IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Application of groundwater aggressiveness assessment method for estimation of the karst process at main gas pipeline construction

To cite this article: A V Ermolaeva 2016 *IOP Conf. Ser.: Earth Environ. Sci.* **33** 012049

Application of groundwater aggressiveness assessment method for estimation of the karst process at main gas pipeline construction

A V Ermolaeva

National Research Tomsk Polytechnic University, 30 Lenin Ave., Tomsk, Russia

E-mail: alyona7@inbox.ru

Abstract. Main pipelines maintenance is connected with hazard engineering and geological working conditions. The article deals with the use of groundwater aggressiveness assessment method to estimate the karst processes development during the construction of main gas pipelines. The possibility of using this method is analyzed on the example of the initial section of the designed gas pipeline "Power of Siberia" (section "Chayanda-Lensk"). The calculation of the nonequilibrium index Ca was made in accordance with the geotechnical survey data. The dependencies between the geomorphological features of the terrain and the natural waters aggressiveness were determined.

1. Introduction

At present, the key criteria for transportation systems are industrial and environmental safety. At the moment, the Russian pipeline system – is one of the largest transportation systems in the world. Typically, the main gas pipelines maintenance occurs in the complex of dynamic, engineering-geological and nature-climate conditions. In recent years, there is an increase in gas pipelines accident rate due to geological hazard. Particular difficulties arise at the construction of the pipeline facilities in the karst areas due to the complexity of process development identifying and forecasting.

One of the key problems in the karst areas assessment study is the degree of karst process hazard zoning. The TSN 22-304-06 gives the following definition of karst hazard assessment - karst hazard is expressed in terms of probability of karst displacement occurrence for a given period of time (for example, the service life of the construction in the area of site location), which may cause unacceptable strain of the construction. A common integral measure of karst hazard for a long-term period was the average annual doline occurrence intensity (doline occurrence/km^2 a year) proposed by ZA Makeev (1948) and also applied in TSN 22-204-06. According to the results of the analysis conducted both in Russia and abroad, the following features that characterize the karst hazard could be highlighted:

1. Presence of surface karst forms;
2. Dissolving ability of natural water;
3. Presence of zone of the unconsolidated soil, recorded according to geoelectrical and velocity abnormality;
4. Intensive vertical filtration;
5. Presence (absence) of aquaclude which covers soluble rocks.

Among these features, the one should be noted that characterizes the future of karst processes development through space and time: the aggressiveness of natural waters. Since this feature describes the "behavior" and the intensity of the process in whole, the assessment on its base will be promising not only at the design stage, but also during the main gas pipeline maintenance. Under natural conditions, the system "water - rock" has equilibrium-nonequilibrium character. In this case, water, irrespectively of depth and speed, is always in nonequilibrium with some minerals by dissolving them, but is in equilibrium with others by generating them. Great contribution to the study of this process was made by the American researchers R M Garrels and Ch L Kraist.

Any form of interaction reaction could be expressed by the following schematic equation: $aA + bB \leftrightarrow cC + dD$, where A, B, C, B – stoichiometric coefficients of initial substances and reaction product. Thermodynamic equilibrium ratio of this process is defined by the equation: $K_a = \frac{a^*(C)^c \cdot a^*(D)^d}{a^*(A)^a \cdot a^*(B)^b}$. Equilibrium ratio characterizes the correlation of initial substances thermodynamic activity and materials in a state of ohmic equilibrium, in accordance with mass action law. Water aggressiveness index is used for natural water aggressiveness assessment, which characterizes the ability of water to transform solid substance in to the solution: $A = \lg \frac{K_a}{P_i \cdot a_i^{v_i}}$, where $P_i \cdot a_i^{v_i} = \frac{aC^c \cdot aD^d}{aB^b \cdot aA^a}$. The index of aggressiveness is often used for underground water dissolving ability comparison. The higher is the index A the faster is the substance dissolving process. To identify the character of the process (dissolving/sedimentation), the nonequilibrium degree index is used: $\theta = \frac{\Pi_i \cdot a_i^{v_i}}{K_a}$. The nonequilibrium degree characterizes undersaturation (θ < 0 – dissolving process occurs) or oversaturation (θ > 0 – mineral formation process occurs). Thus, application of the above mentioned method could help to estimate the probability of the process development along the main gas pipeline sections, which are predisposed to the development of karst.

2. Experimental design

The above mentioned method was applied to assess the influence of natural waters aggressiveness along the initial section of the designed gas pipeline "Power of Siberia" – Chayandinskoye oil and gas condensate field - Lensk, length – 160 km. The laboratory tests of water composition sampled through the period from 2010 to 2012 were used as the initial data for calculation.

Ground waters at the present site are characterized by sporadic distribution. Waters confined to the deluvial deposits are thin and low-yield, tapping at a depth of 3-5 m, according to the composition – bicarbonate, magnesium-calcium, sodium-magnesium-calcium. Aquaclude is presented by rocky and half-rocky soil, randomly multi-year soils.

Waters confined to deluvial-proluvial deposits are associated with over-permafrost and permafrost taliks. The calculation was done on the basis of 23 chemical water analyses, sampled throughout the studied area, available from the results of engineering surveys.

The assessment of carbonate rocks equilibrium was carried out with the help of HydroGeo software complex [1], designed by M B Bukaty (1999).

The following was taken as a system of calculation: water and basic ions such as H+, Na+, Mg^{2+}, Ca^{2+}, OH-, Cl^-, $(HCO_3)^-$, $(SO_4)^{2-}$; associate: $(CO_3)^{2-}$, H_2CO_3, $(CO)^{2+}$, CO_2, $NaHCO_3$, Na_2CO_3, $(NaCO_3)^-$, Na_2SO_4, $(NaSO4)^-$, $NaHSO_4$, NaCl, NaOH, $Mg(HCO_3)_2$, $(MgHCO_3)^+$, $(Mg(CO_3)_2)^{2-}$, $MgCO_3$, $MgSO_4$, $(Mg(SO_4)_2)^{2-}$, $(MgHSO_4)^+$, $Mg(HSO_4)^2$, $MgCl^+$, $MgCl_2$, $Mg(OH)_2$, $MgOH^+$, H_2SO_4, $(HSO_4)^-$, HCl, $(CaHCO_3)^+$, $Ca(HCO_3)_2$, $(Ca(CO_3)_2)^{2-}$, $CaCO_3$, $(Ca(SO_4)_2)^{2-}$, $CaSO_4$, $Ca(HSO_4)_2$, $(CaHSO_4)^+$, $CaCl^+$, $CaCl_2$, $CaOH^+$, $Ca(OH)_2$; the following minerals $MgCO_3$ (corr.) – magnesite (corr.), $MgCO_3$ - magnesite, $CaCO_3$ – calcite, $CaCO_3$ (IV) - calcite - IV, $CaCO_3$ a - aragonite,

$CaMg(CO_3)_2$ н – dolomite (disordered.), $CaMg(CO_3)_2$ – dolomite (ordered), $CaMg_3(CO_3)_4$ - huntite, $CaMg(CO_3)_2$ - dolomite, $NaHCO_3$ – nahcolite. Results of nonequilibrium index calculation (Ca) are given in Table 1. It is obvious that in most cases rock dissolving process will occur.

Table 1. Results of nonequilibrium index calculation.

№ Sampling point (well/site)	Salinity, g/dm^3	Nonequilibrium index θ (Ca)	Absolute marks of wells (height, m)	pH
101	0.153	-1.6	247.89	7.38
103	0.219	-0.4	243.27	7.6
211	0.791	0.99	461.74	7.35
156	0.618	-1.1	244.31	6.59
6943	0.356	0.26	357.2	7.2
6969	0.225	1.6	447.5	8
17	1.13	0.13	387.88	7
35	0.8	0.42	439.33	7.04
36	0.6	0.072	434.87	6.99
38	0.6	0.1	433.75	7
42	0.6	0.23	423.31	7
43	0.7	0.78	424.03	7.13
54a	0.4	-0.035	344.71	7.22
74	0.4	-1.7	416.50	6.54
85	0.4	-1.4	396.50	6.71
1034	0.548	0.2	347.45	7.2
1352	0.425	-0.54	414.95	7.01
2152	0.589	-0.15	458.3	6.99
2207	0.605	0.27	277.5	7.04
2211	0.395	0.13	276.5	7.4
2225	0.401	-1.3	276.08	6.74
2255	0.22	-1.6	253.67	7.08
2278	0.4	-1.1	255.87	7.33

According to the calculation results of calcite equilibrium to the studied waters, correlation dependence was derived, which allowed assessing the possibility of karst process origination in the studied area. Relation of nonequilibrium index CaCO3 and water salinity value was plotted as a diagram in accordance with the obtained results [2]. Analysis of the data showed that waters with a salinity value of more than 0.66 g / L are saturated to calcite. Thus, these areas of water sampling are free from karst process origination or the karst process will be of passive character. During the analysis of nonequilibrium index and pH relation, it was revealed that the waters in the studied area are weakly alkaline and the pH ranges from 6.5 to 7.8 [3, 4, 5]. In the sampling points where the pH value was more than 7.35, waters are likely to be rich in calcite, thus there is no threat of karst process origination.

For a more accurate prediction of karst hazard it is advisable to identify the relationship between the value of nonequilibrium index and terrain features in the area of pipeline construction . To reveal this dependence, the relationship between the wells absolute marks (from which water samples were taken) and the value of nonequilibrium index was analyzed [6, 7].

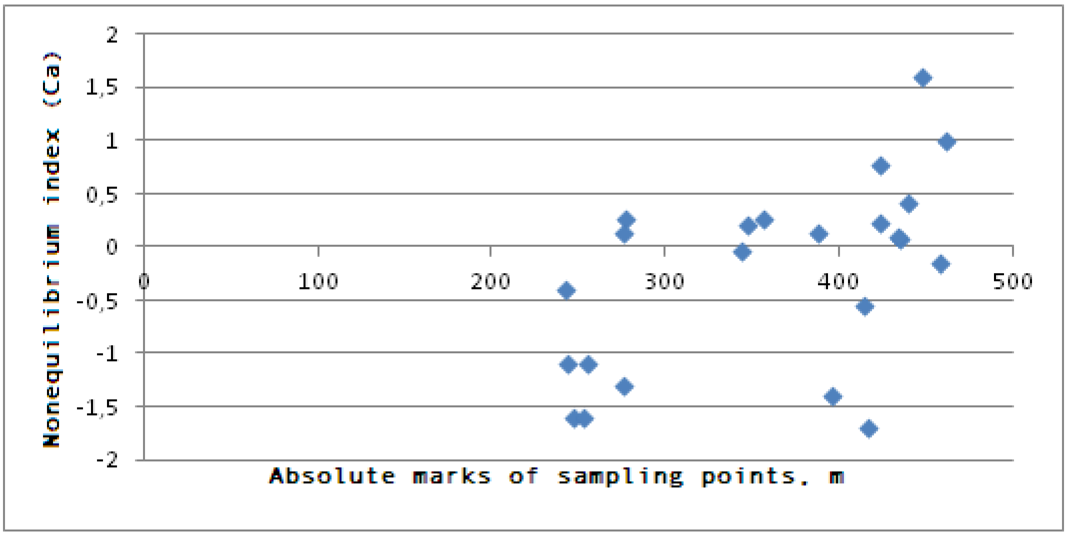

Figure 1. Variation of nonequilibrium index (Ca) regardless the absolute marks.

3. Summary

The correspondence between the geomorphological features of the territory and the groundwater aggressiveness could be noted as a result of the research.

The researched method is promising for the study of geoengineering conditions during the design of linear structures in karst areas [8, 9]. Thus, the samples collected from surface streams and wells confined to the bottoms of the local depressions relate to the negative values of the nonequilibrium index relative to calcite. Origination of less water saturation zones relative to calcite is determined by the increase of water exchange intensity. [10]

Consequently, on the ground of the geoengineering research results within the area of the initial section construction [11-13] of the main gas pipeline "Power of Siberia", the influence of the chemical composition of groundwater on the development of karst process was studied. It seems appropriate to perform such hydrogeochemical modeling across the whole gas pipeline.

References

[1] Bukaty M B 1997 Development of the software in the field of oil and gas hydrogeology *J Investigation and protection of a subsoil* **2** 37 (in Russian)
[2] Garrels R M and Christ C L 1968 *Solutions, minerals, equilibria* (Moscow: Mir) p 368 (in Russian)
[3] Gvozdetsky N A 1981 *Karst* (Moscow: Myisl) p 214 (in Russian)
[4] Gvozdetsky N A 1988 *Karst landscapes* (Moscow: Moscow State University Press) p 112 (in Russian)
[5] Zverev V P 2007 *Underground waters of crust and geological processes* (Moscow: Scientific world) p 256 (in Russian)
[6] Katayev V N 2001 *Methods and practice of comparative and evaluation karst division into districts* (Perm: Perm State University Press) p 85 (in Russian)
[7] Makeev Z A 1948 Principles of engineering-geological division into districts *Karstovedeniye* **4** 43 (in Russian)
[8] Maksimovich G A 1963 *Karst bases* (Perm: Perm State University Press) **1** p 443 (in Russian)
[9] Strokova L A, Dutova E M, Ermolaeva A V, Alimova A N and Strelnikova A B 2015 Karst hazard assessment in the design of the main gas pipeline (South Yakutia) *IOP Conf. Ser.: Earth Environ. Sci.* **27** 12032
[10] Teterin E A and Strokova L A 2015 Methods for karst hazard forecast and pipeline protection in South Yakutia *IOP Conf. Ser.: Earth Environ. Sci.* **27** 12033
[11] Waltham T, Bell F and Culshaw M 2005 *Sinkholes and Subsidence. Karst and Cavernous Rocks*

in Engineering and Construction (Berlin: Springer) p 404
[12] Antaki G 2003 *Piping and Pipeline Engineering: Design, Construction, Maintenance, Integrity, and Repair* (CRC Press) p 564
[13] McAllister E 2009 *Pipeline Rules of Thumb Handbook*: A Manual of Quick, Accurate Solutions to Everyday Pipeline Engineering Problems (Gulf Professional Publishing) p 762