

## 5.9 Mineral Water, Thermal Water, and Medicinal Water

The terms mineral water, thermal water, and medicinal water describe water that has special chemical and physical properties. Special healing properties have been attributed to water from certain sources since antiquity. Such water has been used medicinally for more than 2000 years. Some of the well-known health resorts, e.g., Aachen, Bad Bertrich, Baden-Baden, Bad Gögging, and Badenweiler, trace their origins back to Roman baths at these locations.

In the past, mineral water from natural springs was used primarily therapeutically, either for bathing or for drinking. In modern times, mineral water is used mainly for drinking in place of tap water. Thermal water occurrences have been increasingly used over the last several decades as a source of geothermal energy, e.g., at Erding and Straubing in Bavaria.

There are about 650 brands of mineral water and 70 brands of medicinal water on the market in Germany (BUNDESANZEIGER 1999). In 2001 there were 235 mineral water companies, 29 of these in the States of the former East Germany. According to a press release of the Verband Deutscher Mineralbrunnen e.V., about 7832 million liters of mineral water and 265 million liters of medicinal water were sold for EUR 2.75 billion in 2001. That corresponds to a consumption of 104 liters per person.

There are about 370 health resorts in Germany. At about 160 of these, mineral water, thermal water or medicinal water is used for therapeutical purposes. According to the Deutscher Heilbäderverband e.V., 6.2 million persons visited German mineral and balneological baths for a total of 42 million overnights.

### Requirements placed on mineral water

The "Nauheimer Beschlüsse" of 1911 defined and classified mineral water according to the minimum content of dissolved minerals, gas, and trace elements, as well as temperature. The definitions in use today have developed from those of 1911.

#### Mineral water

The legal requirements placed on natural mineral water are laid out in the "Verordnung über natürliches Mineralwasser, Quellwasser und Tafelwasser" (Regulations for Natural Mineral Spring Water and Table Water) (MINERAL- UND TAFELWASSERVERORDNUNG (MTVO) 1984, BGBl. I, p. 1036, revised on 29 October 2001, BGBl. I, p. 2785). According to this law, natural mineral water is derived from protected groundwater taken from one or more natural springs or from wells.

The mineral water must be naturally pure and contain no micro-organisms. Limiting and guideline values are given in the regulations. Content and temperature must remain within the range of natural variation. The regulations also require that the water be bottled at the site of the spring or well, for which a permit is required, and the water must be officially certified. If the water contains less than 1000 mg/l total dissolved solids or less than 250 mg/l free carbon dioxide, the physiological nutrient properties of the water must be demonstrated in order to be certified.

#### Medicinal water

The requirements placed on natural medicinal water are laid out in the "Begriffsbestimmungen – Qualitätsstandards für die Prädikatisierung von Kurorten, Erholungsorten und Heilbrunnen" (Definition of Terms: Quality Standards for the Certification of Health Resorts and Mineral Water Springs and Wells) (DEUTSCHER HEILBÄDERVERBAND e.V. & DEUTSCHER TOURISMUSVERBAND e.V. 1998). These standards, however, do not have the force of law. According to these standards, natural medicinal water is taken from a spring or well and is suitable for pharmacological purposes. The suitability for therapeutic purposes must be demonstrated by a balneological medical study. The absence of bacteria must be demonstrated by regular control analyses. The concentrations of the characteristic components may not vary by more than 20%; the carbon dioxide content may not vary by more than 50%.

According to the criteria laid out in the "Definition of Terms", natural medicinal water must have a minimum of 1000 mg/l or a concentration greater than the limit given in Table 1. If neither of these criteria are fulfilled, the suitability of the water for medicinal purposes must be clinically demonstrated. If the water is bottled and shipped, it is considered as a pharmaceutical and requires certification by the Bundesinstitut für Arzneimittel und Medizinprodukte (BfArM).

**Table 1** Minimum contents required to be classified as medicinal water

iron-bearing water	≥	20 mg/l iron (Fe <sup>2+</sup> )
fluoride-bearing water	≥	1 mg/l fluoride (F)
iodide-bearing water	≥	1 mg/l iodide (I)
sulfur-bearing water	≥	1 mg/l sulfide (S <sup>2-</sup> )
radon-bearing water	≥	666 Bq/l radon (Rn)
carbonated water for bathing	≥	500 mg/l free dissolved carbon dioxide (CO <sub>2</sub> )
carbonated water for drinking	≥	1000 mg/l free dissolved carbon dioxide (CO <sub>2</sub> )
brine	≥	5.5 g/l sodium (Na <sup>+</sup> ) and 8.5 g/l chloride (Cl <sup>-</sup> ) = 14 g/l NaCl
thermal water	>	20°C natural temperature at the spring

The criteria for labeling as natural mineral water differ from those for natural medicinal water, which use balneological terms. Because the sources of mineral water and medicinal water do not differ, the two types of water are described here using the criteria for medicinal water to facilitate comparison. All ions with a concentration greater than 20 meq% (milliequivalent percent) of the sum of the cations and anions are included in the chemical characterisation of the water.

### The genesis of mineral water

Mineral, thermal, and medicinal water are taken from the general water cycle. Precipitation infiltrates the ground and passes through porous rocks, called aquifers, which can lie at quite different depths. The water in the pores and fractures of the rocks is in direct contact with the rock, from which it dissolves minerals and trace elements. Depending on the composition and solubility of the rocks, as well as the temperature and free carbon dioxide concentration, the water becomes "mineralized". Mixing and ion exchange lead to the final composition of the water content.

Mineral water is classified as bicarbonate, sulfate, or chloride water, depending on which of the three anions predominates:

**Bicarbonate** mineral water results from the passage of the water through carbonate-bearing sediments, e.g., calcium bicarbonate or calcium magnesium bicarbonate water results from passage through limestone or dolomite. Sodium bicarbonate water results from ion exchange and is characteristic of the transition zone between fresh water and saline water.

**Sulfate** mineral water has a wide distribution and results mainly from the passage of water through evaporites, such as gypsum and anhydrite, or by the oxidation of sulfide-bearing rocks.

**Chloride** mineral water, e.g., sodium chloride water, is usually a mixture of fresh water and brine. Brine is usually mineral water formed by contact of water with rock salt or it is sea water that was originally in the pores of sediments deposited in the sea.

**Sulfidic** water is formed by bacterial reduction of sulfate. Most carbonated water results from post-volcanic degassing, and frequently occurs in the area of a recent volcano.

**Thermal water** is water that is heated during its passage through the earth's crust and must have a temperature of more than 20°C at the spring or well. Considering a mean temperature gradient of 3°C per 100 m depth and a mean temperature of 10°C for near-surface groundwater, thermal water can be expected at depths below about 400 m. Higher temperature gradients are present in areas with a positive temperature anomaly (e.g., recent volcanic activity or a magma chamber at relatively shallow depth). Thermal water can ascend along deep-seated, highly permeable fracture zones, emerging from springs at the surface (Fig. 2).



**Fig. 2** Thermal water spring

### Map Structures

Map 5.9 shows the distribution and composition of the mineral, thermal, and medicinal water occurrences in Germany. The map was prepared using data from the State Geological Surveys and other sources. Only a representative selection of wells and springs is presented on the map for areas where mineral water with similar chemical composition is obtained from many springs or wells. If several analyses are available, only the most recent ones were used for the map.

The data are shown in pie charts on the map in meq%, with the cations sodium (Na<sup>+</sup>), potassium (K<sup>+</sup>), magnesium (Mg<sup>2+</sup>), and calcium (Ca<sup>2+</sup>) in the upper half and the anions chloride (Cl<sup>-</sup>), sulfate (SO<sub>4</sub><sup>2-</sup>), and bicarbonate (HCO<sub>3</sub><sup>-</sup>) in the lower half.

The amount of total dissolved solids is indicated for each mineral water occurrence by the size of the pie chart: 0 to 1 g/l, 1 to 5 g/l, 5 to 20 g/l. Brine is indicated by a triangle.

Carbonated water (CO<sub>2</sub> ≥ 1000 mg/l) is indicated by a blue circle within the pie chart or triangle, thermal water (T > 20°C) by a red margin. Components that are pharmaceutically effective according to the "Definition of Terms" for medicinal water, e.g., iron (Fe<sup>2+</sup>), fluoride (F<sup>-</sup>), iodide (I<sup>-</sup>), sulfide (S<sup>2-</sup>) and radon (Rn) are indicated by the respective chemical symbol next to the graph.

The numbers next to the pie charts and triangles correspond to the numbers in the tables of spring and well data. The tables give the name of the location of the spring or well, the depth of the spring or well, the total dissolved solids, and the chemical type of water.

### Distribution of mineral, thermal, and medicinal water in Germany

Occurrences of mineral, thermal, and medicinal water are not evenly distributed throughout Germany. They are concentrated in south-western Germany, in a wide band from the mid-Rhine across the Hessisches Bergland (Hessian Uplands) to the Fichtelgebirge (Fichtel Mts.), along the Leine graben, and between the Westfälisches Bergland (Westphalian Upland) and the Norddeutsches Tiefland (North German Lowlands). The occurrences are associated mainly with fault zones in the outcropping basement (Fig. 1), through which mineralized water ascends to the surface from great depths. Until the early 20th century, mineral water was taken mainly from springs. Today, the water is mostly taken from wells, also in regions in which there are no springs. The depths of today's mineral, thermal and medicinal water wells vary from several meters to 4850 m (the Endorf 2 well in Bavaria). Most of the wells have depths of less than 1000 m (Table 2).

**Table 2** Distribution of well depths

depth in m	0 – 10	>10 – 50	>50 – 100	>100 – 200	>200 – 500	>500–1000	>1000–4850
number of wells	39	87	67	64	72	56	27

Most of the mineral water occurrences are chloride or sulfate water. Saline water and brine are widely distributed at depth, particularly in the area of the North German Lowlands, in the Cretaceous basin of the Münsterland region, in the upland region of Hesse and Lower Saxony, in the Thüringer Becken (Thuringian basin), the Upper Rhine graben, and central and southern Germany. The saline water and brine result from the leaching of salt rock or is former sea water in the pores of marine sediments. Leaching of salt occurred from deposits of the Zechstein, the Röt Formation of the Lower Triassic, the Middle Triassic, the Münder Mergel of the Upper Jurassic, and the Lower Oligocene.

Carbonated water occurs frequently in an East–West zone of Tertiary and Quaternary volcanic rocks. This zone extends from the Eifel mountain region through the Siebengebirge, Neuwieder basin, Westerwald, Vogelsberg, the Rhön region, to the Fichtel Mts. and the Oberpfälzer Hügelland (Upper Palatinate region). Other occurrences are in the Urach region of volcanic rocks in the Swabian Jura and in northern Hesse.

Natural occurrences of thermal water are found in areas with a positive temperature anomaly, e.g., in the Swabian Jura and the Upper Rhine graben. Occurrences are also found at the southern margin of the Taunus and along the Middle Rhine.

### Practical Information

Owing to the small scale of the map, only a representative selection can be shown of the mineral, thermal, and medicinal water occurrences in Germany. Detailed information is available in numerous publications and larger scale maps of the individual Federal States. A comprehensive description of the geology, chemistry and genesis of about 2200 mineral water occurrences in Central Europe is given in "Die Mineral- und Thermalwässer von Mitteleuropa" by CARLÉ (1975). "Mineral- und Thermalwässer – Allgemeine Balneologie" by MICHEL (1997) provides detailed information about the definition of terms, the physical properties, the genesis, investigation methods, development of well fields, and legal and economic aspects of mineral and thermal water.

Further information about mineral and medicinal water in Germany is available from the Verband Deutscher Mineralbrunnen e.V. in Bonn. The Deutscher Heilbäderverband e.V. in Bonn and the Heilbäderverbände (medicinal water associations) in the individual Federal States provide information about medicinal water and the therapeutical properties.