The Experience of Implementation of Innovative Technology of Quarry Waste Water Purifying in Kuzbass Open Pit

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Abstract. Among all industries in Kuzbass (Western Siberia, Russia) the coal industry provides the most environmental threat. However, the construction of new and maintenance of existing open pit mines do not often correspond to the tasks of improving the environmental safety of surface mining. So the article describes the use of innovative quarry waste water purifying technology implemented in Kuzbass open pit mine «Shestaki». This technology is based on using artificial filter arrays made of overburden rock.

1. Introduction
In the twenty-first century environmental protection and rational use of natural resources is one of the major problems of society. The most actual problem of environmental protection is in major industrial regions such as Kemerovo region [1, 2]. The strategy of social-and-economic development of the region provides to increase the volume of coal production in the region up to 250-300 million tons by 2025 [3, 4].

One of the constraints for the increase of coal produced volume is an intense pollution that leads to a change in the landscape, disruption of air quality. However, the greatest harm open pit mining does to hydrosphere. This is due to the complex composition of the open pit waste water, which is contaminated with suspended solids, oils, heavy metals, oil and explosion products simultaneously. Every year the water bodies of Kemerovo region receive 2.033.800.000 m^3 of quarry water [5], more than 500 million m3 of them coal enterprises discharge without any treatment [6]. Aggregate weight of pollutants reaches 606.12 thousand tons [7]. The main polluting substances in pit waste water are suspended solids, represented by finely-dispersed rock and coal particles. The concentration of suspended solids in pit water is 50-250 mg / l, reaching in some cases 2000-3000 mg / l [8].

2. Material and Method
For purifying quarry waste water in Kuzbass various methods and techniques of treatment, including the settling ponds and filtering arrays built of overburden rock are currently used [9, 10].

The advantages of such artificial filter in comparison with settling ponds are small land capacity, stationarity, simplicity of construction, low cost of waste water treatment, as evidenced by the conducted researches [11, 12].

Water purification process is based on the colmatation phenomenon [11] (Fig. 1).

In rock masses the sedimentation of suspension in the pores and lightening of filtering quarry waste water take place, suspended particles are trapped in a porous medium as a result of getting stuck in narrow pores, and sticking to the wide pore channels.

The design of the filter depends on the terrain and the properties of the upper layers of the soil of underlying surface, and the parameters are determined by the quantity of water inflows, its contamination and filtration characteristics of the filter material.
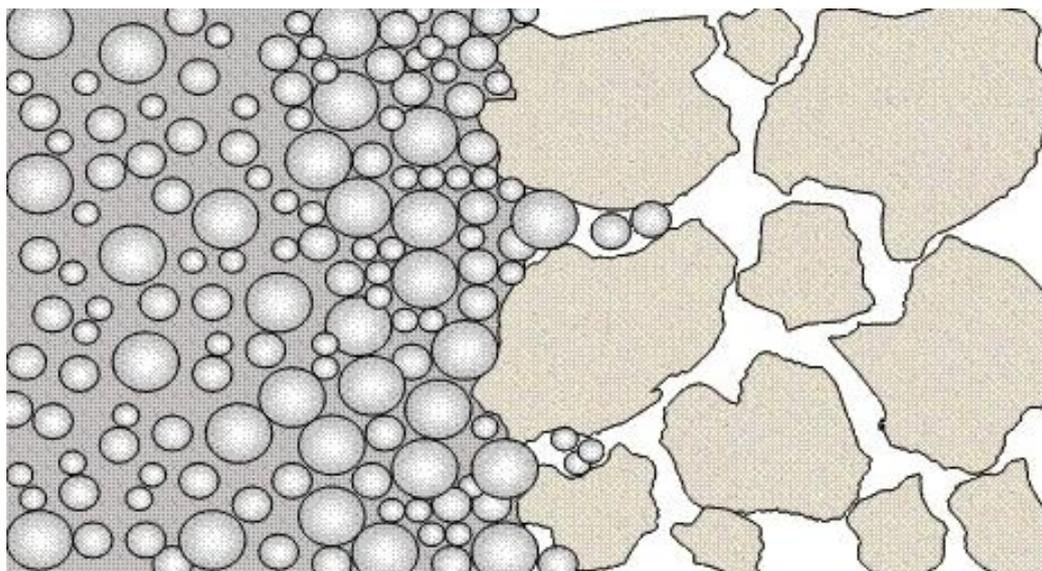

Fig. 1. The scheme illustrating colmatation process

The main filter elements are the unit for supplying polluted water, filtering array, filter body, a device for collecting and draining purified water (Fig. 2).
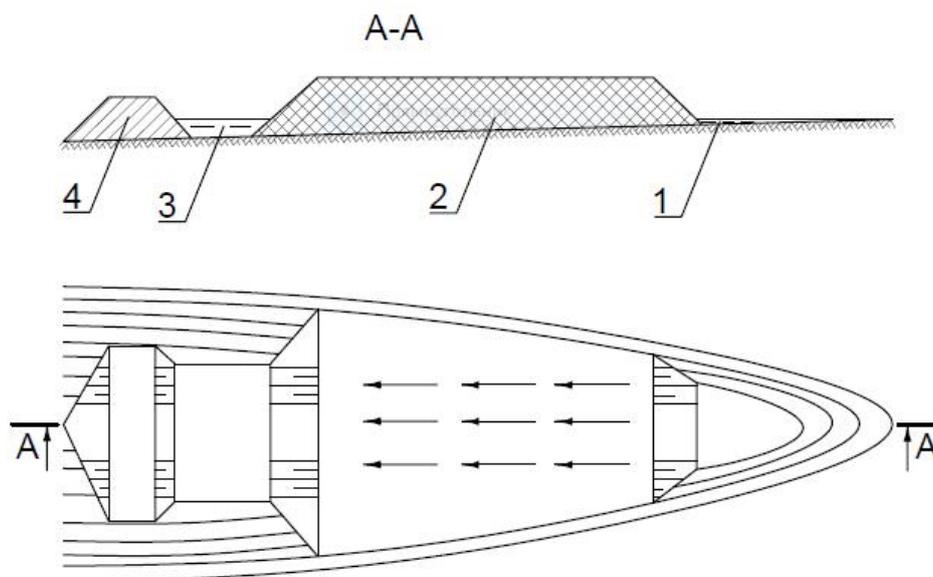

Fig. 2. Common scheme of filtering array: 1 – the pond in the place where waste water enters the filter; 2 – filtering array; 3 – collector for purified water; 4 – water collecting dam

The filtering array consists of crushed rock and semi rock with grain size of 20 to 200 mm or more, the process of its creation doesn't differ from the peripheral dumping technology. The rock laying into the filter array must have a softening ratio not less 0.8 and not dissolve in water. When dumping bottom of such filter semi rocks are used, when they are softened form a dense layer with low permeability.

The filter itself works in the following way: contaminated water (suspended mixture) flows by gravity through a pipeline in to the water intake, from where it drains through the filter array. After mudding of lower layers of the filtering array water level in the water intake increases, and new fresh layers of rock are being involved in the process of filtration. The content of suspended solids in the influent quarry waste water is not limited, but in the purified water is 0-10 mg / l. Filter size is determined by the volume of water flow and the required degree of purification.

3. Results and Discussion

We considered quarry waste water purification problem by the example of JSC "Open pit Shestaki". JSC "Open pit Shestaki" has been a part of the companies group JSC "Strojservis" since 2000. It is located on Bachatski coal deposit (Guryev municipal district, Kemerovo region (Kuzbass), Western Siberia, Russia). The company produces high-quality coal of coking and energy brands. Production capacity of this open pit is 1 million tons of coal per year.

On the 1st of April, 2015, the sewage treatment plant of "Open pit Shestaki" represent a settling pond, which is organized by dumping earth dam of open pit overburden rock, with impervious screen of loam. Purification of quarry waste water takes place in the settling pond by settling (mechanical precipitation).

Qualitative characteristic of the water, discharged after treatment into the river Small Bachat, is given in Table 1.

Table 1. Quantitative characteristics of quarry waste water and the water disposed after purification using artificial filter array on JSC "Open pit Shestaki"

	Defining Ingredients (Pollutants)	Units	Maximum Permeated Concentration (MPC)	Concentration of Pollutants Before Purifying	Concentration of Pollutants After Purifying (in Disposed Water)
1	pH		6.5-8.5	7.5	7.21
2	Chlorides	mg / l	300	86.85	19.1
3	Ammonium ion	mg / l	0.5	1.18	0.44
4	Nitrate ion	mg / l	40	321.84	8.5
5	Nitrite ion	mg / l	0.08	6.42	0.19
6	Ferrum	mg / l	0.1	0.62	0.17
7	Sulphates	mg / l	100	389.42	76.1
8	Petroleum products	mg / l	0.05	3.45	0.13
9	Suspended solids	mg / l	Exceeding of concentration in the water body not more than by 75 mg / l	154.24	6.0
10	Dissolved oxygen	mg / l	More than 4	4.5	8.5
11	Cuprum	mg / l	0.001	0.006	0.0012
12	Manganese	mg / l	0.01	0.029	0.001

Taking into account the values given in Tab.1 we defined the efficiency of the existing on "Open pit Shestaki" water purifying facilities for major pollutants, which is:
- for suspended solids - 70.0% ;
- for petroleum products - 99.5% ;
- for sulphates - 50.0%;

- for chlorides - 50.0%.

Actual and permissible concentration of polluting substances in discharged waste water is accepted on the basis of the materials used in MPC developed in Russia.

The volume of water wasted in open pit mining of coal deposits in Segment number 2 of "Open pit Shestaki" constitutes 6,118.56 m³ per year. Using treated waste water for technological purpose (moistening of exploded block, hydrodedusting of dumps' surface, roads irrigation) will reduce the amount of waste water discharged. Water consumption for technological purposes amounts 452.09 thousand m3 per year. Consequently, the volume of waste water discharged into the river Small Bachat after purification will be 5666.47 thousand m³ per year.

Based on the purpose of the artificial filter array, its possible location on the JSC "Open pit Shestaki" must meet the following criteria:

1. Positive slope (water entry point to an array must be above the exit point of it).

2. Favorable location to existing water pipes to minimize costs.

Since the places with the natural groove are preferable to form the filtering array but not easy to find, for "Open pit Shestaki" we choose a site 150 meters long with a mellow slope (46.6 ‰) and relatively flat terrain.

A general view of artificial filter array implemented on JSC "Open pit Shestaki" is shown in Fig. 3.
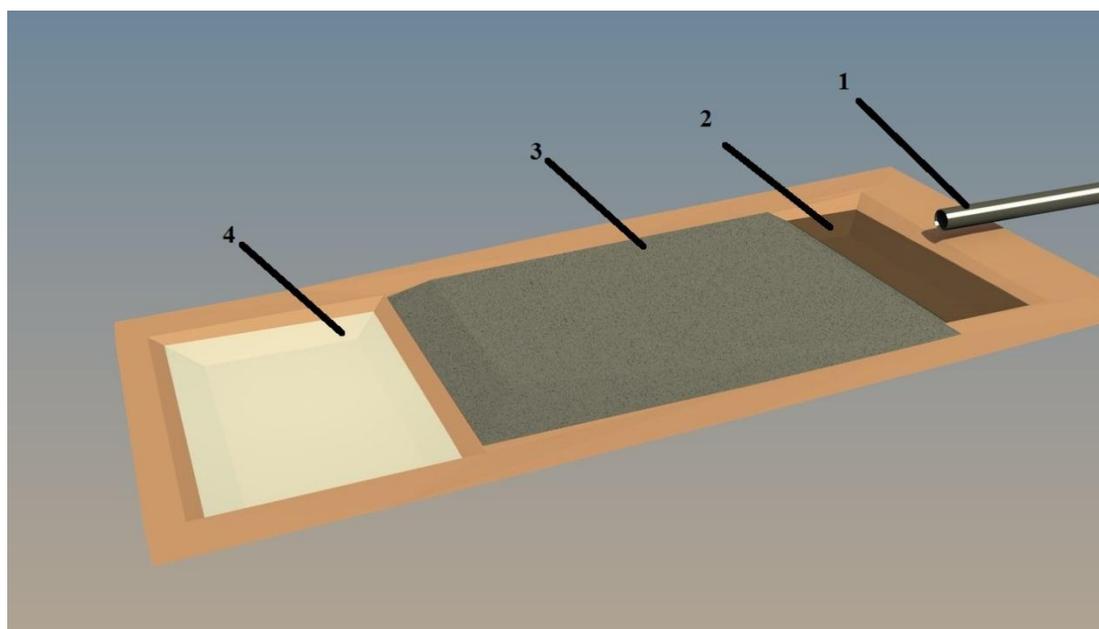

Figure 3. Common view of artificial filter array implemented on JSC "Open pit Shestaki": 1 – quarry waste water feeding pipe; 2 - quarry waste water collector; 3 – filtering array of overburden rock; 4 – purified water reservoir

Parameter determination of artificial filter arrays was performed by the method described in [12, 13] as:

- determination the length of the filter array (required filter length L);
- defining the width and height of the filter array;
- determination of the filter life-cycle;

The determination of filter array length is based on the quarry waste water purification to the Maximum Permitted Concentration (MPC) and can be calculated as:

$$L = \frac{1}{\eta} \ln \frac{C_{in}}{C_{mpc}} = \frac{1}{0.035} \ln \frac{154.24}{6} = 92.7 \ m,$$

wherein: C_{in} – the initial concentration of suspended solids in quarry waste water (for 09/30/2015 C_0 = 154.24 mg / l);

C_{mpc} – MPC for suspended solids (C_{mpc} = 6 mg / l);

η – rate of filtration (for Kuzbass is in average 0.035).

We took the length of the top of filtering array as L = 95 m.

Determination of the width and height of the filter array is based on the conditions of purifying all incoming for treatment water without overflow over the top of the array or over the dam edge (in case of the construction of the filter on a horizontal surface). This sets the width of the filter array B.

Taking into consideration the topography, we assume the width of the filtering array B = 50 meters.

We used previously collected data of the filtering arrays on many open pits of Kuzbass observed in our later articles [8, 14] and defined the exact depth of filtration as 4.2 m.

We defined the average life-time (T) of filtering array accordingly its given height as:

$$T = \frac{1000 \times K_{use} \times L \times B \times h_{d.f} \times \rho_d}{Q_{av.an}(C_{in} - C_{mpc})} = \frac{1000 \cdot 0.15 \cdot 95 \cdot 50 \cdot 4.2 \cdot 1500}{646.85 \cdot (154.24 - 6)} = 46812 \; hours = 5,34 \; years.$$

wherein K_{use} – coefficient of using the volume of filtering array; $h_{d.f}$ – depth of filtration, m; ρ_d – density of sludge, $Q_{av.an}$ – average annual volume of waste water.

So, it can be set as 5 years and 5 months.

Conclusion

With this artificial filter array at the JSC "Open pit Shestaki" we can significantly improve the quality of water discharged into the river Small Bachat. Together with the existing waste water treatment plants such filter will allow to reduce the concentration of suspended substances, bringing them to the level significantly below the MPC. Finally, technological innovation in the open coal mining make it possible to increase the investment attractiveness of mining enterprises, to accelerate the modernization of Kuzbass coal cluster and to bring the environmental component of mining operations on the modern international level [15-18].

Acknowledgement

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