SUBSOL

*Bringing coastal **SUB**surface water **SOL**utions* to the market

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Abstract

Coastal areas are the most productive and economically dominant regions in the world. High water demand in these regions however, puts tremendous pressure on coastal freshwater resources and ecosystems. This leads to problems like seasonal water shortages, saltwater intrusion, and deterioration of freshwater dependent ecosystems such as wetlands.

Building on national, regional and European research and innovation programs, in the past five years, a set of innovative, practical concepts has been developed for protection, enlargement and utilization of freshwater resources in coastal areas. These subsurface water solutions (SWSs) combine innovations in water well design and configuration, allowing for advanced groundwater management, and maximum control over freshwater resources. SWSs have successfully been piloted by public-private partnerships. Full-scale pilots have demonstrated the capacity of SWSs to support sustainable, economic and energy-efficient freshwater supply and food production in coastal areas.

Various similarities exist between SWS implementation sites in Europe and the northern Chinese coastline (e.g. along the Bohai Bay) such as strong within-year variation of precipitation, growing demand for freshwater which is partially satisfied by groundwater abstraction and intrusion of seawater. Hence, SWSs may also enable end-users in China to take control of their fresh groundwater resources and spur sustainable agriculture and other socioeconomic activities.

By demonstration, market replication, standardization and commercialisation, SUBSOL targets a market breakthrough of SWSs as a robust answer to the challenges freshwater resources face in coastal areas. SUBSOL's ambition is to introduce a paradigm shift in water resources management as well as to promote sustainable development of coastal areas worldwide.

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Introduction

Coastal regions are among the most productive and populated regions in the world. About 44% of the world's population live within 150km from the coast which induces enormous pressure on coastal freshwater resources including groundwater.

Freshwater is less dense than saltwater and in a typical unconfined coastal aquifer, freshwater floats on top of an underlying seawater body. Abstraction of fresh groundwater in coastal regions reduces the hydrostatic pressure of the overlying freshwater body which results in an inland-directed compensatory flow of saltwater from the ocean (*saltwater intrusion*). As a result, the *transition zone* or *saltwater freshwater interface* moves inland and often impairs socioeconomic activities such as agriculture or other freshwater dependent activities.

The development of Subsurface Water Solutions (SWS) is stimulated by the lack of solutions which support sustainable freshwater-dependent socioeconomic activities in coastal regions with salinized aquifers.

The problem

In temperate climate zones most precipitation occurs in winter whereas the demand for freshwater, e.g. for agriculture, is particularly high during the summer months. This within-year variation of gross precipitation and water demand creates a precipitation surplus (Paalman et al.; Zuurbier, Paalman 2012) which is often stored in surface storage solutions. These surface storage solutions tend to be expensive and compete for valuable land. In coastal regions where freshwater resources are scarce, within-year imbalances of freshwater availability may be addressed by energy intensive desalinisation processes.

As an alternative, Aquifer Storage and Recovery (ASR) was introduced in order to address the imbalance between water availability and demand by using the subsurface as natural water storage. In coastal regions however, ASR proved to be inefficient due to density-driven buoyancy effects.

The Subsurface Water Solution

Subsurface Water Solutions (SWSs) are a set of innovative technology concepts which protect, enlarge and utilise fresh groundwater resources in salinized coastal aquifers and allow a much more advanced management of fresh groundwater (Zuurbier et al. 2016). SWSs are innovative because they are widely applicable technology concepts that enable end-users to directly manage and enhance an ecosystem service (fresh groundwater) and thereby, protect freshwater resources in coastal areas.

Table 1: Comparative summary of Subsurface Water Solutions (Zuurbier et al. 2016).

SWS	Purpose	Target conditions	Artificial recharge	Saltwater interception	Well type	Water treatment
ASR-Coastal	Temporal storage	Brackish aquifers	Yes	No	Multiple partially penetrating wells	Pre-treatment
Freshkeeper	Protect wellfields	Stratified groundwater quality	No	Yes	Partially penetrating well, multiple partially penetrating wells	Optional post-treatment
Freshmaker	Temporal storage	Freshwater lenses	Yes	Yes	Horizontal directional drilled well	Pre-treatment

Table 2: SWSs have successfully been tested at reference sites and are being replicated at varies sites for varying purposes.

Reference and replication sites	Drinking water supply	Agriculture	Industrial water supply	Water reuse	Ecosystem services
Noardburgum, The Netherlands	X				
Ovezande, The Netherlands		X			
Nootdorp/Westland, The Netherlands		X			
Falster Island, Denmark	X				
Schinias, Greece		X			X
Dinteloord, The Netherlands		X	X	X	
Maneadero Valley, Mexico		X		X	

Water stress and saltwater intrusion in China

In many regions of China water stress is *extremely high.* Overall, more than 650 million people in China live in highly water stressed regions (Wang, J., L. Zhong, and Y.Long 2016).

Sixty percent of China's population live in fourteen coastal provinces, in many of which water scarcity is aggravated by saltwater intrusion (Shi, Jiao 2014). The pressure is mainly caused by unsustainable agricultural practices, continuous population growth and urbanisation (Han et al. 2014). Among others, densely populated settlements around the Bohai Sea are under particularly high water stress. In fact, the saltwater-freshwater interface in Bohai Bay area lies 25 kilometres from the coast and moves inland at a rate of approx. half a kilometre per year, posing a threat to sustainable socioeconomic development in the region (Han et al. 2014).

Present counter measures

Previously, large-scale efforts have been undertaken to inhibit or reverse saltwater intrusion along the Bohai coastal regions. For instance, a river infiltration project along the Huangshuihe River with more than 2,500 infiltration wells, 448 impounding canals as well as 773 impounding basins was implemented to counter saltwater intrusion. Another measure is an underground concrete wall with a length of more than five kilometres and an average depth of 26.7 metres (Wu et al. 2008).

Subsurface Water Solutions in China

In contrast to large centralised measures to counter saltwater intrusion, SWSs hold potential to empower specific end-users in agriculture and horticulture to participate in the groundwater resources management and exercise more control and ownership, in order to promote more sustainable agribusinesses along the Chinese coast. Hence, SWSs offer a decentralised and environmentally benign solution for the end-users in coastal regions that are affected by salinization.
Regions that may be considered for implementation of SWSs in China include the Laizhou Bay (part of the Bohai Sea) e.g. its east-coast (Longkou, Laizhou) south-coast (Changyi, Shouguang, Binhai), near-coast areas in the south of Laizhou Bay as well as other coastal areas along the Yantai Peninsula. Please note that the suggested sites require further investigation and may be complemented by additional locations.

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