials	UFZ-ISOBIO	Nanjing Agricultural University
	Biomonitoring	TUD-IHB BBE	CAS-IHB (Wuhan)
	Effects of global change on water quality	TUD-IHB	CAS-IHB (Wuhan)
	Antibiotic resistance	TUD-IHB	University of Hongkong Tsinghua University Normal University
	Environmental Information Systems for Urban Catchments	UFZ-ENVINF	TONGJI
4.1.1 Surface water quality			
	Nutrient transport and retention in agricultural subtropical watersheds in China	UFZ-ASAM	Chinese cooperation partners
	Increasing the significance of biological indicators in water quality assessment	TUD-IHB	Chinese cooperation partners
	Antibiotic resistance affecting public health in China	TUD-IHB UFZ-UBT	Chinese cooperation partners
	Water quality monitoring and modelling for lakes and reservoirs and its integration into water resources planning and management	UFZ-SEEFO	Chinese cooperation partners
	Longitudinally (Lagrangian) continuous monitoring of rivers	TUD-ISW	Chinese cooperation partners

	Desalination Technologies	UFZ-CATHYD DME - Deutsche Meerwasser-entsalzung e.V.	Chinese cooperation partners
4.1.2 Safeguarding and managing groundwater resources			
	Groundwater resources management	UFZ-ENVINF TUD-IGW	CRAES
	Catchment hydrology, water scarcity	UFZ-CATHYD	BNU (Research Centre of Groundwater Pollution, Control and Remediation)
	Coastal aquifer systems	TUD-CONHYD UFZ-ENVINF	Ocean University of China (OUC)
	Managed aquifer recharge (MAR)	TUD-IGW TUD-IAK	Chinese cooperation partners
	River bank filtration (RBF)	TUD-IGW TUD-IWC UFZ-GWS	Chinese cooperation partners
	Isotope research, isotope forensics for analyzing sources and sinks of organic contaminates at catchment scale	UFZ-ISOBIO UFZ-CATHYD	NIGLAS, CUG, CUST (Beijing)
	Isotope biogeochemistry	UFZ-ISOBIO	CAS-Institute of Urban Environment
	Site characterization, risk assessment, groundwater remediation	UFZ-TUCHEM UFZ-GWS	TONGJI CAS Institute of Soil Science (Nanjing) searching for further partners
4.1.3 Urban flooding mitigation			
	Effect of low impact development on urban flooding reduction, Integrated assessment of urban flooding mitigation strategies for robust decision making	TUD-ISW	TONGJI

5.2.2 Land use, soil and biodiversity

Topic	Content	German partners	Chinese partners
Land use and soil			
	Effects of changes in land use on soil erosion and export of nutrients to surface water in the Loess plateau	TUD-IBS	Chinese cooperation partners
	Phosphorus and nitrogen exports and transfer effects from various land use types in the Miyun reservoir, Beijing region	TUD-IBS	Chinese cooperation partners
	Soil organic matter formation and carbon storage capacities	UFZ-UBT	CAS Institute of Applied Ecology (Shenyang)

	Antibiotic resistance affecting public health in China	UFZ-ISOBIO	CAS Institute Environmental Sciences, Institute of Urban Environment (Environmental Soil Science & Biogeochemistry) (Xiamen)
	Soil remediation	UFZ-ISOBIO	Chinese cooperation partners
	Land use change and water quality (Loess plateau)	TUD-IBS	Northwest A&F University, College of Natural Resources and Environment
	P and N export depending on land use (e.g. Miyun reservoir)	TUD-IBS	Chinese Academy of Forestry, Beijing Capital Normal University

Topic	Content	German partners	Chinese partners
4.2 Biodiversity			
	Mountain ecosystems	UFZ-NSF	NIGLAS

5.2.3 Renewable energy resources

Topic	Content	German partners	Chinese partners
4.3.1 Geothermal energy			
	Shallow geothermal systems	UFZ-ENVINF UFZ-MET TUBAF	Shandong University Zhongrui Ltd.
	Engineered geothermal systems	UFZ-ENVINF TUBAF	IGG-CAS, SinoPec, Petroleum University Beijing, CAS Wuhan
4.3.2 Energy from biomass			
	Impedance sensors	UFZ-UMB	Dalian University of Technology
	Calorimetric sensors	UFZ-UMB, TU Freiberg, RWTH Aachen	Wuhan-University
	Community sensors	UFZ-UMB	

5.2.4 Waste water management

Topic	Content	German partners	Chinese partners
4.4.1 Decentralized concepts and technologies			
	Decentralized treatment and reuse of waste water	UFZ-UBZ TUD-ISW TUD-IWC	

	Decision support tools for implementing clusters of decentralized wastewater technologies	UFZ-UBZ	
	Integrated wastewater treatment and reuse system for urban areas	UFZ-UBZ	
	Decentralized treatment and reuse of waste water	UFZ-UBZ TUD-ISW TUD-IWC	
4.4.2 Monitoring concepts			
	Microbial community monitoring in wastewater to increase efficiency in water purification, biogas production and phosphorus recovery	UFZ-UMB	
	New metabolic activity sensors for control of sanitation and wastewater cleaning		
	Monitoring of waste water cleaning and sanitation	UFZ-UMB	University of Wuhan
	Waste water monitoring	TUD-ISW	NIGLAS
4.4.3 Innovative waste water treatment technologies			
	Novel functional materials for efficient catalytic degradation of hardly biodegradable contaminants in industrial effluents	UFZ-TUCHEM	
	Near natural treatment approaches for agricultural surface water runoff and waste water in informal settlements	UFZ-UBT	
	Pharmaceutical waste water	UFZ-UMB	CRAES
	Integrated wastewater treatment and reuse system	UFZ-UBZ	
	Near natural treatment approaches	UFZ-UBT	National Engineering and Research Center for Organic Pollution Control and Resource Reuse, Nanjing University; State Key Laboratory of Environmental Chemistry and Ecotoxicology (CAS), Beijing
4.4.4 Drinking water quality			
	Effect of pre-oxidation of chlorine dioxide on Microcystis aeruginosa	TUD-ISW	
	Changes of algae cells, EOM and IOM after disinfection by chlorine dioxide	TUD-ISW	
	Formation rule of disinfection byproduct of organic chlorine dioxide disinfection	TUD-ISW	Fuzhou University

	Attenuation and end-products of algae organic matter after chlorine dioxide disinfection in the water treatment plant	TUD-ISW	
4.4.5 Recycling (wastewater in a circular economy)			
	Wastewater reuse (Fit for purpose)	UFZ-UBZ	
	Nutrient recovery and bio-chars	UFZ-UBZ	
	Production of platform chemicals	UFZ-UBZ	

5.2.5 Municipal solid waste management

Topic	Content	German partners	Chinese partners
4.5 Municipal solid waste management			
	Introduction of separate waste collection systems	TUD-IAK	Shenyang Aerospace University Shanghai Jiaotong University
	Optimization of anaerobic digestion of biowaste for CH_4-rich biogas generation, anaerobic Digestion of low value biogenic waste/residues	TUD-IAK	Shanghai Jiaotong
	Improvement of waste incineration	TUD-IAK RWTH Aachen	

5.2.6 Air pollution and urban climate

Topic	Content	German partners	Chinese partners
4.6 Air pollution and urban climate			
	Air pollution and urban climate	UFZ-SUSOZ	Zhejiang University (Hangzhou)
	Assessment of air pollution and health effects in selected Chinese megacities	UFZ-STUDIEN Tropos Leipzig	School of Public Health, College of Environmental Sciences and Engineering, Peking University

5.2.7 Environmental information science

Topic	Content	German partners	Chinese partners
4.7 Environmental information science			
	Environmental Information Systems	UFZ-ENVINF AMC, WISUTEC	TONGJI CAS-IGSNRR HC System, EWaters

5.2.8 Environmental management, governance, and urbanization

Topic	Content	German partners	Chinese partners
4.8.1 Water governance			
	Quality objectives, implementation	UFZ-UPR	Wuhan University, Research Centre of Environmental Law
	Water sensitive urban planning	UFZ-UPR	Wuhan University Research Centre of Environmental Law Nanjing University Tsinghua University
	Waste water standards		Chinese Research Academy of Environmental Sciences (CRAES)
	Governance	UFZ-SUSOZ	Land Resources Ministry
4.8.2 Urbanization and land-use			
	Multifunctionality of Green Infrastructure	UFZ-SUSOZ	Peking University, College of architecture and landscape architecture
	Land use and land-use changes	UFZ-SUSOZ	China Agricultural University (CAU), College of Resources and Environmental Sciences, Beijing

5.3 Events

Chronological overview of events in China and Germany

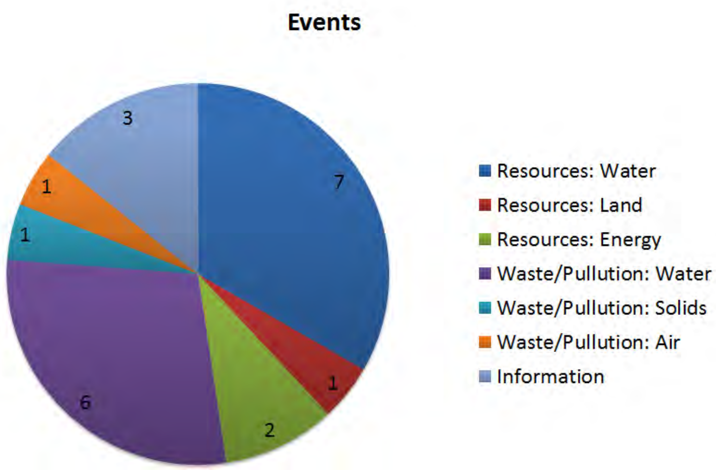

Figure 5.1: Events since 2010

Fig. 5.1 shows the distribution of cooperation events in China and in Germany between the different disciplines. Most listed activities have been conducted in water and land resources, so far.

China

Dates	Topics	Participants
09.12.2016	BMBF#MoST Water Conference led by MinDir. W. Kraus in Shanghai	O. Kolditz, C. Chen, T. Berendonk, D. Jungmann
15.-21.10.2016	Helmholtz-Delegation led by Prof. Wiestler in China (Qingdao, Beijing, Shanghai)	O. Kolditz, C. Chen
September 2016	Round trip, visit and lectures at the Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, China	UFZ-UBT M. Kästner A. Miltner K Nowak
September 2016	Visit, conference planning and lecture at the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China	UFZ-UBT M. Kästner
September 2016	Round trip, conference planning and various lectures at the State Key Laboratory for Pollution Control and Resource Reuse, Nanjing, China and School of the Environment, Nanjing University	UFZ-UBT Prof. M. Kästner Dr. A. Miltner Dr. K Nowak

07-09.06.2016 Shanghai	German – Chinese Symposium on "Waste Reduction and Recycling: Challenges and Trends for Source Separation"	TUD IAK 39
23-29.05.2016 Nanjing, Shanghai	Urban Catchments project: Meeting potential new project partners	Aubron (UBZ)
22-29.05.2016 Dalian	Sino-German Symposium "Environmental Accounting and Management Control in China and Germany"	Guenther (TUD)
16-22.05.2016 Hubei	Saxony delegation and entrepreneurs travel under the guidance of Minister of State Martin Dulig (Saxon State Minister for Economic Affairs, Labour and Transport, SMWA)	C. Chen
25-27.01.2016 Shanghai	Sino-German Symposium "Novel materials and techniques for recalcitrant pollutants immobilization from aqueous media" Tongji University, Shanghai	Kopinke (TUCHEM), Weiss (GWS), Voigt (ISOBIO)
30.10.2015 Hefei	Feierliche Unterzeichnung des Kooperationsvertrages zwischen UFZ und CLMA im Rahmen des BMBF-CLIENT Verbundvorhabens „Managing Water Resources for Urban Catchments“ Pressemitteilung UFZ	
26-28.10.2015 Beijing	Sino-German Geothermal Symposium on Sustainable Utilization of Geothermal Energy http://www.intranet.ufz.de/index.php?de=31339&nb_item=663	
15-21.10.2015 Chongqing, Wuhan, Beijing	Saxony delegation and entrepreneurs travel under the guidance of Minister of State Thomas Schmidt (Saxon State Ministry for Environment and Agriculture, SMUL)	O. Kolditz, C. Chen
29.07.2015 Beijing	Roundtable discussion on managed aquifer recharge in Beijing – achievements and challenges	10
20-24.10.2014 Nanjing	Common training lectures and workshops at the School of the Environment, Nanjing University	UFZ UBT M. Kästner
12-16.10.2014 Shanghai	14^{th} IWA conference on Wetland Systems for Water Pollution Control	UFZ UBT Matthias Kästner
17-23.11.2014	Sino-German Symposium on Sustainable Water Management and Ecosystem Restorations in the Poyang Lake Basin	UFZ (CLE, ENVINF, UBT, UMB...), TUD (HYB, BWL), UNIs
11-18.06.2013 Shanghai Beijing	Tongji University und CRAES: Start of strategic cooperation activities on institutional level Georg Teutsch, Olaf Kolditz, Peter Krebs, Thomas Berendonk, Sabine Attinger, Werner Brack, Ralf Merz, Susann Müller, Hans-Hermann Richnow, Cui Chen, Ursula Schmitz	UFZ#TUD delegation

Germany

11-14.10.2016 Leipzig	IS PTS – International Symposium on Persistent Toxic Substances, Lepzig, Germany http://www.pts2016-leipzig.de/index.html.	UFZ-UBT M. Kästner (Organiser) + ∼ 100 CAS members

12-13.01.2016 Leipzig	Delegation from Ministry of Science and Technology of China (MOST) led by Mr. YANG Zhe visited UFZ. Sino-German collaboration projects in the area of clean water and renewable energies were presented and intensively discussed http://www.intranet.ufz.de/index.php?de=31339&nb_item=709	
12.01.2016 Leipzig	Renewal of the cooperation agreement between UFZ and Tongji University in the framework of the 13. FYP	
15-18.11.2015	Delegation der Chinesischen Akademie für Umweltwissenschaften zu Besuch am UFZ http://www.intranet.ufz.de/index.php?de=31339&nb_item=669	
21.01.2014	Delegation from Ministry of Science and Technology of China (MOST) visited TU Dresden. Sino-German collaboration projects in the area of water management were discussed.	TUD 20
12-17.11.2007	Water Management through Forest Management. IUFRO-FAO-UNESCO-Workshop, Beijing	K.H. Feger, A. Wahren
27-30.11.2006	The Role of Forests and Forest Management in the Water Cycle. Sino-German DFG Symposium at Dresden	K.H. Feger & Y. Wang (organizers)

5.4 Projects

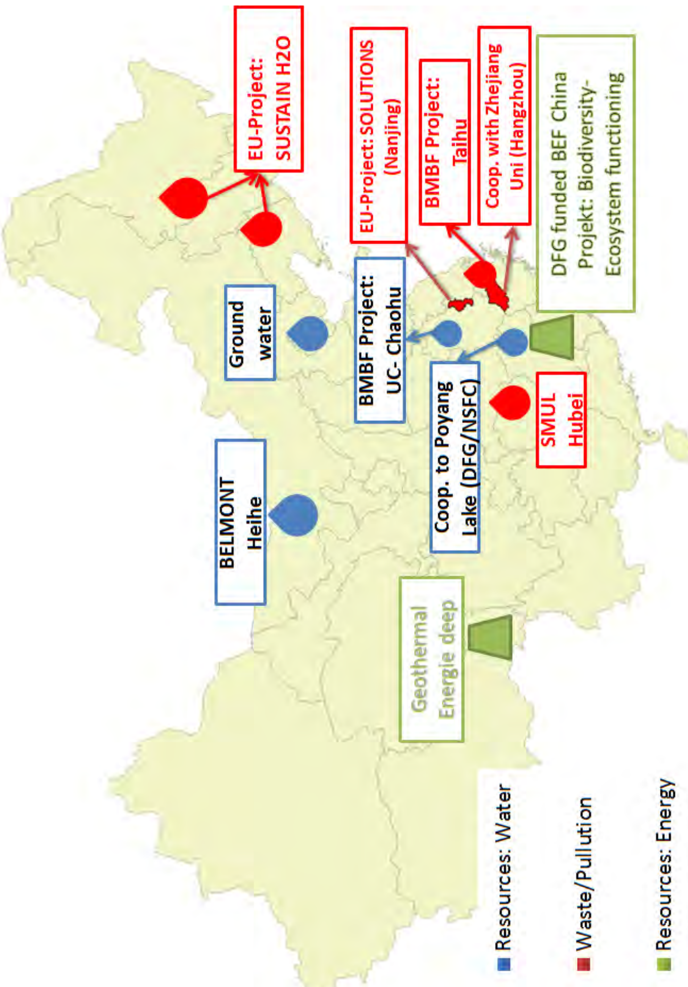

Figure 5.2: Activity map - projects

5.5 Personnel exchange (long-term)

Stays of Chinese PhD Students / PostDocs etc in Germany; Longer research stays (> 2 months) of German researchers in China

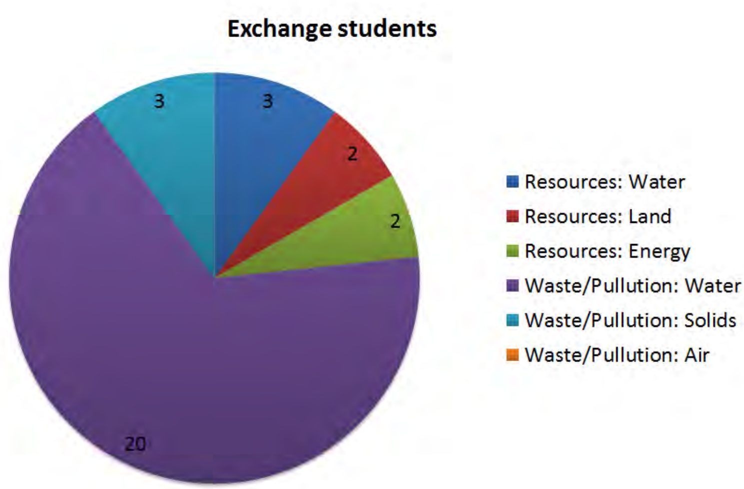

Figure 5.3: Exchange since 2010

Fig. 5.3 shows the distribution of long-term personnel exchange between the different disciplines. Most exchange activities have been conducted in water resources, so far.

5.6 Partners

Overview of CAWR#China partners

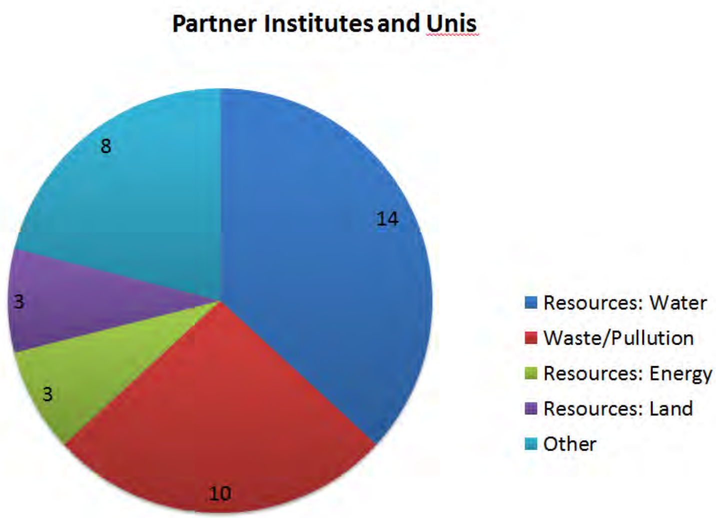

Figure 5.4: Cooperation partners in disciplines

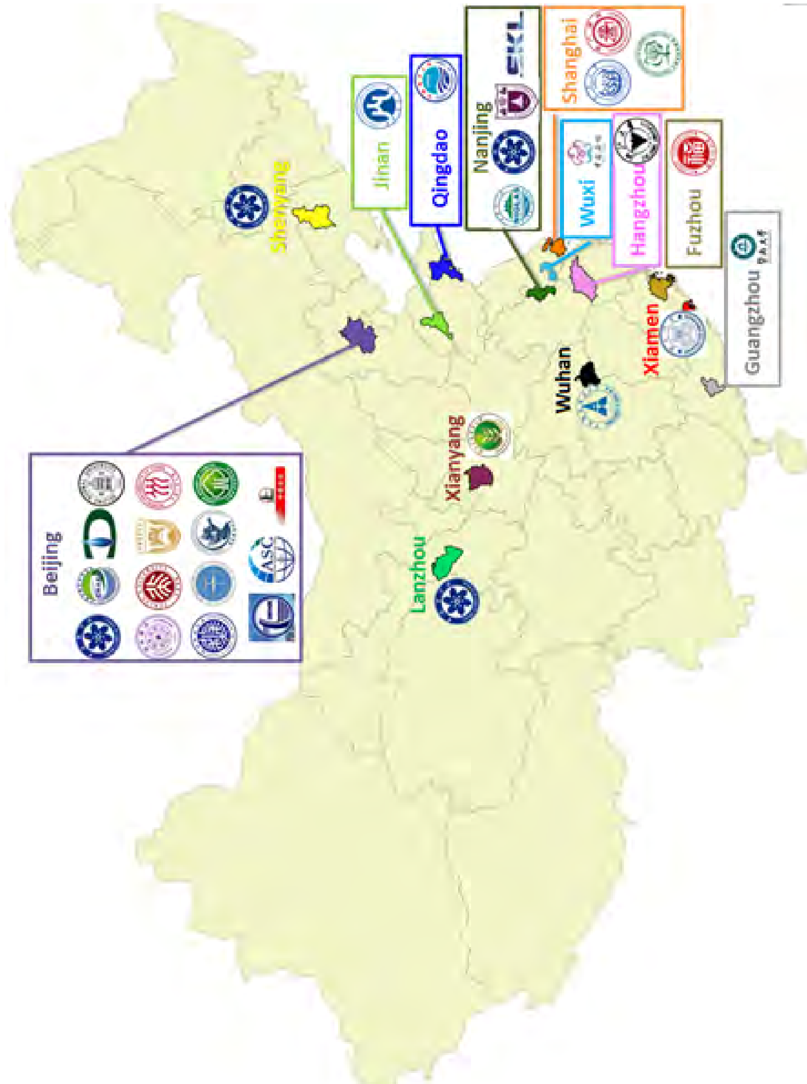

Figure 5.5: Geographical overview of cooperation partners in China

Figure 5.5 illustrates a geographical overview of our cooperation partners in China. The network in Environmental Sciences is wide spread and covers high-ranked institutes of the Chinese Academy of Sciences and Universities. Stakeholder and company contacts also belong to the comprehensive network. (Not meant to be complete, will be updated continuously on request.)

Org	**Partner institution** **PIs** **Topics**	**Chinese PIs**	**German** **PIs**
Beijing			
ASC	Accounting Society of China	Zhou, Shouhua	
IHEG	Beijing Institute of Hydrogeology and Engineering Geology	Dr. Liu Jiurong	TUD IGW
CAF	Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry	Prof. Dr. Yanhui Wang	TUD IBS Feger
	Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry	Dr. Xiong Wei	TUD IBS Feger
CAS	Institute of Microbiology Editor for Applied and Environmental Microbiology Organisation of a Sino-German Workshop in2016 (Microbial chemotaxis and bioremediation of environmental pollutants) Structure, function activity and regulation of rare and uncultured microbial species.	Shuang-Jiang Liu, Ph.D. Professor	UFZ ISOBIO Richnow
	Institute of Urban Environment China- soil-plant interactions, rhizosphere microbiology, biogeochemistry of emerging pollutants, antibiotics and antibiotic resistance, degradation of sulphonamides in soil Sandwich dissertation with CSC fellows (2 year UFZ, 2 year CAS) of Weijing Ouyang.	Prof. Yong-Guan (Yongguan) Zhu	UFZ ISOBIO Richnow
	Chinese Academy of Sciences, Changwu Agro-Ecological Experiment Station	Prof. Dr. Wenzhao Lui	TUD IBS Feger
	Institute of Geographic Science & Natural Resources Research (IGSNRR) Chinese Academy of Sciences (CAS)	Prof. Dr. Lin Zhen	TUD IBS Feger
	Chinese Academy of Sciences, Institute for Geographical Sciences and Natural Resources Research	Prof. YUE	
	Chinese Academy of Sciences, Institute of Geology and Geophysics	Prof. PANG Prof. KONG	
	Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China	Prof. Guibin Jiang (Director)	UFZ-UBT M. Kästner
	Graduate University of Chinese Academy of Sciences, Beijing, China Center for Water System Security &College of Resources and Environment	Prof. Mingyu Wang (Director, Vice Dean)	W. Busch M. Clemens

CAU	Department of Agricultural Engineering, China Agricultural University, Key Laboratory of Clean Utilization Technology for Renewable Energy, Beijing, China	Dr. Shubiao Wu	UFZ-UBT J. Müller
CRAES	Chinese Research Academy of Environmental Sciences, Beijing Water science and technology	Prof. SONG	UFZ-ENVINF O. Kolditz
	Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences (Beijing) Environmental analysis method based on nanometer materials; Non-traditional environmental stable isotope tracer technique	Dr. Qian Liu	(TUD IWC)
CUGB	China University of Geosciences Beijing School of Water Resources and Environment	Prof. Yun Yao	UFZ ISOBIO Richnow
IWRH	Dam and Reservoir management of hydropower and drinking water dams in China, lake monitoring and modelling, water quality management	Prof. Wenqi Peng	UFZ SEEFO Rinke
PU	Peking University (School of Public Health, Health Science Center Beijing)	Prof. Xiaochuan Pan	
	School of Management, Peking University Guanghua School of Management, Peking University	Wang, Liyan Guanghua	
CUFE	School of Accounting, Central University of Finance and Economics	Liu, Junyong	
RUC	School of business, Renmin University of China	Geng, Jianxin	
SINOPEC	China Petrochemical Technology Company Limited (SINOPEC TECH) Oil & gas reservoir microbiology Microbial enhanced oil recovery Remediation of hydrocarbon contaminated environments	Prof. Bingyu Ji	UFZ ISOBIO Richnow
TU	The school of environment, Tsinghua University (Beijing) The analytical methods and environmental behavior of the emerging pollutants; The degradation process and control principle of the emerging pollutants; c. The risk assessment and decision support of the emerging pollutants.	Prof. Gang Yu	(TUD IWC)
	Accounting Department, Tsinghua University	Yu, Zengbiao	

USTB	University of Science & Technology Beijing Civil & Environmental Engineering School Common PhD project, sandwich type (Jia Liu, Dan Zhang) (1 year UFZ / 3 years USTB) Microbial and photodegradation of organophosphate and phthalates Environmental pollution of heavy metals and flotation agents in mining areas.	Prof. Jun Yao	UFZ ISOBIO Richnow
BNU	Beijing Normal University Research Center of Groundwater Polution, Control and Remidation	Prof. Jin Sheng Wang	W. Busch M. Clemens
Shanghai			
SCBG	Shanghai Chenshan Botanical Garden	Gilles Vincent	UFZ UBZ V Afferden
SJTU	Shanghai Jiao Tong University	Dr. Lou Ziyang	
TONGJI	Tongji University, Shanghai Water science and technology Environmental Geotechnology		
	Tongji University, Shanghai College of Environmental Science and Engineering	Prof. Zhenliang Liao Prof, Yalei Zhang	UFZ GWS, Prof. Weiß TUCHEM Prof. Kopinke
	Tongji University, Shanghai State Key Laboratory of Pollution Control and Resources and Reuse CSC fellow Chao Yang (4Y UFZ, PhD at TU Berlin) Anoxic degradation of brominated flame retardants Toxicity of halogenated aromatics to bacteria		
	Tongji University, Shanghai Water science and technology, Environmental Geotechnology	Prof. Qi Zhou	UFZ UBZ V Afferden
	Tongji University, Shanghai Institute of Environment for Sustainable Development (IESD)	Prof. Dai Xiaohu	CatHyd
	Tongji University, Shanghai ISED Institut of Environment for Sustainable Development	Prof. Yalei Zhang Dr. Yiming Su	UFZ GWS Weiss Yan Zhou
Fujian			

	College of Civil Engineering Fuzhou University	Prof. Gongduan Fan	
Guangzhou			
JNU	Accounting Department, School of Management, Jinan University	Shen, Hongtao	
Hangzhou			
ZU	Department of Land Management, Zhejiang University; 866 Yuhangtang Road, Hangzhou, Zhejiang Province, 310058	Dr. Sheng Zheng	
Jinan			
SDUFE	School of Accounting, Shandong University of Finance and Economics	Wang, Aiguo	
Lanzhou			
CAS-CAREERI	Cold and Arid Regions Environmental and Engineering Research Institute	Prof. Ma Wei (Director)	CatHyd W. Busch M. Clemens
Nanjing			
CAS	Institute of Soil Science, Chinese Academy of Sciences, Nanjing	Dr. Ganlin Zhang Prof. Mengfang Chen	TUD IBS Feger UFZ TUCHEM Georgi, Mackenzie
NIGLAS	Nanjing Institute for Geography and Limnology	Prof. WU	
	Nanjing Institute for Geography and Limnology	Prof. Hengpeng Li	UFZ UBZ V Afferden
NU + SKL-PCRR + NERC-OPCRR	School of the Environment, Nanjing University + State Key Laboratory for Pollution Control and Resource Reuse (SKL-PCRR) Associate Director, National Engineering Research Center for Organic Pollution Control and Resource Reuse (NERC-OPCRR), Nanjing, China	Prof. Dr. Rong Ji	UFZ-UBT M. Kästner A. Miltner J Müller K. Nowak UFZ
Qingdao			

OUC	Institute of Water Environment Engineering, Ocean University of China (Qingdao) -water quality, suspended particles removal	Prof. Dr. Xilai Zheng	(TUD IWC)
Shenyang			
IAE-CAS	Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, China	Prof. Xudong Zhang (Director) Dr. Chao Liang Dr. Hongtu Xie	UFZ-UBT M. Kästner
Wuhan			
ZUEL	School of Accounting /School of Graduate, Zhongnan University of Economics and Law	Tang, Guoping	
Wuxi			
City of Wuxi	Wuxi bureau of Science and technology; Urban water resilience and Nature-based Solutions EU Horizon 2020; submitted project proposal, 1st stage; Notice: Separate co-funding possibilities for Chinese partners	Ms. Zhongyuan Xu Mr. Baochun Zuo	
Xiamen			
XMU	School of Management, Xiamen University	Fu, Yuanlue	
Xianyang			
A&F	College of Natural Resources and Environment, Northwest A&F University, Yangling	Prof. Dr. Jianbin Zhou	TUD IBS Feger
	College of Water Resources and Architectural Engineering Northwest A&F University	Prof. Lei Wu	

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Helmholtz Centre for
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Permoserstraße 15
04318 Leipzig I Germany
www.ufz.de