

## Groundwater budget and quality in Vilnius wellfields studied by isotope methods

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Groundwater quantity and quality depends upon the sources of its budget formation. If we know the concentrations of certain specific indicators in the sources, we can calculate their input into the budget of abstracted groundwater. Because most of those indicators are neither specific nor stable, hydrochemical studies of Vilnius wellfields were supplemented by some isotope (helium He, tritium  $^3\text{H}$ , radiocarbon  $^{14}\text{C}$ ) methods. Results of isotope studies show that only the He-method is adequate for identification of saltwater intrusion and calculations of groundwater budget in Vilnius wellfields. In Vilnius wellfields this input was found to vary within 9–10% up to 30–35%. Almost the same result was obtained using the hydrochemical Cl-method and groundwater simulation. Atmospheric radiocarbon and tritium are suitable only for indicating surface water inflow.

**Key words:** Vilnius, wellfield, groundwater, isotopes

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### INTRODUCTION

Groundwater budget and chemical analyses show that the main features of the evolution of groundwater chemistry formation in operated wellfields are determined by natural hydrogeological conditions and human impacts (Klimas, 1994; 2006). Different combinations of these factors determine the chemical composition of groundwater in wellfields of Vilnius (Klimas, 1995; Klimas, Plankis, 2003). Therefore, groundwater budget items and water quality from those wellfields should be assessed first.

However, the problem is that groundwater quality indicators in those groundwater budget items are often not specific (e. g., chlorides) or not stable (e. g., sulphates):  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  ions are typical indicators not only of saltwater intrusion, but also of groundwater contamination (Klimas, Gregorauskas, 2002). Of course, there are typical indicators of groundwater pollution, e. g., nitrates, which can enter aquifers only from land surface. But the concentration of nitrates rapidly decreases in subsurface, because  $\text{NO}_3^-$  actively participates in redox processes (Klimas, 2002). Therefore, other indicators of groundwater budget items are necessary. Certain isotopes may serve as such indicators.

The object of our research was Vilnius city wellfields. The hydrogeological conditions of the Vilnius wellfields have been well investigated because the majority of them have been explored in detail and the groundwater resources of this area have been cal-

culated and modelled several times (Klimas, 1995; Klimas et al., 1995; Bendoraitis et al., 2003; Klimas, Plankis, 2003; Klimas, 2006). However, extensive studies of radioisotopes in Vilnius wellfields in 2005–2006 were organized for the first time. The crucial stimulus was essential support of the studies, offered by “Vilniaus vandenys” Ltd exploiting these wellfields.

### METHODS

There are two types of wellfields supplying the Vilnius City with drinking water pumped from the aquifers comprising the Quaternary groundwater system: 1) located nearby the rivers; 2) located farther from the rivers (Klimas, 1995; 2006). The main difference is the origin of the water replenishing groundwater withdrawals: in the first case, pumped aquifers are more or less recharged by river water (Klimas et al., 1995).

Nevertheless, groundwater simulation shows that the main source of groundwater resources taken from Vilnius wellfields is fresh groundwater flow from the hills surrounding the city. This flow crosses the central part of the city and moves towards the Neris River (Бендорайтис и др., 2003). Along all this way, the pumped aquifer is permanently recharged by shallow groundwater which is noticeably polluted in the urbanized part of the Neris River valley. The main indicators of pollution are sulphates, chlorides, unoxidized organic substances, nitrates and ammonia

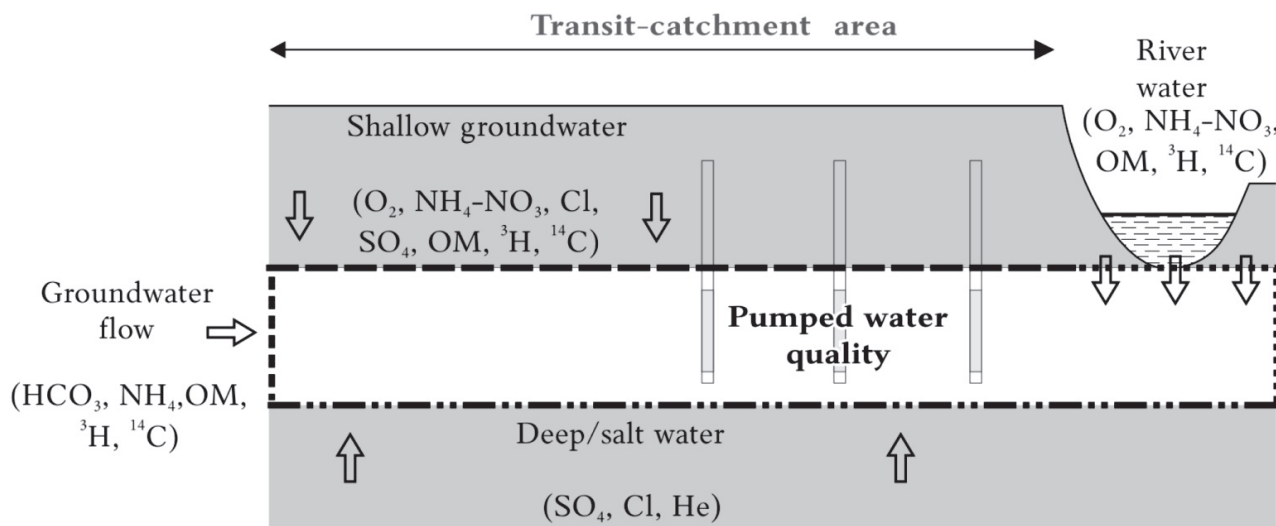


Fig. 1. Conceptual model of groundwater chemistry formation in Vilnius wellfields (OM – organic matter)

1 pav. Konceptualus požeminio vandens cheminės sudėties formavimosi Vilniaus vandenvietėse modelis (OM – organinė medžiaga)

(Klimas, Gregorauskas, 2002). Flowing towards the Neris River, the pumped aquifer is more and more intensively recharged by the even deeper Permian and Devonian aquifers. This deep water is not everywhere fresh. Intruding into the pumped aquifer, it contributes some sulphates, chlorides into the fresh water flow. Lastly, one more groundwater budget item have wellfields of the 1<sup>st</sup> type, where pumped aquifers are recharged by river water, which also yields some sulphates, chlorides, unoxidized organic substances, nitrates and ammonia into the abstracted water mixture.

That is why pumped water quality in Vilnius wellfields fairly varies (Klimas, 2006). Because certain characteristic ions (e. g., sulphates, chlorides) are present in various sources recharging pumped aquifers, it is rather difficult to identify those sources and to estimate their contribution into the resulting drinking water quality (Fig. 1).

Certain isotopes seem to be a good tool for the determination and separation of those sources; even from a simple scheme (Fig. 1) we can see that a unique source of m  $^3\text{H}$  and  $^{14}\text{C}$  is surface and shallow groundwater, but the exclusive source of He is deep water.

Isotope methods in groundwater studies in Lithuania have a 40-year-long history (Juodkazis et al., 1995). It is well known that three isotopes, tritium ( $^3\text{H}$ ), radiocarbon ( $^{14}\text{C}$ ) and helium (He), are best suitable for this purpose.

The first of them,  $^3\text{H}$ , is a radioactive isotope of hydrogen. Because hydrogen (i. e.  $^3\text{H}$  also) is part of the water molecule  $\text{H}_2\text{O}$  and flows together with water, tritium is an ideal tracer for groundwater flow studies. The advantage of another, He, method is the fact that helium does not participate in chemical reactions. But the main merit of those two isotopes is their unique source:  $^3\text{H}$  is produced in atmosphere from nitrogen atoms impacted by cosmic or A-bomb neutrons. Helium is a product of the radioactive decay of U, Th and other radioactive metals present in the Earth's crust. Therefore,  $^3\text{H}$  is an ideal indicator of surface and shallow groundwater input into a pumped aquifer, and He unambiguously shows deep / saltwater intrusion into a freshwa-

ter aquifer. When deep freshwater aquifers are studied, the radiocarbon ( $^{14}\text{C}$ ) method is also popular (Juodkazis et al., 1995; Mažeika, 2002).

But  $^3\text{H}$  is an unstable, short-age isotope of hydrogen: its half-life is only 12.34 years. It means that tritium is completely absent in 50-year-old groundwater. Because the recharge time of confined fresh water aquifers is usually significantly longer,  $^3\text{H}$  simply does not enter those aquifers. Moreover, the main source of high concentrations of this isotope in the atmosphere (2000–3000 TU, tritium units) was A-bomb tests banned in 1952–1963. Therefore, the present day concentrations of  $^3\text{H}$  in precipitation hardly exceed 5–17 TU (Juodkazis et al., 1995). All these facts complicate the interpretation of small and unstable concentrations of  $^3\text{H}$  in fresh groundwater; e. g., a low concentration of  $^3\text{H}$  can show that the water is old if the initial concentration was high, or it is young, but the entering concentration of the isotope was low. Nevertheless, the  $^3\text{H}$ -method is still popular in hydrogeological studies and models (Mažeika, Petrošius, 1994; Jakimavičiūtė et al., 2000; 2002).

Radiocarbon  $^{14}\text{C}$  is also produced in the atmosphere. Like  $^3\text{H}$ , it enters groundwater aquifers together with precipitation and river water. The main advantage of the  $^{14}\text{C}$ -method is a comparatively long half-life (5720 years) of this element. Therefore, radiocarbon can be used for measuring groundwater age up to 50 000 years. But measuring the radiocarbon age of groundwater is rather sophisticated, because  $^{14}\text{C}$  is derived from the dissolved carbonate, part of which can be very “old” (e. g., dissolved “old” soils) or very “young” (e. g., destructed “young” organic matter). This circumstance may be fraught with certain mistakes: usually the radiocarbon age of groundwater is older (rarely smaller) than its real age (Mažeika, 2002). Nevertheless,  $^{14}\text{C}$  can be used for the identification of groundwater recharge by surface water, because surface water is always younger than groundwater.

Another isotope, helium (He), was also successfully used for the identification of deep/ salt water intrusion into freshwater aquifers, both in Lithuania and abroad (Июдказис, Тибар, 1989). Highest concentrations of He (0.01–0.15 ml/l) were detected in

the Nemunas River valley (in Druskininkai) where salt water, enriched with He, rises from the crystal basement to the land surface (Mokrik et al., 2002). In other places He concentrations are considerably less and do not reach  $10^{-3}$ – $10^{-4}$  ml/l. Nevertheless, even very small concentrations of He are easily and reliably detected in groundwater (Mažeika, 2002).

Because He concentration in fresh groundwater should be proportional to the input of salt water into the water mixture, the He-method can be controlled by the hydrochemical method: it is well known that sulphates and chlorides are good indicators of saltwater intrusion (Klimas, Gregorauskas, 2002). When the source of these anions is not evident or not unique (e. g., pollution and salt water intrusion), the origin of the anions can be detected from the  $[\text{SO}_4^{2-}] : [\text{Cl}^-]$  (meq/l) ratio, because this ratio in a particular source (e. g., in brine) is rather constant (Klimas, 2006).

Items of groundwater budget can be easily defined, invoking simple equations of groundwater balance. For example, the concentration of a certain isotope or a characteristic ion  $C_{\text{mix}}$  in the total volume of pumped water  $Q_{\text{mix}}$  will be equal to the sum of product volume and the concentration of every item of the mixture (Klimas, 2006):

$$C_{\text{mix}} = [(CQ)_{\text{gwf}} + (CQ)_{\text{sgw}} + (CQ)_{\text{sw}} + (CQ)_{\text{riv}}] / Q_{\text{mix}}, \quad (1)$$

where  $(CQ)_{\text{gwf}}$  means groundwater flow towards the wellfield,  $(CQ)_{\text{sgw}}$  is shallow groundwater input,  $(CQ)_{\text{sw}}$  and  $(CQ)_{\text{riv}}$  is saltwater and river water input.

## RESULTS

Isotope studies in Vilnius wellfields were organized in 2005–2006. The studies started from salt water intrusion identification in the Nemenčinė, Viriai, Vingis, Jankišškės, Bukčiai and Sereikiškės wellfields where certain symptoms of this phenome-

non had been known (Klimas, 1995; Klimas, Plankis, 2003). Supposing that the highest concentrations of sulphate ( $\text{SO}_4^{2-}$ ), chloride ( $\text{Cl}^-$ ) and helium (He) are indicators of saltwater intrusion, in 2005 groundwater samples were taken from the wells producing more mineralised water. Simultaneously samples of raw water (producing well) mixture were taken. In 2006, saltwater intrusion symptoms were studied in other wellfields located in Ž. Paneriai, Pečiukai, Pagiriai, Trakų Vokė and N. Vilnia. Instead the poorly informative  $^3\text{H}$ -method, in 2006 the  $^{14}\text{C}$  method was tried.

Considering the fact that the unique source of tritium is precipitation, we expected that the  $^3\text{H}$  method could show the input of shallow groundwater and surface water into the budget of pumped water of the wellfields studied. The results of those tests are shown in Table 1.

Raw groundwater mixture for radiocarbon detection in 2006 was sampled at the same wellfields where tritium concentrations had been analysed in 2005. The results of analyses are provided in Table 2.

Supposing that He concentrations can be higher in more mineralised groundwater characterized by increased concentrations of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  ions, and assuming that those ions in the wellfields together with He rise from the deep aquifers into a pumped one, we sampled the wells producing water with high concentrations of sulphates and chlorides. Also a raw water mixture was sampled here. The results are presented in Table 3.

Interpretation of the measured concentrations of He,  $^3\text{H}$ ,  $^{14}\text{C}$  and certain ions needs comments which are provided in the next chapter.

## DISCUSSION

The highest concentrations of  $^3\text{H}$  in groundwater, sampled from Vilnius wellfields did not exceed 6–7 TU (Table 1) and were almost as low as the present concentrations of this isotope in

Table 1. Tritium concentration in raw groundwater of some Vilnius wellfields

1 lentelė. Tričio koncentracijos kai kurių Vilniaus vandenviečių gręžinių neapdoroto vandens mišinyje

Wellfield	Sampling data	$^3\text{H}$ volum. activity		Measurements bias, $\pm\text{TU}^*$	Water t, $^{\circ}\text{C}$
		TU*	Bq/l		
Bukčiai	05. VII. 2005	7.1	1.8	0.8	8.4
Jankišškės	05. VII. 2005	6.4	2.1	0.8	8.6
Viriai	04. VII. 2005	6.2	2.0	0.7	8.0
Nemenčinė	04. VII. 2005	4.4	2.5	0.5	8.2
Vingis	04. VII. 2005	2.7	1.8	0.3	10.2
Sereikiškės	04. VII. 2005	<dl**	0.9	<dl**	9.8

\* Tritium units; \*\* – Below detection limit.

Table 2.  $^{14}\text{C}$  activity and assumed age of raw groundwater from some Vilnius wellfields, 2006

2 lentelė.  $^{14}\text{C}$  aktyvumas ir sąlyginis vandens amžius kai kurių Vilniaus vandenviečių gręžinių vandens mišinyje 2006 m.

Wellfield	$^{14}\text{C}$ activity, pmC	Bias of the experiment, pmC ( $\pm 1\sigma$ )	Assumed (not corrected) $^{14}\text{C}$ age: year BP starting from 1950
Sereikiškės	42.4	0.5	6890
Bukčiai	59.2	0.7	4210
Vingis	65.2	0.7	3440
Jankišškės	66.4	0.7	3290
Viriai	67.5	0.7	3150
Nemenčinė	98.5	1.2	120

Table 3. Concentrations of helium (He) and indicator ions in groundwater of some Vilnius wellfields where salt water intrusion is visible  
3 lentelė. Helio (He) ir indikatorinių jonų koncentracijos Vilniaus vandenviečių, turinčių mineralizuoto vandens prietakos iš apačios požymių, vandenyje

Wellfield	Well No. mix.*	Sampling data	$\Delta I, \mu A$	He concentration, $10^{-5}$ ml/l	Indicator ions. mg/l and $[SO_4^{2-}] / [Cl^-]$ ratio		
					$SO_4^{2-}$	$Cl^-$	$[SO_4^{2-}] / [Cl^-]$
Viriai	29	14. VII. 2005	48.5	136.2	291	120	2.43
Viriai	2	–	35.0	99.7	210	69.8	3.01
Viriai	mix.*	3. X. 2006	4.7	17.9	96	31	3.10
Nemenčinė	31	–	48.0	134.8	143	175	0.82
Nemenčinė	2A	–	31.5	90.3	103	99.5	1.04
Nemenčinė	7a	22. VII. 2005	6.5	22.8	40.3	34.2	1.18
Nemenčinė	mix.*	14. VI. 2006	4.5	17.4	40.2	25	1.61
Bukčiai	52	VII. 05. 2005	4.0	16.0	52.2	16.4	3.18
Bukčiai	37	–	1.5	9.3	48.9	18.2	2.69
Bukčiai	48	–	1.0	7.9	53.7	13.5	3.98
Jankišškės	11	–	5.5	20.1	57.5	38.5	1.49
Jankišškės	52	09. XII. 2005	3.0	13.3	33.5	35.6	0.94
Jankišškės	44	–	1.5	9.3	66.8	67.4	0.99
Jankišškės	mix.*	14. VI. 2006	1.8	10.1	43.5	38	1.14
Sereikiškės	55	04. VII. 2005	3.0	13.3	67.8	33.4	2.03
Sereikiškės	46	–	1.5	9.3	11.2	3.1	3.61
Sereikiškės	64	14. VI. 2006	0	5.2	53	24	2.21
Sereikiškės	mix.*	–	1	7.9	24	9	2.67
Vingis	17	04. VII. 2005	2.0	10.6	80.7	40.4	2.00
Vingis	22	23. XI. 2005	0	5.2	63.0	67.2	0.94
Vingis	mix.*	14. VI. 2006	0.5	6.6	66	48	1.38
Pagiriai	38	–	2	10.6	18	31	0.58
Ž. Paneriai	3a	–	0	5.2	20.4	4.5	4.53
Pečiukai	12	–	0	5.2	10	5	2.00
T. Vokė	9	3. X. 2006	0	5.2	31	13	2.38
N.Vilnia	24	–	0	5.2	10	3	3.33

\* – Raw water (well water) mixture.

Table 4. Salt water input (%) into the yield of some Vilnius wellfields, calculated by various methods

4 lentelė. Giliau slūgsančio mineralizuoto vandens indėlio (%) į kai kurių Vilniaus vandenviečių debitą nustatymo įvairiais metodais rezultatai

Wellfield	Methods of calculation								
	He method				Hydrochemical ( $Cl^-$ ) method				Model
	$C_{mix}$	$C_0$	$C_{Msw}$	%	$C$	$C_0$	$C_1$	%	%*
Nemenčinė	17.4	5.2	134.8	9.4	25	10	175	9.1	5.5–9.3
Vyriai	17.9	–	136.2	9.7	31	–	120	10.0	–
Jankišškės	10.1	–	20.1	32.9	38	15	67	31	10.2–27.2
Sereikiškės	7.9	–	13.3	33.4	9	3	33	30	–
Vingis	6.6	–	10.6	35	48	40	63	35	–

Notes.  $C_{mix}$ ,  $C_0$ ,  $C_1$  – concentrations of He,  $Cl^-$  in raw water mixture ( $C_{mix}$ ), fresh ( $C_0$ ) and salt ( $C_1$ ) water wells; \* – first figure shows salt water inflow at maximum withdrawal, second figure shows the background situation (wellfields not working).

the precipitation. Therefore, tritium seems to be not suitable for the estimation of groundwater age. Nevertheless, the highest and the lowest concentrations of  $^3H$ , measured in 6 wellfields, differed 2.6 times. Moreover, these concentrations are highest in the wellfields pumping water from water table aquifers recharged by river water (Jankišškės, Vyriai, Nemenčinė) and lowest in the wellfields exploiting confined aquifers (e. g., Sereikiškės wellfield).

Radiocarbon data, as usual, seem to be not very informative. First of all, from Table 2 we can see that the radiocarbon age of water from the Nemenčinė wellfield is very diminutive

(120 years). This is not the true age, because water from the adjacent and very similar wellfield Vyriai is 3350 years old. We can only guess that water from the Nemenčinė wellfield became very “young” due to a certain biological influence, or it was just a laboratory mistake. Controversially, water from the rest wellfields seems to be too “old”, but we have mentioned that radiocarbon age is not the true age of water. Nevertheless, a certain hydrogeological sense can be found even in these data: groundwater from unconfined aquifers (Jankišškės, Vyriai wellfields) is almost twice as young as water from confined aquifers (Sereikiškės, Bukčiai wellfields).

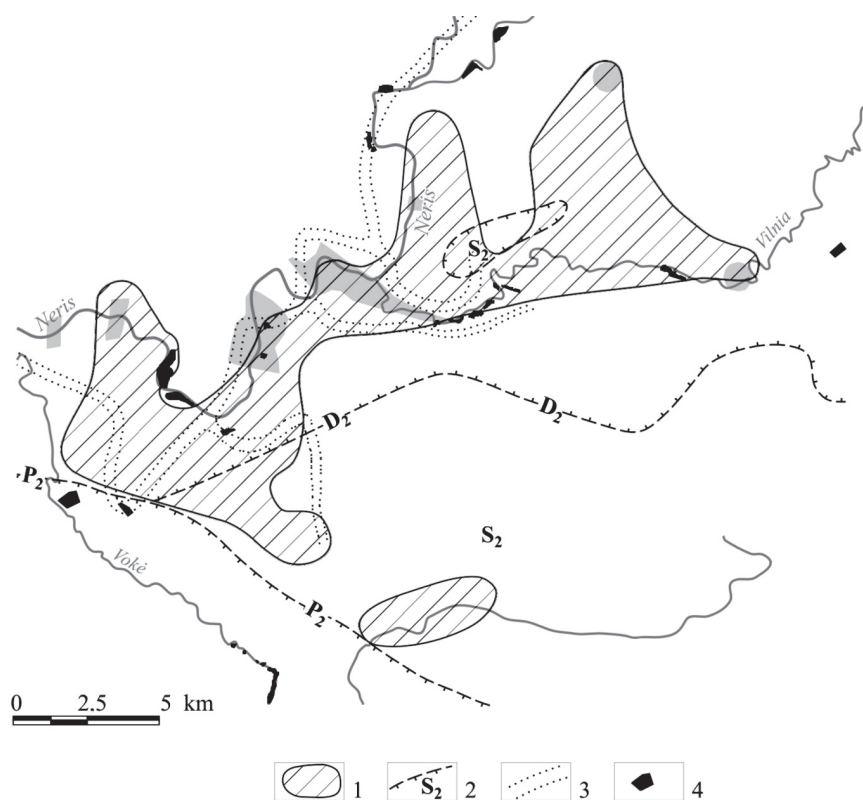


Fig. 2. Sulphate / chloride ratio in pre-Quaternary aquifers in central part of Vilnius (salt water intrusion areas are hatched): 1 –  $[\text{SO}_4^{2-}] : [\text{Cl}^-] < 2$ ; 2 – index of a aquifer; 3 – buried valleys; 4 – wellfields

2 pav. Sulfatų ir chloridų santykis prekvartero sluoksnių vandenyje (sūraus vandens ištakos zonos patamsintos): 1 –  $[\text{SO}_4^{2-}] : [\text{Cl}^-] < 2$ , 2 – vandeningasis sluoksniš, 3 – palaidoti slėniai, 4 – vandenvietės

Very efficient were measurements of He concentrations in separate producing wells and raw water mixtures of Vilnius wellfields. Table 3 shows that the highest He concentrations are 25 times greater than the lowest ones. Moreover, those concentrations are apparently higher in those wellfields and wells where the concentrations of sulphates and chlorides are high, but not always. This discrepancy can be explained by the fact that the unique source of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  – deep salt water – is characteristic only of the Nemenčinė, Vyriai, Pečiukai and Pagiriai wellfields located outside the city. An important source of those ions in the city can be groundwater pollution.

To identify the source of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$ , the above-mentioned  $[\text{SO}_4^{2-}] : [\text{Cl}^-]$  (meq / l) ratio was employed. First of all we tried to find this ratio for water from deep Devonian and Silurian aquifers. A-priori we knew that groundwater from these aquifers is of  $\text{CaSO}_4^{2-}$  type, because the groundwater-bearing beds contain gypsum. Therefore, the  $[\text{SO}_4^{2-}] : [\text{Cl}^-]$  ratio in deep groundwater should be significantly higher than 1: actually it often exceeds 3–5. But such ratio is characteristic only of the wellfields of Vilnius, located at a certain distance from the Neris River valley. The point is that in the centre of the city, in the Neris River valley, groundwater discharges from even deeper Proterozoic and Archeozoic aquifers containing water of Na–Cl type. The above ratio for this water varies 0.18 up to 0.46. Therefore, in the centre of the city, in Devonian and Silurian aquifers, this ratio is also not high – usually less than 1–2 (Fig. 2).

The concentrations of sulphates and chlorides considerably vary in water pumped from Vilnius wellfields. Even more it varies in separate wells of these wellfields (see Table 3). Highest concentrations of those anions are characteristic of the Nemenčinė and Vyriai wellfields located far from the city, where the only source of Cl and  $\text{SO}_4$  ions can be salt water rising from

even deeper aquifers via tectonic faults. In the city, these concentrations are significantly lower.

If increased concentrations of Cl and  $\text{SO}_4$  ions in Quaternary aquifers are related to tectonic faults and deep water, high concentrations of He and Cl,  $\text{SO}_4$  ions should be interrelated. But even from Table 3 data it is obvious that the desired correlation is weak or ambivalent, possibly because groundwater chemistry is formed by several sources (e. g., pollution and salt water intrusion).

Concentrations of He and Cl,  $\text{SO}_4$  ions in groundwater from some wellfields of Vilnius were used for specifying one important item of pumped water budget – salt water intrusion. For this purpose, a simplified equation (1) was used:

$$M_{\text{mix}} = C_{\text{sgw}} \cdot X + C_0 \cdot Y, \quad (2)$$

where  $M_{\text{mix}}$  is the He (or Cl,  $\text{SO}_4$ ) concentration in abstracted water mixture,  $C_{\text{sgw}}$  is the same concentration in salt water (water from the wells producing salt groundwater). Let us admit that  $C_0$  is the background concentration and  $C_0 = C_{\text{sgw}}, C_{\text{sw}}, C_{\text{riv}}$ . Actually, it means that  $C_0$  is the lowest concentration of He, Cl,  $\text{SO}_4$  in pumped wells of a corresponding wellfield. X and Y in equation 2 are part of salt ( $C_{\text{sgw}}$ ) and fresh ( $C_0$ ) water in the abstracted water mixture.

All the data necessary for the budget calculations are available for five wellfields: Nemenčinė, Vyriai, Sereikiškės, Vingis, Jankišškės. These data and calculation results are listed in Table 4. The Table also contains results of groundwater budget simulation, which enabled us to assess the magnitude of deepwater inflow for two North and South, groups of Vilnius wellfields. The maximum pumping rate and the background situation (pre-pumping, natural conditions) were modelled (Бендорайтис и др., 2003).



From Table 4 it follows that the results are surprisingly close. No wonder that the He and Cl methods give similar results, because those two indicators of deepwater intrusion are closely related. But a good result was received also when only Cl-ion was used, because the concentration of another ion, sulphate, participating in redox-reactions is not stable (Klimas, 2002), and the accuracy of SO<sub>4</sub> analysis is always lower.

If we compare results of groundwater budget calculations obtained by the He-, Cl-methods or by simulation, we see that in the last column of Table 4 only the second figure is similar to the He and Cl method results. This difference is easy to explain, because the present pumping rate of Vilnius wellfields is significantly lower than simulated. Moreover, in the Sereikiškės, Vingis, Jankišškės wellfields located in the city, an important source of sulphates and chlorides is not only deep water, but also pollution (Klimas, 2006). Nevertheless, the He- and Cl-methods show that deepwater intrusion in those wellfields today is more significant than pollution.

## CONCLUSIONS

The results of isotope studies organized in 2005–2006 at some Vilnius wellfields show that only the He-method is suitable for groundwater budget and quality assessments. Meanwhile atmospheric tritium (<sup>3</sup>H) and radiocarbon (<sup>14</sup>C) are suitable only for approximate identification of groundwater quality formation sources: as was expected, the <sup>3</sup>H and <sup>14</sup>C age of groundwater from wellfields operating confined aquifers was greater than from wellfields pumping unconfined aquifers recharged by surface water and shallow groundwater. Moreover, due to the objective but significant data bias, the <sup>3</sup>H and <sup>14</sup>C methods are not suitable for groundwater budget calculations.

Because the only source of He is the Earth's crust, the helium method unambiguously shows deepwater intrusion into freshwater aquifers. The He method allows to estimate this intrusion quantitatively and rather reliably. The calculations show that deepwater input varies from 9–10% in the Nemenčinė, Vyriai wellfields up to 30–35% in the Sereikiškės, Vingis, Jankišškės wellfields. Almost the same result was obtained by the Cl method and by simulation.

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Algirdas Klimas, Mantas Plankis

## POŽEMINIO VANDENS BALANSO IR KOKYBĖS TYRIMAI VILNIAUS VANDENVIETĖSE IZOTOPINIAIS METODAIS

### *Santrauka*

Požeminio vandens išteklių kiekis ir kokybė priklauso nuo tų išteklių formavimo šaltinių. Jeigu yra žinomi požeminio vandens kokybės specifiniai rodikliai tuose šaltiniuose, galime apskaičiuoti jų indėlį į vandenviečių debitus, paaiškinti jau įvykusius ir prognozuoti būsimus tos kokybės pokyčius vandenvietėse. Tačiau gana dažnai minėti rodikliai nėra specifiniai, būdingi tik tam šaltiniui, arba jie nėra pakankami stabilūs. Pavyzdžiui, chloridai yra geri ne tik sūraus vandens intruzijos, bet ir taršos indikatoriai. Tuo tarpu nitratai požeminiame vandenyje yra vien tik taršos pasekmė, o būdami nestabilūs jie gana greitai yra redukuojami į nitritus, amonį ir dujinį azotą. Vilniaus vandenviečių hidrocheminiams tyrimams ir jų vandens balanso vertinimams buvo pasitelkti izotopų metodai. Buvo nuspręsta sūraus giluminio vandens intruziją nustatyti helio (He) metodu, o paviršinio vandens prietaką įvertinti pasitelkus radioaktyviosios anglies ( $^{14}\text{C}$ ) ir tričio ( $^3\text{H}$ ) izotopus.

2005–2006 m. izotopiniais požeminio vandens tyrimais Vilniaus vandenvietėse nustatyta, kad He metodu galima ne tik identifikuoti giluminio vandens intruziją, bet ir įvertinti šios intruzijos indėlį į vandenviečių debitus. Atmosferinės kilmės tritis ir radioaktyvioji anglis tinka tik paviršinio vandens prietakos indikacijai, bet ne kiekybiniam šio reiškinio vertinimams. Mat didesnės šių izotopų koncentracijos buvo aptiktos vandenvietėse, eksploatuojančiose atviresnius, paviršiniu vandeniu ir krituliais maitinamus vandeninguosius sluoksnius. Tačiau dėl didokų, nors ir objektyvių paklaidų  $^{14}\text{C}$  ir  $^3\text{H}$  metodai netinka požeminio vandens išteklių balanso skaičiavimams.

Kadangi vienintelis helio šaltinis yra giluminis vanduo, šis izotopas vienareikšmiškai rodo tokio vandens indėlį į tiriamos vandenvietės debitą, ir tas indėlis Vilniaus vandenvietėse kinta nuo 9–10% iki 30–35%. Beveik tie patys skaičiai gauti pasitelkus hidrocheminį metodą (Cl jonas) ir modeliavimą.

Альгирдас Климас, Мантас Планкис

## ИССЛЕДОВАНИЕ БАЛАНСА И КАЧЕСТВА ПОДЗЕМНЫХ ВОД ВИЛЬНЮССКИХ ВОДОЗАБОРОВ ИЗОТОПНЫМИ МЕТОДАМИ

### *Резюме*

Количество и качество подземных вод зависят от источников формирования их запасов. Если знаем величину концентрации какого-либо специфического индикатора в таких источниках, мы можем определить их вклад в баланс отбираемой воды, объяснить уже происшедшие и предсказать предстоящие изменения качества отбираемой воды. Однако такие индикаторы довольно часто не являются специфическими или стабильными. Например, хлориды являются хорошим индикатором не только загрязнения, но и интрузии минерализованных вод. Напротив, нитраты однозначно указывают на загрязнение, но они в подземных водах не стабильны. Поэтому гидрохимические исследования вильнюсских водозаборов мы дополнили изотопными исследованиями.

Результаты изотопных исследований 2005–2006 гг. показывают, что только гелиевый метод пригоден для качественных и количественных оценок источников формирования эксплуатационных запасов подземных вод. Однако тритий ( $^3\text{H}$ ) и радиоуглерод ( $^{14}\text{C}$ ), источником которых является атмосфера, пригодны лишь для качественной оценки: как и ожидалось, возраст подземных вод, определенный  $^3\text{H}$ - и  $^{14}\text{C}$ -методами, существенно меньше на водозаборах, эксплуатирующих приповерхностные водоносные горизонты, интенсивно питаемые атмосферными осадками и поверхностными водами. Однако из-за объективных, но достаточно значительных погрешностей эти изотопы непригодны для количественной оценки баланса подземных вод.

Поскольку единственным источником гелия являются недра земли, гелиевый метод однозначно указывает на интрузию глубинных вод; последнюю можно определить и количественно по концентрации гелия. Установлено, что приток глубинных вод на вильнюсских водозаборах колеблется от 9–10 до 30–35%. Почти те же результаты получены при определении баланса подземных вод на указанных водозаборах гидрохимическим Cl-методом и моделированием.