WATER TREATMENT BY ENHANCED COAGULATION
Operational status and optimization issues

Introduction
Most drinking water treatment plants in Europe are already built. With few exceptions, the major focus for most end-users will be on how to secure safe and sustainable, cost-efficient operation of existing facilities. Retrofitting and up-grading are also important issues. In addition, there will always be a drive for developing new processes and technologies to meet new demands and regulations. Unfortunately, sub-optimum operation of water treatment facilities is a rather widespread phenomenon, thereby compromising water supply safety, sustainability, and cost-efficiency. Natural organic matter (NOM) is a major raw water constituent that affects water supply systems in a number of ways and needs to be removed. NOM interacts with disinfection and coagulation processes; forms disinfection by-products (DBPs); increases disinfectant and coagulant demands; influences on coagulation processes and coagulation performance; influences on the removal of inorganic particles and micro organisms; fouls membranes and blocks GAC pores, thus also affecting the removal of algal toxins, taste and odour. Last, but not least, NOM affects corrosion, biostability and water quality during distribution. NOM has major negative implications for processes like coagulation, media filtration, disinfection, activated carbon applications, and membrane filtration. In many cases, NOM controls the removal process design, performance and operating conditions.

Importance
Identification of optimum operating conditions and implementation of best operation practices at existing drinking water treatment facilities are key challenges in order to secure safety, sustainability and cost-efficiency. Because of the great influence on operation challenges and bottlenecks, NOM characteristics and treatability has to be addressed as part of a required new drive towards increased treatment process optimization. With some exceptions (e.g. UK, Germany, Norway, Sweden, Finland, etc), NOM and NOM-related issues have not gained the same interest in terms of regulations, operation issues, and tailored research activities in Europe compared to countries like USA and Australia. This situation seems to persist, in spite of the fact that due to climate change and global warming a significant increase in NOM has been observed during the past 10-20 years in large parts of Northern Europe. The corresponding increase in seasonal and spatial variation of NOM will impose even more operational challenges.

Approach
The report addresses optimization needs and challenges at existing water treatment facilities employing enhanced coagulation and filtration processes as core treatment. Unlike conventional coagulation processes where removal of turbidity was the main objective, enhanced coagulation processes designed for the removal of NOM (i.e. TOC, colour, UV-abs) involve elevated coagulant doses and strict control of coagulation pH. A number of studies on (enhanced) coagulation and filtration have demonstrated that NOM is the major determining factor with respect to process operation conditions. Thus NOM is a key substance throughout this report. The report is based on state-of-the-art literature surveys, pilot and full-scale experiences on operation issues and best operation practices. Impacts of NOM on water supply systems, and NOM characterization methods and treatability issues are presented and discussed. Furthermore, the report contains enhanced coagulation and filtration

experiences, optimization guidelines, best operation practice assessments, operation models, process control options and a number of case studies.

Results

The concentration, nature and properties of NOM are important characteristics with respect to treatability and optimum coagulation condition evaluations. The seasonal and spatial variability of NOM is significant. Huge increases in NOM concentrations have been reported in Northern Europe and North America as a result of climate change. Relevant NOM characterization methods and results are presented and discussed in the report. Furthermore, plant operation practices are reviewed. It is evident from the results that the operation of enhanced coagulation facilities, e.g. factors like coagulant demand, sludge production and obtained filter run times, is predominantly controlled by NOM rather than turbidity or other substances.

Major operational challenges and bottlenecks in enhanced coagulation processes are presented and discussed. Coagulation pH and coagulant dosage appear to be the most important operational parameters, and compliance with the total residual metal regulations (< 0.1-0.2 mg Me/L) appear as the determining parameter for the minimum coagulant requirement. Temperature and mixing conditions appear to be less important operational parameters in relation to contact filtration processes. Optimal operation is important also from a microbial point-of-view, i.e. the removal of protozoan parasites like *Cryptosporidium* and *Giardia* is compromised by inadequate operation conditions like non-optimal pH and coagulant doses, and by operational disturbances from filter ripening, peaks in hydraulic load/filtration rates, improper management of return flows, early filter breakthroughs and inadequate filter backwash routines. The report also present and discuss optional pre- and post-treatments like ion exchange, activated carbon adsorption, ozonation/oxidation, corrosion control and disinfection. In addition, unit process operation models are presented as optimization tools and possible inputs to the development of a treatment process simulator (WA5.4). Treated water characteristics are presented and discussed, and a number of case studies are presented. This includes water treatment facilities in Finland, Latvia and Norway.

From the reviews, a number of knowledge gaps and research needs are identified, suggesting further activities on: 1) NOM characterization and treatability interactions, including implications of climate change; 2) Improved practical linkage of NOM characteristics and seasonal variations to practical operation routines and actions, including identification of NOM fractions that are recalcitrant/not amendable to removal in general or as a result of specific operation conditions (e.g. sub-optimum coagulant doses); 3) Refinement, development and verification of user-friendly optimization routines, as well as models that can be applied for the purpose of overall process optimization; and 4) Improved process control systems, and development of in-line sensors for treatment process and product control purposes.

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		- Settlement		- Raw water (source)		- Recycle	
- Groundwater		- Bankside storage		- Thickening		- Treated water	x		
- Surface water	x	**Pretreatment**		- Dewatering		**Chemical**			
- Spring water		- Screening		- Disposal		- Organic compounds	x		
- Storm water		- Microstraining		**Chemical dosing**		- Inorganic compounds	x		
- Brackish/seawater		**Primary treatment**		- pH adjustment	X	- Disinfection by-products	x		
- Wastewater		- Sedimentation		- Coagulant	X	- Corrosion	x		
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	x		
- Primary treatment		- Coagulation/flocculation	X	- Pressure	X	- Bacteria		**Trust**	
- Secondary treatment	x	- Sedimentation	x	- pH	X	- Fungi		- In water safety/quality	x
- Sludge treatment		- Filtration	x	- Chlorine		**Aesthetic**		- In security of supply	
Treated water storage		- Dissolved air flotation(DAF)		- Dosing	X	- Hardness / alkalinity		- In suppliers	x
- Service reservoir		- Ion exchange		- Telemetry		- pH		- In regulations and regulators	x
Distribution		- Membrane treatment		**Analysis**		- Turbidity	x	**Willingness-to-pay/acceptance**	
- Pumps		- Adsorption		- Chemical	X	- Colour	x	- For safety	x
- 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		*Bjørnar Eikebrokk, SINTEF* *Stein W. Østerhus, SINTEF* *Talis Juhna, RTU*					
Database		Simple technology		*SINTEF and RTU*					
Spreadsheet		No/low skill requirement		*Bjornar Eikebrokk*					
Model	x	No/low energy requirement		*bjornar.eikebrokk@sintef.no*					
Research		No/low chemical requirement		*Sveinung Sægrov*					
Literature review	X	No/low sludge production		*SINTEF*					
Trend analysis		Rural location		Source					
Case study / demonstration	X	Developing world location		*Dec 2006*					
Financial / organisational				2007-04-26					
Methodology									
Legislation / regulation									
Benchmarking									