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Concrete Structures for Drinking Water Reservoirs

ABSTRACT

The constant supply of healthy drinking water is one of the most important tasks of the World Health Organisation (WHO) and the European Commission. Furthermore, drinking water reservoirs are necessary, e.g., for fire protection in times of ecological crises or war activities, and basically to prevent epidemics. The hygiene and functionality requirements that are placed here are about 20 times higher than for usual food industries, because, in many cases, the population makes use of drinking water over an entire lifetime. Considering these circumstances, there are very special requirements in terms of the construction principles of the reservoir itself and also material limitations in terms of the starting materials, as well as the material design (concrete, polymers, metallic materials), building supplies, repair materials and material changes due to chemical attack by the drinking water and the resulting negative influence on the further water quality. Hydraulic functions must be modelled, and there must be steady fluctuation of water. Stagnant water must be prevented in order to reduce microbiological growth. This article will outline and explain the essential aspects when it comes to developing construction projects, planning, joint construction, limiting crack width, executing constructions, quality assurance and hygiene standards for materials, etc., using practical examples involving new buildings and existing old structures (up to 100 years old) north of the Alps. Among other things, the author is a member of the German Waterways Standards Committee, the chairman of various working groups, and a publicly appointed sworn expert and planning engineer for drinking water reservoirs.

Keywords: drinking water reservoir, material design, hygienic requirements

Introduction

Drinking water is the most important substance for life. Compared to other foodstuffs, drinking water requires a level of protection for human health that is about 20 times higher, since humans are usually based in a particular local region and consume the same drinking water over long periods of time, thus possibly accumulating harmful substances in the body. For this reason, there are a special legal parameters and material requirements for both the drinking water itself and the materials that come into contact with the drinking water (e.g., the Law for the Prevention and Control of Infectious Diseases in Humans [Infection Protection Act – IfSG], the Drinking Water Ordinance [TrinkwV], and the UBA [Federal Environmental Agency]: e.g., Basis of Assessment for Cement-Bound Materials in Contact with Drinking Water, Basis of Assessment for Plastics and Other Organic Materials in Contact with Drinking Water). The European Chemicals Agency (ECHA) in Helsinki, Finland, is currently working on setting limit values for, e.g., concentrations of heavy metals and plastics in cement-bound materials.

In addition to safely supplying the population with drinking water, a drinking water reservoir also has other central functions to ensure:

- a minimum and maximum pressure level in the pipe network, so that the public and private lines, fittings and devices are operated safely and unwanted pressure surges do not lead to biofilms in the pipe network been carried off to the end users;
- the reserve of extinguishing water;
- the emergency supply in the event of disasters and power outages; and
- necessary longer-term storage concepts for drinking water management due to changes in the climate.

Experience has shown that the supply of water solely through the available resources (reservoirs, wells, seawater desalination) via speed-controlled pumps can be susceptible to accidents or energy fluctuations.

This article is intended to help classify the technical and hygienic parameters for the construction of new drinking water storage tanks and their sustainable repair. It should be noted here that, compared to structures for water distribution (e.g., a pipe network), drinking water is stored in large quantities and over longer periods of time. The surface/volume ratio (S/V) of the water chamber, the fluctuation (e.g., water change/d, hydrograph) and the geometric-hydraulic design are important in this regard. A basic tabular overview of the points to bear in mind for drinking water storage tanks is included in the Appendix (see Tables 3 and 4).

Stagnant water in dead zones, swamps and poorly managed reservoirs, but also in joints, cavities, cracks and gravel pockets, generally lead to a concerning microbial environment. The constructions are therefore to be made so as to have as few joints as possible, using special care.

To prevent the migration of harmful pollutants into the drinking water and of microbial films on the surfaces that come into contact with the drinking water, all raw materials, the processed materials, all construction and auxiliary materials (e.g., formwork shell) and the execution of the construction must be subject to special hygiene concepts.

Due to these requirements, the use of construction products that are otherwise customary in the construction industry, such as sealing materials, elasticised plastic-modified crack-bridging coating or lining materials, polymer materials, injection materials and adhesives, etc., is prohibited or restricted to the minimum that is necessary from a technical point of view (minimisation principle). The consequence of this is that special measures have to be taken during planning and construction.

The exposure when it comes to the “storage of drinking water” is generally considered to be harmless in reinforced concrete structures. The usual parameters for concrete constructions, such as pH value (for XA), chloride content (for XD, XS) and water saturation (for the moisture class), etc., are not the only important parameters in this case. As a rule, water has to be treated after it has been extracted. The so-called raw water is not suitable for immediate consumption in its untreated state and chemical composition (in terms of, e.g., hardness, pH value, chloride content, lime-carbonic acid equilibrium, etc.). The water then goes through what are known as preliminary stages (e.g., carbon filters, membrane filters, ozonation systems, chlorine systems, etc.). Only after it has gone through this cycle can one speak of safe drinking water. This drinking water is then temporarily stored until it is consumed.

Smaller tanks have a capacity of a few 100 m^3, whereas large drinking water tanks (for urban areas or industries) can even store up to 100,000 m^3. The storage capacities required depend on their consumption. The so-called hydrograph, with the associated periods of peak consumption in summer and the extinguishing water reserves that will potentially be required, is used for dimensioning.

As a rule, the water in a drinking water tank should be changed at least 1–2 times a day. These so-called water changes serve to avoid the water stagnating and thus prevent the formation of germs. During these water changes, stored water flows out and fresh (pre-prepared) water is continuously reintroduced. As a rule, this does not take place in a constant ratio; rather, more water is consumed at peak times than can be replenished. During the night, the storage tanks then fill up again until the next peak period, so that the full storage capacity is then available again. In addition to the chemical effects, this also results in physical effects on the wall, floor and support surfaces. This impact can be divided into three zones:

- Zone 1: above the waterline
- Zone 2: water change zone
- Zone 3: permanently under the waterline

Due to the permanent water change with fresh drinking water, there is an enormous exchange of fresh water in the water change zone, in particular, and this corresponds to the dynamic-hydraulic conditions described above. This exchange triggers chemical-physical reactions that are not covered by the usual exposures that have been harmonised for Europe. The so-called hydrolysis causes ion transport (from the inside to the outside). As a result, degradation of the lime in the cement stone can be observed (from the outside to the inside). The high pH value on the surfaces of mineral-bonded concrete/coatings ensures that no biogenic surface growth is possible. Due to hydrolysis (also known as ion-exchange leaching), the surface steadily loses its high pH value. This, in turn, increases the risk of surface growth, and thus also of contamination of the tank.

Hydrolysis, Migration and Leaching

Drinking water always represents a chemical attack on the edge zone of the surfaces that come into contact with the drinking water. It is not just the surface that is attacked; deeper layers are also included. This applies equally to plastics, cement-bound materials and metals (see, e.g., Federal Environment Agency UBA: Basis of Assessment for Metallic Materials in Contact with Drinking Water).

The surfaces that come into contact with the drinking water include:

(01) surfaces that come into direct contact with the drinking water (below the maximum fill level); and

(02) surfaces that come into indirect contact with the drinking water (above the maximum fill level due to contact with water condensate and/or CO_2 outgassing).

The lining of the water chambers always represents a “sacrificial layer”. The planned remaining useful life and the wear limit must be taken into account (Figure 1).

The wear reserve relates to the condition before the initial commissioning. It is reduced systematically through various processes:

- Chemical processes (ion transport, chemical conversions, leaching).
- Physical processes (pressure fluctuations, water exchange, abrasion, cleaning, disinfection).

At first, the wear and tear does not progress visibly from the surface into the deeper layers. Physical and chemical processes take place interactively (Figure 2).

Figure 1. *Wear Limit According to the Technical Rule on Maintenance/Breitbach - Sudermann*

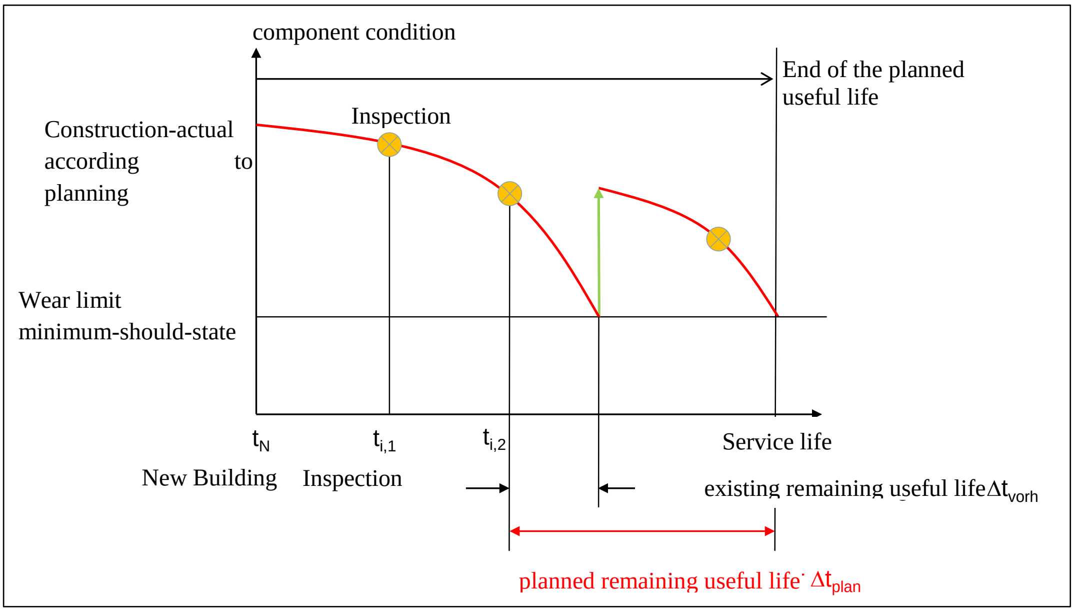
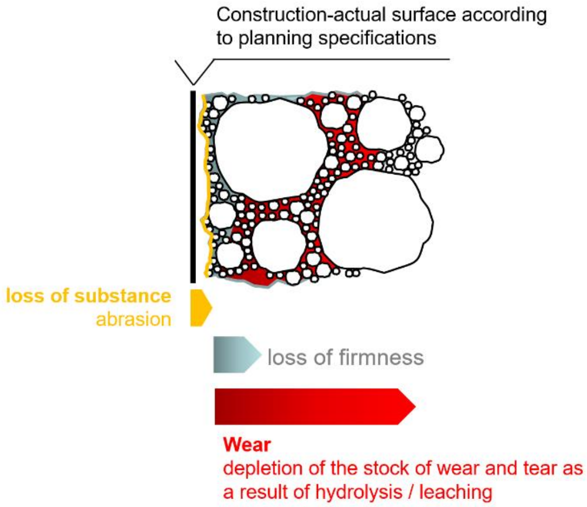


Figure 2. *Damage Processes at the Edge Zone in Contact with Drinking Water/ Breitbach - Sudermann*

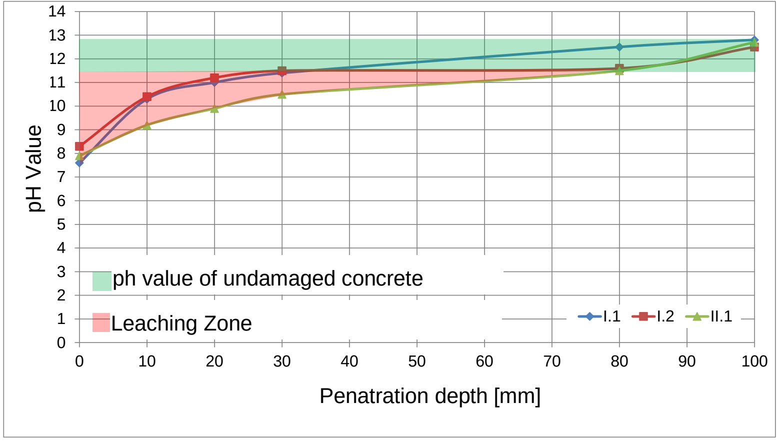


The pH value of drinking water is between pH ≅ 6.5 and pH ≅ 9.5. The pH value of cement-bound materials is mainly determined by the calcium hydroxide, which has a pH ≅ 12.6. Part of the calcium hydroxide is not chemically bonded in the gel pore water of the cement stone; another part is chemically bonded in the cement gel.

The depletion of the remaining useful life occurs on the surface due to the chemical conversion of calcium hydroxide into calcium carbonate, with a pH of ≅ 8. Calcium carbonate is easily soluble in water and converts into hydrogen carbonate. This would initially only lower the pH value spontaneously on the surface, but this is not what happens in practice. Current research (Corrosion protection through mineral coatings taking into account the requirements from the new DVGW worksheet W 300/Hr. Univ.-Prof. Dr. W. Breit & Hr. Univ.-Prof. Dr. M.Raupach) shows that the degradation of the edge zone extends to about 2 mm under normal operating conditions and with drinking water whose composition is not aggressive to concrete. In unfavourable conditions, one can also observe loss of substance, softening and porosification down to a depth of 5 mm.

The transport of ions causes hydroxides from the coating or concrete to be subsequently conveyed to the surface as a result of the difference in concentration, and so, over the course of time, depletion sets in deep into the subsoil (Figure 3).

Figure 3. *Leaching in the Depth Profile (Representative Determination from Another Case of Damage)/Breitbach - Sudermann*



Three processes set in when the leaching occurs:

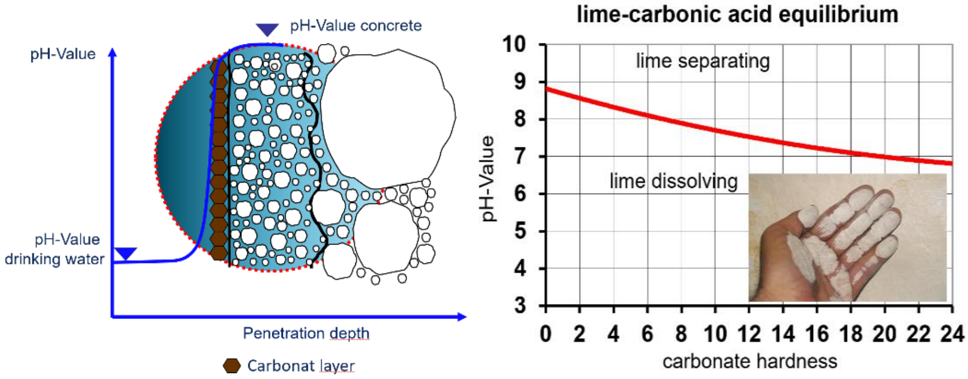
(01) Loss of substance on the surface
(02) Loss of firmness on the surface (softening, paste-like consistency)
(03) Increase in porosity due to the breakdown of cement phases

The increase in porosity, in turn, promotes the penetration of water and also displaces the leaching into the deeper areas.

The question of the concrete aggressivity of the drinking water can be answered by determining the capacity of the drinking water to dissolve calcite. The Tillmans equation (equilibrium curve for the lime-carbonic acid equilibrium) can be used to find first indications of the fundamental relationships (Figure 4).

Waters that precipitate lime are no guarantee of preventing leaching, as would be assumed. The carbonate layer on the surface, with a pH of ≅ 8, can lead to a shift in the water quality in the micro-water layer on the surface.

Figure 4. *Classification of Water According to the Lime-Carbonic Acid Equilibrium /Breitbach - Sudermann*



In practice, migration generally describes the migration of ions or low-molecular-weight substances. Differences in concentration in the pore solution cause a diffusion current of dissolved ions or substances from areas of higher concentration to areas of lower concentration. If building materials are contaminated with soluble salts, these dissolve when a polar liquid is absorbed and are transported with the liquid through the pore structure.

This transportation is founded on the fact that the dissolved substances are smaller than the pore radii. Or, conversely, smaller pore radii reduce/inhibit the transport of substances. In the atomic model, heavy metal ions have a diameter in the order of magnitude of between roughly 0.00005 µm and 0.0001 µm. Macromolecules have a theoretical diameter in the order of magnitude of between roughly 0.001 µm and 0.01 µm.

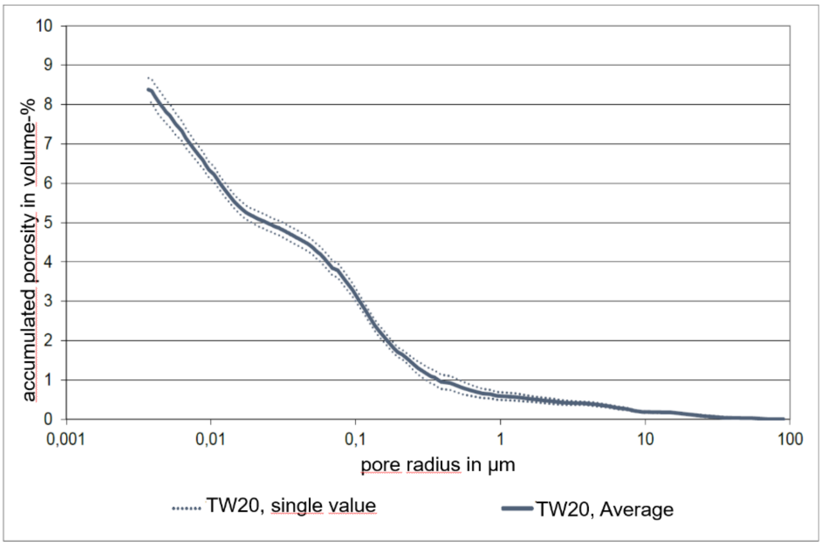
Studies on ion diffusion in cement stone show that it is not only the pore radii that influence the diffusion rate. The type of ions and the composition of the cement stone play an important role in this. The diffusion coefficient of the cement stone is reduced by a decreasing water–cement ratio and by the addition of pozzolanas and latent hydraulic substances. Compared to a CEM I, this reduction can amount to between roughly 60% and 80%.

For these reasons, the porosity and pore size distribution should be determined when using cement-bound materials that come into contact with drinking water.

The total porosity is determined according to the procedure specified in DVGW W 300-5, with mercury intrusion porosimetry at 2,000 bar. The test procedure measures pore radii in the range between 0.004 µm (lower gel pore area) and 100 µm (air voids). Air voids are isolated individual pores and do not contribute to hydrolysis resistance. Gel pores have pore radii between 0.004 µm and 0.01 µm. The capillaries are of an order of magnitude of between roughly 0.01 µm and 0.2 µm.

Pore radii ≤ 0.1 µm are relevant for diffusion. The pore size distribution of ≤ 0.1 µm indicates capillary pores that are so small that diffusion is largely prevented. It serves as indirect evidence of the water–cement ratio (w/c). If the proportion of pores with pore radii ≤ 0.1 µm is ≥ 50% (microcapillary area), the cement-bound material can be classified as diffusion-inhibiting (Figure 5).

Figure 5. *Average Pore Size Distribution from a Practical Example for Cement-Bound Coatings*



Concrete Technology Requirements

In general concrete construction, “concrete formulas based on properties” or “concrete formulas based on composition” are the usual channels for ordering concrete.

In the case of “concrete formulas based on composition”, the customer him/herself determines the ratios of the composition. He or she assumes responsibility at this juncture for maintaining the necessary levels of resistance to the planned effects. Suitability tests are essential.

In the case of “concrete formulas based on properties”, the concrete is created according to its exposure – its external influences. Here, the concrete supplier is responsible for maintaining the required levels of resistance. In turn, they are free to decide which composition is required for this. Each effect is generally sub-divided into aggressive to concrete (XC, XF, XA, XM) and aggressive to reinforcement (XS, XD) reactions. This is not sufficient when it comes to drinking water storage.

Due to the hydrolysis described above, the separate exposure class $X_{\text{drinking-water-reservoir}} = X_{\text{dws-}}$ was required to protect the structure, in order to create appropriate resistance. For X_{dws}, the essential technical characteristics of the concrete are regulated with the following requirements in terms of “composition and properties”:

- w/c < 0.5
- Compressive strength class > C30/37 N/mm²
- Cement content > 320 kg/m³
- *Cement when accounting for substances > 270 kg/m³*
- Fine-grain content < 400 kg/m³

- Grading curve A/B 16 or A/B 32
- Aggregate, free from organic impurities
- Consistency class F 3, middle

Compliance with the above properties ensures that the concrete:

- is sufficiently dense;
- has low porosity;
- has a solid surface so as to provide resistance to mechanical influences (e.g., cleaning);
- has a high pH value at the surface;
- has a thin layer of fine mortar on the formwork surfaces; and
- has a well-graded grading curve with aggregate that can be used hygienically.

The choice of cement is limited, and the use of admixtures and additives is also limited. Care must be taken with the admixtures to ensure that no interactions can occur. The minimisation principle also applies here. Many types of admixtures and additives cannot be used without consideration due to their hygiene rating.

A guideline for assessing the hygiene rating of the technical composition of the concrete can be found in DVGW W347 “Hygiene Requirements for Cement-Bound Materials Intended for Use in Drinking Water Systems – Testing and Evaluation”.

The information sheet DVGW W398 can be used for determining evidence of the “hygienic suitability of in-situ concrete and cement-bound materials produced on site for drinking water storage”.

The specifications described up to this point are based on currently accepted rules of good engineering practice. Unfortunately, these rules are still quite young if you consider the entire era of modern concrete construction, starting roughly in the middle of the 19th century.

The first regulations on providing evidence of the hygiene of materials that come into contact with drinking water were introduced between 1984 (DVGW W 270) and 1999 (DVGW W 347). There is no reliable proof of hygiene available for concrete structures that were erected before this time.

Contamination can be caused by migration or biodegradable organic components/materials. Analogous to the certificates for new materials (cf. section 3.1.1), heavy metals can be present in the earlier raw materials (e.g., aggregates, cement). Organically degradable substances can result from, e.g., concrete admixtures, formwork oil residues, unsuitable joint materials, injection materials, solvent residues or degradation products from coatings. In some cases, this contamination can be detected at a depth of several millimetres to centimetres, e.g., contamination of the edge zone of the concrete with PCBs behind chlorinated rubber coatings, cement-bound asbestos formwork anchors, PCBs to achieve long-term elasticity of waterproof organic plastic coatings, etc. With constructions that are not impervious, contamination can also be brought in from outside, e.g., through groundwater and surface water or sealing materials.

Contamination of the drinking water from the subsoil must be prevented, as a microbiological environment develops, especially with stagnant water conditions (hollows, cracks, joints, swamp ...), and this can reach the drinking water via defective areas and transport processes.

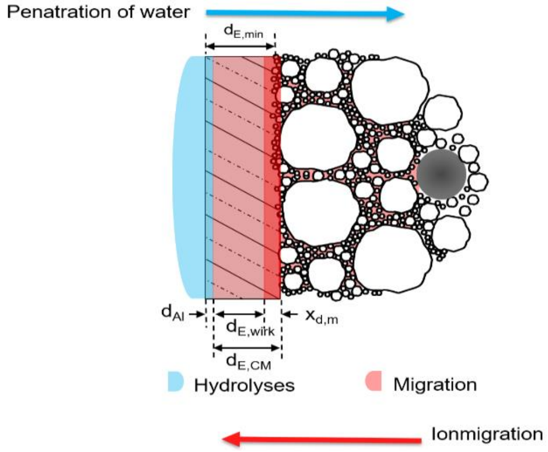
Subsequent examination of contamination in the structure is often not possible to carry out with sufficient certainty due to the nature of the samples required.

If, for example, there is contamination that can negatively affect the quality of the drinking water that is known about from the documents/records or can be identified through investigations/openings in the building, this must be eliminated as far as technically possible.

If the contamination cannot be completely removed for technical reasons, the repair concept must ensure that the remaining contamination cannot negatively affect the drinking water in the long term within the intended remaining useful life.

The necessary minimum requirements for the specific property in question must be determined by a competent planner (Figure 6):

Figure 6. *Model for Migration and Leaching in the Event of Contaminated Substrata in Drinking Water Tanks/Breitbach - Sudermann*



All known, visible or proven contamination must be technically removed before coating. The minimisation principle applies.

The effective layer thickness, $d_{E,eff}$, is ≥ 10mm in accordance with DVGW W 347 /18/.

Statistical allowances for deviation according to DIN EN 1990 for the evenness and roughness compensation, Δd_E, and leaching, Δd_{AI}, must be determined by the competent planner.

The minimum duration of the follow-up treatment is ≥ 14d and must be determined by the competent planner. This period must be guaranteed in practice, so that hydration is as long and undisturbed as possible, and so that the pore volume and pore size distribution are reduced.

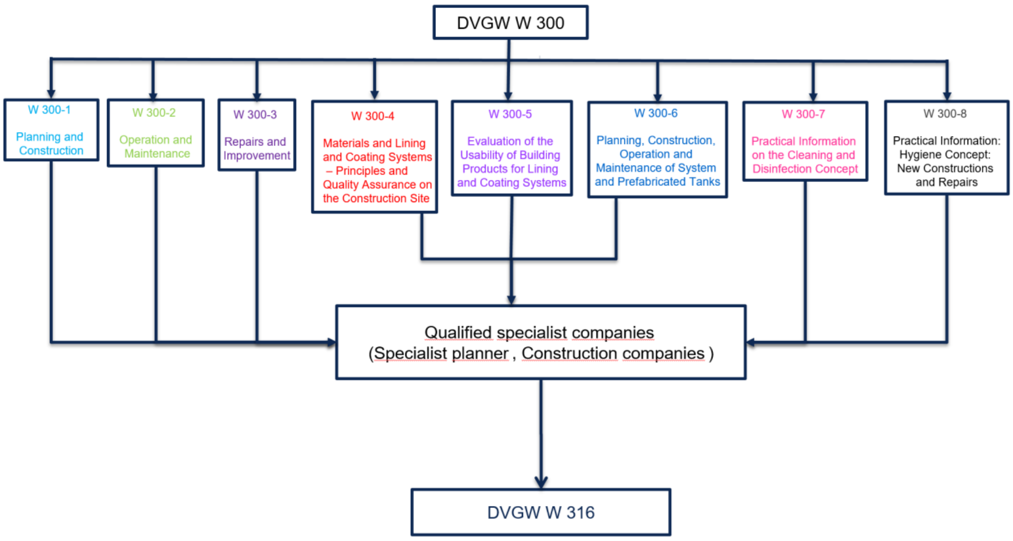
In cases of doubt, the success of the measure must be proven by monitoring.

Hygiene Requirements for Building Materials and other Materials

The Law for the Prevention and Control of Infectious Diseases in Humans (Infection Protection Act – IfSG), section 37: Quality of Water for Human Consumption, results in a significant difference when it comes to the new construction/concrete repair of a drinking water tank compared to a conventional new construction/concrete repair of an engineering structure. The first paragraph there makes clear that "water for human consumption [must] be of such a quality that its consumption or use does not cause harm to human health, in particular through pathogens".

In order to ensure this, additional regulations that have been legally introduced must be observed in addition to the usual specifications contained in the standards for reinforced concrete construction, such as DIN EN 1990, DIN EN 1992, DIN EN 206, standardisation series DIN 1045, standardisation series DIN EN 1504, the Guideline on Waterproof Concrete Structures ("WU Guideline") and the Technical Rule on Maintenance ("TR Instandhaltung") The worksheets DVGW W300-1 to W300-8 were published for this reason (see Figure 7), and these represent the generally accepted rules of good engineering practice.

Figure 7. *System Structure and Relationship Between DVGW W 300-1 to W300-8 and DVGW W316*



According to the Drinking Water Ordinance, section 17, paragraph 2, only materials that meet the following criteria may be used for the new construction or maintenance of systems for extracting, treating or distributing drinking water:

- They do not directly or indirectly reduce the protection of human health provided for under that ordinance.
- They do not adversely affect the smell or taste of the water.
- They do not release substances into the drinking water in quantities that are greater than is unavoidable if the generally accepted rules of good engineering practice are observed.

There are only limited raw materials that may be used for all building materials (concrete/mortar, or for polymer and metallic materials).

The investigation of the migration of constituents into the water is carried out by means of contact tests with stagnant test water over 72 hours. The water is examined for its organoleptic properties (colour, odour, cloudiness, foaming) as well as for TOC and heavy metals (aluminium, arsenic, lead, cadmium, lithium and nickel).

The investigation of the microbiological behaviour of organic substances is carried out by storing the samples in permanently flowing water. At certain intervals, the test objects are removed, the microbial surface growth is collected after the water has dripped off, and the volume of the surface growth is determined quantitatively after centrifugation. The assessment is based on inorganic reference samples.

Only materials that do not exceed the specified limit values may be used in contact with drinking water.

The operators of systems for extracting, treating or distributing drinking water must ensure that only materials that meet the above-mentioned formulation requirements are used for new construction or maintenance.

In the implementation ordinance provided for this purpose, it says – in accordance with section 17 of the Drinking Water Ordinance – “Systems for extracting, treating or distributing drinking water must be planned, built and operated at a minimum in accordance with the generally accepted rules of good engineering practice”.

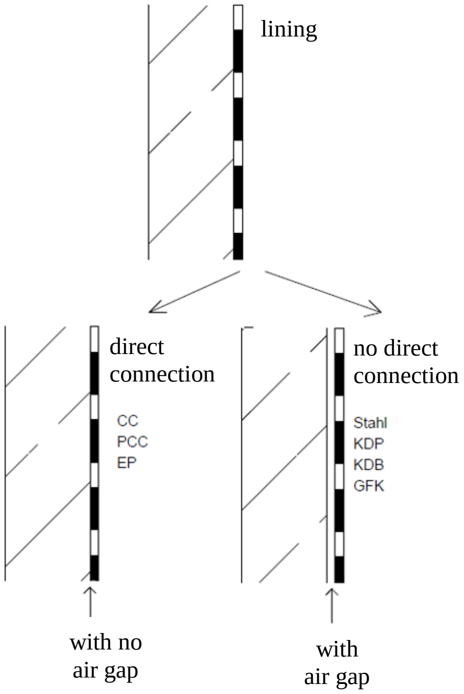
In addition to the purely mineral drinking water tanks, there is the option of integrating further linings in the form of sheets or foils in a tank. The design combination of a static-constructive concrete support structure with a material lining applied to it essentially serves to avoid a hydrolysis problem. This can be necessary in the event of strongly corrosive waters, in particular.

The following materials have proven themselves over the course of time for use in the area of new constructions/repairs in drinking water storage, and are accordingly established on the market:

- Cement-bound materials (CC/PCC)
- Polymer coating (PC)
- PE/PP plates (plastic sealing plates)
- PE/PP sealing liners (plastic sealing liners)
- Stainless steel (NI)
- Glass-fibre reinforced plastics (GRP)
- System tank made from the above substances

Figure 8 shows the systematics for use of the above-mentioned types of lining. The materials that can be used can be divided into two categories.

Figure 8. *Systematics of Linings*



The 1st category has a direct connection to the substratum, and so there is no air gap between the lining and the structure.

The 2nd category has no direct connection with the substratum, and so there is an air gap between the lining and the structure.

A lining principle with a direct connection can be used without hesitation. If a lining variant with an air gap is required, this must be assessed separately from a hygiene and technical point of view. Due to the permanently low water temperature (usually between 8 and 12°C) and high humidity values, condensation can be expected in this air gap. Due to its mineral deficiency, condensation water is a medium that is aggressive to concrete. It must also be ensured that the resulting condensation can be conducted away over all surfaces. Since this water drainage often cannot be ensured, puddles form, in which stagnant water collects, and this can lead to contamination of the substratum. A hygiene assessment of such air gaps is therefore often difficult due to the inability to carry out an inspection.

Maintenance

Drinking water tanks are usually designed so as to consist of two chambers and a control building. If the local supplier does not have the opportunity to get its water from other drinking water tanks in the event of repairs, it is necessary to operate one of the two chambers permanently, because the security of supply is legally regulated. This entails, on the one hand, maintaining a hygienically perfect area exclusively for supplying the population with drinking water and, on the other, a repair measure, with all the usual difficulties and challenges that have to be overcome.

When planning, building, repairing and improving structures, it is not only experience that is important; it is also a matter of whether the necessary legally prescribed and organisational requirements and specialist knowledge on the part of the individual parties involved are available and satisfied. A high standard of qualification requirements and criteria for specialist planners and specialist companies has therefore been stipulated in technical regulations DVGW W 300-ff and W 316.

By successfully completing the certification process according to DVGW W316 at DVGW CERT, planners and specialist companies have the opportunity to obtain a certification that proves the required qualification. This prequalification serves as a preliminary check of the necessary expertise for this specific discipline in planning and execution, which can only be ensured by elaborate subsequent verification. The use of DVGW W316-certified participants greatly reduces the risk potential in the public water supply from a chemical, physical and microbiological point of view and increases the security of supply.

When a drinking water tank is decommissioned and consigned to the appropriate specialist company as part of a (new) construction or repair measure, the responsibility for hygiene is also transferred to that company. Every time materials enter or are used in the water chamber, over the entire construction period, this represents a potential danger of introducing germs and pathogens. It is only when the public health department is able to determine a perfect/germ-free condition once the tank has been put back into operation that the responsibility is transferred again from the relevant specialist company to the supplier/operator.

In order to check whether the necessary care and understanding for this sensitive topic is available, is it possible to have the qualification requirement in the area of planning, construction, repair and improvement of drinking water reservoirs according to DVGW W 316 certified as a specialist company via the DAkkS-reviewed quality management assurance system of DVGW-CERT. This is possible for planners, specialist companies and also suppliers.

The differences compared to conventional repairs of engineering structures and explanations of the accepted rules of good engineering practice in this special area must be clearly communicated in advance, planned from a hygiene point of view, in some cases tendered as a contractual special service, and carried out and monitored with particular care.

Appendix

Table 3. *Key Consideratons for Planning and Building a Drinking Water Tank*

Definitions and terms
Control building
Operating reserve
.Overflow tank
Equalising reservoir
Elevated tank
Extinguishing water reserve
Effective volume
Low-porous
Spatial volume
Storage volume
System tank
Underground tank
Holding tank
Water tank
Water tower

Qualification requirements
Basic assessment
Determination of the network volume
Location in the supply network
Topographical location
Water chemistry
Radon exposure

Preliminary planning
Consideration of variants
Tank construction type
Tank designs
The question of materials in relation to water quality
Economic viability
Making a decision on one variant

Planning
Grounds, outdoor facilities
Functional requirements
Access to the control building and water
Visual access to the surface of the water
Geometry of the water chamber
Selection of hygienically suitable
Concrete – DVW worksheet W347
Technical equipment
Intake
Extraction
Overflow
Drainage
Receiving water
Sampling devices
Technical equipment, under and overpressure protection
Electrotechnical equipment
Building technology, lightning protection
Site security
Measurement and control technology, telecontrol technology
Hygiene concept

Table 4. *Key Considerations for Planning and Building a Drinking Water Tank*

Structural engineering and constructional requirements		**Execution of the construction**
		Documentation, site management
Durability, exposure class for drinking water tanks (water chambers) X_{dwr}		Reinforcement
Durability, exposure class for drinking water tanks (water chambers) X_{dwr} Load effect and determination of the state of strain Effective volume		Size, separation, release agent, built-in parts, and equipment and stripping
		Pretensioning
Load effect and determination of the state of strain		Concreting
		Construction with precast concrete parts
Ultimate limit state		Dimensional tolerances
Serviceability limit state		Supervision by the construction company
Limitation of the stress (proof of stress)		Quality assurance; hygienically suitable place, concrete and mortar
on of the crack width, imperviousness		Quality assurance; use of other hygienically suitable materials
Structural physics		
Constructional requirements for		**Controls, checks and initial commissioning**
Surface		
Concrete admixtures		Water-tightness test
Construction		Hygiene measures
Substructure		Cleaning
Drainage, moisture proofing		Disinfection
Floor		Choice of disinfectants
Walls and columns		Performance of disinfection
Ceilings, roofs		Approval
		Commissioning of the tank and connection to the supply network
		Documentation

Literature

/01/	DIBt MVV TB	German Institute for Building Technology (Deutsches Institut für Bautechnik – DIBt) Sample administrative provision for technical building regulations
/02/	DIBt Technical Rule	German Institute for Building Technology (DIBt) Maintenance of Concrete Structures (Technical Rule on Maintenance – TR Instandhaltung) Part 1: Scope and Planning of Maintenance
/03/	DIBt Technical Rule	German Institute for Building Technology (DIBt) Maintenance of Concrete Structures (Technical Rule on Maintenance – TR Instandhaltung) Part 2: Characteristics of Products or Systems for Repair and Regulations for Their Use
/04/	DAfStb guideline	German Committee for Reinforced Concrete (Deutscher Ausschuss für Stahlbeton – DAfStb) Protection and Repair of Concrete Components (repair guideline, including corrections 1 to 3) Part 1: General Regulations and Planning Principles Part 2: Building Products and Application Part 3: Requirements for Companies and Supervision of Execution
/05/	DAfStb guideline	German Committee for Reinforced Concrete (DAfStb) Waterproof Concrete Structures ("WU Guideline")
/06/	DIN EN 1992-1-1 EC 2	Dimensioning and Construction of Reinforced and Prestressed Concrete; General Design Rules and Rules for Building Construction
/07/	DIN EN 1992-1-2 EC 2	Dimensioning and Construction of Reinforced and Prestressed Concrete; Concrete Silos and Container Structures
/08/	DIN 1045-2	Concrete, Reinforced and Prestressed Concrete Structures – Specification, Properties, Production and Conformity – Application Rules for DIN EN 206
/09/	DIN 1045-3	Concrete, Reinforced and Prestressed Concrete Structures – Execution of Structures
/10/	DIN EN 13 670	Execution of Concrete Structures
/11/	DIN 18 551	Sprayed Concrete, Manufacture and Quality Surveillance
/12/	DIN EN 14 487-1	Sprayed Concrete: Definitions, Specifications and Conformity
/13/	DIN EN 14 487-2	Sprayed Concrete: Execution
/14/	DIN 31 051	Fundamentals of Maintenance
/15/	DVGW (German Association fo Gas and Water) W 300 - 1	Drinking water reservoirs; Part 1: Planning and Construction
/16/	DVGW W 300 - 2	Drinking water reservoirs; Part 2: Operation and Maintenance
/17/	DVGW W 300 - 3	Drinking water reservoirs; Part 3: Repairs and Improvement
/18/	DVGW W 300 - 4	Drinking water reservoirs; Part 4: Materials and Lining and Coating Systems – Principles and Quality Assurance on the Construction Site
/19/	DVGW W 300 - 5	Drinking water reservoirs; Part 5: Evaluation of the Usability of Building Products for Lining and Coating Systems
/20/	DVGW W 300 - 6	Drinking water reservoirs; Part 6: Planning, Construction, Operation and Maintenance of System and Prefabricated Tanks
/21/	DVGW W 300 - 7	Drinking water reservoirs; Part 7: Practical Information on the Cleaning and Disinfection Concept
/22/	DVGW W 300 - 8	Drinking water reservoirs; Part 8: Practical Information: Hygiene Concept: New Constructions and Repairs
/23/	DVGW W 316	Qualification Requirements for Specialist Companies for Planning, Building, Repairing and Improving **Drinking water reservoirs**; Specalist Content
/24/	DVGW W347	1.1 Hygiene Requirements for Cement-Bound Materials Intended for Use in Drinking Water Systems – Testing and Evaluation
/25/	DVGW W398	Practical Information on the Hygienic Suitability of In-situ Concrete and Cement-Bound Materials Produced on Site for Drinking water reservoirs
/26/	UBA (Federal Environment Agency)	Various evaluation bases and guidelines of the Federal Environment Agency: https://www.umweltbundesamt.de/themen/wasser/trinkwasser