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THE ROLE OF THE WELL WATERS OF THE MAUSOLEUM OF KHOJA AHMED YASAVI IN THE FORMATION OF SALTS

Abstract. The work is devoted to the study of the chemical composition of well waters located on the territory of the mausoleum complex of Khoja Ahmed Yasavi. On the basis of experimental studies, the salinity of well waters increases every year. It is especially different in 2019 when, compared to the previous 10 years (2009-2018), there was a sharp increase in the total salt content by 1,5 times in the inner well and about 2,3 times in the outer well. The reason for this is the intense pollution of atmospheric air, soil, plants and other environmental objects due to an increase in the volume of construction work resulting from this waste, the number of servicing vehicles and the emergence of a number of new anthropogenic factors. The article also considers data from the Kazhydromet of the Republic of Kazakhstan that characterize changes in natural and climatic conditions, exactly, the amount of precipitation by month. Based on the calculated data, we have shown that water evaporation is 4-5 times higher than the amount of precipitation in the region. As a result of evaporation, moisture rises through the capillaries and is further saturated with salts found in building materials. Further, the formed saturated salt solution, undergoing various transformations, such as crystallization, contributes to the formation of salt deposits on the surface of the foundation materials and further walls. This negative phenomenon is one of the factors that lead to a decrease in the stability and safety of the architectural monument.

Keywords: mausoleum of Khoja Ahmed Yasavi, well water, chemical composition, salt deposits, factor, preservation of the monument.

Introduction. Turkestan region, including Turkestan city, according to the definition of the "National Report on the Conservation and Balanced Use of Biological Diversity", is included in the second group of regions of Kazakhstan on environmental risk [1-3].

One of the most effective modern tools in the field of preservation of cultural heritage around the world is now recognized as environmental monitoring [4 - 6]. It consists of a system for monitoring the state of immovable monuments under the influence of natural and man-made environmental factors.

The negative impact of environmental risk factors negatively effects to the condition of ancient building materials. Over a long historical period, the destruction of the materials of the historical buildings is inescapable, however, its speed can be increased many times by the effects of natural or anthropogenic factors both individually and collectively. Due to the influence of these factors, climatic conditions, groundwater level, soil composition change, which usually reduces the sustainable preservation of the architectural heritage. An increase in environmental risk causes negative processes at the monument: groundwater harms foundations, capillary moisture suction - walls, the appearance of salt deposits reduce the safety of building structures [7-9].

In order to predict changes in the state of the objects of the Khoja Ahmed Yasawi mausoleum complex and to develop scientifically sound measures for their conservation, it is necessary to assess the impact on the materials of monuments of the corrosive activity of atmospheric air and groundwater. Currently, because of the climatic changes (in particular, due to the increase in the frequency of thaws in winter), the wide usage of solid fuels, intensive construction work in the Turkestan city, there has intensified a car traffic and have appeared a number of new additional sources of environmental pollution [10].

The mausoleum of Khoja Ahmed Yasawi is a very important architectural monument of the late XIV and early XV centuries. Since 2000, the mausoleum has been included in the UNESCO list of world-protected monuments and is protected by international organizations. Inclusion of the property on the World Heritage List is not just an honorary international status, but also a high responsibility to the world community. The preservation of this unique architectural monument of the entire religious Islamic world, which is considered the second Mecca in its importance, is one of the main tasks in the field of preservation and protection of the world heritage [11].

This object, being in the territory where there is an active economic activity, like other objects of historical and cultural heritage, including Kultobe, is under the negative influence of many factors. The most common problems are non-compliance with the temperature and humidity conditions inside the building, the presence of rodents, insects, birds, the development of fungi and mold, as well as air pollution. In total, the studied object is influenced by various factors, both natural (climatic, biological, physical, and other factors) and anthropogenic (pollutant emissions, vibration, new construction, disturbances in the geological environment, salinization of groundwater, etc.)

The preservation of this unique historical monument of the entire religious Islamic world is important task in the field of preservation and protection of the world heritage. Every year, as a result of the intensification of production activities, the rate of negative processes associated with the influence of natural and anthropogenic factors increases exponentially, which can lead to a destruction of the integrity of this mausoleum. In this regard, the result of our research work on initial monitoring of underground well water is of some relevance [12].

Every year, the evolutionary transformations of the historical territories of Turkestan contribute to the acceleration of processes associated with the influence of anthropogenic factors. And anthropogenic factors increase exponentially, which can lead to a destruction of the integrity of this unique architectural ensemble.

The aim of this work is to study the chemical composition of well water in order to establish their effect on the safety of building structures of the Khoja Ahmed Yasawi Mausoleum.

Methods and objects of the research. The object of the study is the well water of the mausoleum of Khoja Ahmed Yasawi. The content of calcium and the total hardness, bicarbonate, magnesium, sulfate and chloride ions were determined by the titrimetric method according to the corresponding GOSTs [13–16]. The active water reaction, characterized by the pH value, was established by the potentiometric method [17-18]. The concentration of trace elements and fluoride ions were determined by known standard methods [19]. Organoleptic indicators according to the method given in GOST [20-22].

The content of safety indicators (mass concentration of nitrate ions) was determined spectrophotometrically according to the relevant GOSTs [23-25].

To account for the total microbial number, coliform bacteria, E. Coli, and other microorganisms, accelerated methods of analysis using petrifilms [26], immunochromatographic rapid tests, and ready-made selective and indicator nutrient media are very promising. Petrifilms are intended for quantitative determination of sanitary-indicative microorganisms, contain special indicators and substrates that facilitate the accounting of grown colonies of microorganisms. When the test sample is introduced to the substrate (1-5 ml of water sample), a gel-like nutrient medium is formed, which (after incubation) takes into account the number of microorganisms. When analyzing water by membrane filtration, the petrifilm is first activated (1 ml of sterile water), then the membrane filter is placed on the petrifilm substrate and the seeding is incubated according to [26].

Results and discussion. The average annual precipitation is not more than 250 mm even in suitable years; in some years, the amount of precipitation decreases to 90-150 mm. Most rainfall occurs in the winter and spring months. In summer, there is practically no rain and therefore high air temperature and the absence of precipitation in the summer months cause a large moisture deficit. Figure 1 shows the amount of precipitation for 2018.

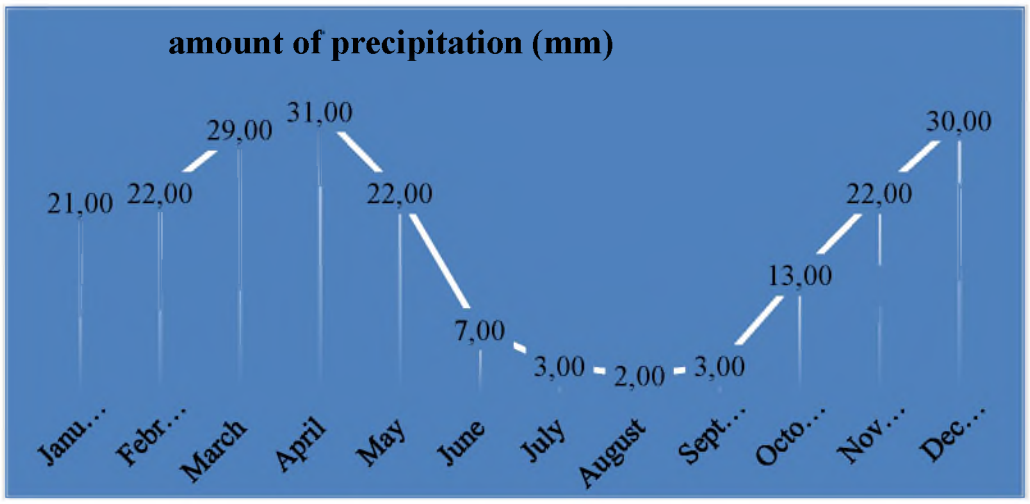

Figure 1 - Monthly changes in rainfall (mm)

As graph shows, the amount of precipitation in 2018 for Turkestan is 554.2 mm, the amount of ions in the precipitation is 21.32 mg / l: sulfate ions - 6.04, chlorides - 2.03, nitrates - 0.51, bicarbonates - 6.54, ammonium - 0.56, sodium - 0.35, potassium - 0.38, magnesium - 0.80, calcium - 4.09 mg / l, The pH of the precipitate is 6.92. The amount of moisture in the soil profile depends on the amount of evaporation. In soil formation, moisture plays a huge role, since all physicochemical, mechanical, biological, and other processes are connected with soil moisture.

The value of evaporation using the information from the weather station of the Institute "Ecology" IKTU named after H. A. Yasawi are defined by the formula: $E_o - 0{,}15\ nc\ D^{0,78}\ (1+0{,}85\omega_{100})$,

where E_o - is the monthly evaporation rate, mm; n - is the number of days in a month; C - is a parameter depending on the average ratios between the temperature of water and air, taken equal to 1.4; D - moisture deficiency; ω - wind speed at a height of 100 cm, m / s.

According to the calculation results, the total evaporation for the year is 1413 mm, and more than 82% of the total amount falls on the growing season (April-September). In the studied region, water evaporation is 4-5 times higher than the amount of precipitation.

Scientific research conducted in the area of the mausoleum. H.A. Yasavi, indicate the need to combine the ecological, geochemical and biological characteristics during spatial and temporal consideration of the elements of the ecological chain: the source of pollution - the surface atmosphere - precipitation - soil cover - plants - water bodies for organizing and adjusting measures to reduce environmental pressure and environmentally dependent pathologies.

As shown by the results of initial visual observation by detouring the residential areas adjacent to the object under study and by experimental research of the territory and objects adjacent to the architectural complex of the Yasavi Mausoleum, an ecologically crisis situation has developed in relation to this monument. This is due to the transformation of the protected area around the mausoleum into a landfill for solid household and various industrial wastes, not counting other pollution routes. This circumstance indicates the need for drastic measures to improve the environmental situation.

In aggregate, various nature factors influence the studied object. The main sources of environmental pollution are combined in two groups:

- natural processes that determine the background content of pollutants in the components of the biosphere (in soil, water, atmospheric air, etc.);

- anthropogenic sources, including a network of intensively constructed facilities, transport accumulations, emissions from numerous boilers of private houses that use solid fuel, parking lots and garbage dumps of household waste stretching over large areas, imperfect sewage systems, many years of unplanned discharge of both solid and liquid agricultural and other waste.

During expeditionary trips from 10 th January 2018 to 18 th August 2019, the collection of full-scale material was carried out on the territory of the mausoleum and territories adjacent to it. Work was carried out to control water bodies, that is, groundwater and groundwater (wells).

The destruction of the materials of the monument is inevitable, but its speed can increase many times due to the increased aggressive action of saline groundwater. With this in mind, we conducted studies to determine the composition of the waters of wells located both inside and in the courtyard of the mausoleum.

Sampling of water was done from drainage wells located around the mausoleum and from a well located inside the monument in the premises of Kudukhana. In addition, another well was investigated, located to the South-East of the mausoleum of Khoja Ahmed Yasawi in the courtyard of the mosque of the XIX century.

The results are presented in tables 1-2 and figure 2, they are compared with the data obtained in the analysis of these waters of the Ecology Research Institute from 2009 to 2019.

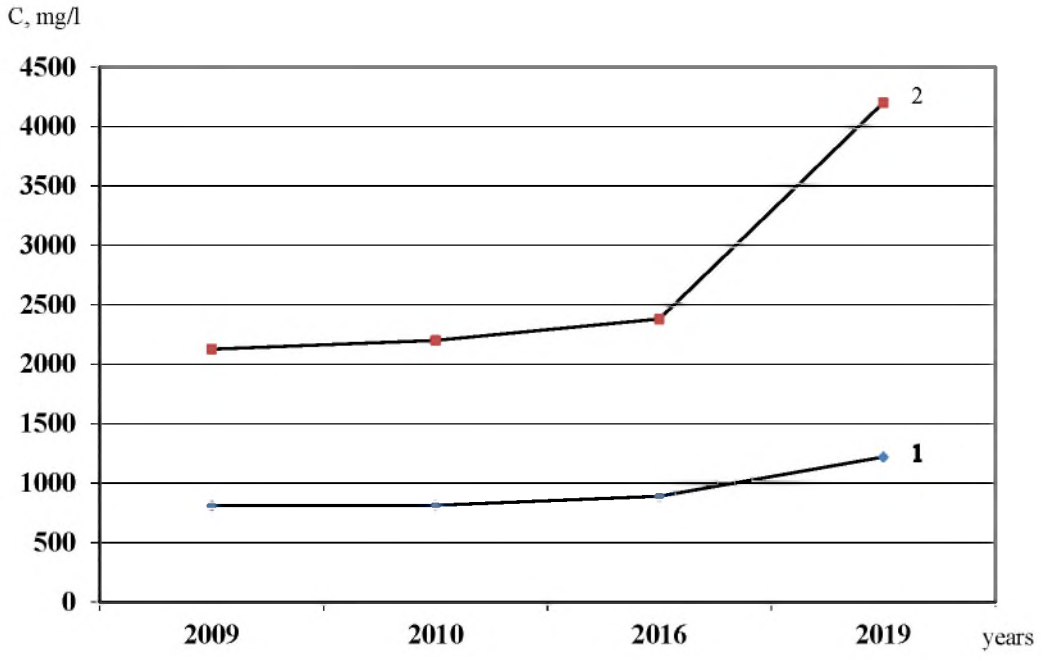

Figure 2 - The results of the analysis of the total salt content in the waters from the internal (1) and external wells (2) of the mausoleum

As can be seen from figure 2, the salinity of water in wells in 2019 compared with 2009-2016. increased approximately on average by 1.5 times inside the mausoleum and more than 2.3 times in well water located in the courtyard of the mausoleum.

The observed salinization of groundwater can have a significant negative impact on the condition of the monument. Moisture containing salts, due to capillary uplift and evaporation, saturates the pores of building materials.

Table 1 – Composition of well water of the architectural complex Yasavi (inside the mausoleum, depth - 3-5m)

№	Name of analyzes	Content of components in water	Method sensitivity	MAC in drinking water
1	2	3	4	5
1	Color, in degrees	2,314	-	no more 30
2	Turbidity, NTU/dm^3	5,554	-	2,6-3,5
3	Smell, taste, in points	0	-	no more 2-3
4	pH	8,586	0,2	6,5-9,0
5	Dry residue, mg/dm^3	1221,0	1,0	1000-1500
6	Permanganate oxidizability, mg·O/dm^3	3,64	0,01	4,0
7	Total hardness, mol / m^3	9,4	0,05	7,0

Continuation of the table 1

1	2	3	4	5
8	Carbonates, mg/dm^3	n/f	0,1	6,5
9	Hydrocarbonate, mg · eq /dm^3	0,56	0,1	6,5
10	Calcium, mg/dm^3	165,5	0,4	180,0
11	Ammonium ions and ammonia, mg/dm^3	0,271	0,05	2,0
12	Nitrite, mg/dm^3	0,033	0,01	3,0
13	Nitrates, mg/dm^3	5,56	0,1	45,0
14	Iron, mg/dm^3	0,42	0,01	0,3
15	Fluoride, mg/dm^3	0,37	0,02	1,2
16	Chlorides, mg/dm^3	64,4	1,0	350,0
17	Sulphates, mg/dm^3	505,0	1,0	500,0
18	Manganese, mg/dm^3	0,019	0,01	0,1

Table 2 - the results of the analysis of well water of the architectural complex (in the courtyard of the mausoleum, depth – 7-10m)

№	Name of analyzes	Content of components in water	Method sensitivity	MAC
1	Color, in degrees	3,680	-	≤ 30
2	Turbidity, NTU/dm^3	17,65	-	2,6-3,5
3	Smell in points	1	-	≤ 2-3
4	pH	7,724	0,2	6,5-9,0
5	Dry residue, mg/dm^3	2980,0	1,0	1000-1500
6	Permanganate oxidizability, mg·O/dm^3	2,74	0,01	4,0
7	Total hardness, mol / m^3	26,9	0,05	7,0
8	Carbonates, mg/dm^3	n/f	0,1	6,5
9	Hydrocarbonate, mg · eq /dm^3	1,35	0,1	6,5
10	Ammonium ions and ammonia, mg/dm^3	0,924	0,05	2,0
11	Nitrite, mg/dm^3	2,092	0,01	3,0
12	Nitrates, mg/dm^3	29,3	0,1	45,0
13	Iron, mg/dm^3	1,32	0,01	0,3
14	Fluoride, mg/dm^3	0,98	0,02	1,2
15	Sulphates, mg/dm^3	1360,0	1,0	500,0

The observed salinization of groundwater can have a significant negative impact on the condition of the monument. Moisture containing salts, due to capillary uplift and evaporation, saturates the pores of building materials. Salts crystallize and destroy the structure, i.e. the destruction of the foundations occurs, and this in turn will lead to a gradual shrinkage, deforming the walls. In order to avoid these processes, it is necessary to develop ways to protect the historical masonry of foundations and walls of architectural monuments from capillary movement of water.

Additionally, bacteriological analysis of water samples from wells on the territory of the mausoleum of Khoja Ahmed Yasawi was performed (table 3).

Table 3 - results of bacteriological analysis of well waters of the mausoleum of Khoja Ahmed Yasawi (2019)

Wells	Sanitary and bacteriological indicators				
	Total quantity bacteria in 1 см^3 of water				Escherichia coli
	15.03	10.05	12.08	05.11	
western	35	42	45	38	not detected
eastern	50	58	63	56	detected
southern	55	65	70	59	detected
Kudukhan	28	40	47	33	not detected
Juma mosque	35	43	45	38	not detected

The results of the study revealed the presence of biological contamination. Drinking water from these wells is dangerous for the health of pilgrims without appropriate decontamination measures.

Conclusion

1. Based on the results of chemical-analytical studies, an increase in the salt content in the waters of wells located on the territory of the mausoleum of Khoja Ahmed Yasavi is established every year. For 2019, the normative indicators for the total salt content are 1.5-2.3 times higher than in previous years.

2. It is shown by the calculation method that the volume of evaporating moisture is 4-5 times higher than the amount of incoming precipitation. An explanation is given of the phenomenon of the formation of salt deposits on the surface of building materials of the foundation and walls.

3. It is concluded that salt corrosion is one of the main factors contributing to a decrease in stability and a reduction in the duration of preservation of the unique ancient, architectural, priceless monument of the Khoja Ahmed Yasawi Mausoleum.

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ҚОЖА АХМЕТ ЯСАУИ КЕСЕНЕСІНДЕГІ ҚҰДЫҚ СУЫНЫҢ ТҰЗ ШӨГІНДІСІНІҢ ТҮЗІЛУІНЕ ТИГІЗЕТІН ӘСЕРІ

Аннотация. Мақала Қожа Ахмет Ясауи кесенесі кешенінің аумағында орналасқан құдық суының химиялық құрамын зерттеуге арналған. Тәжірибелік зерттеулер негізінде жыл сайын құдық суының тұз мөлшерінің жоғарылағаны анықталды. Алдыңғы 10 жылмен (2009-2018 жж.) салыстырғанда 2019 жылы ішкі құдықта тұз мөлшері 1,5 есе, ал сыртқы ұңғымада шамамен 2, 3 есе жоғарылағаны айқындалды. Мұның себебі ретінде атмосфералық ауа, топырақ, өсімдік және басқа да қоршаған орта нысандарының қарқынды ластануы, осы қалдықтар нәтижесінде құрылыс жұмыстары көлемінің артуы, қызмет көрсететін көліктер саны және бірқатар жаңа антропогендік факторлардың пайда болуын алға тартуға болады.

Мақалада сонымен қатар табиғи және климаттық жағдайдың өзгеруін, атап айтқанда, әр ай бойынша жауын-шашын мөлшерін сипаттайтын Қазақстан Республикасының Қазгидромет мәліметтері қарастырылған. Есептелген мәліметтерге сүйене отырып, судың буланuы аймақтағы жауын-шашын мөлшерінен 4-5 есе көп екенін көрсетті. Булану нәтижесінде ылғал капиллярлармен көтеріліп, оны құрылыс материалдарындағы тұзбен қанықтырады. Әрі қарай, мысалы, кристалданудан өтіп, әртүрлі қаныққан тұзды ерітінді іргетас материалдарының беткі қабатында және одан әрі қабырғаларда тұзды шөгінділерінің пайда болуына ықпал етеді. Бұл жағымсыз құбылыс сәулет ескерткішінің тұрақтылығы мен сақталуының азаюына әкелетін факторлардың бірі болып саналады.

Көптеген қайта қалпына келтіру жұмыстары, шұғыл континентальды климат, сонымен бірге уақыт та Қожа Ахмет Ясауи кесенесіне әсерін тигізіп отырғаны белгілі. Осыған байланысты, мәдени мұраның жылжымайтын нысанына экологиялық мониторинг жүргізу, мәселенің ауқымы мен генезисінің объективті көрінісін өңдеу және ұсынудың маңызы артып келеді. Ұңғымалық судың химиялық құрамын талдау тиісті ГОСТ-қа сәйкес титрометриялық, потенциометриялық және стандартты әдістер негізінде жүргізілді.

Түйін сөздер: Қожа Ахмет Ясауи кесенесі, құдық суы, химиялық құрамы, тұз қоры, фактор, ескерткіштердің сақталуы.

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РОЛЬ КОЛОДЕЗНЫХ ВОД МАВЗОЛЕЯ ХОДЖИ АХМЕДА ЯСАВИ В ОБРАЗОВАНИИ ВЫСОЛОВ

Аннотация. Работа посвящена исследованию химического состава колодезных вод, располо-женных на территории мавзолейного комплекса Ходжи Ахмеда Ясави. На основе эксперимен-тальных исследований установлено возрастание с каждым годом засоленности колодезных вод. Особенно отличается 2019 г., когда по сравнению с предыдущими 10 годами (2009-2018), произошел резкий рост общего содержания солей в 1,5 раза во внутреннем колодце и приблизительно в 2,3 раза во внешнем колодце. Основанием этого является интенсивное загрязнение атмосферного воздуха, почв, растений и других объектов окружающей среды за счет увеличения объемов строительных работ, образующихся при этом отходов, количеств обслуживающего

автотранспорта и появлением ряда новых антропогенных факторов. В статье также рассмотрены данные Казгидромета Республики Казахстан, характеризующие изменение природно-климатических условий, а именно количеств атмосферных осадков по месяцам. На основе расчетных данных нами показано, что испарение воды в 4-5 раз превышает количество выпадающих в регионе атмосферных осадков. В результате испарения происходит поднятие влаги по капиллярам и ее дополнительное насыщение солями, находящимися в строительных материалах. Образовавшийся насыщенный солевой раствор, подвергаясь различным преобразованиям, например, кристаллизации, способствует образованию солевых отложений на поверхности материалов фундамента и далее стен. Данное негативное явление является одним из факторов, приводящих к снижению устойчивости и сохранности архитектурного памятника.

Известно, что многочисленные реставрации, резкоконтинентальный климат и, конечно, время безжалостно оставили свой след на мавзолейном комплексе Ходжи Ахмеда Ясави. В связи с этим возрастает значение экологического мониторинга недвижимого объекта культурного наследия, обработки и представления объективной картины масштабов и генезиса проблемы. Анализы химического состава колодезных вод проведен титреметрическим методом по соответствующим ГОСТам, а также потенциометрическим методом и стандартным методикам.

Ключевые слова: мавзолей Ходжа Ахмеда Ясави, колодезные воды, химический состав, солевые отложения, фактор, сохранность памятника.

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