

Hazard Identification and Sensitivity of Potential Resource of Emergency Water Supply

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Abstract—The paper presents the case study of hazard identification and sensitivity of potential resource of emergency water supply as part of the application of methodology classifying the resources of drinking water for emergency supply of population. The case study has been carried out on a selected resource of emergency water supply in one region of the Czech Republic. The hazard identification and sensitivity of potential resource of emergency water supply is based on a unique procedure and developed general registers of selected types of hazards and sensitivities. The registers have been developed with the help of the “Fault Tree Analysis” method in combination with the “What if method”. The identified hazards for the assessed resource include hailstorms and torrential rains, drought, soil erosion, accidents of farm machinery, and agricultural production. The developed registers of hazards and vulnerabilities and a semi-quantitative assessment of hazards for individual parts of hydrological structure and technological elements of presented drilled wells are the basis for a semi-quantitative risk assessment of potential resource of emergency supply of population and the subsequent classification of such resource within the system of crisis planning.

Keywords—Hazard identification, register of hazards, sensitivity identification, register of sensitivity, emergency water supply, state of crisis, resource of emergency water supply, ground water.

I. INTRODUCTION

WATER is the basic prerequisite of human life. It plays a key and unique role in the history of human civilization. The development of cities and whole civilizations was closely connected with the availability of water. The reduced amount and quality of water resulted in the collapse of developed civilizations and migration of population. Water has become a scarce resource with the increase of human population, the increasing water consumption and the changed patterns of its production and consumption. The whole situation is complicated by the fact that the water reserves on the Earth are unequally distributed and its quality and amount have been continuously decreasing.

The global significance of water is being realized not only by each individual, but also by international communities and

organizations. Therefore the 12-point “European Water Charter” has been declared in Strasbourg on 6th May 1968 [1]. In 1993 the UN General Assembly declared the 22nd March to be the World Water Day [2]. The access to the resources of drinking water and the elementary hygiene for all people around the world till 2015 is the criteria of fulfilling one of the developing goals of the current millennium [3].

The importance of drinking water increases during emergencies and crisis situations, when it is necessary to supply population with water in appropriate quantity and quality for drinking, preparation of food and elementary hygiene. Therefore it is necessary to have a list of resources in the regional crisis plans, classified on the basis of risk analysis, which leads to their fast and efficient exploitation.

II. THE ANALYSIS OF CURRENT STATE

The emergency water supply of population is not addressed by Community Law in the EU as a whole. The emergency water supply in the Czech Republic is considered to be the management of water supply under crisis situations. The aim is to provide necessary amount of water in the required quality in such cases when the public water supply system is either fully or partially out of order. The emergency water supply is time limited and may be started only after the state of crisis is declared [4].

The emergency water supply requires the existence of necessary number of water resources supplying the necessary amount of drinking water. The current Czech system of selecting the resources for emergency water supply does not follow the principles of assessing the natural and technological hazards to such resources, their traffic accessibility, availability, richness and other criteria required abroad [5], [6]. Ground waters are primarily earmarked to be the resources of emergency supply as they are much less vulnerable than surface water resources. The basic characteristics of the resource earmarked for emergency supply has to be its resistance against the disturbance of its operational conditions due to an emergency, as being defined in a specific documentation of crisis management [7]–[9].

Planning the emergency water supply is a part of crisis plans. Within the declared state of crisis the tasks are defined for individual elements of Integrated Rescue System, mainly the Emergency Water Supply Service. Although the tasks for the Emergency Water Supply Service are defined below, there are not institutions in individual regions belonging to the above mentioned service.

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The Emergency Water Supply Service has the following main tasks: [7]

- Emergency water supply in crisis situations;
- Provide safety and clearance work on water facilities serving for water supply;
- Take measures to prevent the leakage of contaminants into ground waters, surface waters and soil;
- Eliminate threats and accidental leakages of contaminants into ground and surface waters and soil;
- Find new water resources and establish the intake structures for emergency water supply.

III. APPLIED METHODS

The "Fault Tree Analysis" method in combination with the "What if" method [10], [11] have been applied when developing the general register of hazards [12] and the threatened hydrogeological elements and technological equipment [13] of ground water resource in relation to natural and anthropogenic threats. The general registers have then become the basis for developing the register for a particular resource. There have been seven experts and one laic participating in the assessment.

The Delphi method [14] with two iterations [15] in the group of seven experts and one laic has been applied for assessing the impact (yes-no) of each hazard identified in the general register on individual hydrogeological elements and technical facilities of water resource.

Brainstorming [15] has been used for assessing the levels of identified hazards and the sensitivity of individual resource elements in dependence on the frequency of hazard source activation [12], or the level of damage caused to individual elements [13]. The assessment has been carried out in the group of seven experts and one laic at three joint meetings. Brainstorming has also become the basis for forming the hazard/sensitivity pairs for individual elements of water resource and the point indexation of their levels. The general point index values of hazards and sensitivity have been used in dependence on the hazard source activation frequency, or the level of damage caused to the individual elements of ground water resource.

A. Assessment of the Levels of Hazards and Sensitivity of the Ground Water Resource Elements

The point indexation of the activation of each identified hazard source for the assessed ground water resource has been carried out in real numbers within the interval of (0; 5) and used the data presented in Table I [12]. The semi-quantitative assessment of the sensitivity of individual elements of hydrogeological structure and technological equipment of water resource has been carried out similarly in the interval of (0; 4). The data presented in Table II have been used for the above mentioned purpose. The index point values have been assigned to each ground water resource element on the basis of the assumed level of its damage in relation to each identified hazard [13].

TABLE I
THE MEANING OF INDEX POINT VALUES AS A FUNCTION OF HAZARD SOURCE ACTIVATION FREQUENCY

Interval of the index point values	Hazard activation frequency [year ⁻¹]	Verbal assessment of hazard activation probability
(0; 1)	(0; 10 ⁻³)	Very low
(1; 2)	(10 ⁻³ ; 10 ⁻²)	Low
(2; 3)	(10 ⁻² ; 10 ⁻¹)	Middle
(3; 4)	(10 ⁻¹ ; 1,0)	High
(4; 5)	(1,0)	Very high

IV. OUTCOMES AND DISCUSSION

There have been assessed those drilled wells within the project [16], which have been selected in the water pipeline development plan of an assessed region of the Czech Republic. However, the resources mentioned in that document are not classified according to the methodical instructions [8]. At present there are other possible resources being assessed, which might meet the required function. Risk analysis and assessment are carried out for all drilled wells, which are then methodically classified into particular groups of resources earmarked for emergency water supply.

The presented case study deals with the identification of hazards and vulnerabilities of one of the potential resources of emergency water supply in a selected region.

The assigned index point values for the identified hazard/sensitivity pairs of elements of hydrogeological structure and technological equipment of the assessed ground water resource are clearly shown in Table III.

A. The Characteristics of Potential Resource of Emergency Water Supply

Malínky HV1 drilled well is located in the land register of Brankovice and is owned by a small town called Brankovice. It is located north of Malínky village on the right bank of the Pohraniční creek. The terrain around the drilled well is 285m above the sea level and heads south, towards the Pohraniční creek.

The partial hydrological catchment area of Malínky HV1 drilled well includes part of the Pohraniční creek catchment area on the right bank of the creek, to the north of the assessed drilled well up to the watershed with the Litenčický creek. The drilled well hydrological catchment area is of a triangle shape. The highest point of the catchment area is the unnamed spot height which is 345m above the sea level, north of the drilled well, on the watershed crest with the Litenčický creek.

The lands in the above mentioned catchment area belong solely to the agricultural land resources. There are neither villages nor roads in the catchment area.

The drilled well catchment area does not belong to any large-area protected territory. There are not any small-area protected territories nearby either. There are two natural monuments approx. 1.5km far from the drilled well.

TABLE II

THE MEANING OF SENSITIVITY INDEX POINT VALUES AS A FUNCTION OF DAMAGE CAUSED TO INDIVIDUAL ELEMENTS OF GROUND WATER RESOURCE

Sensitivity point index interval and its verbal assessment	Impact of hazard on the resource of ground water				
	Hydrogeological structure of resource		Technological equipment of resource		
	Hydrogeological conditions	Hydrological regime	Water quality	Water intake structures	Water treatment plant
(0; 1) Negligible	Local damage to an aquifer or the protective function of resource covering layer with a limited possibility of contamination leaking into the layer; the function of water resource is not significantly affected.	Local change in the direction of the current and the level of ground water; the function of water resource is not significantly limited.	Water in the local parts of resource structure rarely does not meet the requirements for the quality of drinking water. It meets the requirements for the quality of emergency water supply without treatment, though.	Isolated intake structures are damaged, exploitation of water is not significantly disturbed.	The change of parameters of isolated technological units, or minor damage to a building of water treatment plant; water supply is not significantly limited.
(1; 2) Marginal	Local damage to an aquifer or the protective function of resource covering layer with a possibility of contamination leaking into the layer; the function of water resource is partially affected.	Change in the direction of the current and the level of ground water at multiple locations; the function of water resource is partially limited.	Water in the local parts of resource structure is contaminated by certain pollutants, but after a simple treatment it meets the requirements for the quality of emergency water supply	Some intake structures are damaged, or not functioning; exploitation of water is partially limited.	The change of parameters of some technological units or their breakdown, building of water treatment plant is partially damaged and water supply is partially limited.
(2; 3) Critical	Extraordinary damage to an aquifer or the protective function of resource covering layer with a significant possibility of contamination leaking into the layer; the function of water resource is significantly limited.	Extraordinary change in the direction of the current and the level of ground water; the function of water resource is significantly limited.	Water in the major part of resource structure is significantly contaminated by a number of pollutants and only after a complicated treatment it meets the requirements for the quality of emergency water supply	Most intake structures do not function or are heavily damaged; exploitation of water is significantly limited.	Technological units have breakdowns or are out of service, water treatment plant is significantly damaged and water supply is significantly limited.
(3; 4) Catastrophic	Destruction of geological layers of aquifer or the resource covering layer; aquifer lost its protection against massive leakage of contamination; the water resource is permanently out of operation	Permanent change in the direction of the current and the level of ground water; the function of water resource is permanently impossible.	Water in the whole resource structure is contaminated and it is impossible to treat it by commonly available technologies to reach the quality suitable for emergency supply.	All intake structures are destroyed, or irreparably damaged; exploitation of water is impossible.	Destruction of technology or water treatment plant; water supply is impossible.

TABLE III

SEMI QUANTITATIVE ASSESSMENT OF HAZARD/SENSITIVITY PAIRS OF INDIVIDUAL ELEMENTS OF MALÍNKY HV 1 GROUND WATER RESOURCE

Potential Hazards	Frequency point index	Sensitivity point index of threatened elements				
		HG	HR	WQ	WIS	WTP
1 Natural hazards (natural disasters)						
1.1 Natural disasters caused by atmospheric changes						
Hailstorms and torrential rains	3.40				0.90	
Drought	3.15		1.82			
1.2 Natural disasters caused by geological changes						
Soil erosion	2.33	1.55			1.40	
2.1 Accidents						
Accidents of farm machinery	2.83			1.98		2.45
2.2 Ordinary activity						
Agricultural production	4.80			1.30		

HGC – hydrogeological conditions, HR – hydrological regime, WQ – water quality, WIS – water intake structures, WTP – water treatment plant.

The drilled well has the protective zone of the first category along the border of fenced area.

It results from the archive aerial photos of the surrounding area of potential resource for emergency water supply called Malínky HV 1 that the previous exploitation of the territory does not differ from the current one. The lands around the drilled well have been used for growing field crops. The significant change of landscape was caused by consolidating the private lands after 1953. Such landscape has remained the same until present time. No ecological burden has been found

in the infiltration area. During the last 150 years the number of inhabitants in Malínky village decreased from 286 in 1869 to 132 in 2010.

The surrounding area of Malínky HV1 drilled well is shown in Fig. 1.



Fig. 1 Malinky HV 1 drilled well

B. Identification of Hazards and Sensitivity of Ground Water Resource Elements

The identification of hazards and sensitivity of Malinky HV1 drilled well has been based on the developed general registers of hazards and sensitivity, the territory reconnaissance and the research of relevant data and information provided by the drilled well operator. The following natural hazard sources have been identified: hailstorms, torrential rains, droughts and soil erosion. Technological hazards include accidents of farm machinery and agricultural production. Based on the above mentioned outcomes the semi-quantitative assessment of hazard/sensitivity pairs for individual elements of Malinky HV1 ground water resource, the survey and assessment of which are shown in Table III.

1. Hailstorms and Torrential Rains

Hailstorms and torrential rains in open and unprotected terrain of the partial catchment area of drilled well may result in flash floods. The synergic effect of hailstorms and torrential rains are soil erosions and slope instability.

Hailstorms and torrential rains do not threaten any element of hydrogeological structure. They are characterized by the short time of duration and the surface outflow of precipitation. Water intake structure may be threatened. The drilled well area may be temporarily flooded and the polluted water may leak into the drilled well. The leakage of surface water into the drilled well is prevented by a concrete ring on the drilled well.

2. Drought

The partial catchment area of drilled well is of a small surface area, solely with the field areas and without any water course running across it. During hot season and the periods of low precipitation the accumulation of ground water decreases there. The occurrence of dry periods becomes more and more frequent in the Czech Republic and becomes the priority of environmental security [17]. During dry periods the wind denudation is intensified and the cleared areas with grown sparse or dry vegetation near the drilled well reduce the protective function of the covering layer of hydrogeological aquifer. Long-term periods of drought may affect the water supply balance of landscape.

The hydrogeological aquifer is not threatened by drought in the hydrogeological structure. Drought may threaten mainly the hydrological regime. The periods of drought result in the

decrease of the level of ground water and the reduced amount of ground water to be exploited from the drilled well.

The long lasting period of drought may hypothetically affect the quality of ground water due to the increased mineralization. Technological equipment is not vulnerable to drought. The oscillating level of ground water may in the long run cause that the drilled well equipment may become obsolete faster.

3. Soil Erosion

The sloping farm land over the drilled well may suffer from wrong agrotechnical procedures or inappropriate seed for sowing, which may result in solifluction and suffosion processes. Such processes will lead to the gradual washing away of soil horizon and impoverishing the soil profile. Intensive soil erosion on the slope above the drilled well may also be caused by hailstorms and torrential rains. The cultivated slope is located north of the assessed drilled well. The synergic effect of soil erosion may lead to easier leakage of agrochemicals from agricultural production into the hydrogeological aquifer.

Neither hydrological regime nor the quality of ground water is threatened by soil erosion in the hydrogeological structure. Hydrogeological aquifer may be threatened by impaired roof cover layer. Water intake structure as part of technological equipment may be threatened by soil erosion. Eroded soil may be stored near the drilled well and cause the subsequent problems during its exploitation. The penetration of eroded soil into the drilled well is not probable because of the concrete ring protecting the drilled well.

4. Accidents of Farm Machinery

Accidents of farm machinery may happen when cultivating the farm land in the partial catchment area of drilled well. The accidents may be caused by the failure of human factor, the breakdown of technical equipment, poor weather conditions and the terrain surface. The accidents may result in mechanical damage to some elements of potential resource of ground water supply. They are usually accompanied by the leakage of operating fluids and transported media, which are harmful to waters in most cases.

Accidents of farm machinery cannot threaten hydrogeological conditions and hydrological regime in the hydrogeological structure. However, the quality of ground water is vulnerable in case of the penetration of POL and other operating fluids into the hydrogeological aquifer. Such a penetration is prevented by a cover layer of loess having a good sorption capability. Distance from the drilled well and the location of accident are significant. The highest threat is represented by an accident of farm machinery near the drilled well, in the fall line above the drilled well. Water intake structure may be threatened as part of technological equipment by an accident of farm machinery. In case such machine breaks the fenced area of drilled well, its well head may be either damaged, or destroyed. The drilled well may also be affected by the leaked POL or other operating fluids.

5. Agricultural Production

Synthetic and natural fertilizers and pesticides are used when cultivating the farm lands in the partial catchment area of the drilled well. The operation of farm machinery may result in minor spills of POL and other operating fluids (oils, lubricants, windscreen wiper fluids, etc.). The synergic effects of agricultural production may be soil erosion and accidents of farm machinery on roads and fields.

Neither hydrogeological aquifer, nor hydrological regime is threatened by agricultural production in the hydrogeological structure. However, ground water has increased sensitivity to contamination in case of agrochemicals leaked or operating fluids spilled into the hydrogeological aquifer. The penetration of contaminants is prevented by a cover layer of loess having a good sorption capability. Technological equipment is not threatened by agricultural production.

V. CONCLUSION

Malinky HV 1 drilled well has been assessed as a potential resource of emergency water supply. The first phase of risk analysis has been carried out, i.e. the identification and semi-quantitative assessment of hazards and sensitivities of individual elements of the resource in relation to each hazard. The following hazards related to the assessed drilled well have been identified on the basis of all available materials: hailstorms and torrential rains, drought, soil erosion (especially in the form of solifluction, suffosion and deflation), accidents of farm machinery and agricultural production. The considered hazards and vulnerabilities have been characterized in relation to specific conditions of the site and with regard to possible hazard for individual elements of the resource of emergency ground water supply. Possible synergic effects have also been assessed together with the estimate of their activation frequency and sensitivity of individual elements of potential resource of emergency water supply.

The acquired outcomes of identification and semi-quantitative assessment of hazards and sensitivity of elements of potential resource of emergency water supply will be used for further analysis and assessment of risks. Malinky HV 1, the potential resource of emergency water supply, will be classified according to the discovered level of risk and according to the newly developed unique methodology reflecting the requirements of crisis management.

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