JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT
Jb. Geol. B.-A. | ISSN 0016–7800 | Band 142 | Heft 4 | S. 591–606 | Wien, Dezember 2000
Danube Region Environmental Geology Programme DANREG — Explanatory Notes | Editor: G. Császár

Water Quality

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Introduction

A brief overlook of the chemical composition of the different waters of the DANREG programme area characterizes the present-day status of the natural waters. The chemical characteristics of the natural precipitation, the surface and the groundwater, as well as the mineral and thermal waters are demonstrated. The natural, geologically influenced situation of the water quality can be observed as well as the men-made contamination. Some decades ago only the drinking water in wells was regularly investigated. The region includes one of the largest drinking water reservoires in Europe and there is also an important water mangement work — the Gabčikovo dam — operating for several years and influencing the regime and the quality propertie of ground- and surface water.

The terrific progress of chemical analytics revealed dramatic contents of toxic components in waters, which never have been expected, *e.g.* chlorinated hydrocarbons.

In 1991, based on the Federal Law of Water Quality Survey, a systematic surveying of the water quality was started in Austria. The basis of that study is the Annual Report 1994 on Water Quality in Austria (SCHWAIGER & GRATH 1995).

Assessment of the different types of natural waters

According to the agreement of the hydrogeochemical experts of the DANREG countries the common guiding principle of the water quality study was to follow the main genetic types of natural waters. These are:

— precipitation water,
— surface waters,
— groundwater (common type),
— thermal and mineral water.

This principle was applied in the Austrian and the Slovak territories.

In the Hungarian part of the region it is possible to describe or characterize the evolution of these waters, by means of their hydrodynamic position. Based on a large number of the water and oil well data from different depths and horizons, the local, intermediate and regional flow systems as well the major stagnant or slow migration zones are delineate (TÓTH 1982, TÓTH *et al.* 1985). As a consequence instead of subheadings: "groundwater" and "thermal and mineral water the following ones are used:

Bank (or river bed) filtration waters
Groundwater partly recharged by surface waters
Springs, representing the infiltrating waters
Intermediate flow systems
Regional flow systems
Stagnant or slowly migrating waters
Altered shallow groundwater.

Under these subheadings above in part the surface water is also concerned.

Review of the natural waters of the DANREG area

Precipitation water

The precipiation water represents one of the region's principal inputs into the hydrogeological cycle. Its assessment is based on the chemical composition of winter precipitation and of snow. Since the mineral content in the precipitation water can either be natural, or anthropogenic, its chemical composition can serve as a source of information on the infiltration water and on the pollution of the atmosphere.

There are no published data of precipitation stations of the Austrian part. The influence of precipitation can be demonstrated by the contamination of Lake Neusiedl/Fertő with phosphorus. It is, calculated to the surface of the lake, 503 mg/m^2 per year. The portion of precipitation is 25 mg/m^2, that is 5% (PESCHEK & HERLICSKA, 1990).

The winter precipitation in Slovakia can be characterized on the basis of the long-term national monitoring using the GSSR network of stations installed within, or next to the Slovakian region or, it can be characterized from the results of detailed research into the quality of snow, carried out by VRANA and others (1992) between 1990 and 1992. The snow as sampled as much as 3–4 times at 207 localities in the broader surroundings of Bratislava (Table 1).

This regional research has shown that the mean mineralization for the DANREG, including the Bratislava area reaches the values of 30–60 mg/l, which 3–5 times exceed the background (forestry areas) and rank among the highest. The mean pH value of snow is around 5.5 and indicates a fairly strong alkalization relative to the average of Slovakia, which is around 4.4. These distinctly increased values indicate the distribution of atmospheric pollution sources, represented mainly by the dry depositions. In the higher grounds, the pollution is progressively dispersed. As shown by the predominating ions, the chemical composition of snow in the region indicates an $Na>Ca>NH_4>Mg$ and $SO_4 \geq Cl > NO_3$ chemical type.

In the Hungarian part of the DANREG area there is no suitable observation site to characterize the chemical composition of precipitation waters. In winter 1996/97 100 snow samples were collected and analyzed in the city and surroundings of Budapest (Table 2). shows three representative results, one from the western part of Buda, one from the downtown and one from the eastern part of Pest. The downtown sample shows stronger contamination of traffic origin. The two peripheral samples have very low pH, indicating external air contamination.

Surface waters in Austria

To demonstrate roughly the water quality of flowing surface waters the parameters ammonium —nitrogen, orthophosphate— phosphorus and atrazin were chosen. By means of these parameters the anthropogenic influence can be recognized (Table 3, 4).

Table 1.

Chemical composition of snow from the broader area of Bratislava (n=603)

	pH	Min	SiO_2	NH_4	Mn	Fe	Al	Cu	F	NO_3	Ni	Pb	Na	K	Mg	Ca	Sr	Zn	Cl	SO_4	HCO_3
x	5.62	39.61	1.28	1.49	0.04	0.45	0.17	0.01	0.07	4.32	0.01	0.03	4.60	0.27	0.68	3.80	0.01	0.08	8.21	8.42	5.85
Max.	10.18	1719.75	18.40	18.40	0.40	0.40	8.75	0.27	7.73	60.00	1.40	1.33	663.20	7.60	6.16	86.60	0.17	3.50	1 030.00	204.20	51.85
Min.	2.98	7.19	0.1	0.01	0.001	0.02	0.003	0.005	0.00	0.64	0.001	0.005	0.01	0.01	0.04	0.16	0.00	0.006	0.06	0.79	0.00
S	1.20	82.21	1.13	1.42	0.06	1.31	0.41	0.02	0.37	3.49	0.07	0.08	29.33	0.60	0.66	5.50	0.02	0.21	45.88	10.86	7.65

Data except of pH are in mg/l.

Table 2

Chemical composition of snow in some parts of Budapest

Locality	pH	Ec	Na	Mg	K	Ca	Fe	SO_4^{2-}	H_2SiO_3	Li	Be	B	Al	V	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Sr	Mo
			µg/l					mg/l		µg/l														
W-Budapest	3.62	27.6	434	100	262	547	76.1	3.45	0.13	<0.10	<0.10	1.66	58.8	2.15	1.29	7.58	0.06	<2.00	2.74	13.0	1.05	<1.00	1.56	0.06
Budapest, Downtown	4.91	25.6	1610	900	265	2650	2380	3.44	4.78	0.81	<0.10	4.11	1370	18.4	4.67	27.6	0.60	6.57	37.0	60.7	3.82	<1.00	12.1	0.71
E-Budapest	3.32	21.2	170	46.0	<100	282	67.2	2.01	0.12	<0.10	<0.10	<0.50	56.2	1.12	<0.50	2.33	0.04	<2.00	1.75	9.33	0.93	<1.00	0.95	<0.05

Locality	Ag	Cd	Sb	Cs	Ba	La	Tl	Pb	Bi	Rb	Th	U
	µg/l											
W-Budapest	0.14	0.19	0.26	<0.05	4.26	<0.05	<0.02	7.03	<0.05	0.24	<0.05	0.02
Budapest, Downtown	0.32	0.34	3.35	0.17	64.5	1.23	0.03	89.1	0.29	1.39	<0.05	0.19
E-Budapest	0.10	0.23	0.27	0.07	3.35	<0.05	<0.02	6.68	0.08	0.17	<0.05	0.02

Table 3

Contamination of flowing water, median values of measurement series

	NH_4-N	o-PO_4-P	Atrazin
	mg/l		µg/l
Donau (Bad Dt. Altenburg)	0.3	0.07	0.1
March (Markthof)	0.5	>0.15	0.1
Leitha (Götzendorf)	0.3	0.07	0.1
Leitha (Pachfurt)	0.3	0.15	0.1
Leitha (Gattendorf)	0.3	0.15	0.1
Leitha (Nickelsdorf)	0.3	0.07	0.1
Wulka (Wulkamündung)	>0.5	>0.15	n.b.

Table 4

On the right hand side of the Danube stream-km 1922, Vienna-Freudenau: 24 hours measurement 12/13 August 1991 (average) (Kreitner 1990)

GH	HCO_3	Cl	NO_3	PO_4	SO_4
°dH	mg/l				
10	179.3	12.7	7.8	0.13	23.5

Surface waters in Slovakia

Most surface waters in the monitored DANREG area are represented by the running waters of rivers and of other surface streams. They may by assigned, by their size and importance, to three groups, as follows:

— *principal river* — Danube

— *second order rivers* — Morava, Váh, Hron, Nitra, Ipeľ/Ipoly and Malý Dunaj

— *third order rivers* — other streams

As already mentioned in the chapter on groundwaters, the importance of surface waters in large DANREG itself —especially those in the Danube River— is seen in the fact that most groundwaters of the Žitný ostrov Island are supplied from these waters, their chemical composition reflects an initial state of mineralization and of the self-purifying processes that take place in the host rock. The reported qualitative properties of surface waters are based on the gauging studies made during the period 1989–1990 throughout the national SHMÚ network.

Principal river — the Danube

The Danube, as the principal river, has an Alpine type of flow and maintains in this area a relatively very stable chemistry. Basically, the water is medium mineralized (around 350–400 mg/l), of an indistinct Ca-Mg-HCO_3 type and has relatively low degree of contamination.

According to the oxygen regime index, the Slovak section of the Danube falls within the 2nd to 3rd class of water quality. However, the basic chemical contamination index and the biological and microbiological contamination indexes match it with the 3rd class of water quality and the chemical supplementary indexes rank it to the 4th class.

Generally, the water quality over the Slovak section of the Danube River is steady.

Basing on the results of extensive monitoring of the Gabčíkovo waterwork during the period 1992–1994 a conclusion may be drawn that this waterwork does not substantially influence the water quality in the Danube. In the old channel, as well as in the dam and in the supply channel, the properties of surface water stay within the limits of the long-term gauging studies.

Second order rivers

Qualitative properties of the second order rivers —the *Morava, Váh, Hron, Nitra, Ipeľ/Ipoly* and *Malý Dunaj*, that are the main tributaries to the Danube, have one feature in common— a higher degree of anthropogenic contamination than in the principal river.

Morava

A decisive role in the water quality in the Slovak section of the Morava River plays the regime effective beyond the Slovak territory. Throughout its Slovak section, the water quality is adverse — it falls within the 5th class. The oxygen regime indexes shift it into the 4th class and the basic chemical and biological indexes into the 5th class.

Váh

The Váh River is the biggest and the water-richest tributary to the Danube. Taking the biological and microbiological indexes as criteria the water in the lower course falls within the worst, 5th quality class. Using the oxygen regime indexes, it falls within the 3rd–4th class and using the basic and supplementary indexes it should be assigned to 4th, or 5th class. According to several indexes, its lower course tributaries — the Dudváh and Trnávka, have the 5th class ratings and can be ranked with the most contaminated streams of Slovakia.

Nitra

The Nitra River belongs to the dirtiest streams in Slovakia. Using the oxygen regime and the basic chemical, biological and microbiological indexes its water falls into the 5th class, except of a short lap near Nové Zámky. The supplementary chemical indexes rank it with the 4th–5th water quality class and the heavy metal contents rank it with the 4th quality class.

Hron

The Hron River also belongs among the most contaminated streams of Slovakia. Most contaminations in its upper and middle course comes from the large-scale industry, while in the lower Hron course, which is a part of the DANREG area, it comes from the large-scale agricultural production.

Using the oxygen regime indexes the Hron water in the DANREG falls within the 3rd quality class and using the basic chemical indexes it falls into 4th to 5th class. According to biological and mirobiological indexes, the monitored section was assigned to the worst, 5th quality class, mainly because of a high amounts of psychrophilous and coliform bacteria.

IPEľ/IPOLY

The Ipeľ/Ipoly River is the last direct confluence of the Danube River that drains the Slovak territory. Inasmuch as the Ipeľ/Ipoly drainage system does not have an important industrial source of contamination, the agriculture is considered to be its major contaminator.

The water quality in the Ipeľ/Ipoly, as well as in its tributaries, is adverse. Taking the biological and microbiological contamination as criteria the water falls within the 5th quality class throughout the DANREG monitored sections. The reason is the insufficient recycling of waste waters and an extensive agricultural production. The oxygen regime, the basic chemical composition, the supplementary indexes and the heavy metal contents place this water into the 3rd–4th quality class.

MALÝ DUNAJ

The Malý Dunaj also represents one of the worst, long-term contaminated rivers of Slovakia. The oxygen regime indexes show that its water falls within the 3rd quality class (only the Bratislava section has the 2nd class). According to the other index groups it falls within the 5th quality class (only the Bratislava section has the basic chemical and biological indexes indicating the 4th class).

Third order rivers — other streams

The chemical composition and the quality parameters in other streams of the region differ from the main rivers by a considerable heterogeneity and instability of their chemical composition. Since the waters in the small discharge streams are most vulnerable parts of the hydrosphere and the DANREG area belongs to the regions with a considerable anthropogenic load, the secondary contamination belongs to characteristic features of the other streams. Owing to both the instant and the latent contamination, practically, all the components relevant from the water management point of view can be found in these waters in excessive amounts. At the same time, not only the iron and mangenese, but also a number of other metals, such as the Cr, Cu, Hg, Pb and Zn become mobilized. Relatively better is the situation in the mountains and foothills —in the Malé Karpaty Mts and in the Ipeľská pahorkatina Upland— where the surface waters represent an average of very good quality groundwaters. However, over most of the DANREG area the small surface streams are strongly contaminated due to a large-scale industrial production and indicate an overall and heavy environmental impact.

Surface waters in Hungary

In the Hungarian part of the DANREG area one major, some second-order and several third-order rivers collect and feed the groundwater. The chemical composition of these rivers is discussed from the point of view of their relationship to the groundwater only.

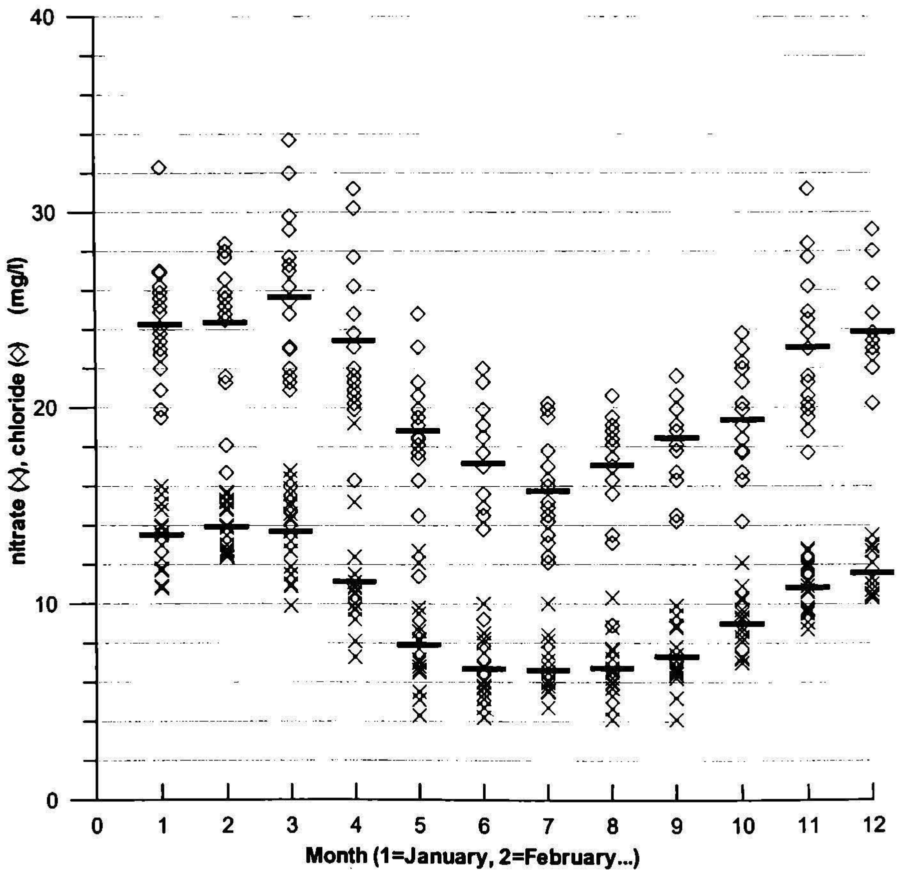

Fig. 1. Periodicity of the chloride and nitrate content of the Danube water, measured data and mean (Győrzámoly, Medve bridge 1990–99)

The principal river of the territory is the Danube. Its chemical characteristics play a very important role in the drinking water supply of Hungary. The river water is utilized usually through a bank filtration system. In the Szigetköz area the Danube was a loosing river before it was diverted in 1992. After 1992 the surface water system of this area became basically artificially influenced and its role of the forming groundwater is being studied extensively.

The chemical composition of the river displays seasonal variation. The fluctuation of some components (Fig. 1) can serve as a natural tracer to study the transport parameters of the connecting alluvial aquifer.

The second order rivers in Hungary (Moson-Danube, Rába, Rábca, Marcal) are the main tributaries of river Danube. Their quality in the low-flow periods is strongly influenced by the base-flow components (*e.g.* the chemistry of groundwater) and the urban, agricultural and industrial impacts as well. The third order rivers ("creeks") show more characteristically these effects. (Table 5)

Groundwater in Austria

The average values of the most important parameters, arranged according to regions, are given in small tables (dl = detection limit)

Marchfeld

	Mean value	Min.	Max.
Conductivity (25 °C) μS/cm	1025	110	4670
Total Hardness °dH	27	8	42
HCO_3 mg/l	341.5	161.0	575.0
Ca mg/l	112.1	<dl	160.0
Mg mg/l	49.9	16.0	81.8
Na mg/l	34.0	4.0	730.0
K mg/l	6.7	<dl	44.0
NO_3 mg/l	52.9	<dl	140.0
SO_4 mg/l	129.3	1.4	236.0
PO_4 mg/l	0.1	<dl	1.7
Cl mg/l	76.2	6.3	1230.0
Atrazin μg/l	1.7	<dl	145.5

Southern part of the Vienna Basin and the Tertiary hill district south of the Danube

	Mean value	Min.	Max.
Conductivity (25 °C) μS/cm	1459	473	5730
Total hardness °dH	36	7	143
HCO_3 mg/l	436.9	227.0	909.0
Ca mg/l	141.1	29.5	397.0
Mg mg/l	72.8	12.0	380.0
Na mg/l	76.0	4.0	1078.0
K mg/l	27.7	<dl	272.0
NO_3 mg/l	79.6	<dl	289.0
SO_4 mg/l	330.8	19.1	4100.0
PO_4 mg/l	0.1	<dl	1.3
Cl mg/l	59.8	2.2	158.0
Atrazin μg/l	0.3	<dl	3.2

Wulka Basin

	Mean value	Min.	Max.
Conductivity (25 °C) μS/cm	701	632	774
Total hardness °dH	22	21.5	23
HCO_3 mg/l	355.9	316.0	377.0
Ca mg/l	100.2	95.0	102.4
Mg mg/l	33.0	25.2	36.5
Na mg/l	5.7	5.5	6.2
K mg/l	<dl	<dl	<dl
NO_3 mg/l	14.2	12.5	16.9
SO_4 mg/l	71.5	57.5	83.0
PO_4 mg/l	0.02	<dl	0.1
C/l mg/l	11.8	8.7	14.5
Atrazin μg/l	<dl	<dl	0.4

Leitha Lowlands north of the Parndorf Plate

	Mean value	Min.	Max.
Conductivity (25 °C) μS/cm	936	603	1146
Total hardness °dH	27	17	36
HCO_3 mg/l	300.6	233.0	396.0
Ca mg/l	119.0	82.8	157.0
Mg mg/l	41.7	19.7	64.0
Na mg/l	15.4	7.8	28.7
K mg/l	8.5	<dl	38.7
NO_3 mg/l	35.6	<dl	87.3
SO_4 mg/l	158.3	68.0	212.0
PO_4 mg/l	0.04	<dl	0.2
Cl mg/l	44.6	17.3	76.2
Atrazin μg/l	0.1	<dl	0.7

Parndorf Plate

	Mean value	Min.	Max.
Conductivity (25 °C) μS/cm	1184	560	1780
Total hardness °dH	33	14	52
HCO_3 mg/l	361.2	213.0	539.0
Ca mg/l	132.3	60.7	231.3
Mg mg/l	65.0	29.7	166.0
Na mg/l	35.7	6.3	406.0
K mg/l	5.7	<dl	18.4
NO_3 mg/l	64.6	<dl	185.2
SO_4 mg/l	220.5	22.0	560.0
PO_4 mg/l	0.1	<dl	0.4
Cl mg/l	52.8	12.9	103.1
Atrazin μg/l	0.2	<dl	5.2

Seewinkel

	Mean value	Min.	Max.
Conductivity (25 °C) μS/cm	1602	762	4910
Total hardness °dH	33	4	121.9
HCO_3 mg/l	468.6	281.0	1521
Ca mg/l	125.5	17.2	538.0
Mg mg/l	70.6	19.1	202.2
Na mg/l	142.0	11.8	973.0
K mg/l	6.4	<dl	67.3
NO_3 mg/l	48.8	<dl	447.3
SO_4 mg/l	357.2	74.0	1846.0
PO_4 mg/l	0.1	<dl	1.6
Cl mg/l	76.8	12.8	456.7
Atrazin μg/l	0.2	<dl	7.1

Table 5

Chemical composition of the rivers and Lake Fertő (January, 1996)

Name of the rivers or lake	Ec	Na^+	K^+	Ca^{++}	Mg^{++}	NH_4^+	Cl^-	HCO_3^-	SO_4^-	NO_3^-
	µS/cm	mg/l								
Duna (Danube), Rajka	425	18	4	58	14.6	0.3	32.3	207.5	42.2	14.6
Mosoni Duna, Mecsér	450	16.5	3.6	66	18.2	0.24	35.1	213.6	47	14
Rába, Győr	726	31	7.2	80	40.1	0.63	66	292.9	111	25.1
Rábca, Lébénymiklós	1001	44.5	7.2	104	45	0.5	70.6	299	232	20.9
Marcal, Mórichida	1003	38.5	7.8	104	53.5	1.08	71	353.9	203	39.5
Által ér, Tata	969	61.5	9.8	90	51.1	1.26	73.8	280.7	248	28.1
Ikva, Fertősztmiklós	1100	60	13.8	116	54.7	2.28	82.4	421	208	43.8
Lajta	664	22.6	4.4	86	31.6	0.47	47.2	268.5	124	17.5
Únyi-patak	1372	130	29	134	85.1	1.59	90.9	414.9	433	38.1
Lake Fertő	2501	430	51	28	128.9	0.06	301	756.6	610	0.34

Groundwater in Slovakia

The relatively complicated geological setting of the DANREG area, notably of its marginal parts, coupled with a strong influence of secondary pollution are the factors determining the development of different genetic types of groundwater with varied chemical composition. The influence of secondary factors is very strong and in most cases, especially in the lowland areas and in the upper parts of aquiferous horizons, it strongly overlaps and modifies the chemical composition of groundwaters, which they acquired through primary factors.

Main genetic types of groundwaters

Petrogenic groundwaters, with the water component of vadose origin and with close genetic links to the chemistry of the host rock.

Fluviogenic waters of alluvial plains and terraces, (especially those of the Danube, Hron, Váh, Morava and Ipeľ/Ipoly rivers) with the water component originating from a surface stream and with a close hydrogeochemical relationship to the surface stream waters.

The groundwaters of the petrogenic type, bound to crystalline, Palaeozoic and Mesozoic rocks of the Malé Karpaty Mts, are only marginally represented. The silicatogenic waters, bound to the crystalline and Palaeozoic rocks, are characterized by their lowest total mineralization of around 200 mg/l and by their indistinct, Ca-Mg-HCO_3 type of chemical composition. The carbonatogenic waters, bound to the calcareous sandstones, clayey and sandy Jurassic limestones and dolomites, are characterized by the total mineralization of 300–600 mg/l and by a distinct, A_2, Ca-Mg-HCO_3 type of chemical composition. The groundwaters in the Neogene formations rank among the three types that relate to lithology. The first type are the waters bound to Neogene sediments of the Záhorská nížina Lowland, clearly A_2 types with a fairly high total mineralization of 600–800 mg/l which is due to the calcareous nature of most host sediments, such as the Badenian limestones, calcareous sandstones and breccias. The majority of them also contains an anthropogenic mineralization characterized by increased contents of HN_4, Fe, Mn, sulphates, nitrates and chlorides. The chemical composition of waters contained in the sedimentary-volcanogenic, Sarmatian-Badenian formations, including the Štiavnica stratovolcano periferal zone, the Ipeľská pahorkatina Highland, the Krupinská vrchovina Upland and the Burda Mts, ranges between a Ca-Mg-HCO_3 and Ca-Mg-SO_4 type. Commonly, the Na-HCO_3 component is increased and the total mineralization values in the predominantly volcanic formations are around 300 mg/l, while in the pyroclastic members they reach as much as 600–700 mg/l. In the groundwaters of the Danubian Neogene sediments that are composed of sands, marly sands, clays and silts with marine and brackish sedimentary intercalations, we encounter the groundwaters with the total mineralization of around 800 mg/l· In the deeper horizons, subject to a high degree of infiltration degradation, the values even exceed 1 g/l and there is an increased rate of S_1(Cl) brackish-water mineralization. In most Quaternary groundwaters, bound to deluvial, proluvial-deluvial to proluvial-fluvial sediments of the foothill areas and to the aeolian sediments of the Záhorská nížina Lowland, are the highest values of anthropogenic contamination, exceeding 1 g/l of the total mineralization. They also contain excessive amounts of the components monitored by the Water Management.

Fluviogenic waters, that is, the waters having a direct hydrochemical relation with the surface stream waters, can be assigned to two basic types — the central depression type (Žitný ostrov Island) and the alluvial type of other rivers (Morava, Váh, Hron, Nitra and Žitava). The alluvial waters of other rivers (excepting the Danube) are noted for their high degree of anthropogenic contamination, with the values of around 1 g/l , but in the settlement interiors, near landfills, agricultural farms *etc.* these may soar as high as 2–3 g/l. Practically, their chemical composition is unpredictable and depends mainly on the character of pollutants entering the groundwaters.

Most important hydrogeological and water management units of the DANREG area are the fluvial sediments of the Danube River, notably the gravel-sands in the area of Žitný ostrov Island. Apart from a narrow, Danube River zone, the first, roughly 25 m of this assemblage are subject to relatively high degree of secondary contamination. Generally, the total mineralization values range between 500 and 700 mg/l and the contents of NO_3, Cl, SO_4, Fe, Mn and NH_4 ions are increased. However, the deeper part contains a good quality potable waters with the mineralization of 350–500 mg/l and with a of Ca-Mg-HCO_3 type chemical composition. In the deepest parts, down to some 100 m, or deeper, the character of water does not change, but excessive amounts of Fe and Mn, or the NH_4 ions may occur due to the oxygen deficit.

Groundwater of Hungary

Bank or river bed filtration systems

Natural bank (or river bed) filtration systems (Szigetköz area)

After the diversion of the Danube, in the Szigetköz the recharge and drainage conditions of subsurface waters changed considerably. Earlier, the main source of recharge was the Danube, with its gravel bed (Table 6). After the diversion this role was transferred to the Čuňovo–Šamorín reservoir. Later the situation became more complex through the effect of different recharge measures and regulation by the underwater weir (at 1843 rkm). Consequently, the branch system of the active flood plain and the protected side, the seepage channel and the upper reaches of the Moson Danube, as well as the 1 km reach of the main channel immediately upstream of the underwater weir were also involved in groundwater recharge. From the early 90's The Geological Institute of Hungary studied and characterized the relationship in the quality of surface and groundwater by means of special sounding along the channels. This sounding method is capable essentially of detecting short-distance (1–2 m) and short-term (a few days) changes in water quality occurring during infiltration from channels toward the groundwater. (See "Recharge channels…" in Table 7). It can also indicate some posterior changes in the water quality occurring in farther and deeper aquifers. Additionally, in channel reaches draining groundwater it reveals the quality of water coming from longer distances (from the background). (See "Discharge to the Danube" in Table 7).

Artificial bank (or river bed) filtration systems

The artificial bank (or river bed) filtration systems along the River Danube serve as the largest water-works and largest drinking water reserves of Hungary. Usually these water-works produce a mixture of waters of different origin. The best indicators of these components are TDS, nitrate and chloride (Horváth & Tóth 1984, Tóth 1982). A typical example is shown in Table 5. The analysis from observation wells situated between the pumping wells and the Danube indicates a strong decrease of nitrate content due to the muddy-gravel riverbed. Two types of water come from the background: a contaminated nitrate rich one from the nearby settlement and an other, with low TDS, nitrate and chloride content, from a smaller loosing stream (feeding by a spring of the andesitic hills). Almost all bank-filtration type waterworks aresimilar to this case, but of course with different weight of the different sources.

Groundwater partly recharged by surface waters

In the margin of the Dunazug Mountains there are some smaller loosing rivers (creeks or streams) which recharge through their alluvial fan the Danube alluvium and modify the chemical character of the groundwater here. A fine example was shown in Table 8.

Springs, representing the infiltration waters ("cold" springs)

The shallow groundwater in the recharge areas (hills and mountains) is the starting-point of the different flow systems. To know the chemical composition of this water (the starting value) is important for the characterization of the flow system as a whole (Egerer *et al.* 1985, Tóth *et al.* 1985). The cold springs with simple character and geologically–pedologically uniform catchment area can serve to determine this type of water. Five different main soil forming rock types have been distinguished in the Hungarian part of the DANREG region, namely limestone, dolomite, loess, metamorphites and andesite (Table 9).

Intermediate flow systems

Thousands of wells have been drilled in the upper 200-300 m of the Pannonian sedimentary sequence. Some of them are near the inner part of the hills and mountains, where the groundwater is directed towards the deeper zones or the farther lowland areas (Tóth 1982). The undisturbed hydraulic potential of these confined aquifers is usually higher then 160 m asl. (recharge zones). The rest of the wells weredrilled in the discharge zones, where the groundwater flow has an upward component. These two

Table 6

Detailed chemical composition of the Danube water (Győrzámoly, Medve bridge, January, 1996)

pH	Diss. O_2	COD_p	COD_{Cr}	Na^+	K^+	Ca_2^+	Mg_2^+	Tot. Fe	Mn_2^+	NH_4^+	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-	NO_2^-	PO_4^{3-}
mg/l																
7.79	12.4	4.4	14	19.0	4.0	58.0	17.0	0.22	0.09	0.25	32.3	207	43.2	13.0	0.11	0.75

Al	Cr	Ni	Cu	Zn	Cd	Pb
μg/l						
90	3.4	6.9	6.3	37	0.20	3.2

Chemical composition of the natural filtration waters and the related surface waters in the Szigetköz area (mean values)

		Discharge to the Danube		Recharge channels with different position and filtered water from the nearby observation wells					
		Danube water	See page to the Danube	Flood plain channels	Bank-filtered water	Protected area's channels	Bank-filtered water	See page channel	Bank-filtered water
N		18	12	33	35	14	14	14	14
Ec	µS/cm	374	455	353	495	361	450	395	467
Diss. O_2		10.6	2.44	12.1	3.04	10.5	1.96	9.45	2.95
DOC		7.52	10.1	7.60	11.2	8.08	15.5	8.45	9.46
Na^+		7.53	8.46	6.98	8.95	6.92	7.62	8.30	9.50
K^+		1.82	2.10	1.68	2.28	1.71	1.92	1.84	2.39
Ca^{++}		58.1	75.1	54.8	85.5	56.3	75.6	62.1	74.0
Mg^{++}	mg/l	11.7	13.4	11.4	14.6	11.5	13.7	13.0	14.9
Fe^{++}		0.09	0.21	0.08	0.46	0.08	0.38	0.08	0.22
Cl^-		11.6	13.5	11.6	14.3	11.2	12.5	12.4	15.0
HCO_3^-		194	242	180	273	193	263	202	354
SO_4^{2-}		27.4	37.0	25.3	43.7	25.2	20.5	28.5	33.5
		7.44	5.59	8.00	5.55	6.73	3.49	5.32	5.03
H_2SiO_3		5.27	7.96	4.21	10.5	5.03	9.25	5.63	7.02
Mn		34.6	123	23.4	431	43.7	560	43.9	104
Li		2.57	2.86	2.40	3.38	2.37	2.83	2.49	3.46
B		37.5	33.1	34.1	40.5	25.9	36.3	39.5	39.2
Al		107	148	97.9	174	92.3	245	94.3	276
V		0.79	0.82	0.77	1.09	0.72	1.86	0.67	0.94
Co		0.31	0.55	0.28	1.52	0.27	1.17	0.30	0.74
Cu		5.23	4.25	4.24	7.68	4.12	6.74	5.33	9.74
As	µg/l	2.02	1.96	1.79	3.36	1.50	4.70	1.98	2.23
Rb		2.09	2.73	2.05	2.62	1.99	1.95	1.53	2.23
Sr		225	263	213	282	215	259	235	257
Mo		1.13	2.25	1.05	2.34	1.09	1.50	1.25	2.67
Sb		0.26	0.30	0.24	0.50	0.23	0.51	0.23	0.43
Ba		27.6	36.0	26.3	45.9	26.3	41.0	28.0	35.5
Pb		0.67	0.87	0.67	0.75	0.55	1.41	0.55	1.16
U		0.93	1.17	0.88	1.75	0.91	1.25	1.04	0.94

large zones combined make up the so called intermediate flow system in this territory (SIPOSS & TÓTH 1989). The differences in the chemical composition of the water of the two zones clearly show the evolution of groundwater quality (Table 10).

Regional flow systems

UPPER PANNONIAN (UPPER MIOCENE) AQUIFER COMPLEX

There are two regional flow systems in the Hungarian part of the DANREG area: one in the Upper Pannonian porous aquifer complex (Pannonian Basin), and the other in the main karst of the Transdanubian Range (KÁRPÁTI *et al.* 1999, LIEBE *et al.* 1984). The recharge and discharge zone of the Upper Pannonian porous aquifer complex was presented in Chapter "Intermediate flow systems". In this chapter additional information will be given on the transitional deep part (the main thermal water bearing horizon) of this system, because of it large economic importance (Table 11). The wide variety of the chemical composition of the waters within this complex offers various utilization possibilities (*e.g.* as mineral and medicinal waters).

MAIN KARST-AQUIFER (TRANSDANUBIAN RANGE)

a) Recharge zones (cold karst waters).

In the inner part of this system, near the old and partly closed brown coal and bauxite mines, there is considerable cold karstic water withdrawal. The chemical composition

Table 8

Chemical composition of the waters in the Dömös bank filtration system

The main components of the bank filtration system	TDS	NO_3^-	Cl^-	alkalinity
	mg/l			
Danube at Dömös Water Works	480	14.0	14.1	3.87
Observation well between the pumping wells and Danube	478	0.5	13.4	4.08
Dömös pumping wells (no. 1–6)	772	13.6	14.00	5.4
Observation well between the pumping wells and village	1224	67.0	37.00	7.2
Observation well close to the background loosing stream	434	2.3	2.04	3.74

Table 9

Chemical composition of the infiltrating water according to the soil forming rock types (Mean values, n=5-10 springs/rock types)

Main soil forming rock type	TDS	Na^+	K^+	Ca^{++}	Mg^{++}	Sr^{++}	Cl^-	HCO_3^-	SO_4^-	H_2SiO_3
		mg/l								
Limestone	496	6	1.2	117	24.4	0.315	11.1	314.8	33	12.5
Dolomite	601	4.2	1.5	108	42.6	0.295	8.2	420.8	30	13.2
Loess	574	14.4	1.2	97	31.7	0.339	8	374.1	42.3	24.1
Metamorphic	330	5.4	0.6	60	9	0.172	10.9	198.6	31.7	16.7
Andesite	283	8.5	2.6	37	8.2	0.153	5.6	143.8	19.9	58.2

Table 10

Chemical composition of the Pannonian (Upper Miocene) confined groundwater, Transdanubian hilly and lowland region (Median values, n=52)

Area	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	SO_4^-	HBO_2	H_2SiO_3	Sr	Ba	Li	As
	mg/l									μg/l			
Recharge zone	18	1.3	70	22	8	500	35	0.09	19	390	28	13	<2
Discharge zone	180	1.9	10	13	10	600	12	0.55	17	220	85	16	3

of these water supply wells well represent of the recharge zone of this regional flow system (EGERER *et al.* 1985, SIPOSS & TÓTH 1989).

b) Discharge zones (thermal karsts).

The discharge zone of the huge Transdanubian karstic system can be characterized by some chemical data of its springs and wells (Table 13.) Note the high fluorine content of these waters. Their relatively low TDS values indicate an intensive groundwater circulation also in the covered part of the basin. Most of the wells are used in spas or for bottling mineral water (LIEBE *et al.* 1984).

Stagnant (slowly migrating) waters

The chemical composition of the groundwater of the aquifers of the deepest part of the Pannonian Basin is known from oil exploratory wells. Because of their high salinity it is supposed that this area contains fossile, stagnant water from the Late Miocene age (KÁRPÁTI *et al.* 1999, TÓTH 1989).

Altered shallow groundwater

The shallow groundwater is very vulnerable and often altered by different effects. In this chapter some extreme examples will be presented. In the discharge zones, where the groundwater table is near to the surface the evapotranspiration from the groundwater can cause some alteration. If the shallow aquifer is clayey, very high magnesium and sulfate content can be expected (TÓTH 1989) (Table 15).

One of the most comon form of alteration is the consequence of the lack of sewage system in the settlements: high nitrate, potassium and chloride content (TÓTH & FEDER 1996) (Table 16). An other typical alteration is the serious contamination by wastes. Good example is shown in (Table 17). This water was collected close to the Kőbánya waste dump site (the biggest communal waste dump of Budapest)

Mineral waters of Austria

In the Austrian part of the DANREG three areas with occurrences of mineral water can be distinguished. They are closely bound to local tectonics. The mineral water sources of Mannersdorf and Deutsch-Altenburg (1) are related to faults at the eastern border of the Vienna Basin. The "Roemerquelle" in Edelstal (2) is situated in the transition area between the Vienna Basin and the Pannonian Basin. Connected to faults at the western border of the Pannonian Basin (3) there are mineral water occurrences at Mörbisch, Rust, Oggau, Purbach, Neusiedl am See, Podersdorf and Illmitz. All faults mentioned are basin-forming faults of the Vienna Basin and the Pannonian Basin.

Mineral water at the eastern border of the Vienna Basin

MANNERSDORF

The thermal springs are at the north-western border of the Leitha Hills.

Na	K	Mg	Ca	Cl	SO_4	HCO_3
			mg/l			
11.2	6.2	85.5	286.5	16.8	830.6	255.3

Trace elements (μg/l):

Fe	Al	Br	J	B
660	20	300	20	817

Calcium-magnesium-sulfate-bicarbonate thermal spring (22,8 °C). Analysis by W. CARLÉ 1975 (in ZÖTL & GOLDBRUNNER 1993, p. 268).

BAD DEUTSCH-ALTENBURG

The the medicinal spring is situated in the Hainburg Mountains on the eastern border of the Vienna Basin.

Table 11

Chemical composition of some typical waters from the bottom zones of the Upper Pannonian (Upper Miocene) aquifer complex (main thermal water bearing horizon)

Locality	pH	COD	K^+	Na^+	NH_4^+	Ca_2^+	Mg_2^+	Fe_2^+	Mn_2^+	Cl^-	SO_4^{2-}	HCO_3^-	PO_4^{3-}	CO_3^-	HBO_2	H_2SiO_3	TDS	Br	J	F	S
	mg/l																				
Mosonmagyaróvár–1	7.83	2.6	18	1650	14.4	5	1.7	0.06	<0.05	1070	33	2620	0.16	0	14	60	5547	3.8	1.32	2.5	<0.01
Lipót	8.42	1.9	4.2	360	1.83	4.3	1.3	0.05	<0.05	66	<25	930	0.14	18	1.4	54	1444	0.12	0.09	1.6	<0.01
Győr–3	8.33	4.5	6.3	500	6.3	5.7	2	0.08	<0.05	175	<25	1130	0.22	18	2.9	54	1902	0.23	0.39	0.8	0.09

Locality	Li	B	Al	V	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Mo	Cd	Sb	Cs	Ba	La	Tl	Pb	U
	µg/l																						
Mosonmagyaróvár–1	722	6554	47.2	0.25	3.44	2.32	<0.1	<2	11.7	25.3	35.3	70.2	38.4	1188	1.37	0.05	0.21	8.02	1061	<0.05	0.07	0.58	<0.05
Lipót	117	396	23.4	<0.05	<0.5	2.38	<0.05	<2	<0.3	<2	46.9	<1	6.78	265	7.1	0.02	0.87	0.45	121	<0.05	0.02	0.39	<0.05
Győr–3	37	647	26.7	0.18	<0.5	3.21	0.08	9.5	26.8	19.2	2.67	5.9	nd	334	1.1	0.06	<0.02	nd	185.6	nd	0.16	1.24	0.07

Table 12

Chemical composition of Tatabánya karstic well, representing the recharge zone of the Transdanubian regional karstic flow system

Locality	Na^+	K^+	Ca_2	Mg_2^+	Cl^-	HCO_3^-	NO_3^-	SO_4^{2-}	H_2SiO_3
	mg/l								
Tatabánya	14.4	1.2	96.8	31.7	8	374.1	0	42.3	24.1

Table 13

Chemical composition of some thermal karstic wells, representing the discharge zone of the Transdanubian regional karstic flow system

Locality	Depth	K	Na	NH_4^+	Ca_2^+	Mg_2^+	Cl^-	TDS	Br^-	J^-	F^-	SO_4^{2-}	HCO_3^-	S_2^-	HBO_2	H_2SiO_3
	m	mg/l														
Komárom Lenfonógyár thermal well	1263	11	145	2.3	143	56	208	1402	1	0.095	1.3	210	460	2.5	3.5	43
Leányfalu beach	1009	6.8	54	0.26	157	56	48	1605	0.36	0.018	2.2	151	710	0.29	4.2	48
Budapest, III. ker. Római-bath, mainspring	0	1.4	14.2	0	104	42.1	7.5	723	nd	nd	nd	64.1	473.7	nd	nd	16
Budapest, XIII. ker. Margit Island, Magda-well	310.7	17	140	0.55	172	36.5	60	1699	164	0.044	2.5	187	560	0.63	4.3	67
Budapest, XI. ker. Apenta II. well	902	25	260	1.68	194	58	263	1912	0.6	0.049	2.7	440	590	nd	9	60

Table 14

Chemical composition of the groundwater in the deepest part of the Pannonian Basin

Well number	Depth	Na^+	Ca^{++}	Mg^{++}	NH_4^+	Cl^-	HCO_3^-	SO_4^-	H_2SiO_3	HBO_2	TDS
	m	mg/l									
Mosonszentjános–2	2400	13267	224	63	44	18260	5358	149	165	312	38550
Ölbő–6	1874	14906	45	97	101	17887	7608	1425	197	270	42560

Table 15

Shallow groundwater altered by evapotranspiration

Locality	K^+	Na^+	NH_4^+	Ca_2^+	Mg_2^+	TDS	Cl^-	Br^-	J^-	F^-	SO_4^{2-}	HCO_3^-	HBO_2	H_2SiO_3
	mg/l													
Nagyigmánd	63	5300	0.01	644	5050	43939.7	650	0.8	0.009	1.9	31200	1010	2.5	17
Budapest-South.	110	5760	0	444	2370	31318.1	491	1.3	0.016	1.1	21360	760	6.6	9

Table 16

Shallow groundwater altered by leaking sewage system of villages

Locality	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	SO_4^-	NO_3^-	H_2SiO_3	TDS
	mg/l									
Ásványráró	79	200	108	64	87	614	185	154	32	4251
Écs	180	840	221	169	546	771	553	947	25	1522

Table 17

Shallow groundwater altered by communal waste of Budapest

Locality	Ec	pH	COD	Na^+	K^+	Ca^{++}	Mg^{++}	$NH4^+$	Mn^{++}	Fe^{++}	Cl^-	NO_3^-	HCO_3^-	SO_4^-	PO_4^{3-}
	μS/cm		mg/l												
Kőbánya	6710	7.5	130	514	385	149	174	303	0.19	2.31	480	3.1	378	455	1.29

Na	K	NH_4	Mg	Ca	Fe^{II}
mg/l					
750.1	56.2	2.22	81.6	318.2	0.07

Cl	SO_4	NO_3	HCO_3	HS	H_2SiO_3
mg/l					
1022.0	192.3	0.12	766.0	14.5	22.2

H_3BO_3	S^{II}	CO_2	H_2S	O_2
mg/l				
76.5	49.4	367	42.8	<0.1

Sodium-calcium-chloride-bicarbonate thermal spring (24.6 °C). Analysis of the "Well of the Directorate" by RABER 1980 (in ZÖTL & GOLDBRUNNER 1993, p. 272).

Trace elements (μg/l):

Li	Be	Ba	U	B	As	F	Br	J
1555	6800	850	0.2	4900	37	5950	3620	1300

Analysis by the Geochemical Laboratory of the Geotechnical Institute Arsenal Vienna (in ZÖTL & GOLDBRUNNER 1993, p. 273).

Transition area between the Vienna Basin and the Pannonian Basin

EDELSTAL–ROEMERQUELLE ("ROMAN SPRING")

This spring is situated in the Hainburg Mountains, which are part of the Little Carpathians.

Na	K	Mg	Ca	Sr	F
mg/l					
13.04	2.00	62.27	152.9	0.45	0.37

Cl	SO_4	NO_3	HCO_3	H_2SiO_3
mg/l				
5.86	324.3	0.90	424.1	29.5

Trace elements (μg/l):

Li	Cu	Zn	B	F	Br	J
23	9	33	65	370	30	36

Calcium-magnesium-bicarbonate-sulfate mineral water. Summary of the complete water analysis by A. J. STEHLIK 1992 (in ZÖTL & GOLDBRUNNER 1993, p. 275).

The Pannonian Basin

MÖRBISCH

The springs occur at the eastern foot of the Ruster Höhenzug.

Li	Na	K	Rb	Mg	Ca	Sr
mg/l						
0.70	8191.32	52.30	0.90	184.78	50.52	2.60

Mn	Fe^{II}	F	Cl	Br	J	SO_4
mg/l						
0.02	4.20	0.10	6067.00	21.00	0.36	8347.00

NO_3	HPO_4	HCO_3	H_2SiO_3	CO_2
mg/l				
3.11	0.25	1858	15.3	130

Sodium-sulfate-chloride mineral water. Analysis of the Caroline Spring (Mörbisch I) by E. SCHROLL and H. KRACHSBERGER (in ZÖTL & GOLDBRUNNER 1993, p. 229).

RUST

The springs are situated at the eastern foot of the Ruster Höhenzug.

Li	Na	K	NH_4	Mg	Ca	Sr
			mg/l			
2.15	6022.2	40.8	10.3	628.5	257.9	8.68

Mn	Fe^{II}	Rb	F	Cl	Br	J
			mg/l			
0.75	16.85	1.05	0.14	4993	14	1.03

Sodide and ferruginous sodium-sulfate-chloride mineral water. Analysis of the well Rust 1 by E. SCHROLL and H. KRACHSBERGER (in ZÖTL & GOLDBRUNNER 1993, p. 230).

A hydrochemically peculiar groundwater with rather high potassium content is known to occur in flat wells in Rust and Illmitz:

Na	K	Mg	Ca	Cl	SO_4	HCO_3
			mg/l			
229.0	678.0	79.6	187.3	365.9	165.4	1810

Potassium-sodium-calcium-bicarbonate-chloride mineral water. Analysis by W. CARLÉ 1975 (in ZÖTL & GOLDBRUNNER 1993, p. 230).

OGGAU

Na	K	Mg	Ca	Fe^{II}	Cl	SO_4
			mg/l			
1637.8	15.7	1025.8	396.4	34.5	1020.3	5913

HCO_3	CO_2
mg/l	
1534	1259

Ferruginous sodium-sulfate-carbonated spring with a content of free CO_2 >1000 mg/l. Analysis by H. KRACHSBERGER Vienna 1963 (in ZÖTL and GOLDBRUNNER 1993, p. 231).

PURBACH

Purbach is situated at the eastern foot of the Leitha Hills.

Li	Na	K	NH_4	Mg	Ca	Sr
			mg/l			
1.6	3126	43.85	0.03	2166.2	459.8	7.5

Mn	Fe^{II}	Rb	Zn	F	Cl	Br
			mg/l			
0.08	0.58	0.88	0.04	0.17	2515.9	0.80

J	SO_4	NO_2	NO_3l	HPO_4	HCO_3	H_2SiO_3
			mg/l			
0.07	12270.2	2.05	9.2	0.20	731.6	8.9

HBO_3	CO_2l
mg/l	
3.2	10

Magnesium-sodium-sulfate-chloride mineral water. Analysis by E. SCHROLL and H. KRACHSBERGER, Vienna 1963 (in ZÖTL & GOLDBRUNNER 1993).

NEUSIEDL AM SEE

Neusiedl is situated at the northern shore of Lake Neusiedl/Fertő.

Li	Na	K	NH_4	Mg	Ca	Sr
			mg/l			
1.9	552.5	31.8	6.0	293.6	273.7	1.48

Mn	Fe^{2+}	F	Cl	Br	J	SO_4
			mg/l			
0.39	5.85	0.21	19.4	0.21	0.04	43.4

NO_3	HPO_4	HCO_3	H_2SiO_3	HBO_3	CO_2
		mg/l			
1.6	0.2	3784	0.7	9.7	2080

Magnesium-sodium-calcium-bicarbonate carbonated spring. Analysis by H. KRACHSBERGER, Vienna 1963 (in ZÖTL & GOLDBRUNNER 1993).

PODERSDORF

Podersdorf is on the eastern shore of Lake Neusiedl/Fertő.

Li	Na	K	NH_4	Mg	Ca	Sr
			mg/l			
0.68	5520	75.8	0.35	76.4	11.6	7.98

Mn	Fe^{II}	Rb	F	Cl	Br	J
			mg/l			
0.12	3.20	1.44	0.71	2677	0.17	0.04

SO_4	HCO_3	CO_2	HS	HBO_3
		mg/l		
2934	5546.7	642	8.65	40.0

Sulphureous sodium-bicarbonate-chloride-sulfate mineral water. Analysis of Well 1 by H. KRACHSBERGER, 1963 (in ZÖTL and GOLDBRUNNER 1993, p. 233).

ILLMITZ

Illmitz lies south of Podersdorf in the "Seewinkel".

Li	Na	K	NH_4	Mg	Ca	Sr
			mg/l			
0.20	2119	25.45	5.12	3.99	5.00	0.22

Fe^{2+}	Rb	F	Cl	Br	J	SO_4
			mg/l			
0.07	0.15	0.50	691	1.53	0.02	545.9

Sulphureous sodium-bicarbonate-chloride mineral water. Analysis by W. CARLÉ 1975 (in ZÖTL and GOLDBRUNNER 1993, p. 233).

Thermal and mineral waters of Slovakia

The DANREG is extraordinarily rich in geothermal, and fairly rich in cold mineral waters.

The geothermal waters are bound to the following areas:

— Danube Basin central depression,
— Komárno block,
— Levice block,
— Láb–Malacky elevation with adjoining down-thrown blocks.

The mineral waters are widespread in the following areas:

— Santovka–Turovce Ridge,
— Ipel'ská kotlina Depression.

The only mineral water spring in the area of Malé Karpaty Mts occurs at Svätý Jur.

Geothermal waters

Danube Basin central depression

Based on the chemical composition, the geothermal waters of the Danube Basin central depression can be assigned to five groups, the character of which does not change suddenly, but gradually in relation to structural-lithological, hydrodynamic, palaeohydrogeologic, tectonic and other factors. The basic hydrogeochemical features of the individual groups defined by their chemistry, is shown in Table 18.

The first group is represented by the distinctly sodium-chloride-enriched geothermal waters, with the mineralization exceeding 10 g/l. They typically occur in the fairly deep, Badenian, Sarmatian and Pannonian aquifers. The total mineralization values range between 11.63 g/l and 126.40 g/l. They are characterized by the S_1(Cl) component and by a relatively low, or totally absent, A_1 component.

The second group represents the geothermal waters of a distinct sodium-chloride type with the mineralization ranging from 5 g/l to 10 g/l. Genetically, they are bound to the Pannonian and Pontian sands to sandstones.

The third group comprises the geothermal waters of sodium-chloride type with the A1 component exceeding 30 mmol.%, or of the sodium hydrogencarbonate type with the S_1(Cl) component exceeding 30 mmol.%. Genetically, most of them are bound to the aquifers situated in hydrogeologically medium-closed structures. Their total mineralization ranges from 2.72 g/l to 8.73 g/l and relates mainly to the degree of degradation.

The fourth group of geothermal waters are of the sodium hydrogen carbonate type with the mineralization ranging from 1 g/l to 5 g/l. They are characteristic for the Pontian and Dacian aquifers.

And finally, we can specify the geothermal waters of a sodium bicarbonate type with the mineralization below 1 g/l, bound predominantly to Pontian and Dacian aquifers. Their total mineralization does not depend as much on the common mineralization processes as on the CO_2 partial pressure in the system. The sodium chloride component is very low and depends on the depth of aquifers, or on their degradation, respectively.

The Komárno block

The Komárno block may be divided into two parts:

— *Komárno high block,*
— *Komárno marginal block.*

The *Komárno high block* is characterized by the waters of Ca-Mg-HCO_3 type with the mineralization of around 0.7 g/l. Genetically, the waters are petrogenic (carbonatogenic) and their mineralization, temperature and chemical composition are almost identical with those on the Hungarian side, *e.g.* at Dunaalmás, or Esztergom.

The *Komárno marginal block* is represented by a water of mixed type with mineralization of 2.2–3.8 g/l. The water is of a combined origin, a mixture of sulpha-to-carbonatogenic waters from the Mesozoic rocks and from the marinogenic waters from the overlying Miocene, distinctly degraded by infiltration and soaked into the carbonate assemblages, mainly during the initial stage of a transgression. In the adjoining part of Hungary (Komárom, Ács), the waters are hydrogeochemically identical with those in the Komárno and its surroundings.

Levice block

The geothermal waters in the Levice block are genetically bound to the Triassic carbonates, or to the Lower Triassic conglomerates, or to the Badenian clastics. They are, in fact, genuine marine waters which soaked into the bottom of the sedimentation area during the Neogene period (probably in the Badenian).

These waters are of a distinct sodium chloride type and their total mineralization is of 19.2 g/l. Based on their isotope composition, they are enriched in oxygen and deuterium in comparison to the meteoric waters. Thus, they are bound to a hydrogeologically and hydrogeochemically closed structure and represent the natural reserves, not the resources.

The Láb–Malacky elevation with adjoining downhrown blocks

Within this structure of the Slovak part of the Vienna Basin, brines were identified with total mineralization

Table 18

Examples of chemical composition of geothermal waters

Locality	Q [l/s]	T [°C]	pH	T.D.S. [g/l]	Na	Mg	Ca	HCO_3/Cl	Cl	SO_4	HCO_3
FGT–1 Topoľníky	23.0	74.0	7.4	1.95	505	32	1202	6.11	114	1	2
Di–1 Diakovce	8.0	38.0	8.1	0.51	113	9	326	0.51	5	0.5	11
DS–1 D.Streda	15.2	92.0	8.3	7.33	2440	3	22	7.39	114	32	1202
FGG–1 Galanta	15.0	62.0	7.45	2.37	868	0.5	11	4.19	283	3	2043
Č–1 Čalovo	7.6	92.0	7.8	4.76	1488	5	40	0.30	1945	6	1019

Contents of ions in mg/l.

ranging from 109.8 to 129.7 g/l. They are distinct sodium chloride chemical types with a minimum value of the A_2 component and with a characteristic, although, varied S_2/Cl/ component. The sulphate contents in the brine are low, not exceeding 600 mg/l, despite the presence of anhydrite in the aquiferous rocks.

Mineral waters

Santovka–Turovce ridge

In the Santovka–Turovce Ridge two types of mineral water occur acratotherms and carbon dioxide waters. The natural springs of mineral waters discharge at the intersections of longitudinal and transversal faults. The best known mineral waters occur at Kalinčiakovo, Santovka–Malinovec, Dudince, Slatina and in their surroundings. While the mineral waters in Kalinčiakovo and Malé Krškany are acratotherms of a HCO_3-SO_4-Ca-Mg type with mineralization not exceeding 1 g/l, the mineral waters in the area of Bory–Horné Turovce are carbon dioxide waters of predominantly HCO_3-Cl-Ca-Na and HCO_3-Cl-Na-Ca type, with mineralization ranging from 1.6 to –9.6 g/l. The acratotherms are bound to the Mesozoic carbonates of the Choč–Gemericum Unit and belong to the waters with transitional, carbonate-sulphatogenic mineralization.

The carbon dioxide mineral waters are bound to the Permian and Triassic sediments that are part of the Mesozoic envelope of the Vepor Unit, or to the Badenian sediments.

By chemical composition they can be assigned to three types, the Dudince, Slatina and Santovka types. The Dudince type is represented by the waters tapped in the boreholes S–3 in Dudince, B–3 in Santovka and M–2 in Mačkáš. Characteristically, all have increased temperatures (26.2–33.1 °C) and combined presence of CO_2 (1.23–1.45 g/l) and H_2S (4.7–11.2 mg/l). Their chemical composition is steady, the mineralization ranges between 5.6 and 6.0 g/l), S_1(Cl) (20.1–21.8) and the HCO_3/Cl values range between 2.1 and 3.3).

The Slatina type is represented by the mineral waters in Slatina, by the waters in boreholes M–1 and M–5 in Mačkáš settlement, by the waters in the borehole S–6 in Dudince and by the waters from several sources in Horné Turovce. The temperature of the water is low (7.3–22 °C), the CO_2 content is, in turn, relatively high (0.84–2.16 g/l) and the H_2S occurs only sporadically. The mineralization is unsteady (1.3–7.0 g/l) and the chemical composition is determined by the ratio of mixing of more mineralized waters of the Dudince type with the less mineralized waters from the Quaternary alluvia.

The Santovka type is represented by the waters a boreholes B–4 to B–9, B–11, B–14 to B–1 and from the borehole HG–4. The temperature of waters ranges between 12.1 and 16.0 °C, the content of CO_2 between 1.4 and 2.43 g/l, H_2S may or may not be present. The mineralization is relatively steady (2.4–6.5 g/l).

Ipeľská kotlina Depression

The carbon dioxide waters of the Ipeľská kotlina depression are bound to the Tertiary–Kiscellian–Egerian (sandy marls, silts-schlieren and sands), Eggenburgian (sands, sandstones, conglomerates), Ottnangian (productive sands), Karpatian (Rzehakia bearing and manganiferous sands) and Badenian (amphibolic sands and pyroclastics) sediments. Chemically, most of them are HCO_3-Ca-Mg types with the mineralization ranging from 0.43 to 2.0 g/l. In most carbon dioxide waters the CO_2 content ranges between 1,1 and 2.0 g/l and sporadically between 0.26 and 0.66 g/l. The temperature of waters ranges between 7 and 18 °C. The yields of small springs are negligible (as much as 0,1l/s), but greater yields, ranging between 1.5 and 6.0 l/s, were also tapped in the boreholes.

Conclusions

The anthropogenic contamination of the waters is of great importance. It is difficult to determine the geogenic portion of contamination of waters instead of dispropotionate investigation detailed ones in the catchment area are necessary, but practically no exclusively geogenically influenced water does exist any more. Even in the most remote regions of the area of study there is a partly of anthropogenically influenced contribution of air pollution.

The most common anthropogenic contamination in the Austrian part of the DANREG area (like in Slovakia and Hungary) are nitrate, chloride, phosphate, sodium and potassium, additionally herbicides and chlorinated hydrocarbons.

Nitrate may occur punctually according to infiltration of polluted water and infiltrates of wastes. Diffuse, larger-area-springs are mainly contaminated by fertilizers in agricultural regions.

Increased values of chlorides may be of geogene nature or can be man-made. In the latter case the contamination may be due to deicing thaw salts along roads, infiltrates of waste deposits or fertilization. Chlorides of natural salt deposits represent geogenic contamination.

The source of phosphate contamination could be sewage and liquid or solid manure. Fertilization can also be responsible for increased phosphate values.

The increased contents of sulfates in the Tertiary hill district south of the Danube are of geogenic nature (evaporites).

Sodium and potassium: Increased values of both elements may be of geogenic nature. The increased values of potassium may be due to leaching of potassium fertilizer or wine residues. If there is contamination by manure, sodium and potassium values are increased together with chlorides, but the values of potassium are higher than those of sodium. In non polluted waters the sodium content is higher.

Atrazin is used as herbicide for the cultivation of corn, apples and for wine-growing.

It has to be concluded that injuries of the extended groundwater resources in the Quaternary basin sediments are mainly influenced by herbicides and fertilizers used in agriculture and by waste disposal.

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