Ultrafiltration with pre-coagulation in drinking water production
Literature review

Introduction
Ultrafiltration is a pressure driven membrane process, which is increasingly applied in advanced drinking water treatment processes, particularly to improve the water quality with respect to organic and microbiological parameters. The combination with coagulation is a promising process combination to remove natural organic matter and maintain a high membrane performance. This hybrid process can also help to reduce subsequent disinfection by-product formation.

Importance
In recent years, surface water purification with ultrafiltration membrane has become an attractive alternative to conventional clarification. No or less need of chemical agents, good quality of produced water independent of feed water quality, good removal efficiency towards microorganisms, less production of sludge, compact process, and easy automation are some of the advantages of ultrafiltration compared to conventional treatment. Originally, ultrafiltration was used to remove turbidity and microorganism from good-quality surface water. Nowadays the main goal is to improve this technology and to apply it to worse quality sources for the removal of microorganisms, natural organic matter (NOM), dissolved organic matter (DOC), disinfection by-products (DBPs), and other components. In order to accomplish this purpose, many experiments have been conducted regarding to pre-treatment, membrane operational mode, membrane material, fouling mechanisms, membrane and water parameters, and the influence of components of the raw water. The aim of this report is to review the current practice in employing the ultrafiltration process with pre-treatment options, mainly coagulation, and to summarise the existing knowledge of application, including operational experiences.

Approach
Many studies on ultrafiltration membranes in drinking water production have been conducted or are currently in progress with the intention to improve the performance of this process. This report ought to give a summary of these studies, which deal with pre-treatment options, membrane types, as well as process and water parameters, membrane fouling, membrane cleaning procedures and operational experiences with UF membranes.

Result
Coagulation coupled with ultrafiltration is one of the most promising drinking water production processes. Regarding removal rates and residual aluminium, aluminium sulphate and polyaluminium chloride are better coagulants than sodium aluminate. Iron chloride is a more efficient coagulant than aluminium sulphate. A pH around 6 is recommended during coagulation. During in-line coagulation, under-dose conditions with acidic

pH show the best performance because it is possible to obtain good removal rates of contaminants and improve physical performance. Nevertheless, standard coagulation is superior to in-line coagulation. Dynamic membranes are a promising alternative to current techniques used in drinking water production, because tests show that they perform better than membranes with standard or in line coagulation as a pre-treatment. Metal membranes have a potential for drinking water production, if the production costs can be reduced. Absolute values of pH and coagulant dose depend on the nature of the raw water and on the operational requirements. Ultrafiltration membranes are a reliable barrier against bacterial, protozoa and viruses. Coupled with coagulation LRVs (log reduction value) of 6.7 can be obtained. This makes them suitable for water disinfection. An improved removal of humic acids can be achieved if fibres with an additive are used for filtration. Fibers spun under an air gap had both higher flux and higher retention than wet spun fibres. NOM causes membrane fouling. It can be subdivided in particulate (P), colloidal (C) and dissolved organic carbon (D). The fouling potential of the coagulated fractions can be ordered as follows: (C) > (C+D) > (P+C+D) = (P+C) > (D). Particulates with coagulation pre-treatment help to minimise irreversible fouling. Coagulation cannot minimise the fouling caused by colloids, which is considered the worst type of fouling.
Chemical cleaning is used to restore the membrane permeability. A higher temperature during the cleaning improves the dissolution of organic and inorganic compounds. A two-step cleaning in the sequence base and acid shows the best overall performance. It can enhance a chemical enhanced backwash (CEB) notably, because strongly fouling hydrophobic compounds can as well be removed as inorganic colloids. Removal of organic compounds in cleaning in place (CIP) and cleaning out of place (COP) can be conducted with an oxidant such as NaOCl and inorganic compound removal is best with a citric acid. A direct comparison of the results of the sources used is difficult because different membrane materials, operational modes, experimental setups, and raw waters were used. Recapitulating, the report shows that ultrafiltration is a reliable technique for drinking water production.

More information

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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	X	- Settlement		- Raw water (source)		- Recycle	
- Groundwater		- Bankside storage	X	- Thickening		- Treated water			
- Surface water		**Pretreatment**		- Dewatering		**Chemical**			
- Spring water		- Screening	X	- Disposal		- Organic compounds			
- Storm water		- Microstraining		**Chemical dosing**		- Inorganic compounds			
- Brackish/seawater		**Primary treatment**		- pH adjustment	X	- Disinfection by-products			
- Wastewater		- Sedimentation		- Coagulant	X	- Corrosion			
Raw water storage		- Rapid filtration		- Polyelectrolyte	X	- Scaling			
- Supply reservoir		- Slow sand filtration		- Disinfectant		- Chlorine decay			
- Bankside storage		- Bank filtration		- Lead/plumbosolvency		**Microbiological**			
Water treatment		- Dune infiltration		**Control/instrumentation**		- Viruses		Consumers / Risk	
- Pretreatment		**Secondary treatment**		- Flow	X	- Parasites			
- Primary treatment		- Coagulation/flocculation	X	- Pressure	X	- Bacteria		**Trust**	
- Secondary treatment		- Sedimentation		- pH	X	- Fungi		- In water safety/quality	
- Sludge treatment		- Filtration		- Chlorine		**Aesthetic**		- In security of supply	
Treated water storage		- Dissolved air flotation(DAF)		- Dosing	X	- 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	X	- Colour		- For safety	
- Supply pipe / main		- Disinfection		- Microbiological	X	- Taste		- For improved taste/odour	
Tap (Customer)		- Dechlorination		- Physical	X	- 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		*Farhad Salehi* *Philipp Meier* *Thomas Wintgens* *Christian Kazner* *Thomas Melin*					
Database		Simple technology		*RWTH Aachen University*					
Spreadsheet		No/low skill requirement		*Farhad Salehi*					
Model		No/low energy requirement		*salehi@ivt.rwth-aachen.de*					
Research		No/low chemical requirement		*Ingo Machenbach*					
Literature review	X	No/low sludge production		*SINTEF*					
Trend analysis		Rural location		Source					
Case study / demonstration	X	Developing world location							
Financial / organisational									
Methodology									
Legislation / regulation									
Benchmarking									