# Environment

## The SIGN-2 Project: Assuring Good Water Quality from the Source to the Tap

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## SIGN项目二期概览：确保从源头到水龙头的优良水质

来自德国燃气与水工业协会水科技中心的Andreas Tiehm教授，同济大学尹大强教授和中国环境科学研究院郑炳辉教授的客邀文章

Water is essential for all life. However, in many parts of the world, water quality is threatened by multiple pollution sources. Access to clean and safe drinking water is crucial for human wellbeing and for the prevention of drinking water-borne disease.

In the last few decades, China has undergone rapid industrial and economic growth. Especially in densely populated areas, the need for clean water is constantly increasing. At the same time, the quality of raw water is often impaired due to significant anthropogenic pollution. The Sino-German research project SIGN-2 (Sino-German Network on Water Supply, second cooperation period) contributes towards improving the water quality in the Lake Tai region close to Shanghai, one of China's most economically prospering areas.

A powerful consortium of research facilities, companies and stakeholders was set up to successfully manage the challenging tasks of the SIGN-2 project. The project partners focus on the quality of the lake, which serves as a water resource, and on the drinking water quality for the adjacent megacities. Assuring the supply with good-quality water requires that the entire water cycle is taken into consideration, including the following:

- Competent management of water resources,
- Adapted and advanced monitoring strategies,
- Capable water treatment processes,
- Efficient distribution of drinking water.

Within the SIGN-2 project, German water technologies and management concepts get specifically developed and adapted to Chinese boundary conditions.

水是生命之源。然而，在世界上的许多地方水质正受到各种污染源的侵害。获得清洁、安全的饮用水对人类健康生存、预防饮用水传播疾病至关重要。

在过去的数十年中，中国的工业与经济发展迅猛。特别是在人口稠密地区，对清洁水的需求在不断升高。与此同时，原水的水质经常受到严重的人为污染。此外，中国可用的水资源不足（仅占全球平均的四分之一）且分布不均，干燥的北方地区缺水严重。中德联合研究项目SIGN二期（中德供水网，二期合作）致力于提升太湖地区水质。该地区紧邻中国经济最繁荣地区——上海，同时也是当前中国水专项重点治理的地区之一，可见其重大的政治意义。

科研机构、企业与利益相关方联手形成了一个强大的实体，成功担起SIGN项目二期具有挑战性的任务。项目各合作方致力于提升太湖水源水质，提高湖区周边特大型城市饮用水品质。为确保优质饮用水的供给，在治理时要将整个水循环都纳入考虑，包括：

- 有效的水源管理；
- 因地制宜、先进的水体监控策略；
- 有效的水处理工艺；
- 高效的饮用水输配。


*Scope and process of the SIGN-2 project*
*SIGN项目二期的范围和过程*
*Source / 图片来源: water-sign.de*

Scientific progress and practical applicability are ensured by the strong linkage between science and practice in Germany as well as in China.

### Water quality and processes in Lake Tai

Due to the very low water depth of Lake Tai, mixing processes between water and sediment have a major influence on the pollutant and nutrient distribution in the lake and thus on the quality of the raw water for drinking water production. To gain a deeper understanding of the dynamics of pollutants and nutrients in Lake Tai, innovative monitoring methods and sensor technologies are developed and tested. For the elucidation of these exchange dynamics, the availability of inorganic and organic pollutants and their toxicity as well as biomass turnover are considered.

Innovative techniques, such as field flow fractionation (FFF), are used to determine the influences of particle size and density on the dynamics of the suspended particles in the water phase. The development of an integrative system for lake monitoring is planned to assess eco-chemical risks of sediment resuspension events with a high resolution in this large and shallow eutrophic lake.

Biological tools are used to assess ecotoxicity as well as mutagenic and endocrine effects. Some microorganisms can be detrimental to water quality and human health, and therefore, powerful molecular biological methods are used to detect bacteria with antibiotic resistance genes as well as pathogenic viruses and bacteria. Another large and often clearly visible problem of Lake Tai is excessive algae growth, along with the production of toxins, compromising drinking water quality. The onset and duration of algal blooms are impacted by the nutrient content of the water as well as by mixing processes. A new method for the online monitoring and specification of algae cells is developed.

### Drinking water treatment

Algal blooms are a large challenge for drinking water treatment and still common in many shallow freshwater lakes in China. Thus, practicable, ecological, and economical solutions for efficient drinking water treatment, e.g. by ultrafiltration, are needed. Taste and odour problems as well as micropollutants, which

SIGN项目二期调整与改良了来自德国的水科技与管理理念，以适配中国当地的状况与条件。通过中德双方科学界与实施方之间紧密的联动，确保科技进程顺畅、应用实施顺利。

*Algae bloom at Lake Tai*
*太湖藻类绽放*
*Source / 图片来源: TZW Karlsruhe, Charlotte Schäfer*

### 太湖水质与湖泊过程解析

由于太湖是浅水湖泊，水与沉淀物的混合过程对污染物和营养盐在水中的分布具有重要影响，从而影响其作为饮用水水源的原水质量。为更好地了解太湖中污染物与营养盐的动力过程，创新的水体监控方法和传感技术做为研究方法被运用。为了阐明这些动态交换过程，监测过程还需考虑无机和有机污染物的存在及其毒性以及生物量周转量。

项目使用场流分级测定技术(FFF)等多种创新技术来测定微粒大小与密度对水相中悬浮微粒动态的影响。另外，计划开发一高精度的一体化湖水监测体系，评估大型浅水湖沉淀物再悬浮过程带来的生态与化学风险。

**China's Water Supply / 中国的供水**

China's big cities' thirst often cannot be quenched by groundwater resources, due to natural restrictions and the sheer amount of water needed. Therefore, if available, surface water is mainly used for water supply. Due to water pollution, advanced treatment technologies and management tools are needed to ensure safe drinking water quality. The project SIGN-2 develops such tools, that can be applied at Lake Tai as well as in other regions with similar problems in China and worldwide.

由于自然条件的限制和需水量的庞大，中国大城市对水的渴求往往无法由地下水资源来满足。因此，如果可用，地表水主要功能就是供水。由于水污染，需要先进的处理技术和管理工具，以确保饮用水质量的安全。SIGN项目二期开发这样的工具，以应用于太湖以及中国和世界上其他有类似问题的地区。

are not removed by conventional water treatment steps, are additional major challenges for drinking water production. On top, antibiotic resistance genes increasingly attract international attention, and the Lake Tai region is no exception. Regarding taste and odour (T&O), emphasis will be placed on mechanism elucidation and prevention of the formation of previously identified T&O compounds. Furthermore, the measurement and assessment of organic pollutants within the various purification steps in Lake Tai waterworks, including the analysis of the elimination efficiency, are part of the investigations. Elimination of antibiotic resistance genes is tracked across the drinking water process, starting with Lake Tai raw water.

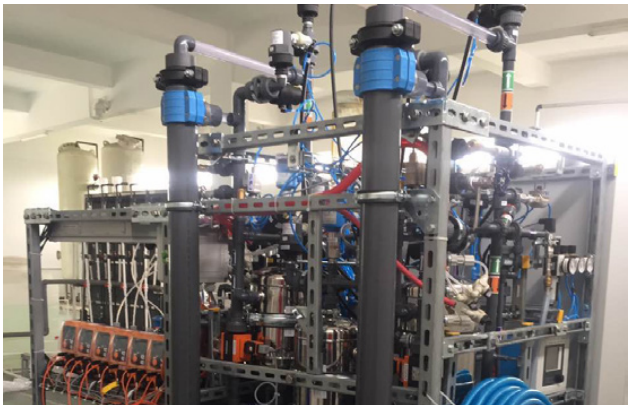
Filtration with tight membranes, such as nanofiltration or reverse osmosis, is a promising solution to retain target compounds in a low-molecular-weight range by means of physical separation. In this project, a membrane with separation abilities that can retain identified low-molecular substances, such as T&O compounds, micropollutants and antibiotic resistance genes, is developed. Using the technology of membrane surface alteration, the so-called "layer-by-layer technology", different separation layers sum up to produce tight ultrafiltration membranes in such a way that certain target compounds can be retained.

## Drinking water distribution

Drinking water as a product from the Lake Tai waterworks has a good and stable quality. However, water discoloration and problems with T&O compounds often reoccur during transport along the drinking water pipes. Regular flushing of distribution pipes is a common practice in Germany. For efficient flushing of large-scaled pipes (as used in China), new algorithms for the extrapolation of calculated flushing intervals from pilot zones to large network areas are developed. For better software-based maintenance of the network infrastructure, new features will extend the parameter spectrum for the rehabilitation modelling of networks.

Because of technical, hygienic, and economic reasons, water suppliers are urged to reduce the water losses from their water distribution networks to a minimum. SIGN-2 applies an innovative monitoring system with newly developed hydrophone loggers in the distribution network on large to very large pipelines.

项目采用生物工具评估生态毒性以及致突变和内分泌效应。有些微生物会对水质和人体健康造成损害，因此采用强大的分子生物方法来检测携带抗生素抗性基因的细菌以及致病病毒与细菌。太湖另一个棘手的问题是藻类的过度生长，释放毒素并危及饮用水水质。藻华的发生和持续时间受到水体中营养物质及其混合过程的影响。项目开发了一种全息影像系统作为藻类细胞检测、定量和定性分析的新方法。



*Membrane pilot plant in China*
*中国膜中试工厂*
*Source / 图片来源: TZW Karlsruhe, Charlotte Schäfer*

## 饮用水处理

藻类水华是饮用水处理的一大挑战，它在中国许多浅水湖泊中仍然十分普遍。因此迫切需要找到切实可行、生态且经济的饮用水超滤处理方法。传统的水处理步骤无法去除气味和味道上的异味（T&O）问题以及微粒污染物，这是在使用太湖原水制备饮用水过程中面临的主要挑战。最重要的是，抗生素耐药基因越来越引起人们的关注，太湖地区也不例外。针对异味（T&O）问题的研究重点是要弄清污染物产生的机制。此外，对太湖水厂各净化步骤中有机污染物的测量和评价，包括对去除效率的分析，也是研究的一部分。从获取太湖原水开始，就要追踪并消除抗生素抗药性基因。

紧密膜过滤，如纳滤或反渗透，是通过物理分离将目标化合物保留在低分子量范围内的一种被寄予厚望的解决方案。项目开发了一种能够过滤拦截已知的低分子物质的膜，如异味化合物、微污染物和抗生素抗药性基因。利用膜表面改性技术，即所谓的"逐层技术"，将不同的分离层叠加起来形成致密的超滤膜，使特定的目标化合物得以截留。

## 饮用水输配

太湖水厂提供的饮用水质量优良、稳定。然而在管道输送过程中，水的变色和异味化合物的问题再次出现。定期冲洗分配管道是德国的常见做法。为了有效

Furthermore, with the additional acquisition of network parameters, such as the status analysis of valves through a valve-turning machine, together with already acquired data from network flushing and leakage incidence, a deduction of rehabilitation strategies is developed through a special software tool. KANEW 3S is a software tool for condition and risk assessment as well as the simulation of asset management strategies of pipe networks. The tool gets extended by several new components to optimise the spatial and chronological planning of rehabilitation activities.

### Training, dissemination, and market implementation

The project's research and development activities lead to the adaptation of the German industrial partners' products for the Chinese market as well as to management concepts for a sustainable water management. Demonstrations, training and workshops at different institutions and companies are conducted to involve collaboration partners in China. All results obtained are actively shared with the scientific community as well as with Chinese stakeholders. Based on the existing Chinese standards and guidelines as well as on the raw water situation of Lake Tai, the most important parameters for drinking water quality will be selected to facilitate future monitoring and control.

地冲洗在中国使用的大型管道，项目开发了新的算法推算冲洗间隔并从试点区域扩大到全网络。为了更好地对供水网络基础设施进行基于软件的维护，新功能将扩展网络恢复建模的参数谱。

由于技术、卫生和经济方面的原因，供水商有必要将其供水网络的水损失降到最低。SIGN项目二期应用项目一期中开发运行的监测系统，并使用最新开发的水声监听记录仪搭载在输配管网的大型及超大型管道上。

此外，随着更多网络参数的获取（如通过阀门转辙机对阀门所作的运行状态分析），结合从网络冲洗和泄漏事件中获得的数据，通过一个专用的软件工具可以推导出管网修复策略。KANEW 3S正是这样一种用于管网设备管理策略仿真和状态评估的软件工具。这一工具还具备几个新拓展组件，用于优化管网修复的空间和时间规划。

### 培训与推广

项目的研发活动有助于帮助德国参与企业的产品的改良和推广应用，使之服务于中国的可持续水资源的管理与保护。在不同机构和公司举办的示范、培训和讲习班，中国的合作伙伴也一同参与进来。中德合作所有研究成果由中德双方共享。根据现有的中国标准、指南和太湖原水特征，筛选最重要的饮用水质量指标以开展进一步的测定和控制。

**Sino-German Water Research / 中德水研究**

The background of the Sino-German Water Research has been shortly described in the Econet Monitor, June 2019. Current topics are the sponge city concept (KEYS, Econet Monitor, June 2019); sludge treatment (IntenKS, Econet Monitor, September 2019); optimization of municipal wastewater treatment plants (MWWTP) (PIRAT-Systems) and removal of organic components in MWWTP (PEPcat). Today's article is about the project SIGN-2 which focuses on drinking water safety

在2019年6月份的Econet Monitor期刊中，我们介绍了德国和中国在水研究领域合作的背景。

目前运行中的五个中德联合水研究项目对应的主题分别是：海绵城市概念（KEYS，详见Econet Monitor，2019年6月刊）、污泥处理（IntenKS，详见Econet Monitor，2019年9月刊）、城市污水处理优化（PIRAT-Systems）、饮用水安全（SIGN-2），去除城市污水处理厂（MWWTP）中的有机成分（PEPcat）。今天要介绍的是致力于饮用水安全的SIGN二期项目

**BMBF-Project Office "Clean Water" / 德国联邦教育研究部（BMBF）"清洁水"创新研究项目办公室**

The BMBF-Project Office "Clean Water" at Tongji University Shanghai supports the Water Research Cooperation between BMBF and MOST and the joint water research projects since July 2012.

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自2012年7月起，位于上海同济大学的BMBF "清洁水" 项目办公室协助BMBF与MOST之间的水研究合作以及联合水研究项目。

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