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ON-SITE AND MODEL TESTS OF SUSPENDED MATTER SEDIMENTATION IN MINE WATER SETTLING TANK OF THE ZIEMOWIT COAL MINE

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COMMUNICATION

Keywords: Sedimentation, mine waters, suspended matter, water treatment.

Abstract: The results of investigations into suspended matter sedimentation from mine waters in the settling tank at the Ziemowit coal mine as well as in the relevant model of the settling tank were presented. It was shown that variations in the performance of the tank are caused by improperly accumulated sediment, which generates privileged water flow in superficial layers. Additionally, impetuous periodical water discharges seem to be important. The investigations performed on the settling tank model were focused on estimating the influence of temperature, flow rate and the aeration of mine water on the suspended matter sedimentation. Reasons for inefficiency of the settling tank were determined, and technological changes enhancing the process of suspensions removal were suggested.

INTRODUCTION

Coal exploitation from mines located in the Upper Silesian Industrial Region makes it necessary to pump out significant volumes of mine waters onto the ground surface. Preliminary observations showed that the waters were polluted with suspended matter whose concentration varied from tens to several hundreds of mg/dm^3, depending on local conditions and the technologies employed [1, 2, 5]. Such values of suspended matter concentration in mine waters (after discharging them into surface waters) lead to the mudding of riverbeds, and in the case of high flow rates, can be the reason for secondary pollution of the rivers.

In the mines, the coarse-grained suspended matter is already removed at individual exploitation levels in so-called main drainage galleries. However, these often do not operate satisfactorily, and the content of suspended matter in the waters pumped out into on-ground settling tanks is still considerable. Periodical (daily and weekly) discharging of mine waters into a settling tank causes varying concentration of suspended matter at the tank inlet. Lowering the efficiency of suspended matter sedimentation can also result from privileged flow streams existing in superficial layers of the settling tanks. These are induced by mud banks, technical difficulties in controlling the water level at the tank spillway, as well as significant temperature differences between the pumped-out and the in-tank water [1]. These reasons are the most valid if sedimentation time is sufficient in relation to proper flow. Therefore, precise knowledge of the phenomena influencing the work of a settling tank is desirable in order to eliminate variations in its performance and make the process of removing mechanical suspensions from mine waters more efficient.

This paper discusses the results of investigations into the natural sedimentation of mine water suspension in real conditions in an existing settling tank at the Ziemowit coal mine as well as in laboratory conditions in a model of a settling tank. The range of the investigations included the assessment of the influence of temperature, water flow rate and water aeration on the sedimentation of suspended matter in the tank.

METHODOLOGY

The process of suspended matter sedimentation from the Ziemowit coal mine waters was analyzed by measuring the total suspended matter in the water samples taken from the settling tank spillway. The water flew out of the settling tank through 6 outlet boxes spaced equally along the longer side of the tank, opposite the feeding channels (Fig. 1) [4]. The concentration of suspended matter was determined according to [3, 6].

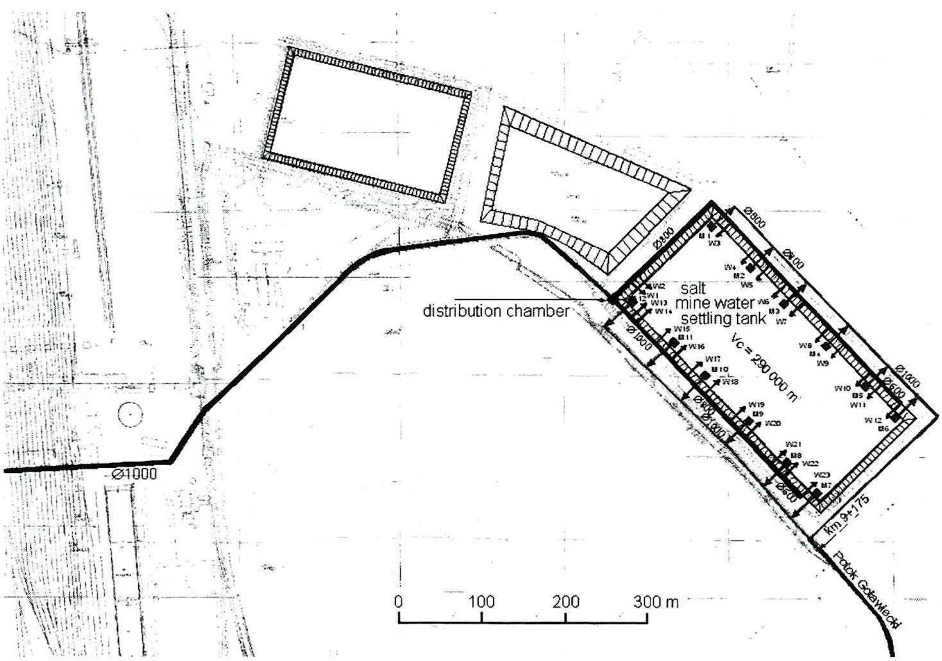

Fig. 1. The settling tank at the Ziemowit coal mine with supplementary objects

In order to assess the influence of the flow rate, temperature and aeration on sedimentation of suspended matter, certain investigations were performed on a settling tank model in laboratory conditions. The model of the settling tank was a plexiglass container, filled with mine water of the volume of 0.08 m³ (200×20×20 cm), simulating conditions occurring in real settling tanks for salt mine waters (Fig. 2).

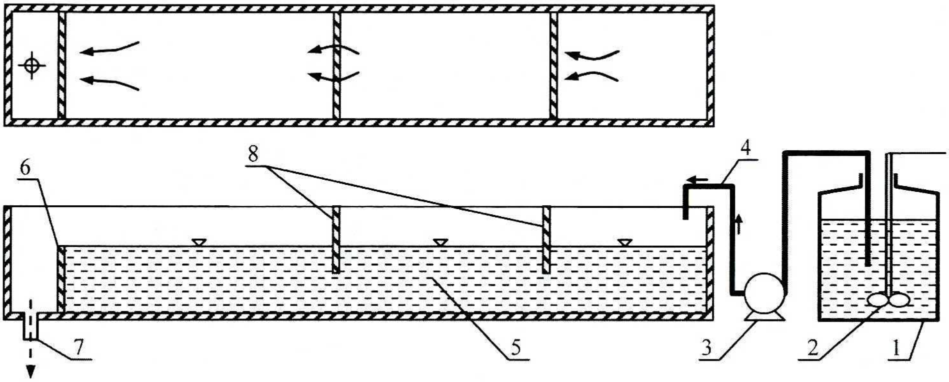

Fig. 2. Diagram of the model of the tank (1 – auxiliary container, 2 – stirrer, 3 – dosing pump, 4 – feeding channel, 5 – horizontal settling tank, 6 – spillway, 7 – water outflow, 8 – barriers)

The settling tank was supplied with mine water from an auxiliary container by a pp1-05 pump. Two flow rates were used: 7.2 dm³/h and 36 dm³/h. The auxiliary container was equipped with a stirrer preventing sedimentation. The stirring rate was 400 rpm. The model was placed in a closed room, at a temperature of 20 ± 1°C, with access to light and atmospheric air.

The investigations were carried out in the following four stages:

- Stage I – the tank was filled with mine water to a level of 5 cm, and the investigations on sedimentation were performed for two flow-rates: 7.2 dm³/h and 36 dm³/h (water retention time equal to 11 h and 2 h, respectively). Next, the measurements were repeated for a water depth equal to 10 cm.
- Stage II – the tank was filled with mine water to a level of 10 cm. A barrier, submerged 5 cm below the water level, was fastened adjacent to the water inlet in order to decrease the energy of the supplied water, and distribute it along, or partially under the barrier. Due to the barrier application, a rise of settling efficiency was expected. This experiment was carried out at a flow rate of 7.2 dm³/h.
- Stage III – the investigations were performed for aerated water. The water was aerated in the auxiliary container for 30 min. After aeration, the water was pumped at a flow-rate 7.2 dm³/h into the tank.
- Stage IV – the influence of mine water temperature on suspension sedimentation was investigated. Determining the sedimentation rate as dependent on temperature is reasonable, because differences in temperature between summer and winter in open settling tanks for mine waters are significant. The tank was placed in a cool room and filled with mine water of the temperature of 7°C to a level of 10 cm. The tank was supplied with water of the temperature of 18°C at a flow rate of 7.2 dm³/h. The auxiliary container was placed in an ultrathermostate. Apart from the thermometer belonging to the ultrathermostate, two additional thermometers were placed in the auxiliary container, at different depths, in order to control the water temperature.

Temperature oscillations did not exceed ± 0.3°C. The experiment was repeated with a barrier submerged 5 cm below the water level.

During the process of suspension sedimentation from mine waters in the model, the measurements of total suspended matter and turbidity of the water samples from the tank outflow were made. Three samples were taken every 30 minutes. In addition, grain composition of the suspension left after sedimentation was determined with an LAU-10 laser analyzer.

RESULTS AND DISCUSSION

The observations of water flow in the settling tank of the Ziemowit coal mine confirmed the underperformance of the tank. They indicate the probable occurrence of local, privileged superficial currents. The basis for this assumption is the observed tint of the water flowing through the settling tank from feeding channels to outlet boxes. The analysis of water samples taken from the central and the two outermost outlet boxes also suggests it. The concentrations of suspended matter in the samples taken from the inlets of the outlet boxes were 98, 36.4 and 59 mg/dm^3, respectively.

A possible way of improving the tank's performance is removing the accumulated sediment and ensuring homogeneous water flow through the settling tank. When acquiring the samples for analysis, a natural barrier made from mud and sand was visible near the first two feeding gutters. Water sample taken from the outlet box situated opposite the barrier had the lowest concentration of suspended matter, equal to 36.4 mg/m^3.

The settling tank is fed from a central collector through 10 pipes spaced equally along the longer side of the tank. The water flowing from the outflows is intensively aerated in a natural way (the water falls from about 1.5 m height), and then flows into the settling tank along concrete gutters. The reason behind the unsatisfactory performance of the settling tank may also be linked to temperature differences between the water pumped out from the mine (average temperature about 18°C) and the water already in the settling tank, especially in winter (about 6°C).

The measurement results for total suspended matter and turbidity of mine water taken from the spillway of the model of the settling tank are shown in Tables 1 and 2. The efficiency of sedimentation was verified by analyzing the grain composition of the suspension. The results are shown in Figure 3.

Table 1. Results of analysis for sedimentation of mine water suspension in the model of the settling tank for water depth 5 cm

Flow rate	Total suspended matter	Reduction of total suspended matter	Removal percentage	Turbidity
[dm^3/h]	[mg/dm^3]	[mg/dm^3]	[%]	NTU
36	579	337	41.8	137
		321	44.6	130
		350	39.5	138
7.2	579	177	69.4	85.2
		167	71.2	81.8
		162	72.0	78.9

Table 2. Results of analysis for sedimentation of mine water suspension in the model of the settling tank for water depth 10 cm

Flow rate	Total suspended matter	Reduction of total suspended matter	Removal percentage	Turbidity
[dm^3/h]	[mg/dm^3]	[mg/dm^3]	[%]	NTU
36	579	216 224 196	62.7 61.3 66.2	98.1 102 113
7.2	579	93 103 102	83.9 82.2 82.4	64.6 67.2 68.6
with the barrier placed near the inflow				
7.2	579	65 57 61	88.8 90.2 89.5	53.1 51.5 54.2
with water aeration at the inflow				
7.2	579	128 130 131	77.9 77.6 77.4	78.5 77.5 78.8
in-tank water temperature 7°C, supplying water temperature 18°C				
7.2	579	178 184 201	69.3 68.2 65.3	100.2 95.0 96.3
in-tank water temperature 7°C, the barrier placed adjacent to the inflow				
7.2	579	136 131.6 129	76.5 77.4 77.7	87.2 84.0 80.9

size [um]	percentage [%]	sum [%]
1	4,68	4,68
2	5,36	10,04
3	8,71	18,74
4	14,56	33,30
5	8,88	42,18
6	7,10	49,28
7	6,46	55,74
8	4,96	60,70
9	5,10	65,80
10	3,41	69,21
11	1,65	70,86
12	0,57	71,43
13	0,53	71,95
14	1,12	73,07
15	2,06	75,13
16	2,47	77,60
18	3,41	81,01
20	1,68	82,68
22	1,40	84,09
24	0,99	85,07
26	0,58	85,65
28	0,29	85,95
30	0,13	86,08
32	0,08	86,16
34	0,11	86,27
36	0,19	86,47
38	0,35	86,81
40	0,57	87,38
42	0,85	88,23
44	1,14	89,38
48	1,39	90,77
56	3,10	93,87
63	1,54	95,41
71	1,39	96,80
80	1,14	97,95
90	0,85	98,79
100	0,57	99,36
125	0,35	99,71
160	0,19	99,90
200	0,10	100,00

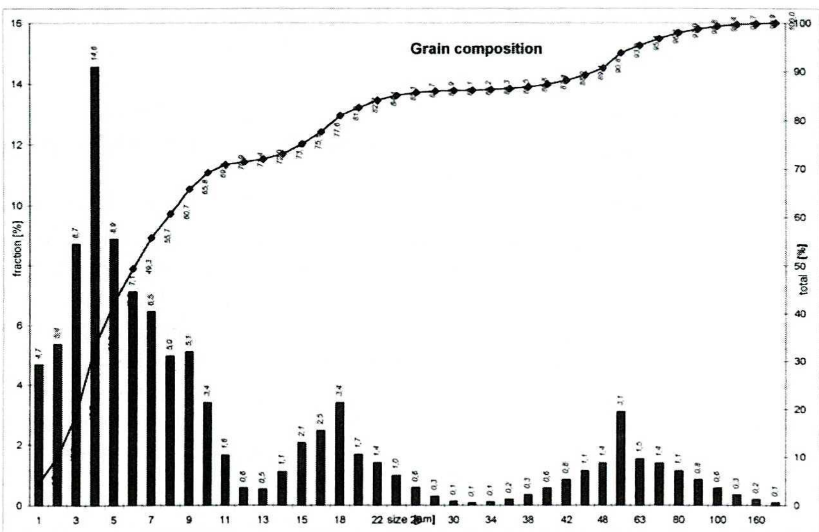

Fig. 3. The results of grain composition analysis of mine water taken from the spillway of the model of the settling tank

Aerating the mine waters at the inflow lowered the sedimentation rate of the suspended matter. Its concentration increased by 30 mg/dm^3 (from 100 to 130 mg/dm^3) at the spillway. This was also confirmed by sedimentation analyses carried out in an Imhoff cone, the results of which are presented in Figure 4.

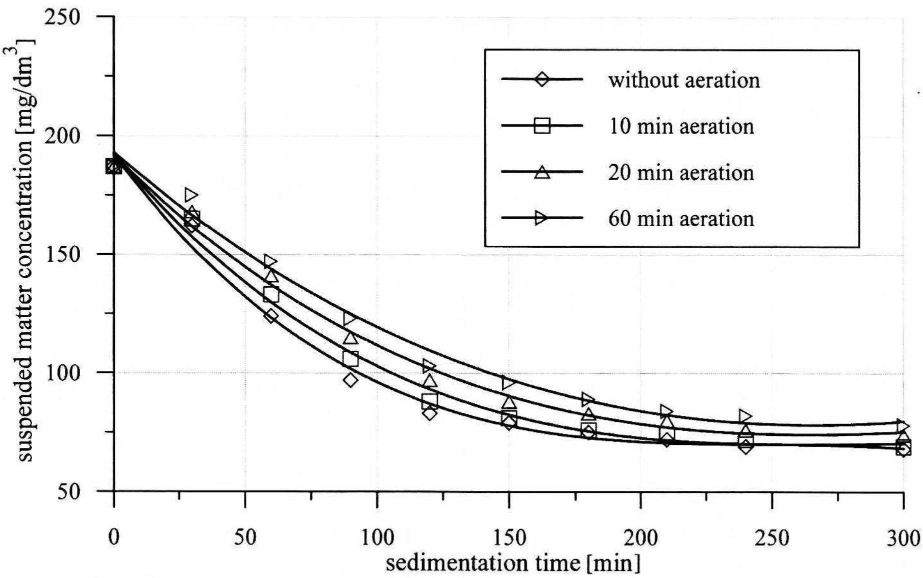

Fig. 4. Kinetics of mine water suspended matter sedimentation for various aeration times

When introducing a larger amount of air into the mine water, the particles forming the suspension remain suspended, which significantly increases the sedimentation time. The depth of the tank has an influence as well, because suspended particles aggregate, becoming larger and larger, and their falling velocity rises. The results obtained for the flow rate of 7.2 dm^3/h and the tank depth of 5 cm showed a decrease in the efficiency of sedimentation of about 13%, in relation to the efficiency for a tank depth of 10 cm, and for the flow rate of 36 dm^3/h – even by 30%.

The investigations into the natural sedimentation of mine water suspended matter in the model of the settling tank (despite the scale difference), reflected to a certain degree the conditions occurring in the actual settling tank, indicating relationships between causes and effects. The results presented in Tables 1 and 2 show that a fivefold increase in flow rate (from 7.2 to 36 dm^3/h) disrupts mine water suspended matter sedimentation. The total reduction in suspended matter, as a percentage, was about 40% for a tank depth of 5 cm and 60% for 10 cm when the flow rate equaled 36 dm^3/h. A significantly greater percentage was obtained for the flow rate of 7.2 dm^3/h – 70% and 80%, respectively. The unsatisfactory performance of the settling tank at a flow rate of 36 dm^3/h was confirmed by the presence of a coarser grain class 13–48 μm in the spillway water. In the model of the settling tank, considerable differences in suspended matter falling velocity were observed due to differences in temperature between the supplied mine water (18°C) and in-tank water (7°C) at the same flow rate. During an 11 h sedimentation, the concentration of total suspended matter fell to about 200 mg/dm^3, i.e. it decreased by about 60%. In summer conditions, at the temperature of 20°C, the sedimentation efficiency was about 30% higher. Temperature differences and, related to them, differences in density between in-tank waters and inflowing waters generate density currents. In the model, a visible stratification could be observed – inflowing water flowed in a superficial layer, which negatively affected the process of suspension removal. Setting a barrier in the model near the feeding channel at a depth of 5 cm decreased the flow cross-section, and improved the performance of the model. The suspended matter reduction percentage obtained was about 90% for identical temperatures of inflowing and in-tank water (20°C), and about 78% for the above-mentioned differences in temperature (at a flow rate of 7.2 dm^3/h). After installing the barrier, the efficiency of the model rose by about 15%, the same for natural conditions, i.e. at the temperature of 20°C, as well as for conditions with temperature differences. However, the barrier did not reduce the suspended matter concentration to the permissible value (30 mg/dm^3), it only improved its performance.

CONCLUSIONS

The observations performed on the model of the settling tank make it possible to state that:

- both aeration and differences in temperature between the in-flowing and in-tank water negatively affect the sedimentation process in the tank model. Water aeration caused a decrease in tank model efficiency by about 10%, and differences in water temperature by about 20%,
- after installing a barrier near the water inlet efficiency rose by about 15%.

There is no doubt that superficial currents occurring in the settling tank have a negative influence on the sedimentation of the suspended matter. These disturbances to the performance of the settling tank can be avoided by removing accumulated sediment and ensuring a uniform flow rate by installing flowing barriers to block the currently privileged superficial flow. Submerging flowing barriers to a depth of about 0.5 m and locating them straight in front of the outlet gutters of the settling tank should disperse the energy of the in-flowing water and distribute it along and partially under the barriers. This solution should significantly improve the sedimentation process in the Ziemowit's settling tank. At first, the barriers may be sited near some outlet gutters only. Comparison of suspended matter concentration in water samples taken from the outlet boxes located straight in front of the barriers with samples from outlets without the barriers should indicate whether the barriers are effective. After confirming that they have a beneficial impact, such barriers should be installed near all inlet gutters. If the above-mentioned operations do not bring satisfactory results, it would be useful to consider aiding the sedimentation process by chemical treatment using suitable coagulants and flocculants.

The analyses carried out on the settling tank model indicate that it is necessary to redesign the inlet box in the existing settling tank. This should reduce water aeration and make water flow as uniform as possible in any cross-section of the settling tank.

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POLOWE I MODELOWE BADANIA SEDYMENTACJI ZAWIESINY W OSADNIKU WÓD DOŁOWYCH KWK „ZIEMOWIT"

Przedstawiono wyniki badań nad sedymentacją zawiesiny zrzutowych wód kopalnianych KWK „Ziemowit" na osadniku ziemnym oraz w warunkach laboratoryjnych na osadniku modelowym. Zbadano przyczyny złej pracy osadnika kopalni i zaproponowano zmiany technologiczne pozwalające uzyskać zrzuty wód o ustabilizowanej zawartości zawiesin i usprawnić proces oczyszczania wód kopalnianych z zawiesiny mechanicznej. Wykazano, że zaburzenia w pracy osadnika spowodowane są nagromadzonym osadem, powodującym uprzywilejowany przepływ wody po powierzchni, a także gwałtownymi periodycznymi zrzutami tych wód. W badaniach modelowych oceniono wpływ temperatury, prędkości przepływu wody i napowietrzenia wody kopalnianej na proces sedymentacji zawiesiny.