

Changes in groundwater supply and consumption in Vilnius in the twentieth century

This paper describes the development of the centralised water supply system in Vilnius. The system of groundwater abstraction has been based exclusively on the exploitation of numerous aquifers. The changes in the volume of abstracted and of supplied and used groundwater throughout the 20th century are emphasised. In general, the abstraction of groundwater was in accordance with the urban and demographic development of the city. In the early period until the middle of this century, industrial capacity was the main factor limiting the use of groundwater in Vilnius. Later on an increase was influenced by an essential reconstruction of the water economy and the construction of new well fields in Vilnius and its surroundings. Since 1967 only the population growth has affected the growth of groundwater consumption. The industrial consumption has been stable, approximately 45,000-50,000 m³ per day. Some groundwater quality problems relating to the increasing exploitation of aquifers are discussed.

Santrauka. Straipsnyje apžvelgiama požeminio vandens išgavimo, naudojimo, centralizuotos vandens tiekimo sistemos vystymosi raida 20-o amžiaus bėgyje. Požeminio vandens vartojimas yra tiesiogiai susijęs su socialiniais ir demografiniais miesto vystymosi rodikliais. Amžiaus pirmoje pusėje požeminio vandens suvartojimo tempai buvo ribojami pramonės pajėgumų. Po II-o Pasaulinio karo, sparčiai vystantis pramonės įmonėms, didėjant žmonių skaičiui, geriamo vandens vartojama vis daugiau, todėl ištvalgomos ir steigiamos naujos vandenvietės. Pastaraisiais dešimtmečiais, pramonei tiekiamas vandens kiekis svyruoja apie 45 000-50 000 m³ per dieną, realizuojami požeminio vandens kiekiai priklauso tik nuo demografinių rodiklių.

Straipsnyje analizuojamos ir geriamo vandens kokybės problemos, susijusios su didele požeminio vandens išteklių slūgsojimo sąlygų įvairove.

INTRODUCTION

Vilnius, the capital of Lithuania, was founded and has flourished at the confluence of the Neris River and the Vilnia River. The second river is much smaller than the first one (catchment areas at the confluence are 14,592 km² and 623.5 km² respectively) and the diminutive form of its name - the Vilnelė River - is popular too. Vilnius is rich in water resources: the total annual run-off of the rivers amounts to 3.5 km³ per year and the average annual supply of renewable surface water is about 6,000 m³ per year per person. These amounts are high on the world scale [8]. Vilnius is 100% dependent on groundwater. This situation is common in Lithuania, although in some cities, for example Kaunas and Klaipėda, today artificial groundwater is also used. This is in contrast to the situation in some European cities, for example Stockholm, that are exclusively dependent on surface water [1].

Vilnius is in an excellent position in terms of groundwater resources. The Neris River Valley stores a huge volume of shallow groundwater and drains six deeper confined aquifers. The Quaternary geological formation in the Neris River Valley is forty to sixty metres thick and productive aquifers capable of holding large quantities of groundwater take up 50-100 % of the strata [5]. Moving towards the river the depth of the water table decreases and the total discharge of aquifers increases. For that reason, the

first centralised groundwater well fields were placed near the confluence of the Neris River and the Vilnia River in the historical centre of Vilnius.

This paper concentrates on the chronological and spatial dynamics of the abstraction and consumption of groundwater resources throughout the 20th century in the context of the expansion of Vilnius. Some problems concerning drinking water quality are also discussed.

GROUNDWATER USE BEFORE WORLD WAR II

Lithuanians have a long tradition of using groundwater for drinking. Country people experienced that spring water was always clean and tasty, compared to the changeable and unpredictable surface water flowing in rivers.

The social and economic development of Vilnius has been related always to the use of groundwater. Since the 16th century the city has had a gravitational water supply system from the natural springs of Vingriai, Zupronys and Ausros Vartai [4]. Water from these springs spurted out and was conducted by open canals and wooden pipes down into the centre of Vilnius to the houses of the prosperous dwellers. The capacity of the water supply system was approximately 1,500 m³ per day. In addition to some public wells in the city, there were many private wells whose number fluctuated, depending on the social and political situation (occasionally the city water supply system did not function).

By the end of the 19th century about 150,000 people lived in Vilnius. At that time Vilnius was a major industrial

¹Vilnius University, Department of Hydrology & Climatology, Ciurlionio str. 21/27, 2009 Vilnius, Lithuania. Tel/Fax +370 2 236362, E-mail kestutis.kilkus@gf.vu.lt and jurgita.peciuraitė@gf.vu.lt

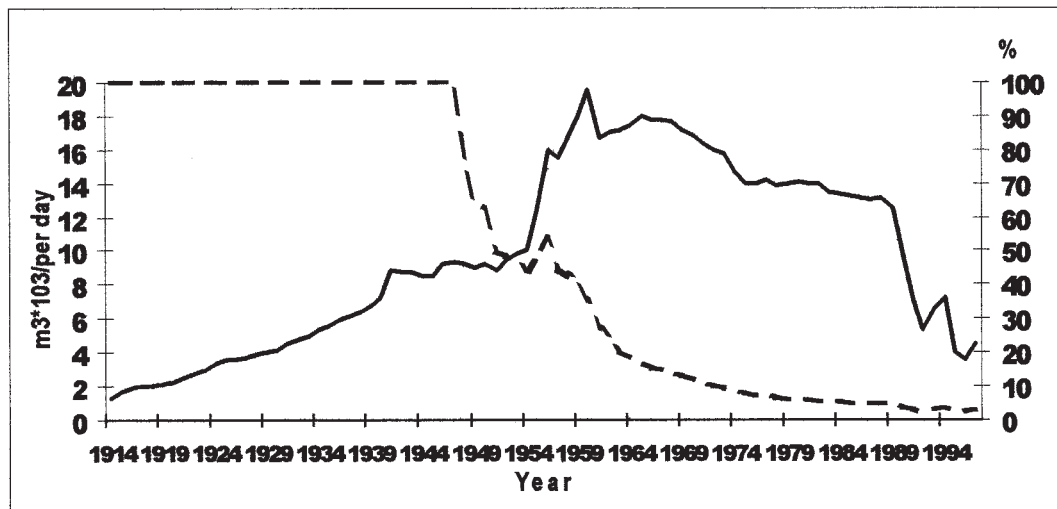


Figure 1. The groundwater output of the Sereikiskes well field since 1914 (solid line) and its percentage of the total amount of the water supply of Vilnius (dashed line)

city in the Russian Empire. Not only the food industry, but also tanneries, wood and metal processing factories and breweries were developed at a great pace. Simultaneously the entire water supply system in Vilnius was reorganised. Reservoirs were built to accumulate water from the above-mentioned springs. Wooden pipes were replaced by cast iron pipes.

Due to an increasing drinking water demand, at the end of the 19th century artesian wells were drilled. However, the authorities in Vilnius had to decide whether to develop the water supply system on the basis of groundwater or surface water. The choice was predetermined by the old Lithuanian tradition of treating the groundwater as the only suitable water source for drinking. Engineer E. Simanski had made an alternative design to use the Neris River as the source of drinking water in 1902, but his plan was never realised. The possibilities of using surface water were never discussed seriously in later years and they disappeared completely when the industrial districts were enlarged and the river water became polluted.

In the plan made by the German hydrotechnician O. Smreker, which was implemented in 1909, groundwater was the only source of raw water. The first centralised groundwater well field (Sereikiskes) was drilled in the Vilnia River near the old town. The supply of drinking water increased from 2,000 m³ per day in 1914 to 9,000 m³ per day in 1947 [12]. The role of public wells began to decrease after

1914. However, Vilnius's citizens continued to use well water until recently.

Sereikiskes remained the only well field until the 1940s (Figure 1). After WW I, when Vilnius became a part of Poland, the development of a central system of water supply and sewerage was almost stopped. Until 1947 the main factor limiting the use of groundwater was a technical one, that is the industrial capacity of the water supply system itself. The total length of the network was only 51 km in 1931, and many wells were providing drinking water to suburban areas. Obviously actual groundwater consumption in Vilnius was much greater than that represented in official statistical reports.

WATER SUPPLY SYSTEM SINCE WW II

After the Second World War, the destroyed city, including the factories and the water supply system, was almost completely rebuilt and/or reorganised. A total of 82 km of cast iron pipes were added to the total network of the water supply system. Water consumption started to increase significantly in the post-war period (Figure 2). In 1947 the second groundwater well field in Vilnius was taken into use, located also in the Vilnia River Valley.

It became clear after the construction of the Sereikiskes well field that certain quantities of surface water pass into it along the Vilnia River banks at times of high flows and that

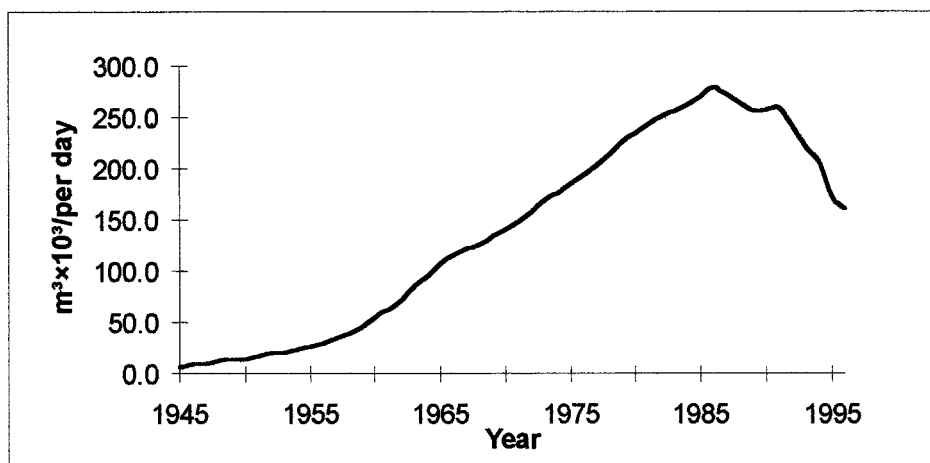


Figure 2. The volume of groundwater abstraction in Vilnius after the Second World War.

Table 1. Groundwater well fields in Vilnius in 1914 - 1998.

Well field	Beginning of exploitation	Groundwater resources, *10 ³ m ³ per day	Number of bore-boles	Area of well field, ha
Serekiskes	1914	unconfirmed	15	2.1
Tupatiskes	1947	unconfirmed	30	18.4
Vingis	1962	30	13	6.0
Zem. Paneriai	1962	unconfirmed	13	2.2
A. Paneriai	1964	10.1	11	5.6
Trinapolis	1965	26	15	6.2
N. Vilnia	1966	22	20	22
Bukciai	1969	12	18	4.6
Turniskes	1969	15	10	2.6
Jankiskes	1970	30	28	18
Smelyne	1971	18	12	18.2
Verkiai	1971	7.3	7	9.5
Viriai	1976	40.5	31	13.7
Peciukai	1981	26.1	20	18.4
Nemencine	1984	52.2	43	40.8
Puckoriai	1987	unconfirmed	8	5.4
Karveliskes	1987	17.4	13	15
Pagiriai	1989	101	17	63

the groundwater mined through the bore-boles should be chlorinated. This was done for the first time in 1941. In 1950-1960, the total amount of mined groundwater increased rapidly from 14,600 to 55,300 m³ per day (Figure 2). [12].

In 1960s as many as seven new groundwater well fields were opened (Table 1).

All the abstraction sites except one were opened in Vilnius during Soviet rule. In this time Lithuania's economy had to cope with unrealistically high projected growth rates. It was therefore more important for hydrogeologists to provide large quantities of groundwater than to secure its high quality [2].

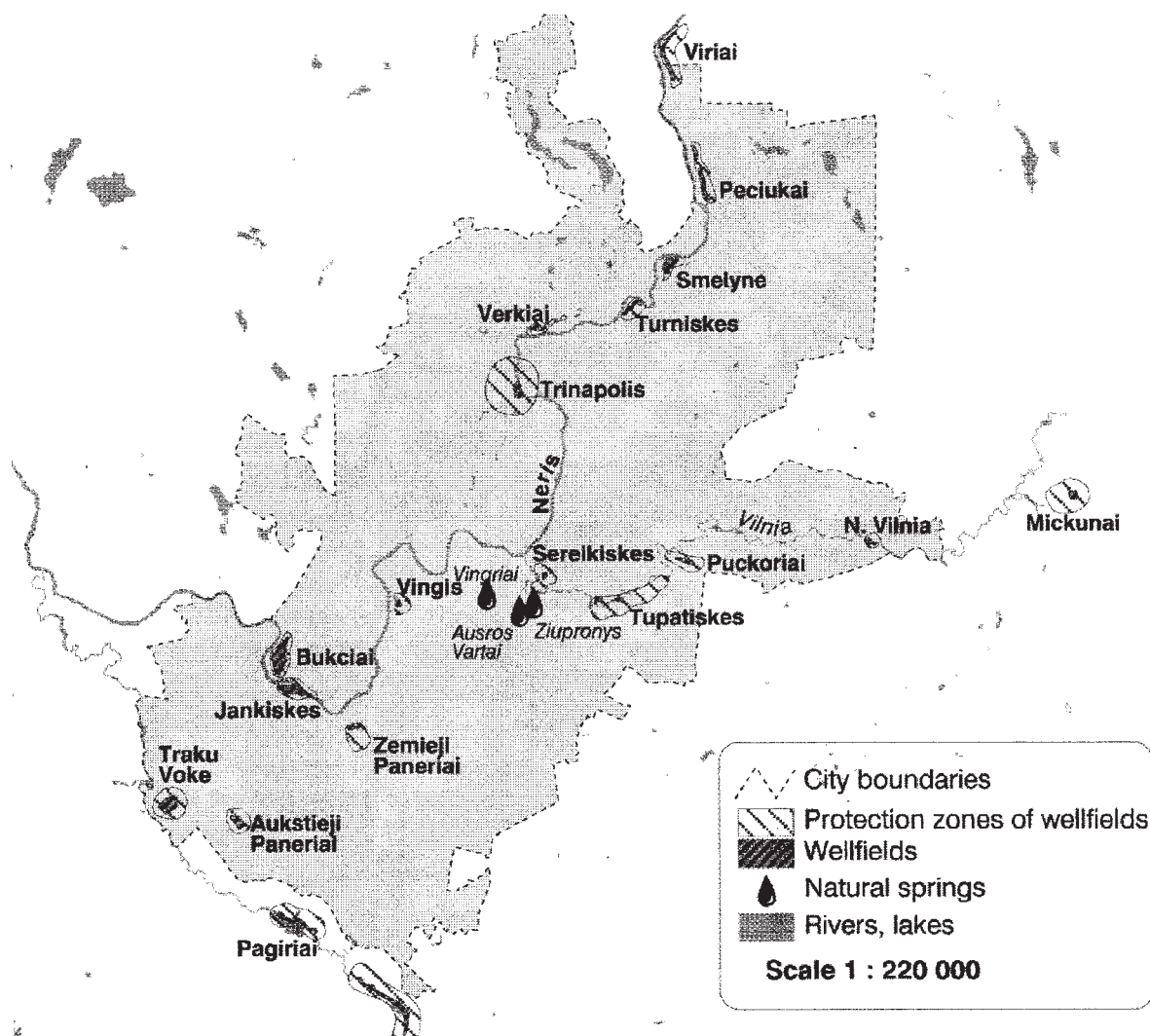


Figure 3. Well fields and the main natural springs of Vilnius.

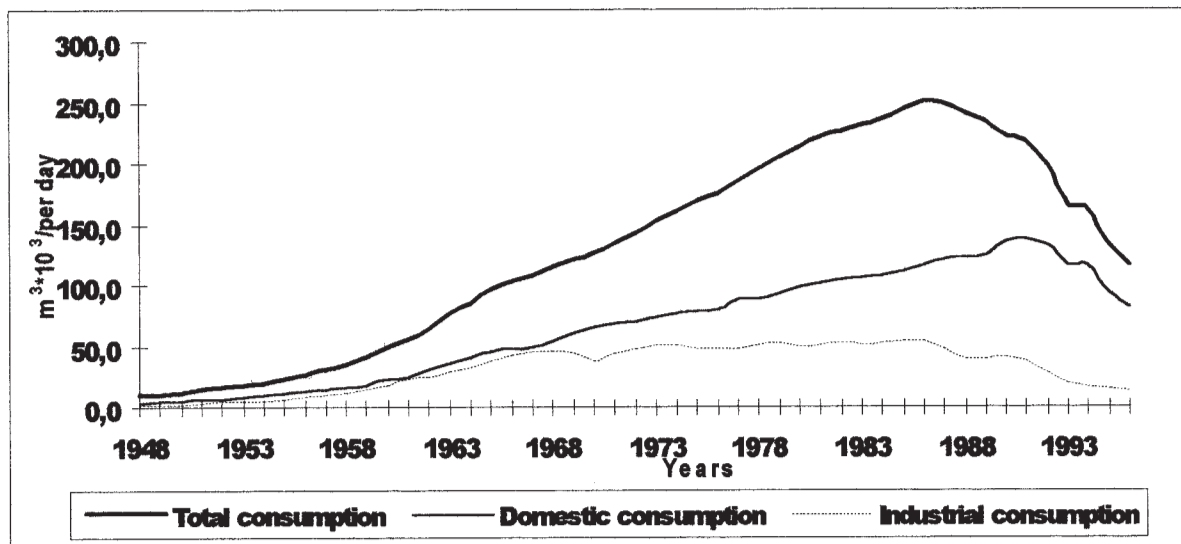


Figure 4. Total, domestic and industrial consumption of groundwater in post-war Vilnius

WATER CONSUMPTION

In general, the abstraction of groundwater (Figure 2) as well as its consumption (Figure 4) in Vilnius through the 20th century was in line with both urban and demographic indexes (Figure 5). Lately it has decreased, although new effective well fields have been taken in use.

In the post-war period, the total consumption of groundwater increased (from well fields). However, the relative water supply (the ratio of the water supply per person) remained low until the 1960s (Figure 6; statistical data available only for the centralised water supply system). Later on there was a break, influenced by an essential reconstruction of the water economy and the exploitation of new well fields. Since 1967, only demographic factors have stimulated the growth of groundwater consumption in Vilnius, as industrial water consumption has not changed during the last two decades and has remained approximately 45,000–50,000 m³ per day (Figure 4).

However, even these needs were also unrealistic. During Perestroika (since 1985), more advanced effluent control systems and effluents charges were implemented. Consequently industrial water use has decreased rapidly. Later this tendency became stronger, due to industrial stagnation and increasing water prices. Domestic water

consumption started to decline noticeably on both absolute and relative scales since 1990–1991. This change took place because of cost-based pricing.

In future Vilnius may rely on groundwater resources because aquifers located in the Upper Perm geological strata hold large groundwater reserves. The exploitation of these aquifers depends on the future needs of Vilnius. According to hydrogeological studies, the total groundwater resources in the environs of Vilnius amount to 388,000 m³ per day. They correspond to the estimated water needs of the city in 2010 [11]. We believe that this figure is an overestimation that reflects the narrow interests of hydrogeological companies rather than the sustainable development of the city. It is clear by now that the price of water will rise significantly in the future. Hence the use of water will continue to decrease. In case more water is needed, we suggest that surface water should be used in some industrial technologies and in city sanitation.

GROUNDWATER QUALITY

As mentioned above, the availability of groundwater in Vilnius and the surrounding area is adequate, due to favourable geological and hydrogeological conditions. Most

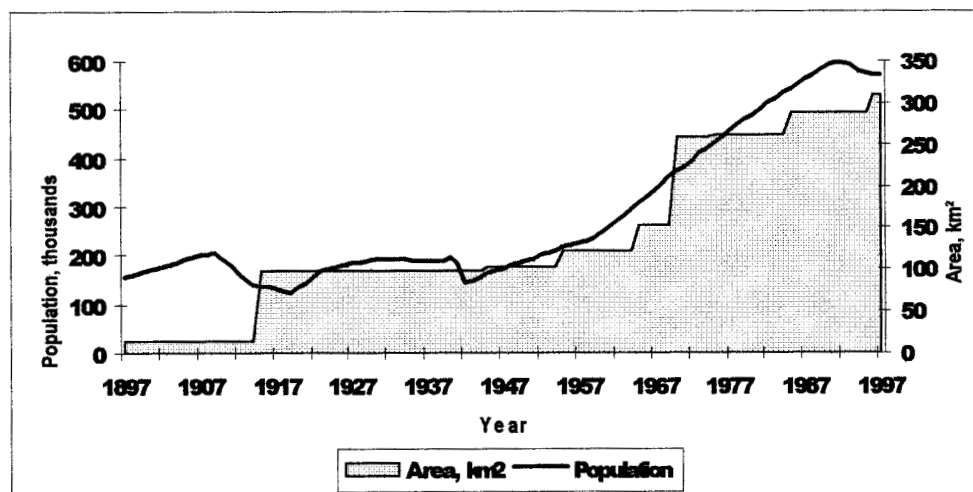


Figure 5. Changes in both Vilnius area (area chart) and population (solid line) through the 20th century.

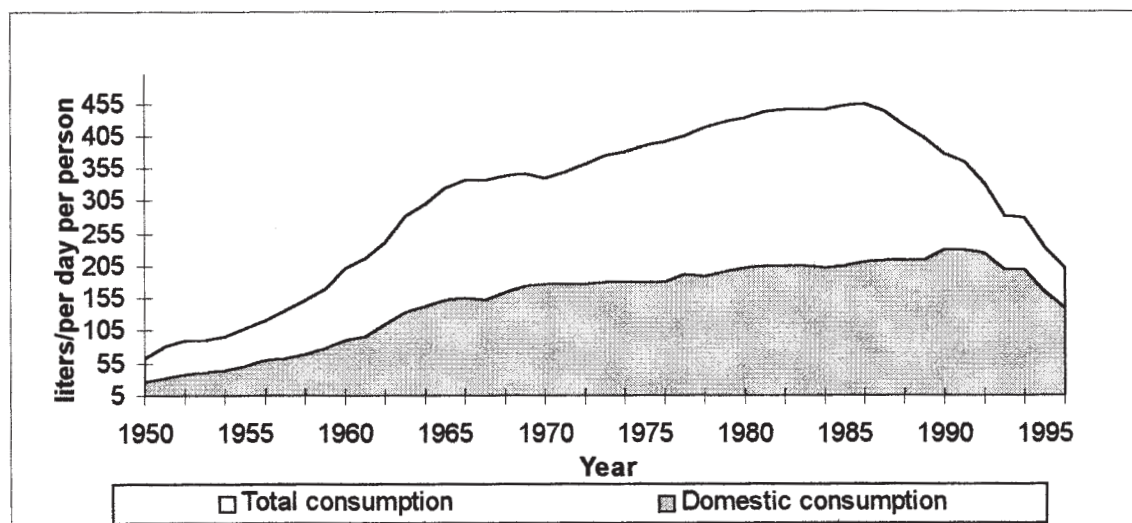


Figure 6. Changes in relative water supply per person in Vilnius during the post-war period.

water stored in the ground comes from residual precipitation at the surface, infiltrating into the soil and percolating downwards through the porous layers.

The quality of groundwater varies due to the hydrogeology of the well fields. For instance, the Zemiejai Paneriai well field mines shallow groundwater from an unconfined aquifer related to the buried old valley, and the Jankiskes well field pumps out the Neris River water infiltrating into the alluvium of the valley. Some well fields, such as Turniskes, Smelyne and Peciukai, are located in intermorainic confined aquifers [5].

The first groundwater well field was established in the centre of Vilnius. The bore-holes were spread out along the Vilnia River banks. For almost four decades this site ensured the city's needs for drinking water of good quality. There was only one case when it was prohibited to use water from this well field. In spring 1941 the Vilnia River overflowed and polluted the bore-holes of the Sereikiskes well field. The authorities of the city did not take countermeasures in time, consequently many people died because of enteric fever and a dysentery epidemic. Although this well field still serves the city today, its future is uncertain. The complicated sanitary-hygienic conditions of the surrounding area and increased concentrations of iron in the groundwater are causes of doubt about its further use. Very similar problems exist in the Turniskes well field, which is also located in the Vilnia River Valley.

The overexploitation of aquifers located in the Quaternary strata has led to a regional depression, between five and thirty-five metres deep and with an area of 250 km². That is why the discharges of groundwater are decreasing

and, on the other hand, the percolation of surface water from the Neris River into the aquifers is increasing. These processes have reduced the quality of groundwater significantly in all well fields located near the Neris River banks.

In 1960-1964 three new groundwater well fields were constructed rather rapidly, in response to the rapid industrial growth at that time. There was no question about what water - surface water or groundwater - was better to use. Groundwater resources had been prospected already and financing was not a problem either, because money for the research and development of the water supply was being provided by Moscow. New well fields started to exploit shallow, unconfined aquifers, which were very sensitive to pollution.

The quality of drinking water in Vilnius can be regarded as good according to various standards (Table 2). National drinking water standards have been proposed, but they have not yet become official. Therefore, the Soviet water quality standard is still in use in Lithuania up to now.

High concentrations of iron and manganese in the groundwater are the main problem concerning the drinking water quality in Vilnius. This water is bad-tasting, brownish and turbid. The large concentrations of these ions are due to the anaerobic environment of mining aquifers.

The mean values of the iron concentrations of Pagiriai, Tupatiskes, Naujoji Vilnia, Sereikiskes, Turniskes and Karveliskes well fields exceed the maximum value of water quality standards (0.3 mg/l). They can even exceed 1 mg/l. Mean concentrations of manganese exceed the water quality standard in ten well fields, the situation is worst in the

Table 2. Groundwater quality indexes in well fields of Vilnius and their value according to three different standards.

Indexes of water quality	Well field	Soviet Standard GOST - 2874-82	World Health Organisation	Proposed Lithuania Standard
Total iron, mg/l	0.25-2.0	0.3	0.3	0.3
Manganese, mg/l	0.002-0.2	0.1	0.1	0.1
Nitrate, mg/l	0-2.2	45	45	50
Sulphates, mg/l	10-85	400	500	

Karveliskes and Turniskes fields. Increased concentrations of chlorides, sulphates and nitrogen may be related to pollution and wastewater discharges.

To eliminate the metal ions, plans have been made to build a water treatment plant. The quality of drinking water changes in pipes on the way to consumers. Since 1941 the water has been chlorinated to prevent bacterial growth. Some basic branches of the water network run 27 km from the well fields to the city. These main pipelines were laid between 1965 and 1976. The cast iron water pipes have already disintegrated and the corrosion process is continuing. Today the total length of the water supply network is 1,030 km. The water company must repair about two breakages per km of the water supply system annually.

As mentioned, the citizens prefer groundwater, especially the water from natural springs. There are many natural springs in the city and its surroundings. Such water has a good taste and low concentrations of iron and manganese. On the other hand, bacteriological pollution is substantial because of urbanisation and pollution.

There are many problems in the supply and use of the groundwater. However, the citizens of Vilnius can feel fortunate in having such a treasure of fresh good water below their feet.

CONCLUSIONS

Due to the old tradition, groundwater has been the only source of raw water in Vilnius. The development of the water supply system has been affected not only by local groundwater abundance, but also by the changing social and political fortunes of Vilnius, which was a large industrial city in the Russian Empire, a provincial town in Poland, the industrialised capital of the Lithuanian SSR, and is presently the cultural, political, and business centre of Lithuania. The natural springs and shallow aquifers were exploited first as a water source. In general, the output of groundwater as well as its consumption throughout the last century were in accordance with both urban and demographic indexes of the city of Vilnius. In 1914-1947 a centralised system was taken into use, and the Sereikiskes well field started to supply water for the city. The 1960s were especially important to Vilnius's water supply system because seven new water supply stations were built. The total output of groundwater in Vilnius reached its maximum of 280,000 m³ per day in 1986 and has decreased since then, despite the new efficient production facilities. This shift was due to water conservation measures adopted by industry during Perestroika as well as to the introduction of cost-based pricing in the 1990s.

In earlier times the main water quality problems were related to the pollution of wells caused by leaks in the

waste collection system. Nowadays, the main quality problems are high iron and manganese concentrations, in addition to the risk of microbiological pollution in some shallow aquifers.

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