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RESEARCH ON QUANTITATIVE EVAPORATION OF WATER FROM THE KOSHKAR-ATA TAILING DUMP

The Koshkar-Ata tailings dump, with a volume of accumulated waste of more than 105 million tons today, poses a potential danger to the health of the population of nearby settlements when the wind blows toxic dust from the dried surface. Currently, due to the decline in production rates, a significant part of the dried pulp waste has been exposed, forming "dusty beaches". In order to minimize the negative impact of tailings dumps and improve the environmental situation, it is necessary to develop and implement highly efficient and cost-effective solutions. Solving the issues of stabilization of the water phase level and dusty "beaches" is a difficult task in terms of technical solutions, capital and operating costs.

The article presents the results of experimental and computational studies to determine the evaporation rate in the Koshkar-Ata storehouse. According to the literature data, the average annual air temperature of the regions of the Mangyshlak region is +9.05 ° C. It was necessary to determine the average level of evaporation of water from the Koshkar-Ata tailing dump at an air temperature and a water temperature equal to +9 ° C. The results of the experiments established that there is a direct dependence of water evaporation on temperature, regardless of the content of mineral salts, and the average level of evaporation of water from the Koshkar-Ata tailings dump at air and water temperatures equal to + 9 ° C is 0.3 cm.

According to calculations over the past fifteen years, the value of water losses for evaporation and filtration in the settling pond of the Koshkar-Ata tailings pond is 1,201 m/year. It can be tentatively assumed that the share of filtration waters accounts for about 9-10% of the total losses, then these losses in height will amount to 0.106 m, i.e. 8.8% of the total loss level.

Key words: pond, evaporation, water inflow, temperatures, tailings, process modeling, dry air, water vapor, temperature, element.

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Қошқар-Ата қалдық қоймасы суының сандық булануы бойынша зерттеулер

Бүгінгі таңда жинақталған қалдықтардың көлемі 105 млн. тоннадан асатын «Қошқар Ата» қалдық қоймасының құрғақ бетінен желмен улы шаңды таратуы кезінде жақын маңдағы елді мекендердің тұрғындарының денсаулығына ықтимал қауіп төндіреді. Қазіргі уақытта өндіріс қарқынының төмендеуіне байланысты кептірілген қалдықтарының едәуір бөлігі ашылып, «шаңды жағажайлар»пайда болды. Қалдық қоймаларының теріс әсерін азайту және экологиялық жағдайды жақсарту үшін жоғары экологиялық және экономикалық тиімді шешімдерді әзірлеу және енгізу қажет. Су фазасының деңгейін және шаңды «жағажайларды» тұрақтандыру мәселелерін шешу күрделі және пайдалану шығындары тұрғысынан күрделі техникалық шешімдер болып табылады.

Мақалада Қошқар-Ата қалдық қоймасының булану жылдамдығын анықтау бойынша эксперименттік және есептік зерттеулердің нәтижелері келтірілген. Әдеби деректерге сәйкес Маңғышлақ облысы өңірлерінің орташа жылдық ауа температурасы +9,05°C. Эксперименттік зерттеулер нәтижесінде минералды тұздардың құрамына қарамастан судың булануының температураға тікелей тәуелділігі және ауа температурасы мен судың температурасы +9°C-қа тең болған кезде Қошқар Ата қалдық қоймасы суының орташа булану деңгейі 0,3 см құрайтыны анықталды.

Соңғы он бес жылдағы есептеулер бойынша «Қошқар-Ата» қалдық қоймасының тұндырылған тоғанында булануға және сүзуге судың шығыны жылына 1,201 м құраған. Сүзгі суларының үлесі шығындардың жалпы көлемінің шамамен 9-10% құрайды деп болжауға болады, содан кейін бұл шығындар биіктігі бойынша 0,106 м, яғни жалпы шығын деңгейінің 8,8% құрайды.

Түйін сөздер: Қошқар ата қалдық қоймасы, негативті әсерлер, су температурасы, судың булануы, қалдық беті, ұсақ шаң, желдету.

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Исследования по количественному испарению воды хвостохранилища Кошкар-Ата

Хвостохранилище Кошкар-Ата, с объемом накопленных отходов на сегодня более 105 млн. тонн, представляет потенциальную опасность для здоровья населения близлежащих населенных пунктов при разносе ветром токсической пыли с высохшей поверхности. В настоящее время в связи со спадом темпов производства, обнажило значительную часть высохших пульпоотходов, образовав «пылящие пляжи». Для доведения до минимума негативного влияния хвостохранилищ и улучшения экологической обстановки, требуется разработка и внедрение высокоэффективных и экономически выгодных решений. Решение вопросов стабилизации уровня водной фазы и пылящих «пляжей» является сложной задачей с точки зрения технических решений, объемов капитальных и эксплуатационных затрат.

В статье представлены результаты экспериментальных и расчетных исследований по определению скорости испарения хвостохранилище Кошкар-Ата. Согласно литературным данным среднегодовая температура воздуха регионов Мангистауской области равна +9,05°С. Необходимо было определить средний уровень испарения воды хвостохранилища Кошкар-Ата при температуре воздуха и температуре воды, равной +9°С сравнительно с дистиллированной водой. Результатами экспериментов установлено, что имеет место прямая зависимость испарения воды от температуры, независимо от содержания минеральных солей и средний уровень испарения воды хвостохранилища «Кошкар-Ата» при температуре воздуха и воды, равной + 9°С ($\Delta H_{ср.}$) составляет 0,3 см.

По данным расчетов за последние пятнадцать лет величина потерь воды на испарение и фильтрацию в отстойном пруде хвостохранилища «Кошкар-Ата» составляет 1,201 м/год. Можно ориентировочно предположить, что на долю фильтрационных вод приходится около 9-10 % от общей величины потерь, тогда эти потери по высоте составят 0,106 м, т.е. 8,8 % от общего уровня потерь.

Ключевые слова: Хвостохранилище Кошкар Ата, отрицательные эффекты, температура воды, испарение воды, поверхность хвостохранилища, мелкодисперсный пыль, вентиляция.

Introduction

Formed by discharges of waste from the Caspian mining and metallurgical plant, sulfuric acid plant and untreated household waste, Koshkar-Ata tailings, with the volume of accumulated waste today is more than 105 mln. tons, currently due to the decline in production rates, exposed a significant part of the dried pulp waste, forming «smoky beaches», representing a potential health hazard for the population of nearby settlements when the wind blows toxic dust from the dried surface. To minimize the negative impact of tailings and improve the ecological situation, it is necessary to develop and implement highly effective and economically beneficial solutions. This question, as a priority of environmental policy, was reflected in the main documents of the economic and social development of the Republic of Kazakhstan for the period until 2030.

Created by industrial wastes of the Caspian mining and metallurgical combine, sulfuric acid plant and untreated household sewage, Koshkar-Ata tailing pond, with more than 105 million tons of accumulated waste as of today, currently, because of the decline in the rate of production, uncovered a considerable portion of the dried pulp wastes, creating «dusty beaches», potentially damaging to health of the population of nearby settlements as the wind spreads toxic dust from the dried surface [1].

The ecological situation in the area of the tailings dump determines the nature and degree of impact on the environment of the industrial toxic waste accumulated in it. Numerous studies conducted by various scientific organizations have not allowed to solve the problems of reducing the harmful impact of tailings in a complex way.

Water level movements may be considered as some phenomena of the global scale. On the basis of these researches, the following statement is obtained. Thus, for the considered sedimentation pond, water balance equalization can be valid:

$$\frac{dV}{dt} = \left(\frac{U_b(t)}{S(H)} - E_b(t) \right) \cdot S(t) \quad , \qquad (1)$$

where: V – the volume of the reservoir at the moment of time t; U_b (t) – water inflow per unit time; E_b (t) – visible evaporation layer ($E_b = E - P$), lost per unit time; E – vaporization; P – precipitation; S (t) – pond surface area.

Meanwhile, considering the absence of incoming drains, the water balance equation can be presented in form below:

$$\frac{dH}{dt} = \frac{U_b(t)}{S(H)} - E_b(t) \quad , \qquad (2)$$

where^ H – is water level in the pond at the time t; $S(H)$ – the surface area of the pond for determining the value of H.

Consider that the success of the study will depend on both the accuracy (methodology) of determining the components of the water balance, and the causes of their changes, the inflow of water, the area of the pond, as well as the water level in it are measured instrumentally and only evaporation is calculated. The lack of study of evaporation leads to the highest uncertainty in the use of water balance equations. Vaporization intensity is greatly influenced by the air flow formed over the water surface. If new masses of air with low water vapor content enter the free water surface, evaporation can intensify. However, with evaporation from large water surfaces, a significant influx of dry air is limited.

It is known that an increase of temperature by only 1 ° C, under otherwise unchanged conditions increases the process of evaporation of moisture by a factor of 10 [2]. In this regard, to achieve conditions of minimum evaporation from the surface of toxic water, it is necessary that the temperature of the outside air was higher than the water temperature by 1-3°C. The following parameters are set for evaporation ponds: air temperature 28-30°C, water temperature 25-28°C, relative air humidity 65-70%. Evaporation of moisture from the water surface of the tailings, in addition to the environmental load, also entails an impact on the humidity of the surrounding air. The intensity of evaporation, will depend on the area of water surface, water temperature, air humidity and airflow rate. There are quite a few calculation formulas for calculating the amount of moisture evaporating [3].

According to experience, empirical dependencies derived from measurements most fully take into account changes in moisture conditions (in closed ponds). Hence Table 1, and graphs to determine the amount of moisture evaporating from 1 m^2 of the surface of the evaporation pond (figure 1).

Numerous literature sources point out the difficulty of modeling water evaporation under laboratory conditions. It is known that when water evaporates, its molecules form water gas called *water vapor*. The atmosphere also contains water in the liquid state in the form of cloud droplets and raindrops [4].

Table 1 – Evaporation intensity for evaporation ponds, g/m^2

Water temperature, °C	**Air temperature, °C**	**24**		**25**		**26**		**27**		**28**		**29**		**30**	
	Ratio moisture, %	**50**	**60**	**50**	**60**	**50**	**60**	**50**	**60**	**50**	**60**	**50**	**60**	**50**	**60**
22		204	182	197	174	190	165	185	156						
23		217	194	209	187	203	178	199	169	187	158				
24		230	208	223	200	216	191	211	182	118	172	192	162		

Table continuation

Water tempe-rature, °C	Air tempe-rature, °C	24		25		26		27		28		29		30	
	Ratio moisture, %	50	60	50	60	50	60	50	60	50	60	50	60	50	60
25				235	213	229	204	221	195	213	185	205	175	196	169
26						244	219	236	210	228	200	220	190	211	179
27								250	223	243	215	235	205	226	194
28										259	230	250	221	241	209
29												268	238	259	227
30														277	244

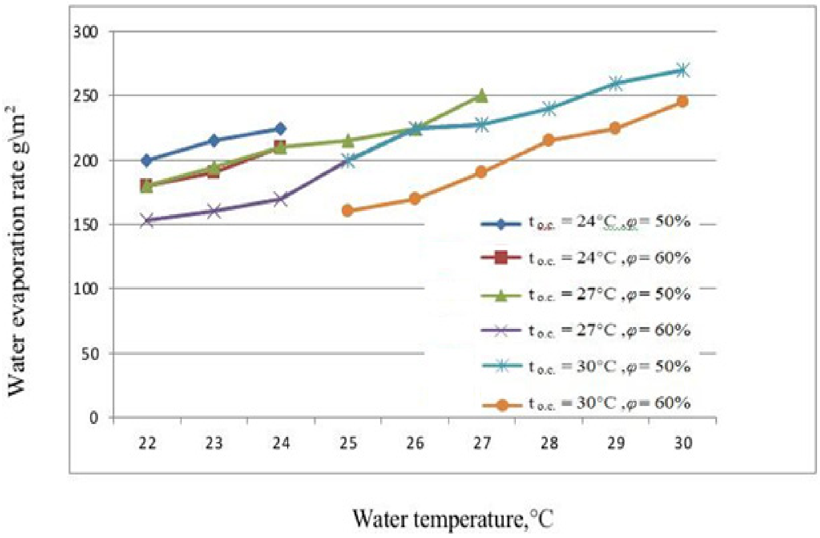


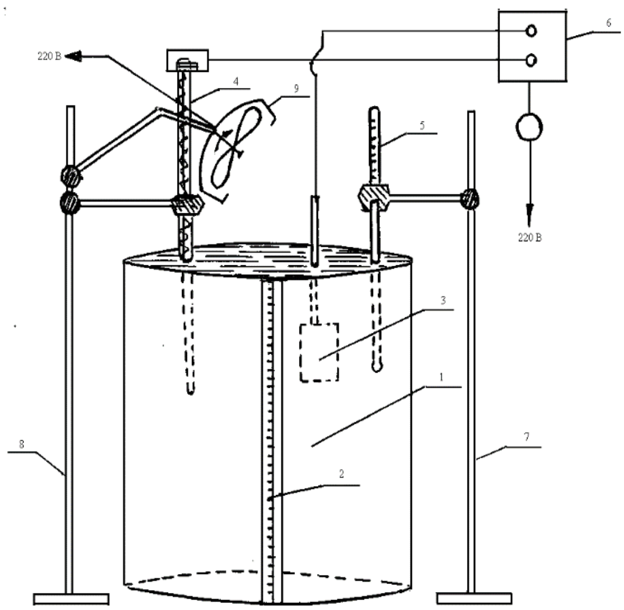
Figure 1 – Dependencies of evaporation intensity of the evaporation pond on temperature and humidity

Unlike most other gases in the atmosphere, the content of water vapor can vary greatly. It depends on air temperature and the condition of the evaporating surface (water, wet or dry soil, ice). In very cold and therefore dry air, water vapor can be present in small, barely measurable amounts; in hot air, its content can reach up to 4 percent of the air volume and then such air becomes humid [5].

In this regard, to determine quite accurately the amount of moisture evaporated a laboratory unit is made (figure 2) [6]. The tank itself with the liquid (water) is made of vinyl plastic sheet (thickness 10,0 mm). As a level to determine the volume of the liquid is used mounted on the tank from the outer side of an ordinary ruler with the divisions, the division value is 1.0 mm.

Part of the cylindrical space along the length of the ruler is made of plexiglass, which allows to fix the liquid volume in the tank without any difficulties. The volume of liquid in the tank is 30,0 dm^3, the upper level of the liquid is opposite to the mark «0». The price of each division by the height of the fluid (from top to bottom) is 0,1 dm^3 (100 cm^3), which allows you to quickly take readings when conducting experiments.

The device works in the following way. The liquid is poured into the tank (1) up to the zero mark. At the contact thermometer (1-3) by means of the upper washer set the set temperature at which the liquid must evaporate (for example, + 20°C ; + 25°C and etc.). After turning on the starter P-6 into the mains there is a gradual heating of the liquid to the preset temperature, and then the relay (device on thermostors) is activated and the liquid heating is switched off.



1 – pond; 2 – level for determination of liquid volume; 3 – heating element; 4 – contact thermometer; 5 – thermometer; 6 – starter P-6; 7 and 8 – racks; 9 – exhaust ventilator (10x air exchange per day).

Figure 2 – Device for determining water evaporation

The reference thermometer (1-4) allows you to record the desired temperature of the liquid. After carrying out the experiment (it is calculated in days) switch off heating of liquid, its temperature is brought to 20°C and take readings. The proposed technique makes it possible to clearly determine the amount of water evaporated from the surface of the liquid per unit time, as well as to estimate this figure by introducing into the evaporated liquid surface-active and other substances that could slow down the process of evaporation of water from the specified liquid.

The average annual air temperature for the region of Mangistau region is 9.05 °C. Nevertheless, during five months (May-September) it fluctuates within an average of (+20 до + 28) °C. Considering the fact that it is advisable to carry out environmental activities in the comparatively warm time of the year, it was necessary to choose specified temperature parameters for the experimental works. After analyzing average monthly and annual air temperatures in this area we came to the conclusion that the parameters on water evaporation should be set at the temperatures of (+20, +25, +30 and +35) °C. Evaporation of distilled water results are presented in the table 2.

From table 2 we can see that, as one would expect, when the temperature rises, the amount of water evaporated increases within 3,7 – 7,4 dm^3/day. For calculating the specific evaporation of water from the surface we proceed from the fact that the area of the circle (*S*) is determined by the formula [7]:

$$S = \pi R^2, \qquad (3)$$

where *R* – circle radius.

Since the tank in the device has a radius of 17.7 cm, the area of the evaporated surface will be:

$$3,14 \cdot (17,7)2 = 3,14 \cdot 313,29 –$$
$$– 983,7306 \cdot \ 983,7 \text{ см}^2 = 0,09837 \text{ м}^2$$

During calculations it is necessary to divide average quantity of evaporated water by the specified area. The obtained experimental data show that specific evaporation of water from the surface increases in the range from 37.6 to 75,2 dm^3/m^2·day, and degree of water evaporation will increase within the range from 3.7 to 7.5 wt %. It should also be taken into account that experimental works were carried out on one system, practically containing no mineral salts. Figure 3 shows graphically dynamics of distilled water evaporation depending on temperature [8].

Table 2 – Quantitative evaporation results of distilled water at elevated temperatures and over time

№ experience	Air temperature, °C	Water temperature, °C	Evaporation time, day.	Quantity of evaporated water, dm³ /day.	Average water evaporation, dm³ /day	Specific water evaporation from the surface dm³/m²day	Degree of water evaporation per day, %
1.	12	20	1,0	4,0	3,7	37,6	3,76
2.	12	20	1,0	4,0			
3.	12	20	1,0	4,0			
4.	12	20	1,0	2,8			
1.	12	25	1,0	3,6	4,1	41,7	4,17
2.	12	25	1,0	4,0			
3.	12	25	1,0	4,0			
4.	12	25	1,0	4,8			
1.	12	30	1,0	6,4	6,4	65,0	6,5
2.	12	30	1,0	6,4			
3.	12	30	1,0	6,4			
4.	12	30	1,0	6,4			
1.	12	35	1,0	7,6	7,4	75,2	7,5
2.	12	35	1,0	7,6			
3.	12	35	1,0	7,6			
4.	12	35	1,0	7,6			

It is remarkable that for all 4 types of experiments there is a direct correlation of quantity of evaporated water with its temperature. Thus, the higher temperature of water, the straight line is closer to the abscissa axis characterizing quantitative parameters of liquid.

Experimental works to define the degree of evaporation on the water taken from the «Koshkar-Ata» tailings pond were carried out according to the developed method on the above-mentioned device. Meanwhile, as in the case of distilled water, we took the same temperature regimes (+20, +25, +30 и +35)°C. Experimental works to define the degree of evaporation on the water taken from the «Koshkar-Ata» tailings pond were carried out according to the developed method on the above-mentioned device.

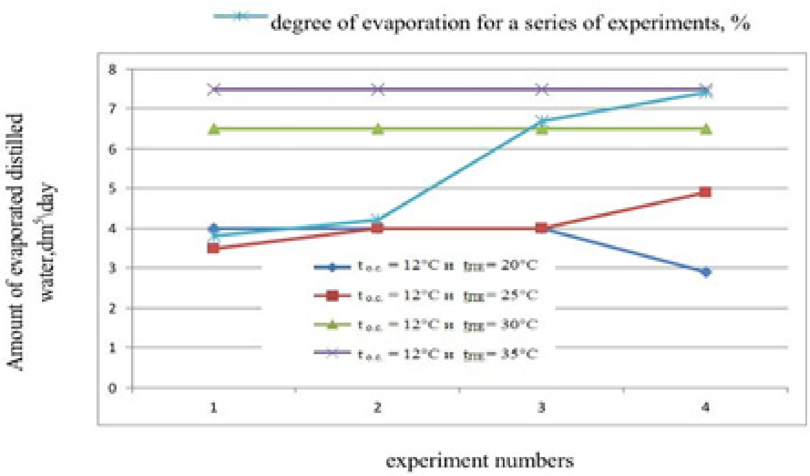


Figure 3 – Evaporation dynamics of distilled water over time as a function of air temperature

Meanwhile, as in the case of distilled water, we took the same temperature regimes (+20, +25, +30 и +35)°С.

The obtained data on water evaporation of the tailings pond are presented in the table 3.

The graphical dynamics of water evaporation of the tailings dump "Koshkar-Ata" depending on the temperature is shown in Figure 4.

It can be clearly seen that for all four types of experiments there is a direct dependence of the evaporation of water on the temperature of the environment. The higher the water temperature, the more the straight line approaches the abscissa axis characterizing quantitative indices of water evaporation [9]. It is established that when the outside air temperature in the "pond" of the tailings pond is within 28-30°C and 70% air humidity, the amount of moisture evaporated is 200 g/m^2 an hour.

Comparing the results on evaporation of distilled water and Koshkar-Ata tailings pond water and dynamic dependence of evaporation on temperature (Fig. 4,5) it is seen that evaporation rate practically does not depend much on temperature.

Table 3 – Experimental results on quantitative water evaporation of the «Koshkar-Ata» tailings dump at elevated temperatures and over time

№ experience	Air temperature, °C	Water temperature, °C	Evaporation time, day.	Quantity of evaporated water, dm^3 /day.	Average water evaporation, dm^3 /day	Specific water evaporation from the surface dm^3/m^{2}day	Degree of water evaporation per day, %
1.	12	20	1,0	2,8	3,12	31,7	3,17
2.	12	20	1,0	3,6			
3.	12	20	1,0	3,2			
4.	12	20	1,0	3,2			
1.	12	25	1,0	3,6	4,1	41,7	4,17
2.	12	25	1,0	4,0			
3.	12	25	1,0	4,4			
4.	12	25	1,0	4,4			
1.	12	30	1,0	6,4	6,3	64,0	6,4
2.	12	30	1,0	6,0			
3.	12	30	1,0	6,4			
4.	12	30	1,0	6,4			
1.	12	35	1,0	7,5	7,575	77,0	7,7
2.	12	35	1,0	7,6			
3.	12	35	1,0	7,6			
4.	12	35	1,0	7,6			

Particular evaporation for both variants differs very little at the same temperature. For instance, at temperature +25°C specific evaporation of distilled water from the surface is 41,7 dm /m·day, and water from the tailings pond also 41,7 dm^3/m^2·day, and at a temperature of +30 °C these data are consequently 65,0 dm^3/m^2·day. and 64,0 dm3/m^2 ·day. As for the water from the «Koshkar-Ata» tailings dump, there is also a direct dependence of water evaporation on temperature, regardless of the content of mineral salts [9].

According to the above data, the average annual air temperature of the regions of Mangyshlak oblast is +9,05°C [10]. It was necessary to determine the average level of evaporation of Koshkar-Ata tailings dump water at air temperature and water temperature equal to +9°C. Since such air temperature was established in the room where experimental works were carried out, we carried out the following preparatory operations for the experiment. Water from the «Koshkar-Ata» tailings pond was placed in the device (Figure 2) up to the «zero mark» (total volume of 30,0 dm3), and then disconnected the relay of the contact thermometer. Two coils connected to the thermostat were lowered into the tank of the device and the water temperature was set to +9°C. Air flow was carried out by exhaust ventilation and fan. The observation data of the above experiment are given in table 4 and the corresponding graphs are plotted (Fig. 6). Proceeding from data of table 2, average evaporation level of «Koshkar-Ata» tailing pond water at air and water temperature equal to + 9°C ($\Delta H_{av.}$) is 0,3 cm. Conventional transfer of this result to the annual time, the fall of the average annual water level (ΔHav.y.) is:

$$\Delta H_{av.year} = 0{,}3\ mm \cdot 365\ days = \\ = 109{,}5\ mm/y = 1{,}095\ m/y.$$

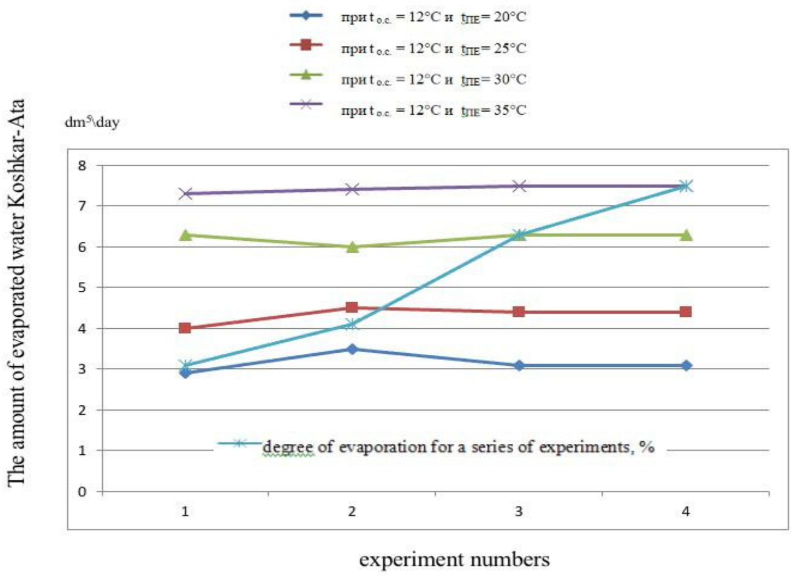


Figure 4 – Dependence of quantitative evaporation of tailings pond water

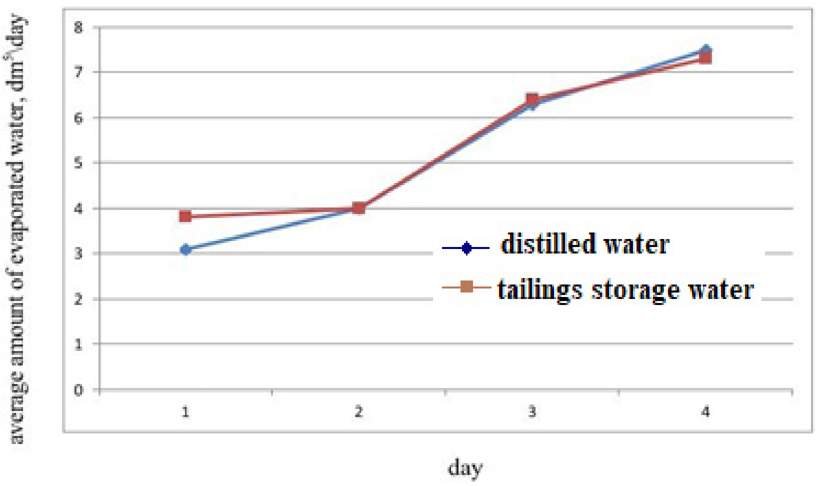


Figure 5 – Average amount of evaporated water of the tailings pond

Table 4 – Findings of the dependence of the level of evaporation of the tailings dam water on the air temperature, water equal to + 9°C, and time

№ experience	Air temperature, °C	Water temperature, °C	Height of initial water level, cm	Evaporation time, day.	Height of water level, cm	Average water evaporation, dm^3 /day
1.	9,0	9,0	300	1,0	298	0,2
2.	9,0	9,0		1,0	295	0,3
3.	9,0	9,0		1,0	292	0,3
4.	9,0	9,0		1,0	288	0,4
5.	9,0	9,0		1,0	285	0,3
6.	9,0	9,0		1,0	282	0,3
7.	9,0	9,0		1,0	279	0,3
						ΔHav.=0,3 cm

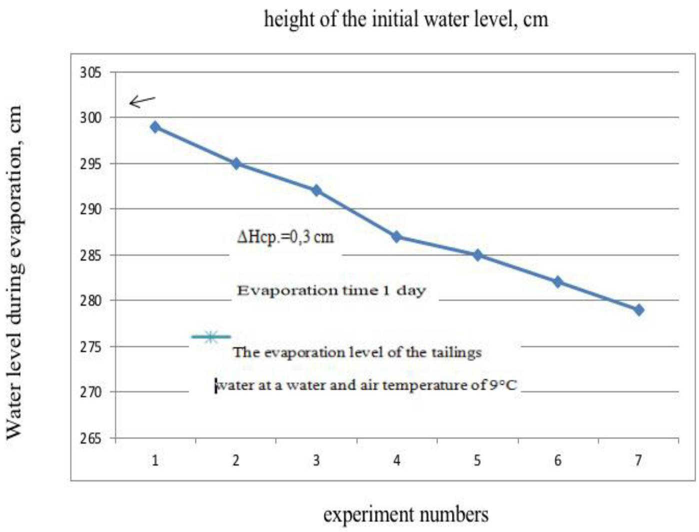


Figure 6 – Level of evaporation per day at equal temperatures of the tailings pond water and the environment

Conclusion

In this way based on calculations for the last fifteen years, the value of water lost to evaporation and filtration in the settling pond of the tailings pond "Koshkar-Ata" is 1.201 m/year. Approximately 9-10% of the overall losses can be assumed to be filtration water, then these losses by height will be 0.106 m, i.e. 8.8% of the total level of losses.

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