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Climate Change and Water Supply

The consequences of climate change and potential adaptation strategies

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Introduction

Climate change and its impacts have been in the focus of public attention for many years. In the last year alone, the UN World Water Development Report and the World Water Forum have drawn worldwide attention to the questions of how climate change will affect the availability and quality of water and how human beings may adapt to this challenge. The European Commission’s White Paper on “Adapting to Climate Change” and the report by the European Environmental Agency on the dangers of water scarcity and droughts have addressed these issues at the European level.

According to present knowledge climate change impacts in Central Europe are likely to be moderate compared to other parts of the world. Nevertheless, it will affect water supply directly, i.e. in terms of raw water availability and quality as well as with respect to the operation of the supply infrastructure.

In 2008 the Federal Government resolved to develop the German Adaptation Strategy (*Deutsche Anpassungsstrategie [DAS]*) to climate change and to submit an action plan on climate adaptation by March 2011 with the objective to identify the adaptation requirements of the societal and economic sectors concerned and to define options and priorities for governmental activities. The DVGW will contribute actively to this process on behalf of the water supply sector.

Given that water suppliers are used to long-term planning and investment periods and know how to cope with changing parameters, they should - in cooperation with researchers, politicians and other stakeholders - be expected to succeed in adapting to the consequences of climate change.

The DVGW homepage provides a platform with information about climate change adaptation, about the activities pursued by the Federal and Laender governments as well as about relevant research projects and plans related to water supply. Beyond this, it offers some examples that illustrate the practical work of water utilities:
www.dvgw.de/water/ressourcenmanagement/klimawandel/

This information paper at hand focuses on climate change impacts and ways and means to adapt to these changes. The water supply industry is nevertheless fully aware of its responsibility for climate change mitigation, i.e. to reduce greenhouse gas emissions from water supply. An ongoing DBU/DVGW research project develops guidelines for water utilities to optimise their energy use and to increase energy efficiency.

Climate change in Germany

Across Germany, annual average temperatures will go up, resulting in warmer and drier summers and milder and wetter winters. There are, however, large regional differences within Germany and in some areas contrary to the general trends observed across the country. As seasonal and spatial climate variabilities increase, the reliability of projections on future water management parameters decreases. Extreme weather events such as hurricanes rain storms, and dry periods are generally more likely to occur. These, in a nutshell, are the climate changes most studies expect to occur until the end of the 21st century. However, regional projections for concrete quantitative parameters are still uncertain and can be made only within relatively wide boundaries. The degree of uncertainty is higher still if we want to determine on the basis of various climate factors (e.g. precipitation, temperature, evaporation) the changes of parameters like, for instance, groundwater recharge or runoff regimes in river catchments.

Climate change may also affect some of the familiar, fixed parameters that serve as a basis for planning and investment decisions, since the parameters derived from long-term time series that describe the availability of resources have ceased to be a reliable basis for information helping to assess future conditions. Increasing climate variability creates a wider range of potential weather conditions and may be part of future climate conditions. This requires precise analyses and monitoring of the development of all climate-related conditions that are relevant for water utilities in order to facilitate an early response to emerging trends. Long-term operating and investment decisions should take into account the expected range of climate changes which may impact the operation of water supply facilities and networks.

Impacts on water supply

Climate change may result in the more frequent or intense occurrence of familiar phenomena that may also spread to other regions. This may include more frequent or intense periods of drought, heat waves or rain storms in regions that so far have been affected by these phenomena either not at all or only rarely. In other words, the water supply industry will not be confronted with vague unknowns but in general with phenomena it is experienced in coping with. This is not supposed to be construed as an all-clear but rather meant to encourage a proactive and unemotional discussion of the effects brought about by climate change.

Quantitative and qualitative aspects of changed water availability

While precipitation and total runoffs that increase on a multi-year average may definitely improve the water supply situation in some regions, the water industry will nevertheless have to adapt to a seasonally or intermittently diminished availability of water. Whether or not a permanent or temporary reduction in water availability will lead to a critical situation for a water supply system depends on a multitude of local factors such as, for instance,

- the existence or non-existence of alternative water sources and sufficiently flexible local water abstraction facilities enabling utilities to respond to a (temporary) loss of individual abstraction types/catchment areas;
- the existence of competing water uses and their increasing significance, if applicable (especially agricultural irrigation); and
- the expected development of water use.

The following consequences of changes in water resources availability loom ahead:

<u>Groundwater:</u>

- A permanently declining and seasonally diminished or absent groundwater recharge entails a concurrent sinking of the water table. The water resources availability situation will deteriorate particularly where (seasonally) diminished groundwater recharge affects comparatively small groundwater systems which are less capable to buffer precipitation variabilities. Springs fed by small or near-surface aquifers are especially sensitive to changes of water resources availability.

- In contrast, in regions where groundwater recharge takes place almost exclusively during winters and where winters are getting wetter, average groundwater levels are expected to rise. This may cause water logging and damage to buildings, especially when increasing recharge is accompanied by a lower water demand.

- Changes in water resources availability may also result in major groundwater quality changes, e.g. a non-dilution of contaminated groundwater may lead to higher pollutant concentrations in the raw water.

- Lower back pressures caused by sinking groundwater levels will lead to deep-well pump cavitation problems and may cause wells to run dry in extreme cases.

- In coastal regions, the expected sea level rise may result in salt water intrusion into coastal aquifers.
- A permanently improved water resources availability is expected for regions with increasing groundwater recharges and larger groundwater resources.

Lakes and reservoirs:

- Seasonally and intermittently sinking levels of lakes and reservoirs will generally diminish raw water availability exactly during peak demands.
- This may result in smaller depths of the storage volumes suitable for raw water withdrawal, a smaller portion of cold deep water (hypolimnion) and in decreasing back pressures at withdrawal points. Beyond this, the capacities to buffer polluted inflows and water withdrawal control options may be compromised.
- Rains storms may adversely affect raw water quality as they may cause erosive runoffs and an increase in spillovers from separate and combined sewerage systems, entailing increased inputs of sediment- and particle-bound contaminants and microorganisms.
- Climatic changes will more severely affect the quality of small and shallow waters and waters with a higher trophic level than that of deep and oligotrophic waters.

Rivers:

- The risk of flooding increases with the rising frequency of rain storms. Floods may adversely affect groundwater quality and mobilise dangerous substances e.g. from industrial brownfields. Extremely high water levels may submerge bank filtration systems and thus directly pollute raw water.
- During extremely low flows water withdrawals from rivers might need to be reduced or even ceased.
- Lower river flows may lead to higher concentration of pollutants and adversely affect raw water quality. This is relevant also when river water is used for artificial groundwater recharge or bank filtration. The polluter-pays principle is particularly significant against this backdrop.
- Rain storms may adversely affect raw water quality as they may cause erosive runoffs and an increase in spillovers from separate and combined sewerage systems, entailing increased inputs of sediment- and particle-bound contaminants and microorganisms.
- Rain storms, floods and persisting periods of drought may interfere with utility operation and, in some exceptional cases, result in a temporary water supply cut-off.

Rising air and water temperatures

- Higher air temperatures increase the vertical temperature gradient in lakes and reservoirs. Thermal stratification tends to become more stable; full circulation - required for the renewal and oxygen supply of the hypolimnion, which is generally crucial for raw water abstraction -, occurs more rarely, decreases in length and may even stay away for good in isolated cases. Moreover, prolonged periods of heat will result in deeper epilimnion strata, thus reducing the depth of the hypolimnion. Increasingly insufficient deep mixing with ensuing deep water replenishment has already been observed in Lake Constance in winter times.
- Higher temperatures generally accelerate biological and chemical processes in water bodies. This tends to adversely affect raw water quality; the extent of the impact however also depends on other parameters such as the availability of nutrients and oxygen. These may foster the growth of algae, for instance, so that algal blooms and a concurrent formation of odours and fla-

vours as well as a release of bacterial exo- and endotoxins may ensue. Another consequence may be delayed phyto- and zoo-plankton growth, resulting in the degeneration of today's food chains within aquatic communities.

- Higher air and soil temperatures may also lead to higher drinking water temperatures in distribution networks. Whether higher temperatures increase the risk of microbial growth and contamination depends very much on the general condition and operation of the supply system. In networks with a given tendency towards microbial recontamination, this tendency will be fortified by higher temperatures.
- Higher air and water temperatures tend to favour the proliferation of a variety of waterborne pathogens. Any impairment of drinking water is possible only in exceptional cases. In general, the monitoring and treatment of raw waters potentially at risk (surface water, near-surface groundwater and spring water) is already focusing on the presence of pathogens.

Indirect consequences

- Higher soil temperatures promote conversion and mineralisation processes in soils and, consequently, the pollution of seepage water. These processes depend on sufficient soil moisture. The trend towards drier summers increase seasonal topsoil desiccation which inhibits mineralisation processes. The conversion and displacement of the accumulating substances is delayed until infiltration of the vadose zone occurs in autumn, which may result in a considerable mobilisation of substances (e.g. of nitrate) and subsequent pollution of seepage water.
- Intensification of agriculture with growing demand for irrigation, fertiliser and pesticide use triggered by the cultivation of energy crops for biofuel production, the extension of the vegetation period, and decreasing precipitation during that period.
- Extreme weather events like rain storms, hailstorms or droughts may lead to crop failures or even ruin the entire standing growth, causing plants not to absorb fertilisers and/or the fertilisers to remain in the plant residues, which may result in massive nitrate pollution of groundwater.
- Conflicts about the use of locally or regionally available water resources: locally and temporarily, water resources may not suffice to satisfy the demand of all users (i.e. water suppliers, households, farmers, commerce and industries) in a region.
- Peak demand increases: the dry summer of 2003, for instance, demonstrated that water consumption increases during dry and hot periods. As a result the gap between average and peak water demands grows. The situation becomes even worse in regions with decreasing average water demand caused by e.g. a population decrease, a change in industrial consumption etc. Under such circumstances water suppliers face new challenges for the design, construction, and operation of water supply systems.
- As extreme weather events and flood events are likely to increase in frequency and intensity, dam and reservoir management will have to focus more on flood protection, which in turn may result in reduced storage capacities for raw water abstraction.

Adaptation options for water suppliers

Adapting to climate change is basically concerns society as a whole. This is true also for the adaption in drinking water supply, although water suppliers play a key role in this regard.

In order to identify suitable adaptation measures, water suppliers should analyse their individual situation comprehensively, focusing on the following questions, for example:

- Which impacts and consequences will affect a supply system?
- Which assets and processes of a supply system are particularly sensitive to the expected impacts?

- Which adaptation options do the ongoing operation schemes and the established management tools offer?
- What needs to be considered with regard to future investments?

A continuous integration of the findings thus obtained into all planning and decision-making processes of the operation is crucial.

The following provides an overview of adaptation options for water suppliers:

Management and protection of water resources

- Trend analyses and drawing up of long-term water availability projections
- Area-specific adaptation of monitoring networks and programmes enabling staff to knowledgeably assess potential quality changes.
- Integrated water resources management taking into account aspects of both quality and quantity
- Securing drinking water supply through official spatial planning and water resources planning and approval procedures.

Abstraction, treatment and network operation

- Redundant abstraction systems allow for a flexible combination of different types of raw water resources and abstraction technologies. This may be achieved by creating networks (developing additional proprietary raw water sources, integrating adjacent local direct supplies, connecting to regional water supply systems).
- Adapting wells and pumping facilities to changing parameters (e.g. permanent or temporary phreatic decline or falling reservoir water levels)
- Adapting water treatment to expected new or changed raw water qualities
- Creating disinfection facilities in storage and distribution systems.
- Creating larger storage capacities in water works and networks to ensure that supplies meet growing peak demands
- Adaptation of network inspection and flushing schemes
- Keeping water losses permanently low

Organisation and management

- Adapting organisational structures and management processes to the expected changes so as to be able to manage risks and crises

What can policy makers, scientists and water suppliers do to adapt to the consequences of climate change?

There is no panacea and no one-size-fits-all solution for climate change adaptation. Regional differences of climate change impacts on water abstraction, treatment and distribution are huge. Impacts and vulnerabilities differ between catchments or even within a supply system. The need for adaptation and the scope for action are always predicated on the prevailing natural conditions, the technical structure of a supply system, interaction with other factors such as societal and economic development or the concurrent industrial and agricultural water uses. The adaptive latitude of a water supplier is also defined by general legal and political parameters. And ultimately, a lot depends on a utility's willingness to actively address climate change issues and to rely on both its own and external know-how. In particular the uncertainties of projections and the knowledge about the increasing variability of climatic conditions need to be systematically analysed and considered in the management of resources as well as in the operation and design of supply infrastructures. In this context, all societal stakeholders need to be repeatedly made aware of the fact that the protection and sustainable management of water resources is an interdisciplinary task to which the water supply industry can contribute its share but which it can by no means accomplish on its own.

Against this backdrop, the DVGW deems it necessary that policy-makers, scientists and water suppliers actively support the following framework conditions:

- Granting priority to drinking water supply before and above all other uses of water resources within catchments.
- Securing drinking water supply through official spatial planning and water resources planning and approval procedures.
- Procuring sufficient water rights to meet peak demands.
- Granting priority to public water supply in the case of uncertain power supply.
- Including water supply facilities into official flood protection programmes and schemes.
- Providing basic data from supra-regional (climate) models for regional (hydrological) models (e.g. groundwater models) for water resources management purposes.
- Limiting agricultural irrigation needs by developing drought-resistant crops and crop rotations and making their use mandatory.
- Optimising safety of water supply, i.a. through the development of integrated supply systems.