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STEAM CONDENSATION IN THE ATMOSPHERIC MOISTURE AND CONDENSATION PROCESSES IN FRACTURED AND KARST RESERVOIR ROCKS

Abstract. This article reviews the main scientific publications on atmospheric moisture condensation and condensation processes in fractured and karst reservoir rocks. Analysis of the results of experiments and observations showed that the recommendation previously proposed by the scientists on not taking into account condensation component in balance calculation, is untenable and it needs to be clarified and finalized. The discovery of the negative impact of water of condensation on the development of karst in frozen rocks makes it possible to solve the ecological problems of these regions in a new way. To conduct research at different altitudes on cliffs were installed devices for measuring humidity, temperature, pressure. Indications from these devices were being taken for a week. However, in connection with the restructuring, the financing of these interesting and important works was discontinued. The study of steam condensation of and condensation processes in fractured and karst reservoir rocks is particularly important for the karst areas of Kazakhstan (Uluchur, Susingen plateau, etc.), where the condensation component of water resources (according to preliminary data of the Institute of Geology of Academy of Sciences of Kazakh SSR) may have a major role.

Keywords: atmospheric moisture condensation and condensation processes, karst, condensation sources, balance formula of Dublyansky, renewable resource of fresh water, steam condensation in frozen rocks.

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Аннотация. В статье произведен обзор основных научных публикаций по конденсации атмосферной влаги и конденсационным процессам в трещинно-карстовых коллекторах. Анализ результатов экспериментов и наблюдений показал, что ранее предложенная учеными рекомендация не учитывать в балансовых расчетах конденсационную составляющую несостоятельна и, ее необходимо уточнить и доработать. Открытие негативного воздействия конденсационных вод на развитие карста в мерзлых породах позволяет по-новому решать экологические проблемы этих районов. Для проведения исследований на разных

высотах на уступах были установлены приборы для измерения влажности, температуры, давления. С этих приборов в течение недели снимались показания. Однако финансирование этих интересны и важных работ было прекращено. Исследование конденсации атмосферной влаги и конденсационных процессов в трещинно карстовых коллекторах особенно важно для закарстованных районов Казахстана (плато Улучур, Сусинген и др.), где конденсационная составляющая водных ресурсов (по предварительным данным ИГГ АН РК) может играть основную роль.
Ключевые слова: сор конденсация атмосферной влаги, конденсационные процессы, карст, конденсационные источники, балансовая формула Дублянского, возобновляемый ресурс воды, пар в мерзлых породах.

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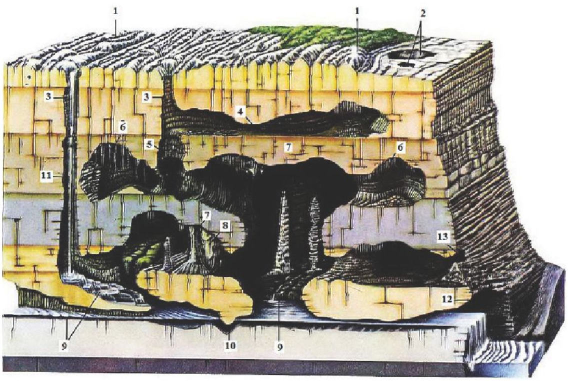
Түйіндеме. Бұл мақалада жарықшақ-карстық коллекторлардағы атмосфералық ылғал мен конденсациялық үрдістердің конденсациясы бойынша негізгі ғылыми басылымдарға шолу жасалған. Эксперименттер мен байқаулардың нәтижелерінің талдауы ғалымдардың бұрынғы ұсыныстары баланстық есептерде конденсациялық құраушыны ескермейтінін, оның негізсіз екенін көрсетті, оны анықтап, аяқтау қажет. Кертпештерде әр түрлі биіктіктерде зерттеулер жүргізу үшін ылғылдылықты, температураны, қысымды өлшеу үшін аспаптар орнатылды. Осы аппараттардан аптаның ішінде көрсеткіштер жазылып алынды. Алайда қайта құруға байланысты осы қызықты және маңызды жұмыстардың қаржыландырылуы тоқтатылды. Жарықшақ-карстық коллекторлардағы атмосфералық ылғалдың және конденсациялық үрдістердің зерттелуі, әсіресе Қазақстанның карстық аудандары (Улучур үстірті, Сусіңген және т.б.) үшін маңызды, мұнда су ресурстарының конденсациялық құрамдас бөлігі (Қазақ КСР ҒА Тау-кен ісі институтының алдын-ала деректері бойынша) негізгі рөлді атқаруы мүмкін.
Түйінді сөздер: атмосфералық ылғалдың конденсациясы және конденсациялық үрдістер, карст, конденсациялық көздер, Дублянскийдің қатып қалған жыныстардағы су буының конденсациясы, конденсациялық су.

According to the geological postulates of F.P. Savarensky, under the Karst (from Karst (German), after the name of Krasus limestone plateau in Slovenia) - the phenomena associated with the activity of groundwater, expressed in the desalination of soluble rocks (limestones, dolomites, gypsum) and formation of voids (canals, caves) in rocks, often accompanied by failures and subsidence of the back and the formation of funnels, lakes and other depressions on the surface of the Earth” [1]. Karst is characterized by a complex of surface (funnels, karrens, gutters, hollows, caverns, etc.) and underground (karst caves, galleries, cavities, lines) forms of relief. Intermediates between surface and subterranean forms are shallow (up to 20 m) karst wells, natural tunnels, mines or dips. Karst funnels or other elements of surface karst, through which surface waters leave the karst system, are called ponors (Figure 1).

Fissured and fissured-karst rocks are widespread everywhere and often occupy huge spaces. The waters confined to them are very diverse, which is closely related to the conditions of their formation and the time of their contact with the water-bearing rocks. Karst waters are underground waters, forming lying or moving in cracks and karst rocks, formed with the inevitable participation of dissolution processes. Usually, leaving in karstic cavities, water accumulates deep under the ground. Very often it serves as a source of water supply. For example, the water supply of Crimea resort is almost entirely dependent on karst water. Finally, without karst, there would not have been many mineral springs of Czechoslovakia, Hungary, the USA and our "Borjomi, Narzan and Essentuki". For the development of karht is not enough only soluble rock and water. If it is dense, without cracks, limestone or even gypsum is poured by water, it can stand for hundreds of years, turn into a saturated solution, but will not create



1 - carrens; 2 - funnels; 3 - natural mines and wells; 4 - cave gallery; 5 - vertical cave cavity; 6 - stalactites; 7 - stalagmites and stalagnate (filamentary column); 8 - filigree draperies; 9 - underground watercourses; 10 - siphon; 11 - underground waterfall; 12 - mainsail with a karst source of Fontaine de Vaucluse type; 13 - entrance to the cave system

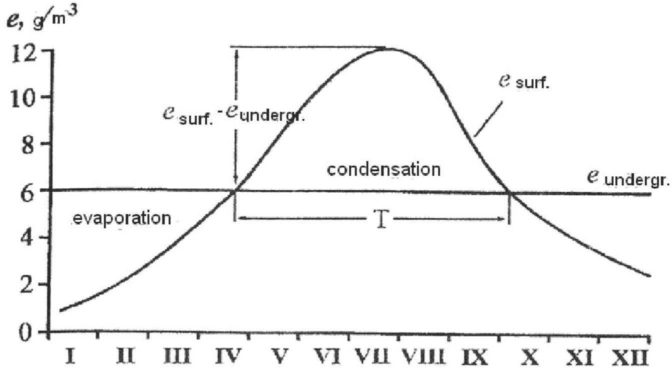
Figure – 1 Scheme of karst processes in the mountain massif [2] karst forms. For the growth of funnels and caves, it is necessary that the rock has pores or cracks along which water would carry away the dissolution products. Passing through the cracks, the water not only dissolves, but also erodes the rock, accelerating the growth of cracks and voids, preparing conditions for failures and extensive underground passages.

Industrial enterprises of Kazakhstan, the Urals, most of Leningrad and many other cities use karst waters. However, wherever cooking and other salts are being quarreled, the water is unsuitable for either technique or for everyday life. So, in Western Yakutia, artesian water is not water, but brine.

Until recently, it was believed that in the formation and feeding of fissured-karst waters, mainly infiltration waters [3] take part, and the possibility of their condensation feeding in balance calculations was not taken into account. It has now become clear that the accumulation of empirical material has led researchers to critically reconsider their attitude to the old paradigm. It turned out that the solid of the Earth is corroded not only by rainwater and running water penetrating deep into it, but also by the so-called condensation moisture. In underground voids, this moisture is rapidly saturated with carbon dioxide and becomes even more active solvent of carbonate rocks than water seeping from above; there is reason to believe that condensation moisture is ten times more active. But in fact, perhaps, in all over the world you will not find a cave, where there would be no condensation moisture. For example, T.I. Ustinova painstakingly calculated that in the summer in the cave cavities of the Crimea for each cubic meter of emptiness there is at least half a liter of condensation water. Subsequent researchers have proved that this figure can be significantly increased.

It all began with a thorough study of the agrophysicist A.F. Lebedev, who found that “pumping” through the pores and cracks in the rocks of a large amount of air is not necessary for condensation. Water vapor moves independently from areas with large to regions with a smaller partial pressure of water vapor and air temperature. From this it follows that in a warm period condensation is theoretically possible in fractured rocks and karstic cavities, and in cold period - evaporation (Figure 2). [4]

For the period from 1869 to 1987 about 1000 scientific articles have been published on the problem of condensation of atmospheric moisture [5]. To date the number of publications has increased significantly. 10% of the researchers consider that condensation of atmospheric moisture under the ground is impossible, 30% believe that the condensation of the warm



T – condensation duration, days (e_{surf} - e_{undgr}) – absolute air humidity, mm of mercury

Figure - Line of absolute humidity (mm of mercury) on the surface (e_{surf}) and underwater, in neutral zone of caverns (e_{undgr}).

period is compensated by the evaporation of the cold period and its role in the water balance is negligible, 50% assigns some role to it in the water balance, but abstains from quantitative estimates and only 10% recognize its significant hydrogeological significance. In modern reference and methodological literature it is noted that *"in connection with the complexity and laboriousness of quantitative determination of condensation in balance studies, it is not yet expedient to take it into account"* [6, p.120]; *"due to practical difficulties of definition, condensation is conditionally taken into account along with precipitation and evaporation"* [7, p. 89] and others.

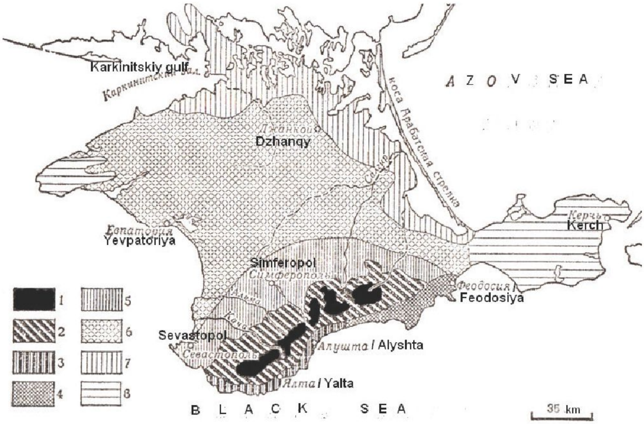
The greatest volume of research of condensation processes in fissured-karst cavities falls to the share of speleologists and karstologists. However, they still do not have a common point of view on the problem.

A review of the work on the role of condensation in speleogenesis and karstology was carried out by V.N. Dublyansky, in which he gives a summary of these opinions. Thus: E. Martel rejects its possibility, F. Tromb and N.A. Gvozdetsky give it a significant role, and B.A. Gergedava - even the dominant role in speleogenesis. In the fundamental summary of D. Ford and A. Williams it is only mentioned that condensation has a seasonal course, and condensation waters produce significant corrosion work [8].

Long-term studies of the karst of the Crimea, the Caucasus and other regions of the former USSR attest to the great role of condensation in the formation of karst waters and speleogenesis (Figure 3). The most significant contribution to the clarification of the significance of condensation water in fissured-karst collectors and their share in the balance and formation of groundwater belongs to the recently graduated doctor of geological and mineralogical sciences, professor Viktor Nikolayevich Dublyansky. The inconsistency of the infiltration theory for a number of geographic regions was proved by numerous studies later. So, in response to the conclusions of the Crimean expedition of geologists T.I. Ustinova and L.G. Reznikova (1955-1956 yy.), who reduced themselves to the assertion that condensation moisture can provide the activity of just one small source, and in fact is impossible, the geologist V.N. Dublyansky and the mathematician V.V. Ilyukhin came to the directly opposite conclusions. Used as a basis the limestone remains Mangup - the source of the second ridge of the Crimean Mountains, where there are no glaciers, and practically no snow deposits, isolated and surrounded by precipices, a source that has been operating since the 12th century! No wonder, at this time was the capital of the principality Theodoro Gothia, and then the Turkish fortress. Having processed the data, V.N. Dublyansky came to the conclusion that in the whole Main Ridge of the Crimean Mountains air exchange in the karst cavities occurs from 1 time in 5 days to 157 times a day, i.e., on average 14 times a day! The actual duration of condensation for the Crimea under various conditions averages from 44 to 238 days a year, and its magnitude for all voids of the Crimean mountains reaches 7.1% of the annual amount of precipitation, i.e., the condensation water yields almost all year-old runoff of the Crimean rivers! These facts can be explained solely by the condensation origin of water. The experiments made it possible to put forward the hypothesis of "open cracking", that is, the use of many small cracks as capacitors [10].

Another peculiarity of the condensation processes occurring in the fissure-karst reservoirs is the multiple repetition of interfacial transformations in the daily cycle in the three-component system "water vapor-liquid water-fissure-karst collector". At the same time, in the presence of an appropriate temperature regime, conditions are created for the formation of condensation waters.

Similar studies confirming the participation of condensation in the formation of groundwater are described for a number of other regions. The review of the huge factual material produced by V.N. Dublyansky allowed him to distinguish four levels of research (global, regional, local and objective),



1 - karst vertex surface of the Yaila;2 - mountain slopes of Yaila with forest landscape;3 - mediterranean landscape of South shore of Crimea;4 - eastern part of the southern coast (Mediterranean landscape);5 - southern forest-steppe and forest-shrub landscapes of cuesta ridges;6 - the steppe Crimea, farmed plains landscape;7 - Prisivashiye, dry steppe landscape with fragments of semi-desert; 8 - Tarkhankut peninsula and Kerch peninsula, hilly-steppe landscape
Figure 3 - Landscape scheme of the Crimea [9]

on which it is expedient to use different methodological approaches and methods of studying condensation. This methodical approach is justified by the fact that data obtained at one level is not always transposed to another [4,7]. There are also more unique types of condensation in the permafrost zone. Most researchers of the North of Russia say that on the Olenyok Plateau between the rivers Lena, Anabar and Vilyuy, where the world's most powerful layer of frozen soils is a mile and a half, there are many karst lakes and funnels. It turns out that the permafrost for water travel is not an obstacle at all? But the way of its formation and movement differs from ordinary flowing waters. Thus arose the hypothesis of film water.

Back in 1890 G.Ya. Bliznin [4, 7] voiced a thought that seemed incredible at the time, that water can move in a frozen rock. True, not by a stream, not by a drop, but by a film. And only a half-century studying the film water began I.A. Tyutyunov [11] and later many other scientists. Now many specialists in geocryology are interested in this topical issue for any construction on frozen soils. They were convinced that only free water freezes in frozen ground. And everywhere in the permafrost there is liquid water in the capillaries penetrating any sedimentary rock, and so-called adsorption water enveloping a thin film of the individual particles of which the rock is composed. Such water freezes is not at zero, but at minus 25^{0}C, but more often starting from -45 - -50^{0}C. And in the permafrost, apparently, there is no colder minus 17^{0}C.

The movement of adsorption-film water is very difficult and not completely studied. Its movement depends on the mineral composition, and on the exchange cations of rocks, their density, the degree of water saturation of the permafrost and much, much more. Simplifying, we can say this: film moisture passes from one rock particle to another because of a change in the attraction field when cooling the upper layers of frozen soil. Specialists in the limb of the permafrost distinguished three layers. The upper, active, with a thickness of 20 centimeters to three meters and freezing in winter, but thawing in the summer. Under the active layer up to a depth of four meters there is always a frozen layer that changes its temperature - in the summer it is warmer and in winter it is colder. Because of these thermal stresses, frozen cracks appear in the frozen rocks, in which water can enter. Still lower is the third, all the time cold and very powerful layer with a constant negative temperature. Any fluctuation in the temperature of rocks stimulates the movement of adsorption-film water to where it is colder. Especially active it moves with a temperature fluctuation from 0^{0}C to -5^{0}C. Traveling, the film water dissolves the limestone it clings to.

Migrating to the freezing front, the water film gives way to fresh moisture. This is sometimes repeated several times a year, when a piece of rock freezes and thaws. With a rapid loss of soil moisture due to the outflow of film water, water vapor, which turns into condensation moisture, also travels several times a year in permafrost. Of course, many details still need to be clarified, but the general scheme of the karst in frozen soils is already clear. And, as you can see, it differs significantly from ordinary karst. However, the result is the same: even in permafrost soils, underground cavities grow, there are gaps and funnels, rivers disappear ... The only difference is that the permafrost binds up rocks, and this longer masks the underground cavities, which are very dangerous for any construction. And it’s useful to know about this not only for specialist in geocryology and geographers, but also for drillers, road and pipeline workers - in general, everyone who works on economic development of the northern territories.

At present, the problems of film water, its forms and migration options are rather fully considered in the thesis of Komarov Iliya Arkadiyevich [12]. However, it does not consider condensation processes in fissured-karst rocks within permafrost. Studying them in connection with the expected global warming and solving the practical needs of the northern regions is one of the most pressing contemporary problems of the planet. The complexity of describing the phase state of water in real frozen rocks is associated with the need to simultaneously take into account the influence of a significant number of factors on it. This, for example, adsorption and capillary forces, the interaction of particles of a dissolved substance with each other, with water and a mineral skeleton, changes in the entropy of the components of the system, changes in the porosity of rocks during phase transitions of water. The questions of the theory of phase equilibrium remain unclear, with an increase in the number of components of the pore substance of rocks, for example, when they are salinized, contaminated with oil products. Both natural and intensively progressive technogenic salinization of soils is widespread in the cryolithozone. Pollution of oil products by the environment in case of accidents at fields, leakage during their transportation and storage is a serious environmental problem for the northern regions. Strengthening of technogenic pressure on the environment predetermines the need for a whole range of scientific research aimed at ensuring the sustainable and safe operation of natural and natural-technical systems.

More properties of bound water require more detailed investigation, in particular, the heat of crystallization, which depends not only on the interaction of water with a solid mineral skeleton, but also on moisture, temperature, pore space structure, and pore composition. There are difficulties connected with both the lack of experimental methods of research and the inadequate elaboration of theoretical questions of the thermodynamics of bound water. In view of all of the above, studies of the conditions of phase equilibrium of pore water in frozen rocks are relevant both in the scientific-theoretical and practical terms. Thus, as follows from the above material, the condensation of vaporous moisture from the atmosphere and condensation processes play a significant role in the formation of fissures and karst collectors, their shape of the volume of cracks and pores, in the creation and maintenance in a stable state of volumes of accumulation of condensation waters sufficient to solve water management tasks in some areas and facilities.

- Condensation waters should be taken into account in all water balance calculations carried out in the areas of the distribution of fissures and fissured-karst rocks.

- The formulas proposed by V.N. Dublyanskiy for calculating the share of condensation waters in the general underground drainage are sufficiently substantiated and confirmed experimentally at all levels. Above mentioned development can be recommended as educational and methodical manuals.

- The discovery of multiple inter-phase transformations in fissured-karst collectors and the possibility to increase the number of microcracks with open porosity allows one to come close to the problem of creating artificial condensation springs with a given capacity. This innovation allows improving the water supply of previously unpromising areas

- The discovery of regularities in the development of negative condensation processes in caves with the presence of Paleolithic painting allows us to select or create and maintain the necessary thermal and moisture regime for preserving the heritage of our ancestors.

- Condensation processes occurring in the karstic rocks of the North cause significant damage and their development is a threat especially in connection with the expected warming.

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