Executive summary

Introduction
In recent years it was discovered that groundwater sources can also be contaminated with organic micropollutants. Traditional groundwater treatment processes with aeration and rapid filtration cannot remove these compounds sufficiently and additional treatment processes are required. Groundwater is in many cases anaerobic and contains ferrous iron. When hydrogen peroxide is added, in-situ formation of hydroxyl radicals (Fenton's reaction) can occur. Depending on the pH, this reaction will be a catalytic reaction (low pH) or a single pass reaction. In this project a combination of Fenton's reaction and ceramic nanofiltration was tested as an alternative for ground water treatment.

Importance
The presence of organic micropollutants in drinking water is undesired and therefore removal is required. Conventional groundwater treatment is in general insufficient to remove organic micropollutants and additional treatment technology is necessary. In this project a new physico-chemical treatment based on in-situ advanced oxidation combined with ceramic nanofiltration (CNF) was tested for this purpose.
With the Fenton reaction, the organic micropollutants will be destroyed, while the CNF will remove the reaction products (AOC, metabolites, and Ferric hydroxides) and other water constituents such as hardness, remaining ferrous iron, manganese etc. After the CNF an aeration and filtration step is still required to remove dissolved gases and to remove ammonium by biofiltration, but it is expected that this filter step can have a much smaller footprint. The combined Fenton CNF process may therefore form an interesting alternative ground water treatment system.

Approach
To test the idea for the new ground water treatment scheme, a small pilot plant with ceramic NF membranes was used. The plant was placed at the Waalwijk pumping station of the water supply company "Brabant Water". In a previous study, it was found that the Fenton reaction was very effective in this water.
The CNF pilot plant was connected to the raw water mains at the pumping station. The idea was to have a continuously running system, where hydrogen peroxide was added to the feed water prior to the membranes. Hydroxyl radical formation was tested by pCBA (p-chloro benzoic acid). Also the formation of biodegradable compounds was tested by AOC analysis and removal of inorganic compounds by the membrane was investigated by sampling and analysis. Spiking experiments with micropollutants were planned as well, but could not be done due to time constraints.

Result

Based on the percentages of pCBA conversion, the Fenton process was effective with this type of water. OH radical formation was proved by the oxidation of the pCBA. The highest pCBA conversion occurred at pH=4 and high H_2O_2 concentration (6 mg/L).

The ceramic nanofiltration membrane could withstand the highly oxidative environment without problems. However, rapid membrane fouling occurred (within minutes); it was probably due to iron$^{(III)}$ oxide precipitation.

The removal of ions by CNF was low (< 30%) under the experimental conditions used. It is expected that removal of organic micropollutants and their oxidation products will be low as well (Molecular Weight Cut-Off = 400 Da), but due to time constrictions and experimental difficulties this could not be verified.

According to the results which were obtained during this experiment, this system has a rising potential for the groundwater treatment but membranes with lower molecular weight cut-off are favourable. However these membranes are not commercially available yet. In addition, this experiment should be extended to investigate the efficiency of the combined Fenton process and ceramic nanofiltration system for micropollutant removal. Ceramic membrane having tighter pore size would be required to obtain higher ion removal and retention of micropollutants and oxidation products.

More information

Deliverable number: D2.3.2.6
Name of authors: Julien Ogier, Jan Hofman

Organisation: KWR Watercycle Research Institute
http://www.kwrwater.nl
Contact person: Jan Hofman
Telephone number: +31 (0) 30 60 69 679
Email: jan.hofman@kwrwater.nl

TKI Categorisation

Classification									
Supply Chain		**Process Chain**		**Process Chain (cont'd)**		**Water Quality**		**Water Quantity (cont'd)**	
Source		**Raw water storage**		**Sludge treatment**		**Legislation/regulation**		- Leakage	
- Catchment		- Supply reservoir		- Settlement		- Raw water (source)		- Recycle	
- Groundwater		- Bankside storage		- Thickening		- Treated water			
- Surface water		**Pretreatment**		- Dewatering		**Chemical**			
- Spring water		- Screening		- Disposal		- Organic compounds			
- Storm water		- Microstraining		**Chemical dosing**		- Inorganic compounds			
- Brackish/seawater		**Primary treatment**		- pH adjustment		- Disinfection by-products			
- Wastewater		- Sedimentation		- Coagulant		- Corrosion			
Raw water storage		- Rapid filtration		- Polyelectrolyte		- Scaling			
- Supply reservoir		- Slow sand filtration		- Disinfectant		- Chlorine decay			
- Bankside storage		- Bank filtration		- Lead/plumbosolvency		**Microbiological**			
Water treatment	X	- Dune infiltration		**Control/instrumentation**		- Viruses		**Consumers / Risk**	
- Pretreatment		**Secondary treatment**		- Flow		- Parasites			
- Primary treatment		- Coagulation/flocculation		- Pressure		- Bacteria		**Trust**	
- Secondary treatment		- Sedimentation		- pH		- Fungi		- In water safety/quality	
- Sludge treatment		- Filtration		- Chlorine		**Aesthetic**		- In security of supply	
Treated water storage		- Dissolved air flotation(DAF)		- Dosing		- Hardness / alkalinity		- In suppliers	
- Service reservoir		- Ion exchange		- Telemetry		- pH		- In regulations and regulators	
Distribution		- Membrane treatment	X	**Analysis**		- Turbidity		**Willingness-to-pay/acceptance**	
- Pumps		- Adsorption		- Chemical		- Colour		- For safety	
- Supply pipe / main		- Disinfection		- Microbiological		- Taste		- For improved taste/odour	
Tap (Customer)		- Dechlorination		- Physical		- Odour		- For infrastructure	
- Supply (service) pipe		**Treated water storage**						- For security of supply	

- Internal plumbing		- Service reservoir				**Water Quantity**		**Risk Communication**	
- Internal storage		**Distribution**						- Communication strategies	
		- Disinfection				**Source**		- Potential pitfalls	
		- Lead/plumbosolvency				- Source management		- Proven techniques	
		- Manganese control				- Alternative source(s)			
		- Biofilm control				**Management**			
		Tap (Customer)				- Water balance			
		- Point-of-entry (POE)				- Demand/supply trend(s)			
		- Point-of-use (POU)				- Demand reduction			

TKI Categorisation (continued)

Contains		**Constraints**		**Meta data**					
Report	X	Low cost		*Author(s)*		Julien Ogier, Jan Hofman			
Database		Simple technology		*Organisation(s)*		KWR Watercycle Research Institute			
Spreadsheet		No/low skill requirement		*Contact name*		Jan Hofman			
Model		No/low energy requirement		*Contact email*		Jan.Hofman@kwrwater.nl			
Research		No/low chemical requirement		*Quality controller name*		**Bas Heijman**			
Literature review		No/low sludge production		*Quality controller organisation*		KWR Watercycle Research Institute			
Trend analysis		Rural location		Source					
Case study / demonstration		Developing world location		*Date prepared*		November 26th, 2008			
Financial / organisational				Date submitted (TKI)					
Methodology				Date revised (TKI)					
Legislation / regulation									
Benchmarking									