Increased Concentrations of Nitrates in Groundwater in Selected Localities of the Moravian – Silesian and Olomouc Regions in the Czech Republic

Petra FOLTOVÁ[1)], Silvie HEVIÁNKOVÁ[1)], Jitka CHROMÍKOVÁ[2)], Alena KAŠPÁRKOVÁ[1)]

[1)] VSB-Technical University of Ostrava, Faculty of Mining and Geology, Institute of Environmental Engineering, 17. listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic; emails: petra.hrbacova@vsb.cz, silvie.heviankova@vsb.cz, alena.kasparkova@vsb.cz
[2)] VSB-Technical University of Ostrava, Faculty of Mining and Geology, Institute of Clean Technologies for Mining and Utilization of Raw Materials for Energy Use, 17. listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic; email: jitka.chromikova@vsb.cz

http://doi.org/10.29227/IM-2018-01-03

Abstract

The paper deals with the issue of nitrates in groundwater, to where they predominantly pass due to the application of nitrogen fertilizers in agricultural areas. Excess concentrations of nitrates in drinking water are undesirable, and may even cause a life--threatening condition called methemoglobinemia. The permissible concentrations of nitrates in drinking water are determined by legislation and the upper limit is 50 mg/l. Approximately 5% of the Czech population draw water from individual sources. In this study we identified and analysed selected samples from wells located in the Moravian-Silesian Region and in the Olomouc Region. The data and test results in this paper show that the nitrate concentration limit of 50 mg/l was exceeded in a half of the analysed groundwater samples. In some cases, the limit was exceeded in the order of tens of mg/l.

Keywords: nitrates, groundwater, limit value, Moravian-Silesian Region, Olomouc Region

Introduction

Nitrates in water are not too dangerous for humans. But, similarly to nitrites, they may cause nitrate dietary methemoglobinemia. In the gastrointestinal tract, nitrates can be reduced by bacterial activity to more toxic nitrites [Pitter, 2009]. Nitrites then react with hemoglobin to form methemoglobin which is unable to transfer oxygen from lungs to tissues. The most endangered are newborns and infants whose blood contains the so-called foetal hemoglobin that is more easily converted to methemoglobin than hemoglobin A, which is in the blood of older children and adults [Elyanow and Persechino, 2012]. At high concentrations, methemoglobin can cause death in infants. Nitrates, if not reduced to nitrite, are excreted in the urine [Pitter, 2009].

Nitrates are found in low concentrations in most natural waters. Groundwater pollution by nitrates is a problem, especially in some agricultural areas, where pollution is the result of excessive uses of nitrogen fertilizers. According to the hydrological balance of water quantity and quality of the Czech Republic in 2015 for nitrate indicator, 1317 samples were evaluated. Of these, 37% were below the limit of 1 mg/l, while the limit of 50 mg/l was exceeded in 11%. The groundwater quality was assessed based on the groundwater quality monitoring data obtained from the national groundwater monitoring network operated by the Czech Hydrometeorological Institute. The evaluation was performed as a comparison with the limit value (i.e. 50 mg/l) for groundwater according to the requirements of Decree 349/2016 Coll. amending Decree 5/2011 Coll. on the delimitation of hydrogeological districts and bodies of groundwater, the method of assessment of groundwater status and the requirements of programs for the detection and assessment of groundwater status, as amended by Decree 264/2015 Coll. [Czech Hydrometeorological Institute, 2015].

Due to the need to protect water against nitrates from agriculture and to prevent such pollution, the Council of the European Communities adopted Directive 91/676/EEC, the so-called Nitrate Directive. The requirements of the Directive were transposed into Czech Water Law in Article 33 of Act 254/2001 Coll. on Waters, as amended, where the Government is obliged by regulation to define vulnerable areas. Vulnerable areas are areas drained into surface water or groundwater and are polluted or threatened by nitrates from agricultural sources. The main qualitative criterion for pollution is the nitrate concentration higher than 50 mg/l or concentrations that could exceed the established limit in the case of neglecting effective measures. In these areas it is necessary to regulate the use and storage of fertilizers and livestock manure, crop rotation and the implementation of anti-erosion measures. According to the Nitrate Directive, the definition of vulnerable areas must be reviewed regularly within four years of its definition. There have been three revisions in the Czech Republic in 2007, 2011 and 2015 [Hrabánková, 2016].

Groundwater contamination is not a problem only in the Czech Republic, but also concerns many other

Tab. 1. Resulting sample values from the Moravian-Silesian Region (*LV – limit value MCL – maximum contaminant level; RV – recommended value)
Tab. 1. Wyniki analizy próek z regionu Sląsko-Morawskiego (*LV – limit MCL – maksymalny poziom zanieczyszczenia; RV – wartość rekomencdowana

Element	Unit of measure	Palkovice	Poruba	Nová Bělá	Krásné Pole, st. Předvrší	Krásné Pole, st. Branecká	Limit	Type of limit
pH		7.4	7.5	7.5	7.8	7.8	6.5 – 9.5	LV
κ	$mS.m^{-1}$	42	54.2	56.6	54.9	67.2	125	LV
t	°C	8.9	9.1	10.4	11.7	10.2	8 – 12	RV
Turbidity	ZF	61.6	17.32	0.4	10.55	1.95	5	LV
Fe	$mg.l^{-1}$	7.2	< 0.1	< 0.1	0.1	0.1	0.2	LV
Mn	$mg.l^{-1}$	0.01	0.06	0	0.04	0.02	0.05	LV
NH_4^+	$mg.l^{-1}$	1.33	0.69	0.19	0.4	0.35	0.5	LV
NO_2	$mg.l^{-1}$	0.39	0.02	0.01	0.01	0.04	0.5	MCL
NO_3^-	$mg.l^{-1}$	18.4	40.5	57.5	66	102.5	50	MCL
Cl^-	$mg.l^{-1}$	0	13.83	40.06	26.59	49.99	100	LV
SO_4^{2-}	$mg.l^{-1}$	46	74	68	74	78	250	LV
Ca+Mg	$mmol.l^{-1}$	2.23	2.55	2.04	1.95	2.56	2 – 3.5	RV
Ca	$mg.l^{-1}$	75.39	72.91	63.97	53.99	62.61	40 – 80	RV
Mg	$mg.l^{-1}$	8.48	17.65	10.82	14.63	24.35	20 – 30	RV

European countries, for example Germany, Switzerland, France, the Netherlands or the United Kingdom [Elyanow and Persechino, 2012]. For nitrate removal in practice, membrane processes such as electrodialysis or reverse osmosis can be used. Electrodialysis (ED) is advantageous for its easy automation, the absence of chemicals and low energy consumption. The current limits to the use of ED are the costs and generated waste. In the field of drinking water treatment using electrodialysis, the capacity of ED to remove nitrates was studied, for example, in Israel [Darby et al., 2012]. Another study points at the removal of nitrates from groundwater in central Australia. The author of the study confirms the quality of water at the level corresponding to the drinking water limits and points to the problem of membrane clogging [Darby et al., 2012]. In addition, an electrodialysis unit was used, for example, to separate nitrates from synthetic solution and industrial wastewater collected from a coke plant in Egypt [Mahmoud et al., 2015]. Studies have also been carried out to remove nitrates from groundwater by electrodialysis and bioreactors [Elmidaoui et al., 2002]. Another way to remove nitrates is ion exchange. When removing nitrates, a strongly basic anion is used, which works mainly in the chloride cycle. At higher sulphate concentrations, sulphates are exchanged prior to nitrate. The application of ion exchange for the removal of nitrates has been tested, for example, in Glendale, USA [Darby et al., 2012].

Materials and Methods

Experimental samples were taken from wells in the Moravian-Silesian and Olomouc Regions, both located in the north-eastern part of the Czech Republic. Five samples were drawn in the localities of Palkovice, Poruba, Nová Bělá, and Krásné Pole (2 sampling points of Predvrší and Branecká Street), all in the Moravian-Silesian Region. In the Olomouc region, five samples were taken in the localities of Věžky near Přerov, Vrbno pod Pradědem, Podolí near Přerov and Tovačov (2 two sampling points of Sadová Street and Street Kapitána Jaroše). As for the indicators monitored in the samples taken from the groundwater, the measured results were compared with the indicators for drinking water according to Decree 83/2014 Coll., amending Decree 252/2004 Coll., which sets out the sanitary requirements for drinking and hot water and the frequency and scope of drinking water control, hereinafter referred to as Decree No. 252/2004 Coll. [Collection of Laws, 2014].

The drawn groundwater samples were analysed in a laboratory at VŠB - Technical University of Ostrava, Faculty of Mining and Geology. Turbidity, ammonium, nitrite, nitrate, manganese, iron and sulphate were determined spectrophotometrically on a Hach DR 2800 instrument. Calcium, magnesium, and chlorides were determined by volumetric analysis, i.e. titration. The conductivity and pH were determined by the WTW pH/cond 340i.

Results and Discussion

In the experiment we determined selected indicators of pH, conductivity, turbidity, iron, manganese, ammonium, nitrites, nitrates, chlorides, sulphates, together calcium and magnesium, calcium, and magnesium. In nitrate analysis, the maximum contaminant level (according to Decree 252/2004 Coll.) was exceeded in samples from Nová Bělá, Krásné Pole (St. Predvrší) and Krásné Pole (St. Branecká). In Nová Bělá, the maximum limit was exceeded by 7.5 mg/l NO_3-. In

Tab. 2. Resulting values of sample analysis from the Olomouc Region (*LV – limit value; MCL – maximum contaminant level; RV – recommended value)

Tab. 1. Wyniki analizy próek z regionu Ołomuńskiego (*LV – limit MCL – maksymalny poziom zanieczyszczenia; RV – wartość rekomencdowana

Element	Unit of measure	Věžky near Přerov	Vrbno pod Pradědem	Podolí near Přerov	Tovačov, st. Sadová	Tovačov, st. Kpt. Jaroše	Limit	Type of limit
pH		6.7	6.5	6.9	7.3	6.6	6.5 – 9.5	LV
κ	$mS.m^{-1}$	67.9	10.9	62.3	97.2	54.1	125	LV
t	°C	9.8	9.2	9.4	10.3	10.1	8 – 12	RV
Turbidity	ZF	0.86	0.62	1.58	1.85	12.33	5	LV
Fe	$mg.l^{-1}$	< 0.1	< 0.1	< 0.1	< 0.1	1	0.2	LV
Mn	$mg.l^{-1}$	0	0	0	0.01	0.04	0.05	LV
NH_4^+	$mg.l^{-1}$	0.31	0.12	0.33	0.50	0.54	0.5	LV
NO_2	$mg.l^{-1}$	0.12	0.01	0.01	0.06	0.04	0.5	MCL
NO_3^-	$mg.l^{-1}$	54.5	7.2	2.7	61.5	20.9	50	MCL
Cl^-	$mg.l^{-1}$	24.12	1.6	11.7	24.64	15.42	100	LV
SO_4^{2-}	$mg.l^{-1}$	120	10	94	100	49	250	LV
Ca+Mg	$mmol.l^{-1}$	2.62	0.69	3.12	4.48	2.51	2 – 3.5	RV
Ca	$mg.l^{-1}$	75.63	17.36	96.27	139.4	73.03	40 – 80	RV
Mg	$mg.l^{-1}$	18.01	6.3	17.35	24.38	16.82	20 - 30	RV

the village of Krásné Pole (St. Předvrší), the maximum contaminant level was exceeded by 16 mg/l NO_3-. In the village Krásné Pole (St. Branecká) this value was exceeded by up to 52.5 mg/l NO_3-.

When analysing nitrates in the samples from the Olomouc Region, the maximum contaminant level (according to the Decree 252/2004 Coll.) was exceeded in samples from the localities of Věžky near Přerov and Tovačov (St. Sadová). At the same time, these samples also show higher contents of calcium and magnesium ions. In the village of Věžky near Přerov the maximum contaminant level was exceeded by 4.5 mg/l NO_3-. In the village of Tovačov (St. Sadová) the maximum contaminant level was exceeded by 11.5 mg/l NO_3-. The groundwater from Tovačov (St. Kpt. Jaroše) complies with the legislative requirements with regard to nitrate concentration, but it exceeded the concentration of iron and ammoniacal ions.

Conclusion

This work aimed at pointing out nitrate problems in groundwater in the Moravian-Silesian and Olomouc Regions. On the grounds of the obtained data, we can confirm that the 50 mg/l nitrate concentration was exceeded in half of the analysed samples. The limit value for nitrates was exceeded in the range from 4.5 mg/l to 52.5 mg/l NO_3-. These were mainly localities located in the areas affected by farming. For this reason, it is advisable to address this issue and to propose an appropriate solution to reduce the nitrate concentration in groundwater. In the next experiment, research will focus on nitrate removal using an electrodialysis unit. In addition, a solution will be proposed on how to handle the concentrate. We assume we succeed in the concentration of the product and recover salt which could be used, based on its purity, in other branches of the industry.

Acknowledgements

This article was written within the project QJ1620148 “Research in possible use of artificial infiltration to increase the capacities of ground water resources in dry periods” financed by the Ministry of Agriculture of the Czech Republic and within project Institute of clean technologies for mining and utilization of raw materials for energy use - Sustainability program. Identification code: LO1406. Project is supported by the National Programme for Sustainability I (2013–2020) financed by the state budget of the Czech Republic.

Literatura – References

1. Czech Hydrometeorological Institute – Úsek hydrologie. 2015. Hydrologická bilance množství a jakosti vody České republiky 2015 [online]. [vid. 2017 – 1 – 10]. Available at http://voda.chmi.cz/opzv/bilance/zprava_bilance_15.pdf (in Czech).
2. DARBY, Jeannie et al.: Drinking Water Treatment for Nitrate. 2012 (Technical Report 6), 1–198.
3. ELMIDAOUI, A.; MENKOUCHI SAHLI, M. A.; TAHAIKT, M.; CHAY, L.; TAKY, M.; ELMGHARI, M.; HAFSI, M. Selective nitrate removal by coupling electrodialysis and a bioreactor. Desalination. 2002. pp. 389–397.
4. ELYANOW, David, PERSECHINO, Janet. Advances in nitrate removal by electrodialysis reversal. In: Conf. & on New Developments in the Treatment & Desalinaiton of Effluents/ Brakish and Other Marginal Waters: December 2012. Israel: Raphael Semiat and David Hasson. pp. 167–178.
5. HRABÁNKOVÁ, Anna. Ochrana vod před dusičnany ze zemědělství. Vodohospodářské technicko – ekonomické informace. Praha. 2016. ISSN 1805–555.
6. MAHMOUD, M. H. H.; ABDEL – AAL, E. A.; ABDEL – HAMED, R. M.; KANDIL, A. T. Denitration of Coke Plant Wastewater Using a Bench – Scale Electrodialysis Unit Via Statistical Design. 2015. International Journal of Electrochemical Science. ISSN 1452–3981.
7. PITTER, Pavel. Hydrochemie, 4. vyd. Praha: VŠCHT, 2009. ISBN 978–80–7080–701–9.
8. Collection of Laws. Decree 83/2014 Coll. amending Decree 252/2004 Coll., which sets out the sanitary requirements for drinking and hot water and the frequency and scope of drinking water control, as amended. 2014. Praha: Ministerstvo vnitra. [2014], 33 p. ISSN 1211–1244.

Zwiększenie stężenia azotanów w wodach gruntowych w wybranych lokalizacjach w Regionie Śląsko-Morawskim oraz Ołomunckim w Czechach

The paper presents the main directions for the modernization of the public management of the organizations in the sphere of public administration in Romania. Modernizing the management of public organizations should contribute to strengthening their capacity in developing and implementing economic and social reform measures. The raising of public management performance is mainly driven by the demand for more and more accountable accountability of institutions in the sphere of public administration, the dimensional and functional transparency of these institutions and the application of new managerial methods.

Słowa kluczowe: azotany, wody powierzchniowe, region Śląsko-Morawski, Region Ołomuniec