23 Drinking Water, Mineral and Table Water

23.1 Drinking Water

Drinking water should be clear, cool, colorless and odorless, free from pathogens (low in microorganisms), perfect with regard to taste, cause no materials corrosion, and contain soluble substances only in narrow limits and minerals normally in concentrations of less than 1 g/l. In individual countries, criteria have been defined by law for the quality of drinking water, especially limiting values for microorganisms and contamination. As an example, limiting values stipulated in the German decree on drinking water are presented in Table 23.1.

Drinking water is recovered from springs, groundwater, and surface water. In sparsely populated areas, springs and brooks provide water that can be used without further pretreatment. Frequently, however, the water available does not fulfil the requirements and must be laboriously purified.

In dry areas, drinking water is obtained by desalting brackish or sea water. The usual processes applied are reverse osmosis with the use of semipermeable membranes for slightly saline brackish water and multistage evaporation, mainly as flash evaporation, for sea water.

23.1.1 Treatment

To remove suspended particles, the water is first filtered through gravel and sand layers of different grain size. Humic acids, which may color water yellow to brown, are flocculated with aluminium sulfate. After clarification, the quality of the water is improved still further, if required, by the application of the following processes.

Water should not contain more than 0.2 mg/l of iron, which is present as the bicarbonate, and 0.05 mg/l of manganese (Table 23.1). The iron can be eliminated as iron (III) hydroxide by aeration. In this process, manganese also precipitates as MnO_2 if the pH is higher than 8.5. Biological processes have also been developed for deferrization and demanganization. Free carbonic acid must be removed because it attacks pipes. The deacidification process applied depends on the hardness of the water and on the concentration of free carbonic acid. The usual process involves aeration and filtration through carbonate rock (e. g., marble or magnesite).

The disinfection of water is mostly achieved by chlorination or ozonation. At a pH of 6–8, the chlorine gas passed into the water forms practically only HClO and ClO^- which, together with the dissolved Cl_2, are expressed as free chlorine. In the case of superchlorination for the killing of very resistant microorganisms, the excess chlorine (>0.1 mg/l of free chlorine) must be withdrawn with the help of SO_2, Na_2SO_3, $Na_2S_2O_3$ and filtration through calcium sulfite or coal. Disinfection with ozone has the advantage that due to its decomposition into oxygen, no chemicals remain in the water. Interfering odor- and taste-active substances are eliminated by filtration through activated carbon.

Overly high conventrations of nitrate (limiting value in Table 23.1) can be reduced by bacterial denitrification, ion exchange, or reverse osmosis. The fluoridation of drinking water is discussed in 7.3.2.10.

23.1.2 Hardness

The total water hardness refers to the total concentration of alkaline earths calcium and magnesium in mmol/l. The concentrations of strontium and barium, which are usually very low, are not considered. The following is valid for conversion to German degress of hardness (°d): 1 mmol/l hardness = 5.61 °d. Factors for conversion to the degree of hardness of other countries are given in Table 23.2.

Table 23.1. Chemical and physical analysis of drinking water

Parameter	Limiting value[a]
General values to be measured	
Temperature	25 °C
pH Value	6.5–9.5
Electrical conductivity at 25 °C	$2000\ \mu S \cdot cm^{-1}$
Oxidizability[b]	$5\ mg\ O_2/l$
Hardness	–[c]
Individual Constituents	mg/l
Sodium	150
Potassium	12
Calcium	–[c]
Magnesium	50
Iron	0.2
Manganese	0.05
Aluminium	0.2
Ammonium	0.5
Silver	0.01
Sulfate	240
Arsenic	0.04
Lead	0.04
Cadmium	0.005
Chromium	0.05
Nickel	0.05
Mercury	0.001
Cyanide	0.05
Fluoride	1.5
Nitrate	50
Nitrite	0.1
Polycyclic aromatic hydrocarbons, calculated as carbon	0.0002
Chlorine-containing solvents, sum of 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, dichloromethane	0.025
Carbon tetrachloride	0.003
Pesticides, biphenyls, terphenyls	0.0001[d]
Surfactants	0.2

[a] The limiting values have been taken from the decree on drinking water, Dec. 5, 1990 (BGBL. I. p. 2612)/Jan. 23, 1991 (BGBL. I. p. 277).
[b] Organic substances are detected on the whole by oxidation, e. g., with permanganate.
[c] No limiting value required.
[d] Per individual substance.

The assessment of water involves an evaluation in accordance with the steps of hardness presented in Table 23.3.

Table 23.2. Conversion factors for degrees of hardness

Value	Alkaline earth metal ions (mmol/l)
Hardness[a]	1.00
1 German degree of hardness (°d)	0.18
1 English degree of hardness (°e)	0.14
1 French degree of hardness (°f)	0.10
1 USA degree of hardness (°US)[b]	0.01

[a] Hardness is now expressed as the concentration of the amount of substance (mmol/l). The following correspond: 1 mg/l $Ca^{2\oplus}$ = 0.025 mmol/l; 1 mg/l $Mg^{2\oplus}$ = 0.041 mmol/l.
[b] 1°US = 1 ppm $CaCO_3$.

Table 23.3. Classification in steps of hardness

Step	Range of hardness (mmol/l)	Degree of hardness (°d)	Characteristics
1	<1.3	<7	Soft
2	1.3–2.5	7–14	Medium-hard
3	2.5–3.8	14–21	Hard
4	>3.8	>21	Very hard

On heating, the hydrogen carbonates dissolved in water are converted to carbonates. On boiling, a part of the calcium salts precipitates out as slightly soluble $CaCO_3$. This part of the hardness is called carbonate hardness.

23.1.3 Analysis

The extent and frequency of the analysis of drinking water are regulated by law in many countries. Apart from monitoring the hygienic state of the water resources and of the treated drinking water, maintenance of limiting values is controlled. The data given in Table 23.1 show that extensive analysis of drinking water is a very laborious process. The question of whether the drinking water supply is possibly endangered by drug residues has risen recently. In spot checks, the concentrations of persistent drugs, e. g., chlofibrinic acid, detected in drinking water have been far below the human therapeutic activity threshold. From a hygienic viewpoint, however, this situation is not tolerable in the long run.

Table 23.4. Classification of mineral water

Description	Requirement
With low mineral content	Solid residue = mineral matter content $\leq$500 mg/l
With very low mineral content	Solid residue $\leq$50 mg/l
With high mineral content	Solid residue $>$1500 mg/l
Bicarbonate containing	Hydrogen carbonate $>$600 mg/l
Sulfate containing	Sulfate $>$200 mg/l
Chloride containing	Chloride $>$200 mg/l
Calcium containing	Calcium $>$150 mg/l
Magnesium containing	Magnesium $>$50 mg/l
Fluoride containing	Fluoride $>$1 mg/l
Iron containing	Divalent iron $>$1 mg/l
Sodium containing	Sodium $>$200 mg/l
Suitable for preparation of infant food	Sodium $\leq$20 mg/l, nitrate $\leq$10 mg/l, nitrite $\leq$0.02 mg/l fluoride $\leq$1.5 mg/l
Suitable for low-sodium nutrition	Sodium $<$20 mg/l
"Säuerling"	Carbon dioxide of natural origin $>$250 mg/l

23.2 Mineral Water

Mineral water comes from a hygienically faultless spring that is protected from contamination. It has a nutritional and physiological effect due to its mineral content.

In many countries, the recovery and composition of mineral water are controlled by the state and only a few processes for quality improvement are permitted. These are: separation of iron and sulfur compounds, complete or partial removal of free carbonic acid, and addition of carbon dioxide. Mineral water is bottled directly at the place of the spring. With regard to the heavy metal content and possible contamination, limiting values have been stipulated by law. The classification of mineral water is presented in Table 23.4.

In Germany, water used for therapeutic purposes (medicinal waters), because of its chemical composition, is subject to the law governing the manufacture and prescription of drugs.

23.3 Table Water

Table water is made from mineral water, drinking water, and/or sea water by using NaCl, $CaCl_2$, Na_2CO_3, $NaHCO_3$, $CaCO_3$, $MgCO_3$, and CO_2. If it contains at least 570 mg/l of $NaHCO_3$ and carbon dioxide, it can be called soda water. Selters is a soda water that comes from Selters on the Lahn.

23.4 References

Heberer,T.,Stan,H.-J.: Arzneimittelrückstände im aquatischen System. Wasser & Boden 50(4), 20 (1998)

Höll, K.: Wasser, Walter de Gruyter, Berlin, 1979

Quentin, K.-E.: Trinkwasser. Springer-Verlag: Berlin. 1988

Weingärtner, H. et al.: Water. In: Ullmann's encyclopedia of industrial chemistry. 5th Edition, Volume A28, p. 1, VCH Verlag, Weinheim, 1996