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2.14 Drinking water quality: Requirements claimed by national and international standards

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SUMMARY: *Drinking water is not an ordinary consumer good and is subject to local peculiarities. When the raw-water is treated into drinking water, its quality should be as high as possible. The pollutants from the raw-water and the residuals from the treatment-chemicals must be minimised. Drinking water must be safe for a person to consume 2 litres per day over a lifetime. The limit values or maximum content levels of parameters are only a (small) part of the requirements; a multibarrier system must protect the drinking-water quality. A process control system has to ensure the quality between the product control analyses.*

Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such: This is the first sentence of the new European legislation on water (EU Water Framework Directive). When applying such proposition to drinking water, it will become evident that any generally valid definition of the composition of drinking water is impossible to make and that the national and local characteristics of raw water and of supply structures have to be taken into account. This is why the requirements of national and international standards for drinking water can only constitute a compromise. When it comes to establishing a public drinking water supply, such compromise has to be adapted to the local conditions existing. Therefore, in the following, reference will primarily be made to the requirements for drinking water in Germany. They are laid down in the German Drinking Water Regulations (Trinkwasserverordnung – TRINKWV 2001) and have been based on the superordinate EU drinking water directive (Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption).

Lifelong consumption: Both the supply of safe drinking water and the disposal of used drinking water effluents constitute the basic preconditions for a hygienic standard of living on the high level that is taken for granted in any industrial country in the 21st century. The philosophy on which the formulation of requirements for drinking water in Germany and Europe is based implies that no health impairment of consumers should be expected from a lifelong daily consumption of 2 litres of drinking water. In this context, the term, »lifelong« refers to a period of 70 years used as a basis for toxicological calculations and risk assessment.

Basic requirements for drinking water

Often, the quality of drinking water has been described in terms of a *negative* description defined by means of limit values. In this way, it has been determined that if such limit values are *exceeded*, the water involved is *no longer* regarded as safe for human consumption. However, the detection of concentrations close to but still below such limit values is not sufficient to characterise drinking water as being safe for human consumption. At best, they may serve to protect the operator of a water supply system from being punished. The German standard (DIN 2000) has defined basic requirements for drinking water. This standard has defined a target in terms of positive parameters for safe drinking water which reads:

> »The requirements for drinking water quality shall be based on the characteristics of safe groundwater drawn from adequate depth having passed sufficiently effective filtrating layers and obtained from the natural hydrological cycle whose quality has not been affected in any way. Drinking water should be appetising and be a pleasing invitation to the palate. It should be colourless, clear and of low temperature, and be of unobjectionable olfactory and gustatory quality. Drinking water should exhibit low microbial counts«.

The following should be added: »As a minimum requirement, drinking water should meet the applicable legal standards (e.g. limit values)«.

The multiple barrier principle

The most effective way to meet such high quality requirements is based on the so-called multiple barrier principle. This principle is characterised by the notion that a safe drinking water supply should have several barriers against any undesirable impairment of water quality (for a detailed description cf.: HÖLL 2002). Such barriers may become effective if the »generally accepted technical standards« are complied with in the protection of the raw water resource involved, in the abstraction of raw water, during its treatment to produce drinking water, during distribution to the users connected to the water supply system and finally, in the domestic installations in the buildings of consumers. The first two of these barriers must be adapted to the local raw water resources because pollution control of the resource and treatment required for example for surface water (river, impounding reservoir, spring) are definitely different from those needed for a groundwater or bank filtrate. However, in addition to being safe in terms of health, drinking water should be appetising and pure. This is why also a reduction of the aesthetic quality (see *Table 2.14-1*), although not necessarily harmful, will constitute an intolerable impairment.

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Requirements for treatment

Natural water from sufficiently protected sources free from anthropogenic pollutants is suitable for drinking without any additional treatment, unless it is found to contain elevated levels of geogenic substances such as iron, manganese or arsenic.

Such water resources should be protected, and other resources which do not or no longer meet the above precondition, should be rehabilitated to restore the favourable conditions described above. Almost any type of food will signal spoilage by its smell or appearance. In contrast, the appearance or taste of drinking water will often fail to reveal whether contamination with bacteria or chemical substances has resulted in a loss of fitness for consumption. The sensory abilities of humans are inadequate to provide sufficient protection against long-term health risks resulting from water which is unfit for human consumption.

At any rate, raw water not complying with the requirements for drinking water should be subjected to treatment to such a degree that its lifelong consumption will in no way involve a risk of health impairment in humans.

Furthermore, it may become necessary to modify the (technical) properties of drinking water in order to prevent it from undergoing adverse changes during transport from the water works to the consumer. Such changes may be caused for example by materials coming into contact with the water in the distribution network of the supplier and in the domestic installations in the homes of consumers. *Table 2.14-2* provides a synoptic view of a number of objectives and targets of water treatment.

According to the present state of knowledge, a central public supply of drinking water will ensure the highest level of safety for the provision of safe drinking water in sufficient quantities and at a supply line pressure as required for technical reasons. However, the requirements for water treatment techniques have changed over the years for a variety of reasons. In this context, important aspects include more stringent requirements resulting from a re-evaluation of geogenic or anthropogenic pollutants, changes with regard to the origin of raw water where water from internal cycles is used, changes with regard to the conditions prevailing in the distribution network, the necessity to take into account the mixing of waters or a long residence time in the distribution network, and finally, requirements to be made due to changes in economic conditions. Examples of more stringent requirements include:

- For a number of geogenic and anthropogenic pollutants, recent evaluations have resulted in more stringent limit values (e.g. for arsenic, lead, nickel).
- Some limit values for toxic or undesirable substances, such as acrylamide, epichlorohydrin and bromates have recently been added to the list of parameters of the German Drinking Water Regulations (TrinkwV 2001).
- Also elevated levels of raw water pollution due to new micro-organisms (pathogenic *E. coli*, transgenic bacteria, parasites, viruses) or new anthropogenic substances (medicinal products, plasticizers, flame retardants) have to be taken into account.

More stringent requirements have also resulted from increasing sizes of distribution networks leading to longer residence times of the treated water on its way from the water works to the consumer. Residence times that are longer than originally envisaged have also resulted from a decreasing demand for water in Germany, whether resulting from water-saving fittings in private households or from increasing shares of recycled water being used by trade and industry. The so-called meshing of networks resulting in a mixing of water of different origin during its transport to the consumer has led to more stringent requirements for treatment in order to provide water of uniform quality (Höll 2002).

Constant improvement of the state of the art is not only required by health standards but also by changes in economic conditions, particularly the necessity of an economical use of available resources e.g. with regard to land use, construction and operating costs of water works.

The onward development of the technical potential for drinking water production by means of increasingly efficient methods has, on the one hand, promoted the use of raw waters which before had been unsuitable for use due to their poor quality. On the other hand, this also means an increased dependency on a perfectly working technology when it comes to eliminating hygienic risks which would not exist at all when using well-protected raw water sources. Thus, an acceleration of the natural hydrological cycle (i.e. evaporation, precipitation, groundwater recharge, abstraction for drinking water production, discharge of used drinking water, surface water, evaporation) by means of intentionally produced short circuits, such as bypassing of underground passages by using efficient membrane filtration methods, will always increase the risk with regard to hygienic safety and will decrease the acceptable response time for operators of such installations in cases of technical failure. This may result in a delay in initiating the disinfection measures required in this case, thus putting at risk the safety of users of such waters.

Protection of resources

For the protection of the catchment area of a drinking water abstraction installation, Technical Rules have been developed in Germany to define so-called protection zones around the water catchment site. For reasons of efficiency, the primary protection zone around a well should be fenced and owned by water suppliers to be able to control this area, which is most susceptible to direct influences. The secondary protection zone in Germany is described by the so-called 50-day-line stating that it takes a flow time of 50 days to reach the well for the water affected by a (e.g. microbiological) contaminant introduced into this area. Within this area, certain restrictions on land use have to be observed (restricted application of fertilisers and pesticides, building restrictions, ban on the storage of substances hazardous to water, etc.). The tertiary protection zone comprises the entire catchment area of the well, i.e. the area from which groundwater will reach the well sooner or later. The protection of resources of surface waters is provided by the avoidance of direct surface runoff from bank areas or of the discharge of untreated waste water into the receiving waters.

Water treatment agents

In the past, the chemicals approved for raw water treatment to produce drinking water were specifically listed in Annex 3 to the German Drinking Water Regulations (TrinkwV) of 1990. Treatment agents approved from 1 January 2003 under § 11 of the TrinkwV 2001 have been listed separately by the German Federal Environmental Agency and published by the Federal Ministry of Health. From now on, this list is updated on a continuous basis. At present, more than 100 substances for a great number of uses are commercially available on the European market. Of these, ca. 90 active substances for 34 uses have been included in the updated »positive list«. Thus, by using these substances, it is possible to produce water for human consumption, i.e. also drinking water, by treatment of virtually any naturally occurring raw water (surface water, groundwater or bank filtrate).

By applying this principle to the new Drinking Water Regulations, legislation has provided for a dynamic »positive list« to be developed by means of separating the list of treatment chemicals from the rigid corset of the text of the Regulations. Thus, it has become possible for this list to follow the state of the art of treatment and to maintain the high quality of drinking water in Germany in the sense of technical progress, also taking into account the minimisation requirement.

The minimisation requirement

The minimisation requirement stipulated by the German industrial standard (DIN 2000) and § 6 para 3 of the Drinking Water Regulations has always been the most important objective when adding treatment agents, and has the aim to keep any additional contamination of drinking water as low as possible. This applies both to the addition of the substances themselves and to their reaction products. In the sense of the minimisation requirement, it follows that not only the level of pollutants in drinking water should be minimised but also that any kind of anthropogenic impact on the raw water yield should be reduced to the minimum unavoidable for technical reasons.

Also during the technical treatment of raw water, it is therefore necessary to continuously re-examine the number of treatment agents used, the quantities added and their degree of purity, in order to comply with the overall minimisation requirement. Where possible, the objective of this approach should consist in a complete discontinuation of the use of chemical additives, by means of optimising the technical method used.

The 10% rule

There is another basic principle of drinking water treatment known as the 10% rule. In particular, the level of contaminants, i.e. impurities of a water treatment chemical contained in treated water may be very complicated to determine. Therefore, an approach was found which, although controversially discussed for a long time among the specialist community, was finally accepted as a consensual solution. As a basis to limit the quantity of a chemical used for treatment, it was established that as a result of the use of such agent, the concentration of a hazardous substance for which a limit value exists must not increase by more than 10% of such limit value (10% rule). Of course, this applies only as long as the level measured in raw water is below 90% of the limit value under the Drinking Water Regulations. In accordance with the minimisation requirement, the 10% rule should be regarded as a minimum requirement. Another prerequisite is the use of water treatment methods according to the generally accepted technical standards. The concentrations of active substances and the maximum levels of contaminants contained in standardised treatment chemicals are known. On this basis and applying the 10% rule, a calculation can be performed to determine the maximum quantity of a commercial product that may be added without additionally introducing into the water more than 10% of contaminants or concomitant substances as referred to the respective limit value.

Therefore, the composition of the agents used must be warranted by manufacturers, i.e. technical product standards are required for such chemicals as a basis for orders of the respective commercial products by water suppliers. Such product standards will describe the treatment chemicals for which the permissible level of contaminants has been limited (toxic substances, contamination arising from the production process) and whose composition has been regulated (concomitant substances, mixed products, share of active substance).

Requirements for water distribution

Requirements for a reliable water distribution are not limited to the supply of water in the quantities required and at a sufficient pressure. They also include a low rate of water loss due to leakage, and a provision of water having no corrosive effect, provided a suitable piping material is used. Particularly concerning the last point, errors used to be frequent in the past. Probably, the use of lead pipes for drinking water supply in the past has been the best known and most serious example of such errors. Due to the health risk involved, the limit value for lead in drinking water was reduced to 10 µg/L. According to current knowledge, levels below this limit value can be reliably achieved only if old lead pipes are exchanged and replaced by a suitable piping material. However, also the use of other metallic materials such as copper, nickel or zinc may result in the release of inadmissible quantities of these metals in the form of corrosion products into the water. Unsuitable plastic materials may promote bacterial growth (biofilm formation) in the pipe system. Therefore, drinking water installations should only be set up by competent specialist firms who are able to choose piping material suitable for the water quality available at the site. Past experience has shown that improper installation of hot-water distribution systems may result in a growth of harmful Legionella bacteria, which may cause »legionnaires' disease«.

Legal requirements

• National regulations

The infection protection act

The German Infection Protection Act (Infektionsschutzgesetz) (IfSG 2002) constitutes the legal basis for the German Drinking Water Regulations. The Act focuses on the prevention of health risks for humans from communicable diseases. § 37 of the IfSG deals with the risk of transmission of diseases through »water intended for human consumption« (drinking water), and through swimming pool water. The authorisation by the Federal Government to promulgate Drinking Water Regulations has been put into practice while regulations on swimming pool water have not been published so far.

The drinking water regulations

In the context of the Drinking Water Regulations, the term of »drinking water« has been defined as a partitive concept in the sense of the European notion that drinking water as a food constitutes only a part of the water used by humans. Therefore, the Regulations refer to »water intended for human consumption«. This concept encompasses both drinking water and water for food production. The basic structure of the Drinking Water Regulations has been developed on the principle of multiple barriers (multiple barrier principle, see above) against the transmission of waterborne communicable diseases, and limit values have been determined for certain microbiological parameters. In addition, the Drinking Water Regulations ensure protection of the population against health impairment from chemical constituents of drinking water. Such protection is based on the limitation of admissible concentrations of certain constituents of water, on requirements to be made in cases where these limits have been exceeded and on the regulation of approved treatment agents and disinfection methods. For a synoptic view of the parameters included in the Drinking Water Regulations and their significance see Grohmann et al. (2003).

In order to control adherence to this multiple barrier system, the regulations rely on the instrument of in-house controls performed by the operators of water supply systems and on the official controls by the responsible public health department.

It can be seen from the facts listed above that the limit values fixed in the Drinking Water Regulations (which are often overestimated) represent no more than a single component in the comprehensive protection system of the central public supply of drinking water. Adherence to these

Table 2.14-1: Objections regarding drinking water from aesthetic aspects.

Type of objection	***Cause***
Appearance	Turbidity due to clay or loam particles, coloration from humic substances
Odour	Degradation processes due to algae (fishy), H_2S (like rotten eggs)
Taste	Reactions of desinfectants with water, e.g. formation of chlorophenol
Temperature	Unfavourable conditions during distribution or storage of treated water, poor quality of domestic installation
Origin	Disgust-producing substances, drinking water production directly from sewage

Table 2.14-2: The main objectives of raw water treatment to produce drinking water (from Höll 2002).

Objective of treatment	***Primary targets of concrete measures***
Removal of geogenic substances	Iron, manganese, turbidity, odour, taste, arsenic, nickel, fluoride
Removal of anthropogenic substances	Nitrate, organically bound carbon, Bacteria, viruses and parasites Pesticides
Increase of the shares of recycled water	Swimming pools (filling water) Industry (food industry) Row water (bank filtration, groundwater recharge)
Protection of the distribution network	Prevention of corrosion Prevention of sedimentation Prevention of bacterial growth
Technical suitability	Softening of drinking water Miscibility of different waters

Table 2.14-3: Limit values of parameters listed in the German Drinking Water Regulations.

MICROBIOLOGICAL PARAMETER		
No.	***Parameter***	***Limit value (Count/100 ml)***
1	*Escherichia coli* (*E. coli*)	0
2	Enterococci	0
3	Coliform bacteria	0

CHEMICAL PARAMETER		
No.	***Parameter***	***Limit value (mg/l)***
1	Acrylamide	0.0001
2	Benzene	0.001
3	Boron	1
4	Bromate*	0.01
5	Chromium	0.05
6	Cyanide	0.05
7	1,2-dichlorethane	0.003
8	Fluoride	1.5
9	Nitrate	50
10	Plant protection products and biocidal products	0.0001
11	Plant protection products and biocidal products total	0.0005
12	Mercury	0.001
13	Selenium	0.01
14	Tetrachloroethene and Trichloroethene	0.01

No.	***Parameter***	***Limit value (mg/l)***
1	Antimony	0.005
2	Arsenic	0.01
3	Benzo-(a)-pyrene	0.00001
4	Lead**	0.01
5	Cadmium	0.005
6	Epichlorohydrin	0.0001
7	Copper	2
8	Nickel	0.02
9	Nitrite	0.5
10	Polycyclic aromatic hydrocarbons	0.0001
11	Trihalomethanes	0.05
12	Vinyl chloride	0.0005

* : Applies from 1st January 2008 (at present 0.025 mg/l)
** : Applies from 1st December 2013 (at present 0.025 mg/l)

INDICATOR PARAMETERS			
No.	***Parameter***	***(Unit, as)***	***Limit value/ Requiremts***
1	Aluminium	*(mg/l)*	0.2
2	Ammonium	*(mg/l)*	0.5
3	Chloride	*(mg/l)*	250
4	*Clostridium perfringens* (including spores)	*(count/100 ml)*	0
5	Iron	*(mg/l)*	0.2
6	Coloration (spectral absorption coefficent Hg 436 nm)	*(m^{-1})*	0.5
7	Odour threshold		2 at 12 °C 3 at 25 °C
8	Taste		Acceptable to consumers No abnormal change
9	Colony count at 22 °C		No abnormal change
10	Colony count at 36 °C		No abnormal change
11	Electrical conductivity	*(µS/cm)*	2,500 at 20 °C
12	Manganese	*(mg/l)*	0.05
13	Sodium	*(mg/l)*	200
14	Total organic carbon (TOC)		No abnormal change
15	Oxidizability	*(mg/l O_2)*	5
16	Sulfate	*(mg/l)*	240
17	Turbidity	*(Nephelometric turbidity units, NTU)*	1.0
18	Hydrogen ion-concentration	*(pH-units)*	≥ 6.5 und ≤ 9.5
19	Tritium	*(Bq/l)*	100
20	Total indicative dose	*(mSv/year)*	0.1

is actually only an indication of the working of the entire chain of the multiple barrier system. Consequently, adherence to certain limit values alone does not guarantee that drinking water supply is safe and free from risks. This is a fact often ignored in the context of privatisation of municipal drinking water supply systems to establish a free market economy in this field. Often, the argument goes as follows: The limit values of microbiological indicators have been adhered to – hence everything is in good order. Hereby it is disregard that a number of other microbial parameter has to be taken into account (viruses, parasites). Owing to the high level of protection afforded by drinking water supply systems, there have been, fortunately, no negative news about outbreaks of diseases that could be attributed to the public drinking water supply in the last decades. However, the feeling of safety experienced as a consequence is deceptive.

Table 2.14-3 gives a synoptic view of the parameters and their limit values and requirements which have been regulated by the German Drinking Water Regulations. However, one should also take note of the comments on the individual parameters that are listed in the Regulations (which have been omitted in the present document).

The foods and other commodities act

The EU Regulation (EC) No. 178/2002 of 28 January 2002 laid down the general principles and requirements of food law… , drinking water is considered as a food »after the point at which it emerges from the tap«. From this point on, the provisions of food law apply, particularly those of the German Foods and Other Commodities Act (Lebensmittel- und Bedarfsgegenständegesetz - LMBG 1997), as well as those of the Regulations on the authorisation of food additives (Zusatzstoff-Zulassungsverordnung) and the Regulations on specification and purity criteria of food additives (Zusatzstoff-Verkehrsverordnung).

Technical standards

In addition to the legal provisions (acts, regulations, EU Directives), there are German national technical standards referred to as Technical Rules. Although not legally binding, the latter have a very strong influence on the quality of the drinking water supplied. In § 4 of the Drinking Water Regulations 2001, explicit reference is made to the »generally accepted technical standards«. In Germany, the German Standards Institute (Deutsches Institut für Normung – DIN), and the German Technical and Scientific Association for Gas and Water (Deutsche Vereinigung des Gas- und Wasserfaches – DVGW) are the competent bodies in the field of drinking water which develop the Technical Rules and provide for their adaptation to technical progress. Thus, it is not required for legislation to include detailed technical requirements in the Drinking Water Regulations. Rather, reference is made to the Technical Rules, that constitute a consensus of the majority of experts. In case of quality complaints (by ignoring the rules) being brought to court, these Technical Rules are considered as an »anticipated expert opinion«. In that case, the operator of a water supply facility will have to prove that the factual situation concerned would also have occurred if he had complied with the Technical Rules.

• International regulations
The EU drinking water directive

For the member states of the European Union, the EU Drinking Water Directive of 1998 (Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption) (EG-TW-Richtlinie 1998) has been binding. It had to be converted into national legislation in the EU member states within a period of two years. This Directive lays down the basic requirements for drinking water and the protection of the population in the member states on a uniform minimum level of protection. When converting into national legislation the limit values fixed in this Directive, they may be modified only to become more but not less stringent.

The European Drinking Water Directive has placed the Member States under a much more comprehensive obligation to inform their citizens, a fact that is highly welcomed. It has made the issue of water quality more transparent for consumers and will eventually serve to increase the acceptance of the notion of drinking water being a food and a wealth that needs to be protected but is not available free of charge. However, in addition to the quality of the product, payments to be made also include the service of supplying with the required quantity of drinking water with a sufficient pressure to every tap of the household.

The WHO Guidelines for drinking water quality

The Guidelines for Drinking Water Quality published by the World Health Organisation (WHO-TW-Guidelines 1993) represent a global assessment standard for drinking water parameters. Updates of these Guidelines are published at regular intervals. They also serve as a basis for the development of national legal provisions intended to ensure protection of the population from health impairment through drinking water. The WHO Guidelines must, on the one hand, deal with the matters relevant in terms of health. On the other hand, they have to take into account the actual conditions and potential for technical implementation in the developing countries.

At present it is being discussed on an international level whether the implementation of a so-called Water Safety Plan, in addition to product control of the water supplied, could result in an improved process control in water supply. It has been the aim of such efforts to make better use of the financial and staff resources available and improve the hygienic safety of drinking water supply.

Conclusions

It has been the purpose of this contribution to explain that the requirements for drinking water stipulated by national and international standards are not limited to the establishment of an arbitrarily defined number of limit values. Such values for limit levels and indicator parameters can only be an instrument to reveal deficiencies of the multiple barrier principle and thus indicating a need for action. A Water Safety Plan should ensure, by means of process control, that the drinking water supplied is safe in terms of health also during the period between two subsequent analyses. Control of the final product alone is completely unsuited as a control instrument because the water examined has already reached consumers and has already been used. Any action commonly taken in food distribution in cases of food alert (detention at the producer's premises, ban on sales by the distributor or retailer or recall from the consumer) would be too late in the case of drinking water. In the case of microbiological contamination of drinking water, a single glass of water consumed may be sufficient to cause illness under certain conditions. However, due to the analytical method, *analytical findings from control* measurements are often obtained as late as several days after the critical event. Nevertheless, the limit values which are binding on the national and international levels are only in part based on public health considerations. Other sensible reasons for their establishment include the precautionary principle, the minimisation requirement and the avoidability of contamination♦