

## Implementation Of A Technical Risk Management Concept Based On Water Safety Plans: A Benefit For German Water Supply?

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### **Abstract**

A Technical Risk Management based on the Water Safety Plan (WSP) concept was implemented at four German water supply systems according to the recommendations of the World Health Organization (WHO). Hazards affecting water quality, continuity and the reliability of supply from catchment to treatment and distribution could be identified by the systematic approach and suitable measures were defined.

The results of four successful implementations of the extended WSP-concept are presented in a detailed case study, covering methods, practical consequences and further outcomes. The method and the benefits for the water suppliers are discussed and an outlook on the future role of WSPs in German water supply is given. For the acceptance of the WSP approach among German suppliers it was essential that the original WHO scope on health issues was widened to supply targets (quality, quantity, pressure, continuity of supply). Positive results from successful pilot implementations increased the acceptance for WSP and proofed the benefit for the operators. Currently, the WSP concept is being prepared to fit into the German technical guideline, thus anticipating a revised European Drinking Water Directive likely to include Water Safety Plans.

### **Keywords**

Drinking Water; HACCP; Quality Control; Reliability; Risk Assessment; Water Safety Plan

## **Introduction**

Within the WHO-framework for safe drinking water (WHO, 2004), Water Safety Plans (WSP) represent a risk-based management approach comprising system assessment, operational monitoring and management plans (including documentation and communication). A corresponding framework, the “Bonn Charter for Safe Drinking Water” is also centred around Drinking WSPs with the goal to ensure “good safe drinking water that has the trust of the consumers” (IWA, 2004). The objectives are to ensure safe drinking water through good supply practice as described by the multi-barrier approach (WHO, 2005), more specifically by the identification of hazards from catchment area to consumer’s tap and by hazard-control according to individual supply systems and specific demands of water suppliers and consumers. This preventive risk management approach on process level by using effective control measures follows largely the “HACCP-concept” (Hazard analysis and Critical Control Points) applied in the food manufacturing industry.

The HACCP-concept has been successfully implemented and refined in several water supply systems to improve drinking water quality and security. Several case studies from industrialized and from developing countries (e.g. USA, Canada, Australia, Japan, New Zealand, Uganda) describe the effective implementation of WSPs (WHO, 2007; Kato et al., 2006). In Europe, WSP implementations have been reported from various countries, e.g. Belgium (Dewettinck et al., 2001), Switzerland (Bosshardt, 2003; Kamm, 2006) and the Netherlands (Hein et al., 2006).

In Germany, the concept of WSPs was discussed from diverse viewpoints. Supporters favoured the systematic approach on the level of the individual supply system, which would help especially small scale suppliers to establish and maintain water safety. Main opponents doubted the benefit of WSPs, claiming that in Germany a high level of drinking water safety in terms of quality, reliability and supply conditions has already been established, based on the pillars of self-organised technical standards for safety, quality control and independent surveillance. The multi-barrier-principle has been incorporated for many years in the technical guidelines, which are implemented in a self-organised process steered by the German Water and Gas Association (DVGW) and are part of the German Drinking Water Ordinance (Anonymus, 2001). In 2003, a conference organised by the German Federal

Environment Agency (UBA), WHO and DVGW was the beginning of a dialogue on the potential role of WSP for German water supply (UBA, 2003).

Concurrent to a UBA-organised project with 5 water suppliers (Schmoll, 2006), the authors started several pilot projects with German water suppliers to directly implement a WSP, derive specific measures for identified hazards, and also to find answers to the following questions:

- To what extent German water suppliers would benefit from WSPs?
- How WSPs would fit into the existing framework of water safety in Germany?
- How to extend the original WHO-focus on water quality to standards of supply?

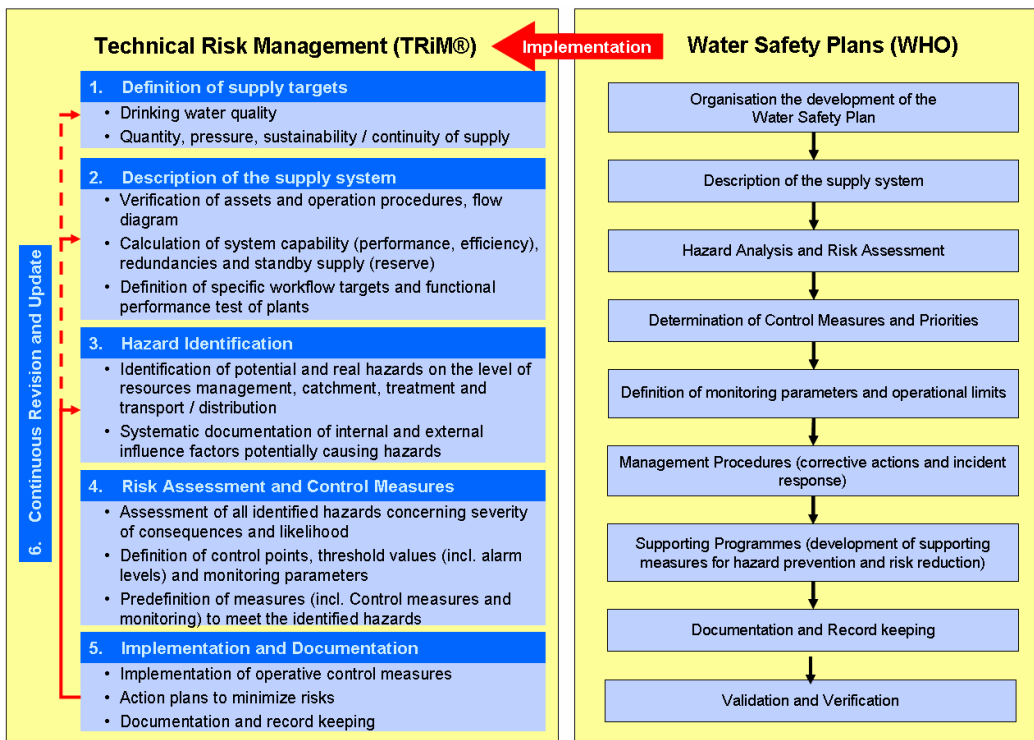
The results of four successful implementations of the extended WSP-concept, called “Technical Risk Management” are presented in a detailed case study, covering methods, practical consequences and further outcomes. The method and the benefits for the water suppliers are discussed and an outlook on the future role of WSPs in German water supply is given.

## Methods

### General introduction of the extended WSP concept

In order to meet and satisfy German drinking water standards, current technical guidelines and expectations of consumers, the WHO framework for safe drinking water was complemented with the following key components:

- **Definition of additional supply targets** (quality, quantity, pressure, continuity of supply) (in addition to the health-based WHO-targets)
- **Calculation of the overall system capacity, redundancies and reserve capacities** (as part of the system assessment in WSP) in terms of quantity and quality
- **Definition of process-specific target values and functional performance test of plants** in standard operation, under peak supply conditions and overload (as part of the operational monitoring in WSP)



**Figure 1** Continuous implementation and adoption cycle of Technical Risk Management in water supply and the analogy to relevant steps of the WSP-concept

In addition to the original goal of WSP to ensure suitable quality of drinking water to avoid diseases, the Technical Risk Management includes the definition of individual supply targets in terms of

quantity, pressure and continuity of supply. The risk assessment is then directed to these individual targets, assessing the consequences on reaching the individual supply targets of the water supplier. Following the WHO-Guidelines on WSP (WHO, 2004), a multi-step approach has been chosen for the implementation process of a Technical Risk Management (Figure 1).

### Hazard identification

The identification of all potential hazards is performed on the different levels in the water supply chain, from resources management, catchment/treatment to transport/distribution. A list of potential hazard causes and resulting potential hazards was prepared (Table 1) on a detailed technical level for resource protection and management (61 potential hazards), catchment / treatment (250), transport/distribution (93). During system assessment for the individual supply system, the actual potential hazard sources were verified and the hazardous events as well as the caused real hazards were identified. The knowledge base of potential hazards was expanded from project to project, so that hazard identification is becoming faster and more comprehensive.

**Table 1** Hierarchy for hazard-identification (examples for water resources protection and catchment management)

HAZARD SOURCE	POTENTIAL HAZARD	HAZARDOUS EVENT	HAZARD
<b>housing areas</b>			
dwellings	oil tank	damaged tank	groundwater contamination by oil
petrol stations	fuel, solvents, lubricants	leakage of fuel, solvents, lubricants	groundwater contamination by fuels, solvents, lubricants
dry cleaner's	volatile chlorinated hydrocarbons (VOC)	discharge of VOC	groundwater contamination by VOC
gardens and agriculture	fertilization, pesticide handling	application/improper use fertilization, pesticides	groundwater contamination by fertilizers/pesticides
storage of solids/liquids with hazardous potential	substances hazardous to waters	discharge of substances hazardous to waters	groundwater contamination by substances hazardous to waters
<b>production sites</b>	...	...	...
<b>lawns, leisure resorts</b>	...	...	...
<b>agriculture, forestry</b>	...	...	...
<b>traffic routes</b>	...	...	...
<b>sewer systems/waste water treatment plants</b>	...	...	...
...	...	...	...

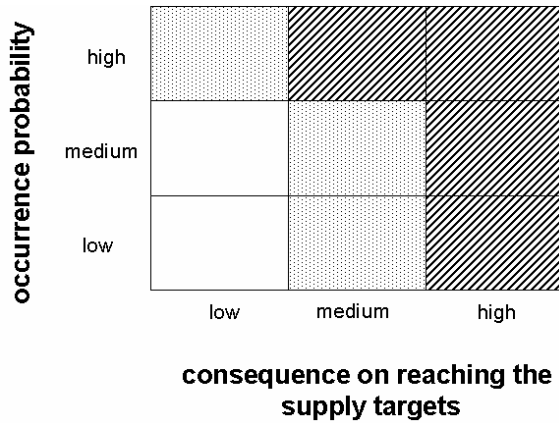
### Risk Assessment and Control Measures

Assessment of the identified hazards evaluates their severity of consequences and likelihood of occurrence in the context of system capability. The relevant questions in the assessment of every identified hazard are:

- How serious are the consequences on reaching the individual supply targets?
- How likely is the occurrence of the hazard in the individual case?

The applied scheme of risk analysis in a 3-by-3 risk matrix is illustrated in Figure 2. Risk perception differs from one operator to the other, so that the individual risk matrix is subject of discussion in every project.

A finer 5-grade classification matrix did not show significant influence on the risk level, slowed down the evaluation process and was finally rejected due to practical reasons. This semi-quantitative approach has proven to be efficient in practical risk audits with water suppliers, facilitated by experts guiding the evaluation process. By contrast, a strict quantitative approach based on standardized consequence classes and vulnerability factors turned out to be less applicable on the detailed technical levels because of lack of information and missing context information. Furthermore, operators did not accept a complicated mathematical “black box” model to evaluate hazards.



**Figure 2** Assessment matrix for risk analysis (with: white = low risk, dot matrix = medium risk, hatching = high risk)

After risk assessment, control points and threshold values incl. alarm levels were defined and measures (incl. control measures) were predefined. Operative control measures and action plans to minimize risks were implemented also for identified upcoming (potential) risks.

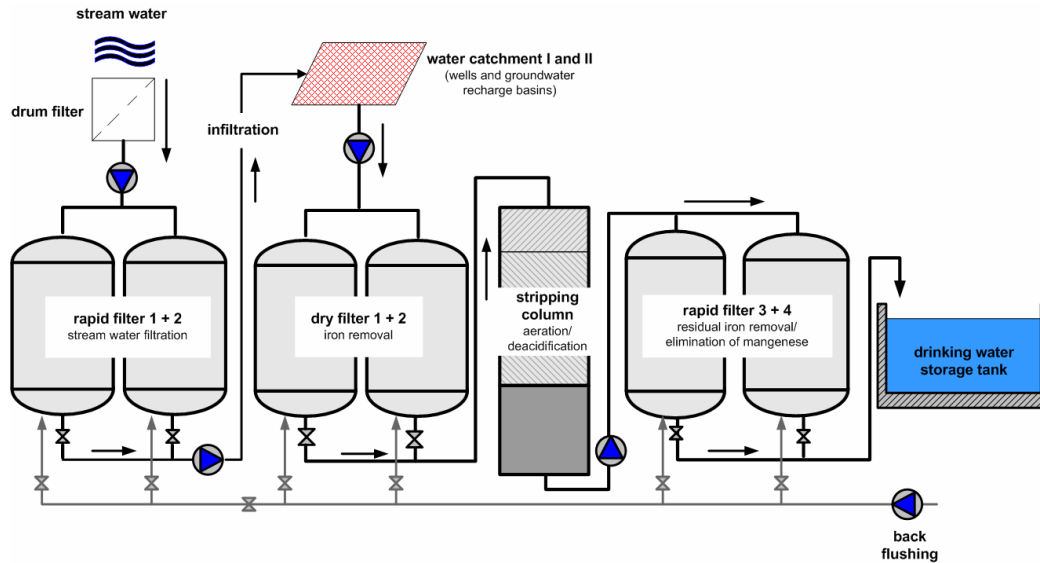
### **Example: Case study in water supply**

A water supply system in the North-West of Germany is operated to supply 97000 inhabitants with 5.2 million cubic metres per year, extracting river water for aquifer recharge, treatment and supply via a distribution system of 480 km lengths. Within a routine drinking water inspection at Christmas Eve 2004 according to the German Drinking Water Ordinance (Anonymus, 2001), limit values for the microbiological parameters (*E. coli*, *coliforms*, *Clostridium perfringens*) were exceeded in treated water after the treatment plant as well as in the distribution network. As a reaction a boiling-dictate was enacted by the local health authority and mobile disinfection devices were installed within the network. Two days later, repeated sampling showed negative results and the boiling-dictate could be withdrawn (Mälzer et al., 2007).

### **Methodology of the technical risk assessment**

#### *Description of the supply system*

The waterwork with a daily capacity of 300 cubic metres per day was built in 1970, using enriched groundwater with in average 25 % groundwater and 75 % stream water. The treatment process is shown in Figure 3.



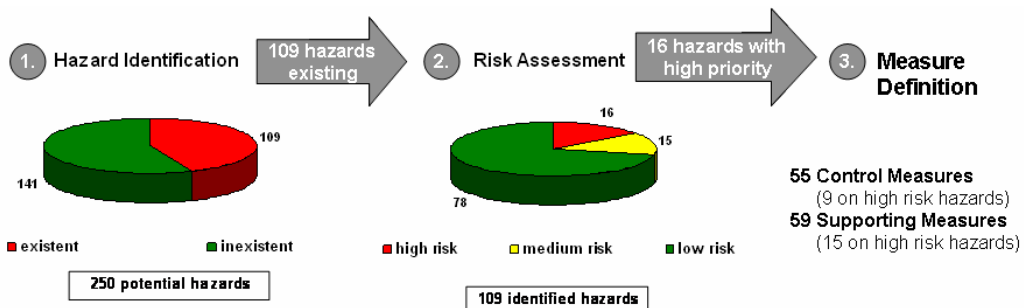
**Figure 3** Flow scheme of water treatment

### Hazard Identification

The hazard identification was carried out on the basis of a systematic catalogue (examples cf. Table 1) for the resource management in the catchment area, the water catchment and a selected distribution pipeline between the water work and an industrial consumer.

### Risk Assessment and Control Measures

All identified hazards were assessed for their probability and consequences on meeting the supply targets, using the risk matrix in Fig. 2. Out of the 290 analysed potential risks on the level of water catchment and treatment, 109 risks were identified from which 16 were rated high risk and 15 medium risk hazards (Fig 4).



**Figure 4** Results of Risk Assessment and Prioritisation – water catchment and treatment

For hazard control, 55 control measures (e.g. daily visual control of filter backwashing) and 59 supporting measures (e.g. fencing of water infiltration ponds) were defined, including location of critical control points, definition of controlling parameters, thresholds and frequency of monitoring.

### Implementation and Documentation

Monitoring programmes, operative actions for process control for parameters out of the control range and responsibilities for execution were defined and included in a process-oriented documentation. It was clearly seen that a continuous monitoring of all hazardous parameters was not possible. Mainly already existing measures for monitoring (e.g. daily visual inspection) and maintenance were formalised and focussed on high risk hazards and their control points. Furthermore, additional measures reducing or eliminating the probability of a hazard (leakage of pollutants into the ground- or

stream water, failure of technical facilities) were derived and integrated in the existing routines. All measures were defined in consideration of the operation manual of the water supplier and the technical rules. The operational guidelines of the water supplier were adapted to the identified risks and measures for hazard control.

### **Examples for identified hazards, risk assessment and defined measures**

The described systematic Technical Risk Management Scheme was used to investigate causes for the impairment of drinking water quality through microbiological exposure and as an instrument for communicating the results and appropriate measures to the inspecting authority. The HACCP-based approach enabled a directed search for the causes of the accident and existing deficiencies of the treatment scheme as well as the prevention of future accidents. Furthermore, it supported the water supplier to generally increase the security of supply. Several examples of risk identification and risk reduction measures in catchment, treatment and quality control proved the effectiveness of the systematic risk management approach.

#### *Resources protection and catchment management*

The dimension of the catchment area (> 80 km<sup>2</sup>), high numbers of hazards sources and potentially harmful substances made a comprehensive monitoring of all potential hazards within the catchment area impossible. Only a few of the identified hazards could be directly influenced or controlled by monitoring.

Nevertheless, regular monitoring made sense e.g. by checking the technical status of third party vehicles being used in protection zone I, close to the wells (event of potential hazard: leakage of oil), or by identifying and removing hazards resulting from illegal garbage dumping causing ground water contamination. Hazards outgoing from utilization within the areas of the infiltration basin, the protection zones of the water work were confronted with regular preventive inspections and lead to a significant decrease of the risks. Some hazards, for example damaged oil tanks of private houses, leaky sewer systems and illegal wastewater disposal from private dwellings, contaminated production sites could only be controlled in collaboration with the responsible water protection authority.

#### *Water catchment*

Monitoring of water quality of surface-, ground- and well water was already implemented within periodic sampling in the context of the raw water quality directive. A continuous on-line monitoring of temperature, conductivity, pH-values, O<sub>2</sub>-concentration, UV extinction (254 nm) and turbidity was suggested for complementing the existing monitoring. Although these parameters are not specific for harmful substances or microorganism they served as indicator parameters for the water status. An accident with seepage of liquid manure which happened in June 2005 could have been detected by means of a decreasing oxygen saturation resulting from ammonia concentration and stream water intake could have been stopped. For defining threshold values it was recommended to monitor the natural variation limit of the relevant parameters for a period of at least one year.

#### *Water treatment*

Water quality monitoring after treatment and in the distribution network followed the German Drinking Water Ordinance. In addition, continuous turbidity monitoring in the stripping columns and the filter outlets was installed as well as a regular functional inspection cycle of the process steps was initiated. Pressure and flow are monitored continuously for early detecting and controlling of deviations from regular operation.

Daily inspections ensure the functional capabilities of apparatus and machinery, e.g. filters, pumps and compressors. Inspections and maintenance work was being organized by using an IT-System to control inspection periods and to generate regular reports.

The technical risk assessment also supported to discover engineering deficits of the treatment plant, which finally led to the microbiological contamination of the drinking water at Christmas Eve 2004: Filters for stream water filtration and for drinking water production were connected with one single collective pipe for backwashing, only separated by automatic valves without non-return valves in the pipe. On Christmas Eve, the waterwork was shut down automatically for a short period of time during a functional test of the emergency power supply unit. During the power outage, the separating valves were automatically opened. That was the reason for blending of stream water after the first filtration step with treated drinking water in the following filters.

Based on the findings of the technical risk assessment, a specific action plan was implemented, that resulted in immediate realization of technical modifications, precise analysis of several hazards and

definition of short-, medium- and long-term measures. Immediate measures were implemented already while building-up the Technical Risk Management.

## Results and experience from other risk management projects

The following results and recommendations are summarized from four similar projects implementing a Technical Risk Management for water supply systems in Germany (cf. Table 2).

### Distribution

Monitoring of drinking water quality is normally realized at defined sampling points within the distribution network and pressure is measured continuously within the distribution network. In addition microbiological parameter should be analyzed at the storage reservoirs. A complete monitoring of all potential hazards caused by transport and distribution is normally not possible. One frequent source of contamination in distribution networks were found in pipes and water meters of third parties (private persons or industrial consumers). To avoid drinking water contamination caused by those installations, inspection and formal acceptance of every new or removed connecting pipeline during commissioning and construction could be useful. Routine inspection of private installations could also be scheduled for the periodical change of water meters. Installation and construction sites of third parties connected to the distribution network should generally be controlled by the water supplier. Construction companies working for the water supplier should be included in the quality management scheme by applying regular trainings, quality assurance protocols and standardized documentation. Only standardized pipes and materials should be used to guarantee sufficient quality. Additional need for action was regularly detected concerning documentation of e.g. quality control of delivered material for maintenance and repair. Regular network flow and pressure calculations supported to identify stagnation zones with elevated risks for microbiological regrowth.

### Communication with authorities and institutions

Technical Risk Management also supports communication with authorities and institutions. The lists of identified hazards, assessed risks and action plans demonstrated the intense efforts of the water supply company to continuously optimizing their supply system and improving the security. The approach as well as the results were presented and discussed with representatives of the responsible authorities. In addition to the specific troubleshooting and removal of the hazard causes the attempt of the water supplier for further optimization of the supply security was evidently recognized. The experience during the conducted studies showed that the professional risk management and open communication increased the trust of public authorities. Public authorities appreciated the transparent and comprehensive procedure, the straightforward implementation of urgent corrective actions and the continuous process of implementing measures according to their priority in terms of risk level.

**Table 2** Examples for short-, medium- and long-term measures derived from risk management projects

Short-term measures
Installation of smoke detectors in air intakes of stripping columns with online control
Evaluation of threshold values for well regeneration
Compilation and update of technical instructions
Evaluation of existing raw water data to identify irregular variations and impacts from activities within the catchment area
Installation of turbidity meters and recording of normal operation and irregular deviations
Evaluation of subsoil residence times for groundwater recharge under different operating regimes
Medium-term measures
Renewal of a asbestos concrete transport pipe (risk of breakage without spare capacity)
Build-up of a GIS-based hazard source map to improve systematic monitoring of hazardous sites
Definition of regular updating activities for the technical instructions manual
Review of legal contracts for emergency supply from neighboring water supply companies
Re-engineering of the backwash pipings for the filters and revision of automation routines
Measures to reduce agricultural use of neighboring farm lands to catchment
Long-term measures

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Renewal program for wells (with investment planning)  
Re-engineering of filter basins to allow for filtrate discharge after backwashing  
Fencing of the groundwater recharge basins  
Integration of WSP measures into the existing quality management system  
Integration of WSP measures into running IT-systems (e.g. SAP-module PM)

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## Conclusions and outlook: WSP - a benefit for German water supply?

The experience from several applications of an extended WSP approach will be summarized from the viewpoint of the individual supplier and from a broader perspective. The four companies directly involved in the risk management studies directly benefited from the systematic and comprehensive approach as described in the case study examples. All of the involved companies operated their supply system according to the German Technical Guidelines and – except for the described incident in the case study for one company – matched the standards of the German Drinking Water Ordinance.

Main positive aspects of the extended WSP approach were considered as:

- Understanding of technical processes is widely enhanced and communicated within the staff
- Systematic hazard identification draws the attention to needs of actions
- Defined routines for action plans keep track of unsolved technical and operational problems
- Documentation enforces the development of explicit, clearly defined processes on the basis of the current technical guidelines
- Measures in action plans are prioritized according to the risk involved of the hazard
- External attendance is not mandatory for the WSP implementation, but helpful to overcome internal routines and limitations

For the acceptance of the WSP approach among German suppliers it was essential that the original WHO scope on health issues was widened to supply targets (quality, quantity, pressure, continuity of supply). Comprehensive analysis of the existing guidelines showed, that fundamental aspects of the WSP concept are already implemented (Bethmann et al., 2006). Thus, the WSP approach fits into the German technical guidelines and is regarded as helpful for the further development of the technical standards.

A higher percentage of German suppliers initiated quality management systems on their own, often applying the DVGW-TSM approach (Technical Safety Management, cf. DVGW, 2005). For those companies, the formal introduction of WSP would not bring additional benefits. The TSM-approach, which implicitly enforces implementation of the entire technical guidelines, covers the WSP outcomes almost completely, but fails to establish a systematic procedure to build up a routine process.

Consequently, the WSP approach is currently being prepared to fit into the German technical guidelines as technical standard DVGW W 1001 (DVGW, in preparation) in order to support German water supply companies to adapt their internal quality management schemes. Thus, WSP-concepts will be used for the further development of the German technical guidelines and anticipate the planned revision of the European Drinking Water Directive (Anonymus, 2003).

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