Introduction
This report presents a fault tree method for integrated risk analysis of drinking water systems and an application to the Göteborg drinking water system. This is one of six case studies carried out in within WA 4 with the aim to: (i) apply and evaluate the applicability of different methods for risk analysis and to some extent risk evaluation of drinking water systems; and (ii) provide end-users with clear examples of how the risk analysis methods can be applied and what requirements exist.

Importance
Risk assessments providing relevant and informative results to assist decision-makers are essential for an efficient risk management. The World Health Organization concludes in their Water Safety Plan document that the most effective way to guarantee safe drinking water to consumers is an integrated risk management approach, including the entire drinking water system from source to tap. However, guidance on methods and tools to assist water utilities in managing risks is lacking. This report describes one type of advanced risk assessment method and an example of its application.

Approach
The applied method is based on fault tree analysis and applies an integrated approach, from source to tap. Based on a system description and identified hazards a fault tree is constructed to model quantity- (i.e. no water is delivered) as well as quality-related failures (i.e. water quality standards are not fulfilled). Input data is based on combinations of expert judgments by water utility personnel and hard data (e.g. statistics on pervious events). Uncertainties in the variables are considered and calculations are performed using Monte Carlo simulations. The risk is express as Customer Minutes Lost (CML) and presented separately for quantity- and quality-related failures. The method also provides information on probabilities of failure, failure rates and duration of failures.

Results
For the analysed system it is concluded that the raw water system pose the largest risk related to both quantity and quality failures. The case study shows that the applied fault tree method can be used to perform integrated risk analysis and consider interactions between events. Risk levels as well as the dynamic behaviour of the system and uncertainties in results can be analysed. Furthermore, the results can be compared to acceptable levels of risk and possible options for risk reduction can be modelled and evaluated.

More information
The results of this work are presented in the report "Risk assessment case study – Göteborg, Sweden".

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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			
- Surface water		**Pretreatment**		- Dewatering		**Chemical**		**Risk Management / Consumers**	
- Spring water		- Screening		- Disposal		- Organic compounds			
- Storm water		- Microstraining		**Chemical dosing**		- Inorganic compounds		**Risk analysis**	
- Brackish/seawater		**Primary treatment**		- pH adjustment		- Disinfection by-products		- Hazard identification	x
- Wastewater		- Sedimentation		- Coagulant		- Corrosion		- Risk estimation	x
Raw water storage		- Rapid filtration		- Polyelectrolyte		- Scaling		**Risk evaluation**	
- Supply reservoir		- Slow sand filtration		- Disinfectant		- Chlorine decay		- Risk tolerability decision	x
- Bankside storage		- Bank filtration		- Lead/plumbosolvency		**Microbiological**		- Analysis of options	x
Water treatment		- Dune infiltration		**Control/instrumentation**		- Viruses		**Risk reduction / control**	
- Pretreatment		**Secondary treatment**		- Flow		- Parasites		- Risk reduction options	
- Primary treatment		- Coagulation/flocculation		- Pressure		- Bacteria		- Decision making	
- Secondary treatment		- Sedimentation		- pH		- Fungi		- Implementation	
- Sludge treatment		- Filtration		- Chlorine		**Aesthetic**		- Monitoring	
Treated water storage		- Dissolved air flotation(DAF)		- Dosing		- Hardness / alkalinity		**Risk Communication**	
- Service reservoir		- Ion exchange		- Telemetry		- pH		- Communication strategies	
Distribution		- Membrane treatment		**Analysis**		- Turbidity		- Potential pitfalls	
- Pumps		- Adsorption		- Chemical		- Colour		- Proven techniques	
- Supply pipe / main		- Disinfection		- Microbiological		- Taste		**Trust**	
Tap (Customer)		- Dechlorination		- Physical		- Odour		- In water safety/quality	
- Supply (service) pipe		**Treated water storage**						- In security of supply	
- Internal plumbing		- Service reservoir				**Water Quantity**		- In suppliers	
- Internal storage		**Distribution**						- In regulations and	

								regulators	
		- Disinfection				**Source**		**Willingness-to-pay/acceptance**	
		- Lead/plumbosolvency				- Source management		- For safety	
		- Manganese control				- Alternative source(s)		- For improved taste/odour	
		- Biofilm control				**Management**		- For infrastructure	
		Tap (Customer)				- Water balance		- For security of supply	
		- 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)*					
Database		Simple technology		*Organisation(s)*					
Spreadsheet		No/low skill requirement		*Contact name*					
Model	x	No/low energy requirement		*Contact email*					
Research	x	No/low chemical requirement		*Quality controller name*					
Literature review		No/low sludge production		*Quality controller organisation*					
Trend analysis		Rural location		Source					
Case study / demonstration	x	Developing world location		*Date prepared*					
Financial / organisational				Date submitted (TKI)					
Methodology	x			Date revised (TKI)					
Legislation / regulation									
Benchmarking									