Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 20, issue 4, 2010, pp. 89-95

EXAMINATION OF THE GROUNDWATER POLLUTION AT LOWLAND SETTLEMENTS

Gyorgy SZABO*, Aniko ANGYAL, Anett CSIKOS, Eva BESSENYEI, Eszter TOTH, Peter KISS, Peter CSORBA, Szilard SZABO
University of Debrecen, Department of Landscape Protection and Environmental Geography

ABSTRACT. In our study we examined the groundwater wells at 6 lowland settlements with different circumstances. The differences among the settlements were partly due to the different stages of development of the sewage system. There was difference among the settlements in the case of the level of the groundwater and the water permeability of the soils. We examined how differences above mentioned had shown themself regarding the water quality of the groundwater wells. We studied the water quality on the base of the following parameters: pH, ammonium- nitrite- and nitrate concentration. We detected that the condition of the water of the groundwater wells were extremely unfavourable in every studied settlement. At the extent of the pollution there were certainly differences within the settlement and among the settlements also. We determined that most of the examined wells could not be used for watering animals, because it could cause serious animal health protection risk.

Keywords: water quality analysis, groundwater pollution, groundwater wells, hygienic risk

INTRODUCTION

One of the greatest challenges of this century is the conservation of the Earth's fresh water resources (Kerényi, 1995; Seiler at al., 1995; Colten, 1998; Agotici et al., 2009; Howden, et al., 2009; Oprean et al., 2009). The state of the fresh water resources has been getting worse quickly in the past decades. The quantity of the available water resources was decreased in many places and it causes an almost unsolvable problem for the inhabitants (Zhang et al., 1996; Hansen et al., 2000; Krapac et al., 2002; Irabor et al., 2008; Pritchard et al., 2008; Rakonczai, 2008).

Although Hungary is not one of the mostly concerned countries, we can not be satisfied with the state of the surface and underground water (Bíró et al. 1998; Szalai, 2004). Earlier, groundwater played the most important role in the fresh water supply of the population but the situation has changed recently (mainly due to the contaminations). Today, most of the used fresh water derives from confined groundwater. However, many people use groundwater e. g. for watering or irrigation, and this means serious health risks in the case of contaminated groundwater (Szabó et al. 2007; Farsang et al. 2009). Groundwater is endangered mainly by the sewage filtering into the soil (Bolgár et al. 2005; Pál et al., 2007; Gavris et al., 2008; Pál et al., 2009), but industrial sewage (von der Heyden et al. 2004), the different fertilizers and pesticides can also worsen the quality of the groundwater. Recently the percentage of the households supplied with sewer system has increased rapidly in Hungary: in 2002 it was 56% and by 2008 it increased to 70%, in this period 700 thousand properties have installed sewer system (MTTE, 2009). Unfortunately, there are still a lot of settlements in the country where sewage filters directly into the soil.

Among the examined settlements, in Mikepércs and Mezőladány sewer network had not been constructed by the time of the examination, in Bodrogkeresztúr, Gergelyiugornya and Görbeháza the sewer network had been constructed partly; and in Tiszabercel the sewer network was 100% constructed but only 65% of the households were supplied with sewer system. The domestic sewage of these households was collected in septic tanks that are not supplied with adequate insulation, thus the soil and the groundwater was exposed to great demand.

In the course of our research the contamination of the groundwater wells was examined, and we tried to determine the reasons of the differences in the water quality.

MATERIALS AND METHODS

The water quality examinations of the dug wells were carried out in different periods between the summer of 2005 and 2009. The groundwater samples were examined monthly, all the year round. In the cases of Gergelyiugornya and Mikepércs the examinations were extended with a year. During the positioning of the wells we endeavoured to cover the whole area of the settlement. The number of the examined wells varied between 16 and 20. The sampling was carried out with a bailer, and the samples were transported in hermetically closed plastic flacons to the geography laboratory of the University of Debrecen. The depth of the groundwater table was also determined in every case of sampling. The determination of nitrate, orthophosphate, ammonium and organic matter and the measurement of the pH were carried out in the laboratory a day after the sampling (Literáthy, 1973). The results were saved in an Excel database and the diagrams were also made with this software. In the course of the statistical

***Correspondence:** György Szabó, University of Debrecen, Department of Landscape Protection and Environmental Geography, 4010 Debrecen, POB. 9. Tel. +36-(52)-512-900/22128, Fax. +36-(52)-512-945, email: gyszabo555@gmail.com
Article received: May 2010; published: November 2010

analyses normality test were executed with Kolmogorov-Smirnov test. Since most of the data were not normally distributed data, Spearmann correlation coefficient was applied during the correlation analysis. SPSS 8.0 software was used in the statistical analyses and to make further diagrams.

The short presentation of the examined settlements

Mikepércs

Mikepércs is situated in the boundary of Hajdúság and Nyírség (Fig. 1). The settlement has diverse pedological conditions as it is in the boundary of two landscapes. In the western part of the settlement chernozem and alluvial soils can be found, but the dominant soil type in the other parts is arenosol with high humus content and this is more sensitive in terms of contaminations than chernozems. The depth of the groundwater in Mikepércs is 1-3 meter, but in the higher reliefs more than 5 meter deep groundwater table can occur. In the settlement of 4000 inhabitants the water supply network is almost 100% constructed, but the construction of the sewer system has begun only in the second half of 2006. Since the construction is going to be finished only in 2010, the positive effects of the sewerage could not be demonstrable in this examination series.

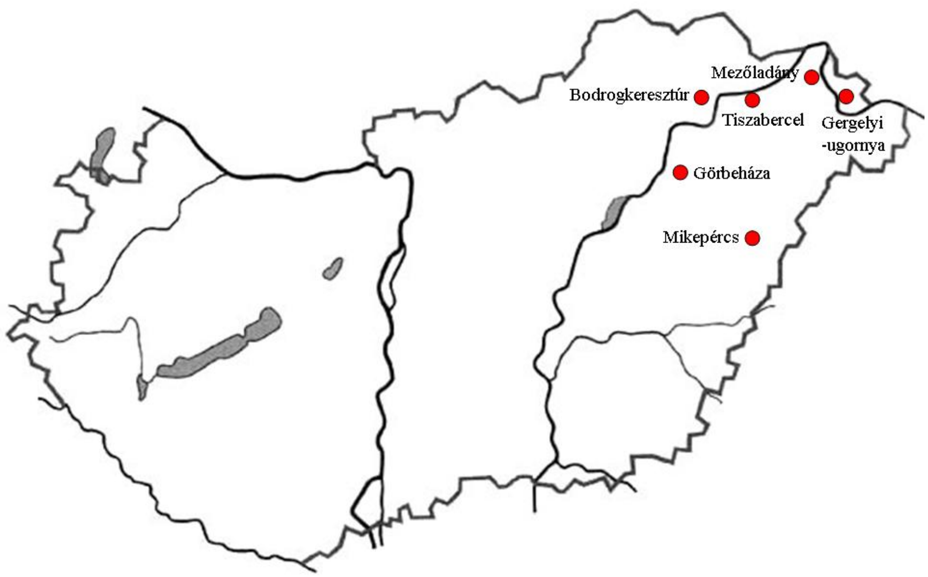

Fig. 1 The situation of the examined settlements

Görbeháza

The settlement is situated in the edge of Hortobágy can be found in the monotonous alluvial plain mainly alluvial soils and alluvial solonetz (Marosi et al., 1990). In 60% of the settlement clayey soils dominate and they can detain the infiltration of the contaminants. In the other parts of the settlement clay loam is typical and this soil type also has weak water permeability. The depth of the groundwater in Görbeháza is 1.5-2 meter, but in the rainier periods higher groundwater table can occur. In the settlement of 2600 inhabitants the water supply network is almost 100% constructed. The first part of the sewage network was finished at the end of the first third period of our examination time, thus 66% of the households are connected to the network. Due to this, the improvement of the water quality in the groundwater wells was not provable.

Bodrogkeresztúr

Bodrogkeresztúr is situated in the eastern part of Zemplén Mountains, in the region of Tokaj-Hegyalja. The hydrogeological conditions are various since Bodrogkeresztúr is a piedmont settlement. In the higher parts of the settlement, water deriving from the precipitation and filtering from the surrounding (higher) areas affects the groundwater conditions, but the lower parts are in the bank of the River Bodrog so the river also has an effect on the groundwater and its flow. The dominant soil types are luvisol, and alluvial soil in the sediments of the River Bodrog (Pinczés et al., 1978). The groundwater table under the examined settlement is not flat, especially in the higher piedmont parts. Here, the average depth is 8-9 m, and in the lower parts it is 3-4 m. In the settlement of 1400 inhabitants the sewage network was constructed in 2001, and the 84% of the households are connected to it till 2006.

Tiszabercel

Tiszabercel is situated in the western edge of Rétköz, directly near the left bank of the River Tisza. Meadow, alluvial meadow and 'kovárványos' brown forest soils can be found here (Marosi et al., 1990). The soils have various granulometric compositions: we can

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 20, issue 4, 2010, pp. 89-95

find almost every kind of soils from the patches of clayey soils to the sandy soils with good water permeability. In the settlement of 1989 inhabitants, 80% of the household are connected the water supply network. Although the sewage network was 100% constructed till 2000, only 65% of the households has been connected to the network till our examinations.

Gergelyiugornya

Gergelyiugornya is a little town situated in the north-eastern part of Hungary. This settlement is a quarter of Vásárosnamény. The settlement is directly near the bank of the River Tisza. Since the settlement is situated in lower areas than the surroundings, excess water often occurs. The dominant soil type is alluvial soil; it is clayey and clayey silty (Marosi et al., 1990). In the settlement of 1766 inhabitants the water supply network is almost 100% constructed but the sewage network is not completed yet (Vásárosnamény, 2008). In the examination time, 50% of the households were connected to the sewage network.

Mezőladány

The settlement is situated in the northern part of Nyírség, in a flood-free bank near the River Tisza. In the higher areas 'kovárványos' brown forest soil is typical, it has good water permeability. In the areas near the river alluvial soil can be found (Marosi et al., 1990). The groundwater table is relatively deep under the surface and it is advantageous in terms of the contaminations. In the lower areas the average depth of the groundwater is 4 m, but in the higher areas 13 m deep groundwater table also can be found. The number of the inhabitants is 1047. The sewage network is not constructed yet.

RESULTS AND DISCUSSION

The depth of the groundwater

The depth of the groundwater is important in terms of contaminations. If the groundwater table is close to the surface, the contaminants can easily get into the groundwater from the soil, but this also depends on the water permeability of the soil. The correlation analyses proved the role of the groundwater depth in the groundwater contamination: every examined water quality parameter (except nitrate) has negative significant correlation with the groundwater depth. This means that the deeper wells are less contaminated. In Fig. 2 it is observable that there are significant differences among the examined settlements regarding the groundwater depth. The average depth is approximately 2 m in Görbeháza and Mikepércs. In the case of Tiszabercel it is 4 m and in Gergelyiugornya and Bodrogkeresztúr it is 5-6 m. The average water depth exceeds 7 m in Mezőladány, but here we measured more than 10 m water depth in some wells.

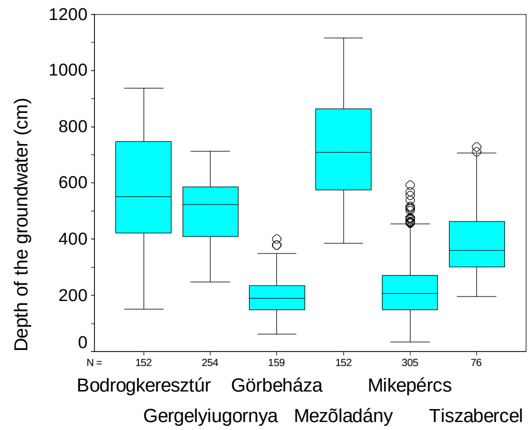

Fig. 2 The depth of the groundwater in the examined settlements

Based on the groundwater depth, Görbeháza and Mikepércs can be considered as the mostly endangered settlements. Moreover, the water permeability of the soils in Mikepércs is very good since sandy soils can be found in most part of the settlement.

pH

The pH of the examined water samples is slightly alkaline, but here and there we found values below 7 (Fig. 3). In every settlement we observed a maximum in the pH in autumn-winter and a minimum in spring and summer (Fig. 4), but the measured values did not exceed (except some values) the 'B' value ($pH < 6.5$ and $pH > 9.0$) of the joint decree no. 6/2009 (IV. 14.) KvVM-EüM-FVM.

Ammonium ion

The ammonium ion concentration of groundwater originated from the biodegradation of organic materials so it is one of the most important indicators of the organic contaminations. In water, ammonia can take up and also release protons. The percentage of the ammonia and ammonium ion in water bodies depends on the temperature and the pH of the water (Barótfi, 2000). With the increase of the pH and the temperature, the concentration of the toxic ammonia is increasing. Most of the examined samples are neutral or slightly alkaline, and the temperature of the water samples varied from 6°C to 18°C. In this range of pH and temperature the percentage of ammonium ion is 97-100% so the toxic, free ammonia is below 3%.

In the examined settlements we found ammonium ion in especially high concentrations which clearly refers to anthropogenic contaminations. Mezőladány was the exception: here, we measured less ammonium ion concentrations than the 'B' critical contamination level (0.5 mg/l; joint decree no. 6/2009) (Fig 5) in 75% of the water samples. In the case of Gergelyiugornya, 50% of the water samples did not exceed the contamination level but the ammonium ion concentration of 13% of the samples exceeded the contamination level tenfold. The most critical situation was in Mikepércs and Tiszabercel where more than 70% of the examined samples contained more ammonium ion than the contamination level. Moreover, in both settlements we found that more than 10% of the samples exceeded the contamination level tenfold.

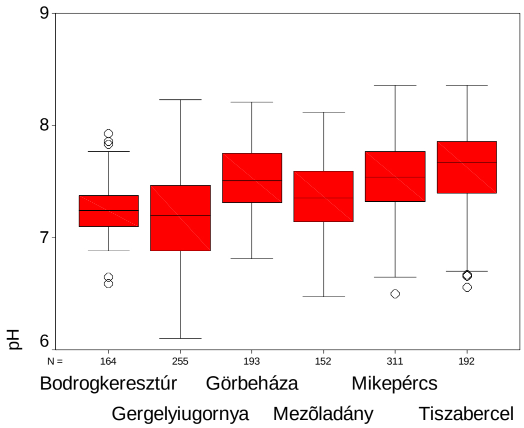

Fig. 3 The pH of the groundwater in the examined settlements (excluding the extreme values)

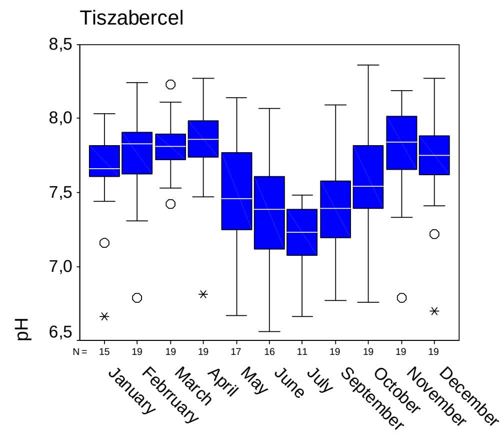

Fig. 4 The temporal changes of the pH in Tiszabercel

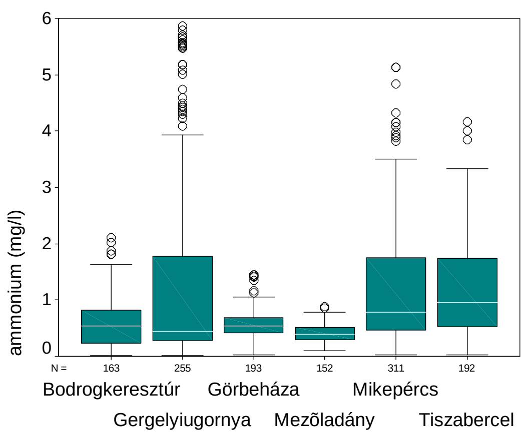

Fig. 5 The ammonium concentration of the water samples in the examined settlements (excluding the extreme values)

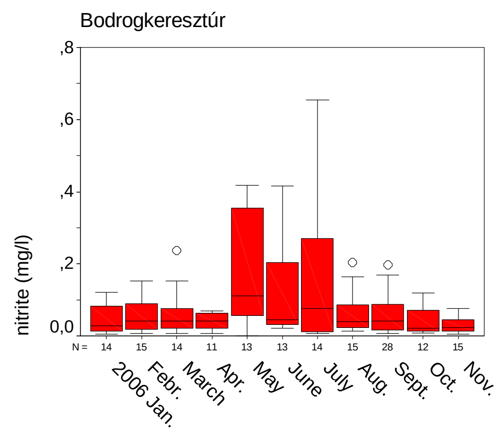

Fig. 6 The temporal changes of the nitrite concentration in the groundwater in Bodrogkeresztúr (excluding the extreme values

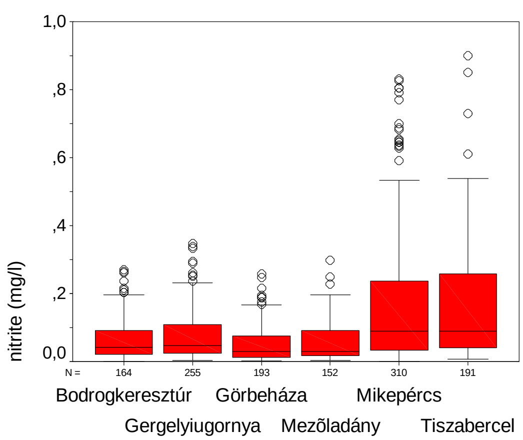

Fig. 7 The nitrite concentrations in the examined settlements (excluding the extreme values)

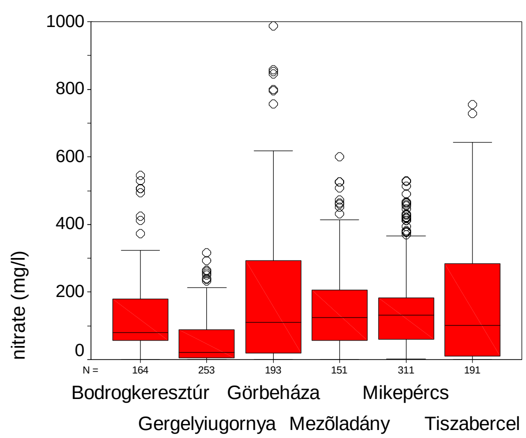

Fig. 8 The nitrate concentrations in the examined settlements (excluding the extreme values)

In Mikepércs, Tiszabercel and Gergelyiugornya we found ammonium ion concentrations exceeding the contamination level more than a hundredfold which refers to direct sewage disposal. In the settlements mentioned above the improper management of the manure derived from livestock farming could contribute to the extremely high concentrations.

The most extreme ammonium concentrations were measured in the autumn-winter months. In these seasons the degradation of the organic nitrogen occurs, but the oxidation of the ammonium to nitrite is detained by the cold since the activity of the nitrifying bacteria slows down below 10°C and ammonium ions accumulates in the water (Bíró et al., 1998).

Nitrite

Nitrite refers to the advanced degradation of organic materials. The ammonia-nitrite transformation is a pH-dependant process; it is the fastest between pH 8-9.5. Besides, water temperature also plays an important role since the nitrifying bacteria do not stand cold, their activity slows down below 10°C, but with the increase of the temperature the nitrite concentration is also increasing (Barótfi, 2000). It is observable based on the temporal changes of the nitrate concentration in the groundwater samples from Bodrogkeresztúr (Fig. 6). However, nitrite immediately oxidizes to nitrate in aqueous conditions; therefore nitrite does not accumulate in high concentrations.

The joint decree no. 6/2009 does not give contamination level for the nitrite concentration in underground water. In surface water bodies 0.3 mg/l nitrite concentration means extremely contaminated water (MSZ 12749/1993). Although some concentrations of the settlements exceeded the 0.3 mg/l contamination level, most of the measurements showed lower concentrations. Similarly to the ammonium, in the case of nitrite the most critical situation occurred in Mikepércs and Tiszabercel (Fig. 7), but 78.7% and 78% of the measured concentrations did not exceed the 0.3 mg/l value. The pH was the highest in these settlements so the conditions were the most advantageous for the ammonium-nitrite transformation here. However, in the other settlements we measured concentrations below 0.3 mg/l in 90% of the samples.

Nitrate

The nitrate concentrations of the examined wells usually exceeded the 'B' limit value of the joint decree 6/2009 (50 mg/l, directive no. 91/676/EEC on nitrate). We found that the nitrate concentration of 68.8% of the examined samples from Gergelyiugornya was below the limit value, but in the other settlements in the majority of the samples we measured higher concentrations than the limit value. In Görbeháza and Tiszabercel the nitrate concentrations exceeded the limit value in a bit more than the half cases of the samples (52.2% and 58.1%), but in the other settlements (Bodrogkeresztúr, Mikepércs, Mezőladány) we measured higher concentrations than 50 mg/l in the case of 80-85% of the samples and concentrations exceeded tenfold the limit value were not rare cases as well (Fig.8).

It is surprising that the number of the samples exceeding the limit value is also very high in the cases of Mezőladány and Bodrogkeresztúr where the groundwater table can be found in very deep, while, compared to the other settlements, the conditions are more advantageous in these settlements regarding the ammonium and nitrite concentrations. This can be explained by the fact that most of the ammonium deriving from the degradation of the organic materials already oxidized to nitrite, then nitrate by the time the contamination reached the deeper groundwater (Pál et al., 2009). Supposedly that is why we could not find any negative significant correlation between the nitrate content of the water samples and the depth of the groundwater (this is the only case among the water quality parameters).

The nitrate contamination of the groundwater occurred due to the infiltration of the sewage from the sewage tanks, but fertilizers containing nitrogen scattered in the vegetable gardens and ploughlands near the wells can contribute to the higher concentrations as well (Szabó et al., 2007).

CONCLUSIONS

In the course of our researches the water quality of the groundwater wells of six different lowland settlements was examined, and based on our results we showed significant differences between the different settlements. The water permeability of the soils in the settlements affects the contamination of the groundwater the most significantly. The water contamination was more considerable in the settlements where soils with good water permeability (Mikepércs, Tiszabercel) can be found.

The depth of the groundwater table was the second most important factor: the water quality of the wells in Bodrogkeresztúr and Mezőladány (where the groundwater table is deeper) was more advantageous than in the other settlements. The most serious problem occurred in Mikepércs where we found sandy soils with good water permeability and the groundwater was close to the surface.

The advantageous effects of the sewage network were proved in Bodrogkeresztúr and Gergelyiugornya, but the depth of the groundwater and the granulometric composition of the soils could contribute to less contamination as well. Although the network was fully constructed by 2000 in Tiszabercel, we could not prove its beneficial effects since examining several parameters the groundwater quality was very disadvantageous in the settlement. This can be explained by the fact that only 65% of the households were connected to the network and, on the other hand, the water permeability of the soils is very good due to the dominant coarser fractions.

The decree no. 41/1997 (V.28) states that "As far as possible water of drinking-water quality should be used for the watering of animals." Unfortunately, it was not carried out in the cases of the examined settlements since the inhabitants water the animals everywhere with the water from the dug wells, but the quality of this water is not adequate regarding the directions. This practice raises serious questions related to not only animal but also human health, since the toxic substances deriving from the polluted water can get into the milk and meat of the animals and the consumption of them can cause several serious problems in the health of human beings.

ACKNOWLEDGEMENTS

The research was supported by the No. 68566 Hungarian Scientific Found (OTKA).

REFERENCES

Agotici V., Ciucanu I., Agotici P.S., Dărăban A., Dehelean G. Micro-solid-phase extraction and GC analysis of volatile aromatic hydrocarbons from water – Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii, Vol. 19, issue 2, 2009, pp. 327-331.

Barótfi I, Environmental technology – Mezőgazda Kiadó, 981 p. 2000. (in Hungarian)

Bíró T, Thyll Sz, Tamás J, Risk assessment of nitrate pollution in lower watershed of the Berettyó River. In: Filep Gy. (ed.): Soil water environment relationships. Wageningen – Debrecen, 239-247, 1998.

Bolgár BE, Pál Z, Spatial pattern of groundwater pollution on a small Transylvanian village example, Environment, research, protection and management international conference, UBB, Facultatea de Stiinta Mediului, Cluj Napoca, 140-150, 2005.

Colten CE, Groundwater contamination Reconstructing historical knowledge for the courts – Applied Geography, Vol. 18, No. 3, 259-273, 1998.

Decree no. 41/1997. (V. 28.) FM on Veterinary regulation, 1997. (in Hungarian)

Farsang A, Fejes I, Contamination and human health risk of groundwater in Szeged – Acta Geographica Ac Geologica et Meteorologica Debrecina 3:(1) 11-27, 2009.

Gavris G., Cărăban A., Tomulescu I., Merca V., Radoviciu Mihaela E. The neutralisation of waste waters containing strong inorganic toxicants Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii, vol. 18, 2008, pp. 345-348.

Government Decree No. 201/2001. (X.25.) on the quality standards and monitoring of drinking waters, 2001

Government Joint Decree No. 6/2009. (IV. 14.) KvVM-EüM-FVM on limit values established for the protection of groundwater and the geological medium, 2009.

Hansen B, Kristensen ES, Grant R, Høgh-Jensen H, Simmelsgaard SE, Olesen JE, Nitrogen leaching from conventional versus organic farming systems – a systems modelling approach – European Journal of Agronomy 13, 65-82, 2000.

Howden NJK, Bowes MJ, Clark ADJ, Humphries N, Neal C, Water quality, nutrients and the European union's Water Framework Directive in a lowland agricultural region: Suffolk, south-east England – Science of the Total Environment 407, 2966-2979, 2009.

Hungarian Standard no. MSZ 12749 1993, The quality of surface water, qualitative characteristics and qualification, 1993 (in Hungarian)

Integrated urban development strategy in Vásárosnamény, Vásárosnamény Város Önkormányzata, 115 p. 2008. (in Hungarian)

Irabor OOO, Olobaniyi SB, Oduyemi K, Akunna J. Surface and groundwater water quality assessment using multivariate analytical methods: A case study of the Western Niger Delta, Nigeria – Physics and Chemistry of the Earth 33, 666-673, 2008.

Kerényi A, General environmental protection – Global issues, potential solutions, MOZAIK Kiadó, 383 p., 1995. (in Hungarian)

Krapac IG, Dey WS, Roy WR, Smyth CA, Storment E, Sargent SL, Steele JD, Impacts of swine manure pits on groundwater quality – Environmental Pollution 120, 475-492, 2002.

Literáthy P, Unitary water examination methods I. Chemistry methods, vol. 1, Vízgazdálkodási Tudományos Kutatóintézet IV. Vízminőségi és Víztechnológiai Főosztálya, 233p., 1973. (in Hungarian)

Marosi S, Somogyi S, Magyarország kistájainak katasztere I-II., Budapest, MTA FKI, 1500 p., 1990.

Ministry of Transport, Telecommunication and Energy (MTTE), http://www.khem.gov.hu, 2009. (in Hungarian)

Oprean L., Poplăcean M., Oancea S., Oprean C., Lengyel E. Monitoring the microbiological and physico-chemical pollution degree of the river Visa – Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii, Vol. 19, issue1, 2009, pp. 203-207.

Pál Z, Aczél M, Pál K, Nitrate contamination of the groundwater in rural settlements – example of Imecsfalva (in Hungarian). Collegium Geographicum 6. sz. Kolozsvár, 43-51, 2009. (in Hungarian with english abstract)

Pál Z, Bálint K, Settlement groundwater contamination patterns by the examples of forestland villages (in Hungarian). Acta Siculica. Székely Nemzeti Múzeum Évkönyve, 49-56, 2007. (in Hungarian with english abstract)

Pritchard M, Mkandawire T, O'Neill JG, Assessment of groundwater quality in shallow wells within the southern districts of Malawi – Physics and Chemistry of the Earth 33, 812-823, 2008.

Pinczés Z, Kerényi A, Martonné Erdős K, Soil degradation in Bodrogkeresztúr. Földrajzi Közlemények (26) 210-236, 1978. (in Hungarian)

Rakonczai J, Global environmental issues – Universitas Szeged Kiadó, 204 p., 2008. (in Hungarian)

Seiler KP, Lindner W, Near-surface and deep groundwaters – Journal of Hydrology 165, 33-44, 1995.

Szabó Gy, Szabó Sz, Szabó A, Szemán B, Spatial and time variations of the groundwater quality of two different landscapes – In: Boltižiar, M. (ed.): Implementation of Landscape Ecology in New and Changing Conditions, ILE Slovak Academy of Sciences, 421-427, 2007.

Szabó Sz, Methodes of environmental investigations – monitoring – coursebook, Debrecen, 144 p. 2008. (in Hungarian)

Szalai Z, Jakab G, Madarász B, Estimating the vertical distribution of groundwater Cd and Cu contents in alluvial sediments (River Danube). Saturated and Unsaturated Zone; Integration of process knowledge into effective models. (Eds. Per Aagard et al.): La Gordialica Pavese, Rome, 303-312, 2004.

Szalai Z, Spatial and temporal pattern of soil pH and Eh and their impact on solute iron content in a wetland (Transdanubia, Hungary) AGD Landscape and Environment 2 (1). 34-45, 2008.

von der Heyden CJ, New MG, Groundwater pollution on the Zambian Copperbelt: deciphering the source and the risk – Science of the Total Environment 327, 17-30, 2004.

Zhang WL, Tian ZX, Zhang N, Li XQ, Nitrate pollution of groundwater in northern China – Agriculture, Ecosystems and Environment 59. 223-231, 1996.