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Implementation of hydrogeological and hydrological monitoring in the Czech Republic

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Abstract

This paper describes the current procedure of monitoring surface water, groundwater in boreholes and house wells near highway and bypass construction sites in the Czech Republic. The subject of this borehole and house well groundwater monitoring is to keep track of its quality by performing chemical analysis in a certified laboratory and its quantity by measuring groundwater level. With surface water, only quantity is monitored by performing chemical analysis in a certified laboratory. The analysis results are processed in text processors and spreadsheets. In regular intervals final reports with clear results are created and handed to an accountable person, who is representing the construction. The results are stored in an archive for an eventual control of the course of monitoring and possible changes. Monitoring is an important part of preventing the water source pollution or even its loss. These are changes, which could be caused by the highway or bypass construction. This contribution describes the procedure of acquiring water samples from hydrogeological and hydrological objects and also possible contaminants and it´s limits are described.

Keywords: monitoring; chemistry; hydrogeology, hydrology, water

1. Introduction

For smooth course of the construction without potential conflicts between construction and third parties, certain procedures are realised as a form of prevention. In reality, these procedures include geotechnical monitoring of construction objects, stableness calculations, compactness trials, assessment of possible contaminants and preventing them from escaping into nature, protection of protected animals and plants, monitoring of chosen hydrogeological objects in certain distance, monitoring of surface watercourses in the vicinity of the construction site etc. Hydrogeological and hydrological monitoring is carried out according to a drafted and approved work project. Project has to be created with accordance with the current legal regulations and ordinances of the Czech Republic.

Project determines the way of realisation of the monitoring in a form of observation of the groundwater in selected boreholes and house wells – sampling the groundwater and observing its quality by physicochemical analysis in a certified laboratory and watching the level of groundwater in regular intervals. With surface water, only quality is monitored in regular intervals. A part of the monitoring is a possibility to declare a warning alert in case serious changes in quality of surface water or quality or quantity of groundwater are found (Matouskova, 2008).

2. Characteristics of the problem

Water is universally considered one of the most important elements for lives of humans, animals and plants. That is the reason, why it is important not to destroy it by human interventions. Drinking water is described by law as a water, which is not harmful for health and by its regular usage health problems do not occur (Kozisek, 2003). Drinking water can be acquired by purification by adding chemicals or from uncontaminated protected natural reservoirs. During liner construction (bypasses and highways) in the Czech Republic, it is mandatory for the construction not to have negative effects on hydrogeological conditions in both its vicinity and broader surroundings. The aim of the monitoring is to observe quality and quantity factors of home wells, hydrogeological objects and surface waters in order to prevent loss of the water reservoir or its destruction (Krajca, 2006).

Each construction has established zone, in which the monitoring is then carried out. The aim of the construction contractor is to perform measuring of the level of groundwater and sampling of groundwater and surface water, in regular intervals in the appointed zone, samples are then analysed in a certified laboratory (Albarede, 2009). Based on the submitted and previously approved project, the monitoring is carried out. The project clearly states the total period of monitoring, planned starting date of the monitoring, surveyed contaminants, frequency of monitoring and frequency of sampling. The project also states procedures for cases, when the amount of substances in chemical analysis exceeds the limits and when there is a sudden loss of the water source.

3. Monitoring of the surface water

Monitoring of surface water in the vicinity of liner constructions is always dependent on individual hydrological situation of the locality. Details of hydrological monitoring are based on the project, which is prepared by the contractor and subsequently approved by the contracting authority. Discharge troughs are marked into the hydrogeological monitoring project, the monitoring will be carried out in their close proximity, and also distance from the construction site (most often 50 meters) is determined. Next, coordinates of the location, where samples of the surface water will be taken in regular intervals, are established.

Analysed sample must represent quality of water in the sampled area. At the location of sampling, a sample of surface water is acquired, the amount is pre-defined, and it is placed into a special sample tube (Horakova, 2000). Sample is during its acquisition always labelled with date and name of the discharge trough, it is then ready to be sent or to be taken into the laboratory. After the sampling and during the transport of the samples it is important to be mindful of not destroying it by high temperatures, direct sunlight etc. Physicochemical characteristics of the water samples are analysed in the laboratory.

Table 1: Overview of the monitored substances

pH	OH^- - hydroxide ions
conductivity	ammonium ions
KNK - 8,3	chlorides
KNK - 4,5	sulphates
ZNK-4,5	nitrates
ZNK-8,3	nitrites
Ca+Mg	phosphates
Calcium	Ca
magnesium	Fe dissolved
carbonate	K
Establishing forms of CO_2 - free	CO_3^{2-} - carbonates
NEL	Mn
HCO_3^- hydrogen carbonates	Na

This way the quality of surface water and effectiveness of impermeable barriers are primarily checked. Barriers are built by the accountable construction worker to ensure the discharge troughs are not contaminated. Indicators of pollution at the locality in situ are also the color of the flow, turbidity and possible smell. During the sampling, the water flow is visually checked (Horakova, 2000).

Impermeable barriers are used during the construction at all surface discharge troughs. It is a passive method of protection of the water flow from pollution. Impermeable barriers are polymer sacks filled with air and attached to the shore of discharge troughs by ropes (fig. 1) (Fetter, 2008).

Figure 1: Barriers placed in discharge trough

Source: Mertova, 2020

4. Monitoring of the groundwater

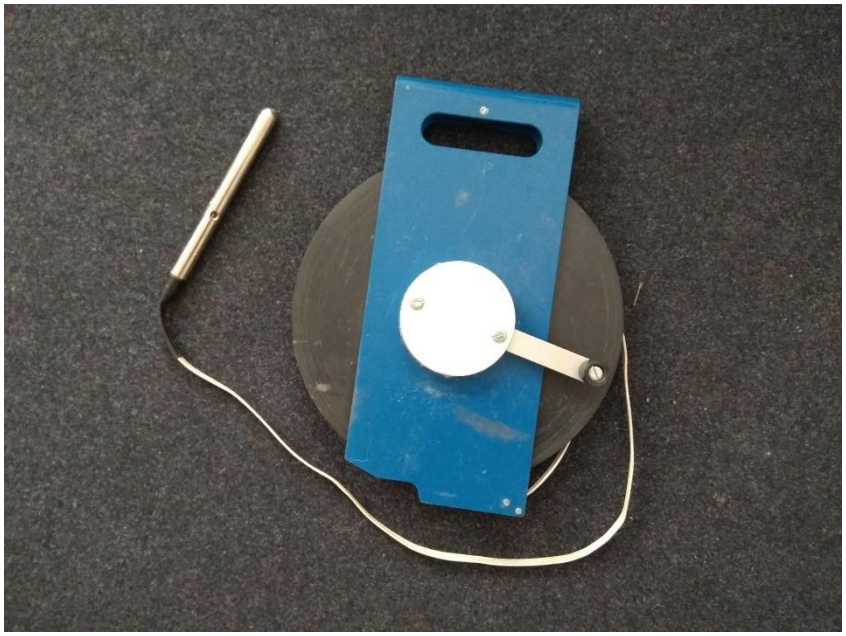
Monitoring of groundwater is realized in a similar way to monitoring of surface water. During hydrogeological monitoring, distance of the monitored objects from the construction site is usually set at 100-300 m. Within this area, hydrogeological bore holes and households with wells on their properties are defined based on maps and thorough geo technical explorations. The next step before the monitoring is commenced is to make rounds and inform the owners about the aims of the hydrogeological monitoring and in case of their agreement with monitoring the surface levels and accessing their properties, the introductory measurements are taken.

Introductory measurements include:

- Depth of the well,
- Height of the sampling point,
- Type of the well – digged x drilled,
- Current surface level of groundwater,
- Ways of utilizations – drinking water x non potable water, ▪ Photo documentation of hydrogeological objects.

The surface level of groundwater in a well or bore hole is detected by a level gauge with light and sound signaling, as shown on figure 2.

Figure 2: Level gauge



Source: Mertova, 2020

The level of groundwater is measured usually 4 times a year, in order to cover all seasons. Sampling of the groundwater is carried out twice a year, in spring and in autumn. The water samples are handed to the laboratory for basic physicochemical analysis. Monitored substances are the same as with the surface water, but a more extended physicochemical analysis can also be made. The extended analysis includes lower hydrocarbons and polycyclic aromatic hydrocarbons (PAH).

The sampling is realized with sampling vessel tied to a rope. It is a plastic cylinder with a sieve at its bottom part, so that there is no contamination with leaves, insects etc. during the sampling. Water is put into previously prepared plastic and glass sample containers.

Immediately after the samples are taken, they are labeled with the name of the sampling place and date. Samples labeled like this are ready to be transported into a certified laboratory.

Figure 3: Sampling test tubes for water samples

Source: Mertova, 2020

This is a method primarily for inspecting quality and quantity parameters of groundwater in bore holes and home wells.

Figure 4: Taking a sample from a hydrogeological borehole

Source: Mertova, 2020

5. Evaluation and processing of the results

Evaluation is done in several parts. First, completeness of laboratory protocols from the certified laboratory is verified. Next, results are evaluated in a spread sheet, where the figures are matched to individual objects. European Union declares limits for individual parameters in decree 2000/60/ES. In the Czech Republic, the limits are regulated by Decree 252 (2004). Figures from the laboratory protocols are compared with Decree 252 (2004) and potential exceeded limits are marked as excess values. Each individual measuring is then summarised into a final report, which is showing the results of the monitored period.

In this text part a brief commentary is made about the time period, when the measuring took place, if there was a drop in the water level in hydrogeological objects or on the contrary if there was an increase during the heavier rain periods, if the limits of the observed contaminants were or were not exceeded and if so, what could have been the cause.

Limits of observed parameters enshrined in Decree 252 (2004) are shown in table 2.

Table 1: Overview of the monitored substances

Indicator	Abbreviation	Units	Limit
Ammonium ions	NH_{4+}	$mg.l_{-1}$	0,50
Arsenic	As	$\mu g.l^{-1}$	10
Benzene		$\mu g.l^{-1}$	1,0
Benzo[a]pyrene	BaP	$\mu g.l^{-1}$	0,01
Bromates	BrO_3^-	$\mu g.l^{-1}$	10
Total organic carbon	TOC	$mg.l^{-1}$	5,0
Nitrates	NO_{3-}	$mg.l^{-1}$	50
Nitrites	NO_{2-}	$mg.l^{-1}$	0,50
Fluorides	F^-	$mg.l^{-1}$	1,5
Aluminium	Al	$mg.l^{-1}$	0,20
Magnesium	Mg	$mg.l^{-1}$	10
			20-30
Free chlorine	Cl_2	$mg.l^{-1}$	0,3
Chlorates	ClO_3^-	$\mu g.l^{-1}$	200
Chlorethene (vinyl chloride)		$\mu g.l^{-1}$	0,50
Chlorides	Cl^-	$mg.l^{-1}$	100
Chlorites	ClO_2^-	$\mu g.l^{-1}$	200
Chrome	Cr	$\mu g.l^{-1}$	50
Cadmium	Cd	$\mu g.l^{-1}$	5,0
Conductivity	k	$mS.m_{-1}$	125

Total cyanides	CN^-	$mg.l^{-1}$	0,050
Manganese	Mn	$mg.l^{-1}$	0,050
Copper	Cu	$\mu g.l^{-1}$	1000
Microcystine-LR		$\mu g.l^{-1}$	1
Nickel	Ni	$\mu g.l^{-1}$	20
Lead	Pb	$\mu g.l^{-1}$	10
Ozone	O_3	$\mu g.l^{-1}$	50
Pesticides	PL	$\mu g.l^{-1}$	0,10
Total pesticides	PLC	$\mu g.l^{-1}$	0,50
pH	pH	-	6,5-9,5
Polycyclic aromatic hydrocarbons	PAU	$\mu g.l^{-1}$	0,10
Mercury	Hg	$\mu g.l^{-1}$	1,0
Selenium	Se	$\mu g.l^{-1}$	10
Sulphates	SO_{42-}	$mg.l^{-1}$	250
Sodium	Na	$mg.l^{-1}$	200
Tetrachlorethylene	PCE	$\mu g.l^{-1}$	10
Trihalomethanes	THM	$\mu g.l^{-1}$	100
Trichlorethene	TCE	$\mu g.l^{-1}$	10
Trichlormethane (chloroform)		$\mu g.l^{-1}$	30
Uranium	U	$\mu g.l^{-1}$	15
Calcium	Ca	$mg.l^{-1}$	30
			40-80
Calcium + magnesium	Ca + Mg	$mmol.l^{-1}$	2-3,5
Turbidity		ZF (n)	5
Iron	Fe	$mg.l^{-1}$	0,20

Source: Appendix of Decree 252 (2004)

6. Observed substances and characteristics of water

To monitor quality, it is important to sample surface water and groundwater and subject it to laboratory analysis and determine what substances it contains. Most often, only basic physicochemical analysis of the sampled water is done, as shown in table 1, but in necessary cases, a complete physicochemical evaluation is done, see table 2. Characteristics and parameters of the of the monitored parameters are briefly described lower (Appelo & Postma, 2005).

Conductivity (specific conductance) is a concentration of dissolved substances in water. Indirectly it tells the content of mineral substances. It shows mineralization in water. Optimum level is around 200-400 $mg.l^{-1}$. If water contains more than 1000 $mg.l^{-1}$ it is considered unsuitable for continuous drinking – it is considered as a mineralised water. Such high mineralisation can cause digestive problems in humans but it also lowers the lifespan of piping.

Calcium and magnesium (Ca + Mg) are elements with good influence on cardiac and vascular systems. They have a positive influence on humans and the recommended amount is 2 – 3,5 $mmol.l^{-1}$. Minimal amount for magnesium is 10 $mg.l^{-1}$ and for calcium it is 30 $mg.l^{-1}$. With higher amount of these elements in water, technical problems with appliances and piping can occur. From a medical standpoint, higher amounts are not dangerous for humans.

pH expresses acidity or alkalinity of water. The limit for drinking water is 6,5 – 9,5. Optimal level is in between 6 and 8. Higher or lower figures do not have negative influence on humans. Water can have unpleasant taste and can lower the effect of disinfection. Low pH is connected to an aggressive water and possibility of metal corrosion.

Nitrates (NO^{-3}) amounting to $mg.l^{-1}$ are natural components of water. Due to exceeding use of fertilisers, sewage leaks from septics and cesspits their amount can increase up to hundreds of $mg.l^{-1}$. They are dangerous for humans, because they are reduced to nitrites in alimentary canal and these are toxic. In a stomach they further react with secondary amines, which are contained in food, and are carcinogenic. The limit is 50 $mg.l^{-1}$, but the optimal amount is around 10 $mg.l^{-1}$.

Nitrites (NO^{-2}) are more reactive form of oxidised nitrogen than nitrates, but they share the same origin and health risks (as written above). The limit is 0,5 $mg.l^{-1}$.

Ammonium ions (NH^{+4}) serve as an indicator of possible faecal contamination of groundwater. Absolute concentration based on geological bedrock is not important (from a medical standpoint, even 30 $mg.l^{-1}$ could be tolerated), a sudden and distinct increase in concentration above the level of geological "background" is. Combination of simultaneous presence of ammonium ions, nitrates and higher amount of organic compounds (CHSK-Mn) signalizes a fresh contamination by animal waste and proves an ad hoc water pollution. The limit is 0,5 $mg.l^{-1}$.

Chlorides (Cl^{-}). They are a marker similar to ammonium ions, one of the main macro constituents of water with usual natural amounts of tens of $mg.l^{-1}$. The limit is 100 $mg.l^{-1}$. If the higher content is influenced by geological bedrock, 250 $mg.l^{-1}$ can be tolerated. Higher concentrations have negative effect on taste and corrosion ability of water. This is often connected to a higher level of sodium, which can be a risk for patients with sodium diet and its continuous higher intake can lead to higher blood pressure (hypertension).

Sulphates (SO_4^{2-}) are an important component of natural water. The limit is 250 $mg.l^{-1}$. Higher concentrations can influence taste of the water and in compounds with magnesium it

can lead to diarrhea mainly in temporary users. They can also lead to technical difficulties such as sedimentation of scale or certain metals corrosion.

Iron (Fe) is a common component of natural water, its amount in drinking water can be increased by a corrosion of piping. At concentration 0,3 $mg.l^{-1}$ and higher it can have negative effect on sensory quality of water (bitter oppressive taste, yellowy color, rusty sediment), it can color the laundry or create turbidity. Irony bacteria can create sediments in piping. There is no health risk with concentrations below 1 $mg.l^{-1}$. The limit is 0,2 $mg.l^{-1}$. In cases when the higher amounts of iron in a crude water source are due to the geological environment, 0,5 $mg.l^{-1}$ can be considered passable, assuming there is no negative influence on organoleptic characteristics (smell, taste, colour) of water.

Manganese (Mn). Similar problematic as with iron, often common occurrence. It colors brownish-black. The limit is 0,05 $mg.l^{-1}$. For manganese with natural origin, 0,2 $mg.l^{-1}$ is tolerated if organoleptic quality of water is not influenced. Health risk in these low concentration (up to 0,4 $mg.l^{-1}$) is non existent.

Turbidity is a decrease in water transparency, which is caused by a presence of colloid substances such as pollen, dust, finely dispersed inorganic and organic compounds, plankton and other microscopic organisms. High turbidity turns water to non drinkable and it can lower the efficiency of possible disinfection. Sudden increase of turbidity is an important signal of contamination. The limit amount is 5 FTU.

Color is an important sensory characteristic of water quality. It is influenced by presence of color -creating organic substances such as humin (from leaves, plants and soil organic matter decay), metal compounds (for example compounds with iron, manganese or copper), colored particles of plankton or undissolved substances, rarely even industry chemicals. Water should be colorless. The limit is 20 $mg.l^{-1}$ on Pt scale. Together with turbidity it is an indicator of contamination.

7. Conclusions

Monitoring of chosen hydrological and hydrogeological objects during constructions of bypasses and highways in the Czech Republic contains a complex set of activities, which aim to prevent contamination or complete destruction of water source in the vicinity of construction site. It is quality and quantity monitoring of surface and groundwater.

The fieldwork part of the monitoring is done on previously determined spots with a level gauge, sampling cylinder and special sample tubes, which are then sent to a certified laboratory for a basic or a more extensive physicochemical analysis.

The next step in monitoring is the processing of results from the laboratory. Values from laboratory protocols are written into the prepared spreadsheet editor, which contains basic data on the monitored objects. Using the preset formulas and values specified in Decree 252 (2004), the exceeded values are immediately visible. Based on the results processed in this way, a final

report summarizing possible changes in surface and groundwater is prepared for each measurement performed.

Collected data and laboratory protocols are archived for eventual later checks. Result in a form of final reports and corresponding documentation of exploratory works are also handed over to a state geological archive Geofond in Prague, where they are collected and catalogued.

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References

[1] Albarede, F. (2009). *Geochemistry: an introduction*. 2nd ed. Cambridge: Cambridge University Press. ISBN 978-0-521-70693-3.
[2] Appelo, C. A. J., Postma, D. (2005). *Geochemistry, Groundwater and Pollution*. ISBN: 978-0415364287.
[3] Decree of the Czech Mining Authority No. 252/2004 Coll., Laying Down Hygiene Requirements for Drinking and Hot Water and the Frequency and Extent of Drinking Water Inspections. In: *Collection of Laws of Czech Republic*, amount 82. 1. 5. 2004. (*in Czech*)
[4] Fetter, C. W. (2008). *Contaminant hydrogeology*. Second edition. Long Grove: Waveland Press. ISBN 978-1-57766-583-0.
[5] Horakova, M. (2000). *Water Analytics*. Prague: University of Chemistry and Technology Prague. ISBN: 80-7080-391-6. (*in Czech*)
[6] Kozisek, F. (2003). *Well as a source of drinking water*. State Health Institute (*in Czech*)
[7] Krajca, J. (2006). Monitoring of environmental geofactors: (advanced technology and its application in the Czech and Slovak Republics). I, Groundwater quality monitoring. Znojmo: JAKR. ISBN 80-239-6973-0. (*in Czech*)
[8] Matouskova, M. ed (2008). *Ecohydrological monitoring of watercourses: in the context of the European Water Framework Directive 2000/60/ES*. Praha: Charles University in Prague, The Faculty of Natural Science, 2008. ISBN 978-80-86561-54-7.
[9] *Water science and technology*. (1981). Oxford: Pergamon Press, ISSN 0273-1223.