Development and validation of novel treatment concepts for water reuse based on sequential managed aquifer recharge technology

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Background
Due to climate change, environmental pollution and water resource overuse, as well as growing urbanization, water scarcity and quality are becoming an increasingly global problem. Treated municipal wastewater is generally discharged into surface water, making it part of the natural water cycle (Figure 1), whereby increasing the potential for pathogens and persistent organic chemicals to contaminate source waters for drinking water treatment. This practice, called unplanned water reuse, can increase potential risks to human health and environment, and therefore requires appropriate countermeasures. Besides, the rising water demands in numerous regions encourage the exploitation of water reuse opportunities, as treatment of wastewater provides a reliable alternative to unstable and shrinking freshwater sources. Therefore, introducing advanced wastewater treatment technologies that ensure a sufficient quality for further reuse schemes would help to overcome the problem of water shortage and water quality caused by unplanned water reuse. Indirect potable reuse (IPR) through managed aquifer recharge (MAR) systems provides a highly-controlled option to augment drinking water supplies with treated wastewater effluent.

Figure 1: Unplanned water reuse praxis.

Recent studies on MAR systems show that biotransformation of many TOCs by microbial communities is enhanced under oxic and carbon limited conditions [1, 2]. These conditions can be provided through sequential managed aquifer recharge technology (SMART), which combines two conventional MAR systems with an intermediate aeration step [3]. Ongoing research is focusing on a
highly engineered hybrid infiltration system, SMARTplus, for direct treatment and potable reuse of secondary effluent, which is hydraulically decoupled from groundwater. This system is distinguished by high infiltration rates with defined flow regimes, controlled in-situ reactive zones, and easily manipulated redox conditions.

**Research objectives**
The overall objectives of this study are to estimate the relevance of unplanned water reuse and its impact on the drinking water supply and to develop a novel treatment concept, SMARTplus, ensuring sufficient quality for intended potable reuse schemes. Development of SMARTplus includes the implementation of an intermediate, in-situ oxygenation/oxidation step to establish favorable redox conditions for increased TOrC removal. A diffusive introduction system will be developed for pure oxygen, hydrogen peroxide and ozone with the aim of providing bubbleless, homogenous distribution of electron acceptors into SMARTplus. Furthermore, different process combinations with robust removal mechanisms to reach targeted log removal values for pathogens and threshold values of chemical pollutants will be developed.

**Methods**
The share of treated sewage in rivers in Germany is determined by calculating the dilution of WWTP effluents at discharge points into rivers through an ArcGIS script to identify river stretches with a high amount of treated sewage. Based on these findings and a risk assessment, hazard categories for the selected locations will be determined.

A horizontal flow pilot scale system (length: 6 m) was set-up to investigate the SMARTplus concept for indirect potable water reuse. The hydraulics, flow regimes and porous media used in the system are extensively characterized through tracer tests. Process performance will be evaluated based on water quality parameters (e.g. dissolved organic carbon, dissolved oxygen, UV absorbance, trace organic chemicals, pathogens). The efficiency of the process will be studied and improved through active manipulation of redox conditions, once microbial communities responsible for TOrC degradation have been established. To meet the required microbiological oxygen demand, process control methods will be investigated, where dissolved oxygen concentrations will be monitored as a surrogate parameter for microbial growth. Bench scale experiments mimicking the pilot scale SMARTplus will be conducted to provide oxygen or oxidant release rates for different emitters, which will be used for system design in the pilot scale system.

**References**
