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SUBSTANTIATION OF RATIONAL PARAMETERS OF PERFORATED AREA OF PARTITIONS IN AN IMPROVED MINE WATER SETTLING BASIN

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ОБҐРУНТУВАННЯ РАЦІОНАЛЬНИХ ПАРАМЕТРІВ ПЕРФОРОВАНОЇ ОБЛАСТІ ПЕРЕГОРОДОК В УДОСКОНАЛЕНОМУ ВІДСТІЙНИКУ ШАХТНОЇ ВОДИ

Purpose. Scientific substantiation of the most rational geometrical parameters of the perforated area (shape and configuration of holes relative to each other) of vertical cross partitions placed in an improved mine water settling basin in order to increase their flow factor and, consequently, the efficiency of treatment (clearing) of water through removal of suspended particles.

Methodology. Selection of a partition perforation pattern is carried out on the basis of study and comparison of perforated area geometrical parameters, namely shape, size of holes and their configuration relative to each other; a correction factor that allows determining a distance between hole centers (perforation pitch); partition perforated area flow factor.

Findings. The partition perforated area flow factors have been determined for various perforation patterns. Analytical dependences of a partition perforated area flow factor change on the distance between hole centers have been obtained.

Originality. Revealed regularities of the partition perforated area flow factor change with a correction factor value allow determining a distance between hole centers for various perforation patterns. The dependencies (in the form of graphs and regression equations) between suspended particles settling depth in the improved settling basin and mine water treatment efficiency have been first identified for various perforation patterns.

Practical value. The research findings allowed justifying rational geometrical parameters of the perforated area of vertical cross partitions placed in an improved mine water settling basin. Implementation of findings will allow increasing efficiency of mine waters cleaning from suspended particles, as well as decreasing the level of surface waters contamination in coal mining regions.

Keywords: *mine waters, suspended particles, water body pollution, horizontal settling basin, perforated partitions, treatment efficiency*

The problem substantiation. Mine waters are distinguished by a wide variety of chemical composition and exhibit properties, which exclude their usage for engineering purposes or their discharge into the neighboring bodies of water without pretreatment [1]. Opening of coal deposits under complicated geological and hydrological conditions, as well as carrying out of mining operations at deeper levels result in increased volume of mine waters pumped away to the surface and increased level of their pollution by various chemical substances [2]. Subsequently, the discharge of contaminated mine waters poses an environmental hazard to the components of the environment, particularly for the neighboring surface bodies of water, in which the quality of water changes for the worse in respect of pollution content level [3].

The quality of water in surface bodies of water located in coal mining regions does not comply with the environmental safety standards in respect of the level of maximum permissible concentration of pollutants as a consequence of mine water discharge. The worsening of ecological condition of surface bodies of water is observed after the discharge of mine waters from operational storage ponds [4]. Mine waters also have a significant negative impact on underground waters, in this case deterioration of conditions of providing population with qualitative drinking-water is observed [5].

Mine waters pumped away to the surface in the course of coal mining contain a significant amount of pollutants including heavy metal compounds with toxic properties [6]. The distinctive feature of their behavior in the hydrologic system is absorbability on the surface of water-suspended particles of coal and rock with different particle-size distribution, which contribute to accumulation of toxic substances in the settling gravitating to the bottom of a body of water. The abovementioned issues become front most during coal mine abandonment [7].

Horizontal settling basins are widely used by collieries of Ukraine for increase of the environmental safety level of mine water discharge into the surface bodies of water by removing suspended particles from it (clearing). Their operating efficiency on the disperse phase removal is around 30 %. It should be noted that only coarse fractions are mainly removed, and almost all fine particles are discharged with water into the neighboring bodies of water, the level of contamination of which exceeds the level of maximum permissible concentration. In view of this, the existing settling basins do not comply with the requirements of the current *Regulations on Surface Water Protection against Recirculated Water Pollution* providing for the discharge of pollutants into the bodies of water in quantities that should not exceed their MPC value. It is evident that the further increase of the efficiency of treatment of contaminated mine waters and thus the increase of the environmental safety level of their discharge should be associated with the efficient removal of fine particles. This is precisely why the existing horizontal settling basin constructions are required to be improved in respect of enhancement of the process of settlement of the finest suspended particles and, as a consequence, increase of the environmental safety level due to the discharge of highly clarified mine waters into the surface bodies of water.

The mine water treatment process improvement will allow ensuring coal comprehensive use [8], as well as sustainable development and further reorganisation of mining industry [9].

Review of the related researches. Papers by A. I. Bereza, K. V. Gnedin, V. A. Gorshkov, M. V. Demura, L. F. Dolina, A. A. Kroik, I. I. Levi, D. M. Mints, I. L. Mongayt, G. I. Nikoladze, P. I. Piskunov, D. G. Sukhorukov, K. D. Tekinidi, A. A. Kharionovskiy, S. M. Shyphrin, S. M. Epoyan, etc. are focused on solution of the issue of enhancement of mine water treatment efficiency at mining enterprises.

The analysis of published findings of research of the existing industrial horizontal settling basins allows coming sufficiently to improvement of their constructions. It was found that a necessary condition for effective operation of settling structures, as well as consistency of the clarified water is the existence of its laminar flow regime. With regard to the above mentioned, it is important to maintain its stability as turbulence increases the transporting capacity of suspended matter in the flow, and water clarification efficiency is lowered. Consequently, a settling basin design should ensure the maximum uniform flow rate distribution over its cross-section and possibly more complete utilization of its volume by removal of stagnation areas [10].

It is believed that the best condition for settling industrial waste waters is a horizontal movement of the main water flow, which is perpendicular to the motion of settling suspended particles. In such event, settling rate is not increased, but only the reduction of disturbance of flow motion of liquid is achieved during the process of its clarification.

The improvement of conditions of the suspended matter settling process in the presence of a free surface in the flow can be achieved by creating a stable hydrodynamic flow pattern, i.e. by means of reducing the intensity of highly turbid bottom flows and the elimination of large-scale vortexes in the upper part of the flow. This may be achieved by placing along the length of a settling basin some intermediate perforated vertical partitions covering almost the whole vertical cross-section of the settling basin body. Meanwhile, the partition holes divide the flow of the liquid to be treated into a great number of individual layers (streams) of small height (size).

The effect of partitions consists in a change of a longitudinal velocity diagram, at which flow velocity vertical components directed to the settling basin bottom occur under the effect of viscosity forces. The value of these velocities exceeds significantly the settling rate (median fall diameter) of suspended particles retained in the settling basin. Meanwhile, the direction of transport force effecting a particle is the same as the direction of gravity force, that leads to the enhancement of the efficiency of suspended particles settling upstream of each partition.

The intermediate perforated partitions covering the settling basin cross-section contribute to dissipation of energy of bottom and surface flows, adjustment of horizontal velocity profile in all cross-sections of the structure, as well as make for increase in the factor of its volume utilization and enhancement of settling intensity of particles in the water to be clarified.

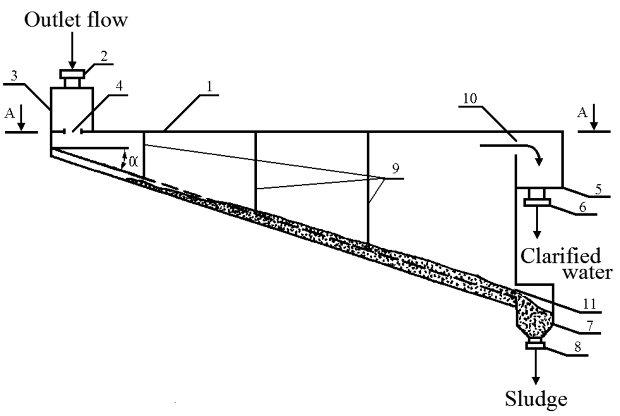
Experimental research of the functional mock-up of the settling basin with intermediate perforated partitions [10] showed that its structural volume is used completely enough (about 70 %) and, thus, the actual time of waste water settling and the flow rate approximate to the calculated values. Furthermore, the settling capacity of the settling basin having partitions increases significantly (by 30–50 %) compared to typical horizontal settling basins at the same degree of clarification (treatment) of water.

The allocation of unsolved issues. A horizontal settling basin of a unique design for waste water treatment from mechanical impurities (suspended particles) with polydisperse composition by means of gravity settling in a flow has been proposed for the purpose of ensuring environmental safety conditions where mine water discharge into surface bodies of water takes place [10]. This treatment plant can be used in various industrial sectors, including coal mining, for waste water treatment from undissolved solids with mainly homogeneous chemical composition and specific density exceeding water density.

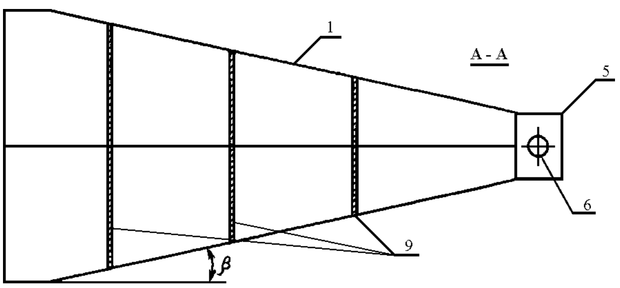
The main difference between the proposed settling basin design and the traditional structures for mechanical treatment of waste waters from suspended particles (matters) is that the body of the first is made in the shape of a trough, which tapers towards the drain with increase of its depth.

The perforated vertical cross partitions with cross-sections conforming to the settling basin body variable cross-section have been sequentially installed inside the settling basin (Fig. 1). The perforation shall mean punching of holes in various shapes and sizes in the partition material, generally, in a metal plate. The primary purpose of partitions is an adjustment of profile of horizontal velocity of movement of water to be treated along the depth when its level is gradually decreased along the length of the settling basin rather than solids retention. This significantly improves the hydraulic operation of the settling structure, and, therefore, increases the efficiency of treatment (clearing) of contaminated water.

Available perforated partitions, installed in different settling areas having variable shapes, allow a change of liquid flow trajectory and make an unidirectional laminar behavior of the flow, that in turn, contributes to more efficient precipitation of mechanical impurities (suspended particles) at the bottom of the settling structure. Laminar water flow regime in improved horizontal settling basin accelerates the settlement and precipitation process of fine particles. In addition, it eliminates the destruction of sludge bed, sliding down the inclined bottom, i.e. essentially eliminates the "effect of repeated sludge breaking" in the bottom water.



a



b

Fig. 1. The improved settling basin structural diagram:

a — side view; b — A-A sectional view of settling basin: 1 — settling basin body; 2 — pipeline for supply of polluted water; 3 — tank for distribution of streams; 4 — perforated holes at the tank bottom; 5 — water-collecting tank; 6 — pipeline for clarified water drain away; 7 — receiving hopper for collection and compaction of sludge; 8 — pipeline for compacted sludge drain away; 9 — perforated partitions; 10 — clarified water drain; 11 — sludge drain; α — slope of settling basin bottom towards horizontal area; β — settling basin contraction angles

The flow structure is also significantly affected by hole shapes in partitions. Most commonly the two types of distributive partitions such as perforated and slotted ones are installed in settling basins, where the slits may be horizontal or vertical. In paper [10] it is noted that coefficient of efficiency of horizontal settling basins having cross partitions with vertical slits is somewhat higher, than those with horizontal ones, and is only slightly different from the efficiency coefficient of settling basin having perforated partitions. However, the scientific literature gives no unambiguous answer to the question on what shape the holes shall have and on their configuration relative to each other.

The purpose formulation. The objective of the paper is scientific justification of the most rational geometrical parameters of a perforated area (shape and configuration of holes relative to each other) of vertical cross partitions placed in an improved settling basin in order to increase efficiency of cleaning mine waters of suspended particles (substances).

The main part. For practical perforation of a settling basin partition it is important to calculate parameters of the perforated area, namely, to determine the partition flow factor (k) and select the required distance between the centers of holes (p). In addition, the main geometric parameters of the perforated area to be considered in the calculation are shape and configuration of the holes relative to each other, their size and the correction factor (K_p) which allows the distance between the centers of holes (perforation pitch) to be determined.

The choice of a partition perforation pattern depends on the flow factor of the perforated area, which is determined from the formula

$$k = \frac{f}{S_{total}},$$

where f is area with perforated holes, cm^2; S_{total} is total area on which the holes are placed, cm^2.

For the purpose of justification of rational geometric parameters for a perforated area of partitions placed in an improved mine water settling basin, the most common shape of holes in settling basin partitions and their configuration relative to each other were analyzed. The obtained values of factor k were compared to each other. When choosing the perforation pattern, the preference was given to that one with which factor k would be maximum and the efficiency of suspended particles removal from mine waters should also increase.

To calculate the factor k the following parameters of a perforated area were taken:

- hole shape: round, square, rectangular, hexagonal;
- configuration of holes relative to each other: square pattern, rectangular pattern, hexagon pattern, with offset;
- hole size (w, cm): diameter and side length for square and hexagonal holes or width (a) and length (b) for rectangular holes. In calculation the values w and width a ranged from 1 to 10 cm, and value b from 0.1 to (a–0.1) cm;
- correction factor, which allows the distance between the centers of holes (K_p) determination.

Since the perforation pitch (p) should not be less than the size of a hole itself, in calculation the factor K_p ranged from 1.1 to 1.3.

Table 1 gives a systematized description for the type of perforation holes of different shape showing the key formulas for factor k calculation.

Using design ratio given in Table 1 (columns 1–4), the coefficient k values were determined for various holes patterns and their types in partitions with varying the preset geometric parameters of perforated area.

The obtained calculation data showed that with the same area of different types of the holes (like circle,

Table 1

Determination of partition flow coefficient (k) with various hole shapes and their configurations relative to each other

Pos.	Configuration of rows of holes in the partitions	Design ratio to calculate coefficient k	Description and permissible variations of design ratio parameters	Formula for calculation of coefficient k
		1. For round holes		
1.1	straight rows as square pattern	$f=4\cdot S_s=4\cdot\frac{1}{4}\cdot S_w=\frac{\pi\cdot w^2}{4}$; $S_{square}=p^2$; $k=\frac{\pi\cdot w^2}{4\cdot p^2}$	S_s is area of the hole part (sector), cm^2; S_w is hole area, cm^2; w is hole diameter, cm (w = 1–10 cm); p is distance between centers of the holes, cm; ($p = K_p\cdot w$, with K_p = 1.1–1.3)	$k=0.785\cdot\frac{1}{(K_p)^2}$
1.2	offset rows as hexagon pattern	$f=3\cdot S_s=3\cdot\frac{1}{6}\cdot S_w=\frac{\pi\cdot w^2}{8}$; $S_{triangle}=\frac{1}{2}\cdot p\cdot\left(\frac{p}{2}\right)\cdot \mathrm{tg}60°=\frac{p^2\cdot\sqrt{3}}{4}$; $k=\frac{\pi\cdot w^2}{2\cdot p^2\cdot\sqrt{3}}$		$k=0.9064\cdot\frac{1}{(K_p)^2}$
1.3	straight rows as rectangular pattern	$f=4\cdot S_s=4\cdot\frac{1}{4}\cdot S_w=\frac{\pi\cdot w^2}{4}$; $S_{rectang}=p_1\cdot p_2$; $k=\frac{\pi\cdot w^2}{4\cdot p_1\cdot p_2}$	p_1 is vertical distance between centers of the holes, cm; ($p_1 = K_p\cdot w$, with K_p = 1.1–1.3); p_2 is horizontal distance between centers of the holes, cm ($p_2 = p_1 + 0.1... p_2 = p_1 + 0.4$)	$k=0.7144\cdot\frac{1}{(K_p)^{1.9228}}$, at $p_2 = K_p + 0.1$
1.4	diagonally-offset rows as square pattern, rotated by 45°	$f=S_w+4\cdot S_s=S_w+4\cdot\frac{1}{4}\cdot S_w=\frac{\pi\cdot w^2}{2}$; $S_{square}=p^2$; $k=\frac{\pi\cdot w^2}{2\cdot p^2}$	$P = 0.7071\cdot p_d$, at $R^2 = 1$; p_d is diagonal distance between centers of the holes, cm; ($p_d = K_p\cdot 2w$, at K_p = 1.1–1.3)	$k=0.785\cdot\frac{1}{(K_p)^2}$
		2. For square-shaped holes		
2.1	straight rows as square pattern	$f=4\cdot S_s=4\cdot\frac{1}{4}\cdot S_w=w^2$; $S_{square}=p^2$; $k=w^2/p^2$	w is square side, cm (w = = 1–10 cm); p is distance between centers of the holes, cm; ($p = K_p\cdot w$, at K_p = 1.1–1.3)	$k=\frac{1}{(K_p)^2}$
2.2	straight rows as rectangular pattern	$f=4\cdot S_s=4\cdot\frac{1}{4}\cdot S_w=w^2$; $S_{rectang}=p_1\cdot p_2$; $k=\frac{w^2}{p_1\cdot p_2}$	see description to point 1.3	$k=0.9101\cdot\frac{1}{(K_p)^{1.9228}}$, at $p_2 = K_p + 0.1$
2.3	diagonally-offset rows as square pattern, rotated by 45°	$f=S_w+4\cdot S_s=S_w+4\cdot\frac{1}{4}\cdot S_w=2\cdot w^2$; $S_{square}=p^2$; $k=\frac{2\cdot w^2}{p^2}$	see description to point 1.4	$k=\frac{1}{(K_p)^2}$

The end of the Table 1

Pos.	Configuration of rows of holes in the partitions	Design ratio to calculate coefficient *k*	Description and permissible variations of design ratio parameters	Formula for calculation of coefficient *k*
2.4	offset rows as hexagon pattern	$f=S_w+4\cdot S_s=S_w+4\cdot\frac{1}{4}\cdot S_w=2\cdot w^2;$ $S_{rectang}=p_1\cdot p_2;\ k=\frac{2\cdot w^2}{p_1\cdot p_2}$	see description to point 1.1 and 1.3	$k=\frac{1}{(K_p)^2}$
3. For rectangular-shaped holes				
3.1	straight rows as rectangular pattern	$f=4\cdot S_s=4\cdot\frac{1}{4}\cdot S_w=a\cdot b;$ $S_{rectang}=p_1\cdot p_2;\ k=\frac{a\cdot b}{p_1\cdot p_2}$	*a* is hole width, cm (a = 1– 10 cm); *b* is hole length, cm (b = 0,1... a – 0.1 cm); p_1 is horizontal distance between centers of the holes, cm; ($p_1 = K_p\cdot a$, at K_p = 1.1–1.3); p_2 is vertical distance between centers of the holes, cm ($p_2 = K_p\cdot b$, at K_p = 1.1–1.3)	$k=\frac{1}{(K_p)^2}$
3.2	offset rows	$f=S_w+4\cdot S_s=S_w+4\cdot\frac{1}{4}\cdot S_w=2\cdot a\cdot b;$ $S_{rectang}=p_1\cdot p_2;\ k=\frac{2\cdot a\cdot b}{p_1\cdot p_2}$	the range of selected values *a*, *b*, p_1 is given in description to *p*. 3.1; $p_2 = K_p\cdot 2b$, at K_p = 1.1–1.3)	$k=\frac{1}{(K_p)^2}$
4. For hexagon-shaped holes				
4.1	offset rows as hexagon pattern	$f=\frac{1}{2}\cdot S_w=\frac{1}{2}\cdot\frac{1}{2}\cdot w^2\cdot n\cdot\sin\frac{360°}{n}=$ $=\frac{3\cdot\sqrt{3}\cdot w^2}{4};\ S_{triangle}=\frac{1}{2}\cdot p\cdot\left(\frac{p}{2}\right)\cdot tg60°=$ $=\frac{p^2\cdot\sqrt{3}}{4};\ k=\frac{3\cdot w^2}{p^2}$	*w* is hexagon side, cm (w = 1–10 cm); n is number of regular polygon sides (n = 6); *p* is distance between centers of the holes, cm; $p = 1.7321\cdot K_p\cdot w$, at K_p = 1.1–1.3)	$k=0.9999\cdot\frac{1}{(K_p)^2}$
4.2	straight rows as square pattern	$f=4\cdot S_s=4\cdot\frac{1}{4}\cdot S_w=$ $\frac{1}{2}\cdot w^2\cdot n\cdot\sin\frac{360°}{n}=\frac{3\cdot\sqrt{3}\cdot w^2}{2};$ $S_{square}=p^2;\ k=\frac{3\cdot\sqrt{3}\cdot w^2}{2\cdot p^2}$	$P = K_p\cdot 2w$, at K_p = 1.1–1.3	$k=0.25\cdot\frac{1}{(K_p)^2}$

square, hexagon and rectangle) the coefficient *k* depends only on the perforation pitch, i. e. the correction factor K_p. Therefore, the coefficient *k* value can be determined by the formulas shown in column 5 of Table 1.

At the end of the analysis we determine the settling depth of suspended particles of different settling velocity for various types of partition perforated areas and for their related flow coefficient (*k*), calculated from the formulas obtained. The calculations are performed with assigning the specific values of effect of suspended particles removal from mine waters (*P*, %), by the method described in [10].

For the calculation of initial data we select the following geometric parameters of the settling basin: initial width B_0=10 m, slope of bottom $\alpha \approx 30°$, plan view of the contraction angles $\beta \approx 84°$ and the length of the settling basin L = 20 m, finite width B_k = 6 m and maximum depth H_k = 11.5 m.

The calculation data for six hole types and their configuration in partitions are given in Fig. 2 with related curve fitting equations provided below:

- first perforation pattern – offset, diagonally-offset and straight rows of square and rectangular holes as square pattern; offset rows of hexagon holes: $h_{os} = -0.0017\cdot P^2 + 0.0396\cdot P + 10.728$, at $R^2 = 0.992$;
- second perforation pattern – offset rows of round holes: $h_{os} = -0.0022\cdot P^2 + 0.058\cdot P + 10.55$, at $R^2 = 0.989$;
- third perforation pattern – diagonally-offset and straight rows of round holes as square pattern: $h_{os} = -0.0032\cdot P^2 + 0.0961\cdot P + 10.178$, at $R^2 = 0.984$;
- fourth perforation pattern – straight rows of hexagon holes: $h_{os} = -0.00146\cdot P^2 + 0.03566\cdot P + 8.2592$, at $R^2 = 1$;
- fifth perforation pattern –straight rows of square holes as rectangular pattern: $h_{os} = -0.002\cdot P^2 + = 0.0508\cdot P + 10.624$, at $R^2 = 0.992$;

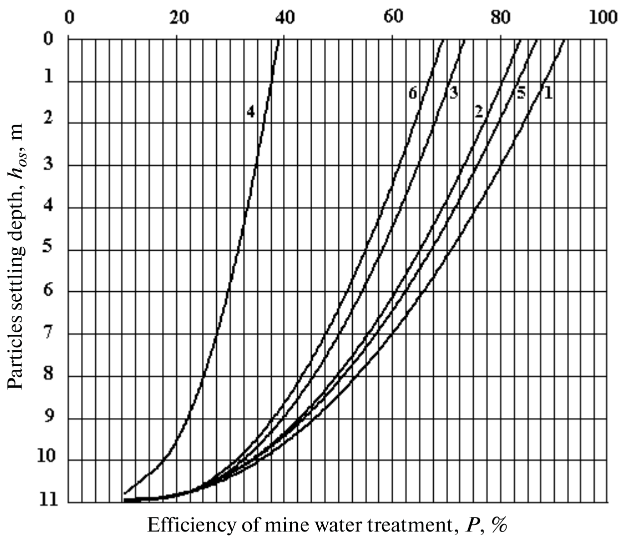


Fig. 2. Settling depth of suspended particles versus efficiency level of mine waters treatment for various perforation patterns:

1 — offset, diagonally-offset and straight rows of square and rectangular holes as square pattern; offset rows of hexagon holes; 2 — offset rows of round holes; 3 — diagonally-offset and straight rows of round holes as square pattern; 4 — straight rows of hexagon holes; 5 — straight rows of square holes as rectangular pattern; 6 — straight rows of round holes as rectangular pattern

- sixth perforation pattern — straight rows of round holes as rectangular pattern: $h_{os} = -0.0037 \cdot P^2 + 0.1108 \cdot P + 10.09$, at $R^2 = 0.988$.

Some of the expected process parameters of horizontal settling basin as per partition perforation patterns are shown in the Table 2.

Presented relationships and values illustrate obviously the effect of removal of particles of different settling velocity from mine waters. As we can see, the maximum effect of mine water treatment is provided by the perforation pattern 1.

Table 2

Values of the expected process parameters of a horizontal settling basin as per patterns

Perforation pattern	Expected effect of mine water treatment, P, %	Approximate settling depth of particles, hos, m	Settling velocity of particles, mm/s
1	91.0	0.25	0.073
2	83.0	0.21	0.120
3	73.0	0.14	0.228
4	38.0	0.73	2.070
5	86.0	0.20	0.100
6	69.0	0.12	0.292

Therefore, the vertical cross partitions with square, rectangular or hexagonal holes are recommended to set in an improved horizontal settling basin. In this case their configuration related to each other may be as follows:

- in case of square perforation pattern — with straight rows as square pattern, with offset or diagonally-offset rows;
- in case of rectangular perforation pattern - with straight or offset rows;
- in case of hexagon perforation pattern — with offset rows.

The conclusions and further development prospectives. Based on the investigations performed, the following results and parameters have been obtained and determined:

- flow coefficient of the partition perforated area for various perforation patterns;
- analytical dependences of variation of flow coefficient of the partition perforated area - on pitch of holes that allows determining a distance between holes centers for various perforation patterns;
- characteristic curves and analytical dependences of suspended particles settling depth on the effect of mine water treatment for various perforation patterns;
- the most rational geometric parameters of perforated areas of partitions installed in the improved settling basin to enable obtaining the maximum efficiency of mine waters cleaning of suspended particles with regard to their settling velocity.

As the future research activity prospective, it is planned to implement the results obtained and to assess operational efficiency of improved horizontal settling basins in mines of major coal mining regions of Ukraine.

References / Список літератури

1. Zvereva, V. and Krupskaya, L., 2015. Rare earth elements in mine, slime, and river waters in the Kavalerovsky and Dalnegorsky districts of the Russian Far East. *Russian Journal of General Chemistry*, Vol. 85, No. 12, pp. 2867–2873.

2. Perkova, T.I. and Rudakov, D.V., 2014. Study of leaching in fractured rocks affected by mineralized mine water, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, No. 5, pp. 5–10.

Перкова Т.И. Исследование выщелачивания трещиноватых пород под влиянием минерализованных шахтных вод / Т.И. Перкова, Д.В. Рудаков // Науковий вісник НГУ. – 2014. – № 5. – С. 5–10.

3. Biliaiev, M.M., Kirichenko, P.S. and Kharytonov, M.M., 2013. Numerical Simulation of the Sea Pollution for the Case of Mine Waters Discharge. *Black Sea Energy Resource Development and Hydrogen Energy Problems Part of the series NATO Science for Peace and Security Series C: Environmental Security*, pp. 315–324.

4. Gorova, A., Pavlychenko, A., Kulyna, S. and Shkremetko, O., 2013. *The investigation of coal mines influence on ecological state of surface water* *bodies*. In: Annual Scientific-Technical Collection Mining of Mineral Deposits. Leiden, The Netherlands: CRC Press / Balkema, pp. 303–305.

5. Kroik, A.A., 2014. Ecological safety of subterranean water on the territory of mining enterprises, *Journal of Water Chemistry and Technology*, Vol. 36, No. 4, pp. 198–202.

6. Wei, X., Wolfe, F.A. and Han, Y., 2014. Mine Drainage: Characterization, Treatment, Modeling, and Environmental Aspect. *Water Environment Research*, No. 86(10), pp. 1515–1534.

7. Wolkersdorfer, Christian, 2008. *Water Management at Abandoned Flooded Underground Mines: Fundamentals, Tracer Tests, Modelling, Water Treatment*. Springer-Verlag Berlin Heidelberg.

8. Savchuk, V., Prykhodchenko, V., Buzylo, V., Prykhodchenko, D. and Tykhonenko, V., 2013. *Complex use of coal of Northern part of Donbass*. In: Annual Scientific-Technical Collection Mining of Mineral Deposits. Leiden, The Netherlands: CRC Press / Balkema, pp. 185–191.

9. Vagonova, O.G. and Volosheniuk, V.V., 2012. Mining enterprises' economic strategies as derivatives of nature management in the system of social relations, *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, No. 2, pp. 127–134.

Вагонова О.Г. Економічні стратегії гірничих підприємств як похідна раціональності природокористування в системі суспільних відносин/ О.Г.Вагонова, В.В.Волошенюк // Науковий вісник НГУ. – 2012. – № 2. – С. 127–134.

10. Kolesnyk, V.Ye. and Kulikova, D.V., 2013. Justification of quantity perforated partitions and intervals their placement in improved sedimentation tank of mine water. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, No. 4, pp. 92–98.

Колесник В.Е. Обоснование количества перфорированных перегородок и области их размещения в усовершенствованном отстойнике шахтной воды / В.Е.Колесник, Д.В.Куликова // Науковий вісник НГУ. – 2013. – № 4. – С. 92–98.

Мета. Наукове обґрунтування найбільш раціональних геометричних параметрів перфорованої області (форми й розташування отворів один щодо одного) вертикальних поперечних перегородок, що розміщуються в удосконаленому відстійнику шахтної води, для підвищення коефіцієнта їх пропускної здатності та, як наслідок, ефективності очищення (освітлення) води від завислих часток.

Методика. Вибір варіанту перфорації перегородок здійснювався на основі вивчення та зіставлення геометричних параметрів перфорованої області, а саме: форми, розміру отворів і їх розташування один щодо одного; поправочного коефіцієнта, що дозволяє визначити відстань між центрами отворів (крок перфорації); коефіцієнта пропускної здатності перфорованої області перегородки.

Результати. Визначені коефіцієнти пропускної здатності перфорованої області перегородки за різних варіантів перфорації. Отримані аналітичні залежності зміни пропускної здатності перфорованої області перегородки від відстані між центрами отворів.

Наукова новизна. Виявлені закономірності зміни коефіцієнтів пропускної здатності перфорованої області перегородки, у залежності від величини поправочного коефіцієнта, дозволяють визначити відстань між центрами отворів за різних варіантів перфорації. Уперше встановлені залежності (у вигляді графіків і рівнянь регресії) між глибиною осідання завислих часток в удосконаленому відстійнику та ефективністю очищення шахтної води для різних варіантів перфорації перегородок.

Практична значимість. Результати дослідження дозволили обґрунтувати раціональні геометричні параметри перфорованої області поперечних вертикальних перегородок, що розміщуються в удосконаленому відстійнику шахтної води. Впровадження отриманих результатів дозволить підвищити ефективність очищення шахтних вод від завислих речовин і знизити рівень забруднення поверхневих вод у вугледобувних регіонах.

Ключові слова*: шахтні води, завислі речовини, забруднення водойм, горизонтальний відстійник, перфоровані перегородки, ефективність очищення*

Цель. Научное обоснование наиболее рациональных геометрических параметров перфорированной области (формы и расположения отверстий друг относительно друга) вертикальных поперечных перегородок, размещаемых в усовершенствованном отстойнике шахтной воды, для повышения коэффициента их пропускной способности и, как следствие, эффективности очистки (осветления) воды от взвешенных частиц.

Методика. Выбор варианта перфорации перегородок осуществлялся на основании изучения и сопоставления геометрических параметров перфорированной области, а именно: формы, размера отверстий и их расположения друг относительно друга; поправочного коэффициента, позволяющего определить расстояние между центрами отверстий (шаг перфорации); коэффициента пропускной способности перфорированной области перегородки.

Результаты. Определены коэффициенты пропускной способности перфорированной области перегородки при различных вариантах перфорации. Получены аналитические зависимости изменения пропускной способности перфорированной области перегородки от расстояния между центрами отверстий.

Научная новизна. Выявленные закономерности изменения коэффициентов пропускной способности перфорированной области перегородки, в зависимости от величины поправочного коэффициента, позволяют определить расстояние между центрами отверстий, при разных вари-

антах перфорации. Впервые установлены зависимости (в виде графиков и уравнений регрессии) между глубиной оседания взвешенных частиц в усовершенствованном отстойнике и эффективностью очистки шахтной воды для различных вариантов перфорации перегородок.

Практическая значимость. Результаты исследования позволили обосновать рациональные геометрические параметры перфорированной области поперечных вертикальных перегородок, размещаемых в усовершенствованном отстойнике шахтной воды. Внедрение полученных результатов позволит повысить эффективность очистки шахтных вод от взвешенных веществ и снизить уровень загрязнения поверхностных вод в угледобывающих регионах.

Ключевые слова: *шахтные воды, взвешенные вещества, загрязнение водоемов, горизонтальный отстойник, перфорированные перегородки, эффективность очистки*

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