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MINE DRAINAGE TREATMENT IN POLISH LIGNITE MINING

by

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ABSTRACT

The paper presents volumes and characteristics of water discharged from some Polish lignite open pit mines and discusses methods for its treatment. Results of research work concerned with increase in mine drainage efficiency by using processes of radiation, flocculation and filtration through a set of bog plants, iknown as grass filter are also discussed

INTRODUCTION

The lignite mining operations require considerable volumes of mine water to be drained to the surface water courses. The amount of water pumped mainly depend on the geological, hydrogeolgical-meteorological conditions which are specific for particular open pits. The yearly precipitation is in the range of 530 and 700 mm per annum. The average amount of mine water pumped out in m^3 per ton of lignite production is 10:1 but it varies between 0.7:1 to 25:1. In general, mine drainage can be divided into "pure" and "dirty" water.

The pure water is most commonly obtained from drainage wells while "dirty" one is drained from the open pit itself and active underground dewatering galleries used in some of the Polish surface lignite mines. The "pure" water presents no special pollution problem due to mine water drainage into surface water courses. Their quality is in most cases conform to the 1st or 2nd class of purity as per Polish standards, and they can be pumped to the surface water courses without being treated. In very few cases, those waters can contain sandy suspension which is easily removed in the sand settling ponds when retained during 0.5 - 20 hours. Depending on the chemical characteristics of groundwaters in the region of lignite mining, they can have increased iron, manganese, chloride, sulphate and TDS contents.

A different situation arises with "dirty" water which is mostly polluted by a suspended matter consisting of mineral (Sand, dust, clay) and organic (lignite) particles washed out from the open pit surface by underground and surface water if raised from underground drainage galleries.

The suspended matter contained in mine water concentration is between 10 mg/dm^3 and 15,000 mg/dm^3. An accidental and variable mineral to organic particles ration results in their varying sedimentation features and makes their treatment difficult. A size of suspended particles varies most frequently from colloids to 2 mm-dia. grains.

MINE DRAINAGE VOLUMES

The mine drainage volumes in lignite mining operations vary depending on the geological and hydrogeological conditions, mining intensity, weather and other conditions.

The approximate average drainage volumes in some lignite operations are given in Table 1.

Table 1

Open pit	Approx. average drainage volumes in m^3/min		
	"pure" waters	"dirty" waters	total
Adamow	30	5	35
Wladyslawow	40	20	60
Jozwin	5	46	51
Kazimierz	1	33	34
Patnow	13	42	55
Lubstow	22	13	35
Turow	12	42	54
Belchatow	254	66	320
Grand Total	377	267	644

As can be seen from the above table that the"dirty" water contributes to some 42 per cent of total mine drainage. For newly designed open pits, it is expected to reduce dirty water volume down to about 20-25 per cent owing to the more extensive use of drainage wells producing pure water.

CHARACTERISTICS OF LIGNITE MINE DRAINAGE

The chemical composition of waters drained from active lignite open pit mines depends mainly upon the quality of groundwater. The chemical impurities are in excess of values than allowed by Polish regulations only in single cases. This is mostly the case of iron and manganese contents. The content of some imutities in the mine water is given in Table 2.

As can be seen the main and only at some open pits, pollution in excess of standards is caused by a suspended matter, relevant high turbidity, and high BOD_5 and oxygen consumption in few cases. The Turow mine drainage oly, apart from a high suspended solids content, shows increased concentration of sulphates iron and TDS and sometimes, low pH. The quantity and quality of suspended solids in mine water vary to ao considerable extent and depend on many factors, such as meteorological, geological and mining conditions including mainly types of overburden and lignite, angle of slopes, gradient of benches and open pit bottom, lignite and overburden transportation methods, mining techniques and inner spoil disposal reclamation and many others. The observations and tests made did not allow to formulate explicit relationships between the quantity and quality of suspended solids in the mine drainage and aforesaid factors.

For Konin, Adamow and Belchatow Lignite Open Pits, the average volume of suspended solids in 100-200 mg/dm^3 . For Turow this value is higher. the max. volume of suspended solids in the mine drainage can periodically come at short time intervals even up to 15,000 mg/dm^3 . The examinations of grain-size distribution have shown that gains larger that 10μ of the number 2.6 x 10^{-4} are 52 - 88.

The sedimentation process analysis, shows that the suspended solids remaining in the mine water after 16-20 hours indicate disturbances caused by the Brownian movements and cannot be practically removed from the water using only natural sedimentation in the settling ponds.

MINE DRAINAGE TREATMENT

In practice treatment of dirty waters from the surface lignite mines is mostly limited to the suspended solids reduction. The coarse suspended solids are reduced in the settling ponds near the pit bottom pumping station. Further reduction of suspended solids to achieve values required by the standards (below 30 mg/dm^3) in most cases, takes places in large sedimentation basins located in the proximity of open pits and in the recent time, within internal dumps (Konin, Adamow). The total area covered by the sedimentation ponds is now above 100 ha.

In Table 3 the characteristic parameters and operating effects are given for four largest sedimentation ponds. As can be seen from the values given in Table 3, the mine drainage treatment in the sedimentation ponds allows to reduce the suspended matter fown to 30-60 mg/dm^3 and, with use of additional grass filter, down to 20 mg/dm^3. This technology is insufficient in the periods of unfavourable weather conditions and when a substantial amount of colloidal suspended matter is contained in the mine drainage. Under these circumtance, a coagulation or flocculation process is required. Those processes were periodically used at the Adamow Open Pit, and effects depended on a type of flocculant in use. With cation flocculants, very good results were obtained.

More and more frequently expected utilisation of mine drainage for cooling power plants, municipal utilities, agriculture, as well as increased prices of land for new sedimentation ponds and higher and higher requirements of water quality standards have forced to develop new, more effective and cheaper methods. Techniques based on the use of the following processes have been examined:

- radiation,
- flocculation,
- filtration through mineral deposits,
- filtration through grass filter.

The research has been carried out in cooperation with the U.S. Environmental Protection Agency.

USE OF RADIATION

The effect of water irradiation on the acceleration of suspended solids sedimentation was examined on laboratory scale. The analysis of results has enabled to find that CO-60 gamma radiation accelerates the suspended solids sedimentation rate and practically, an important effect is observed beginning from an absorbed dose of 500 kRad. The sedimentation rate accelerating effect depends on the absorbed dose and this relationship is proportional. The waters of high natural oxygen consumption have

Table 2

Some Features of Surface Mine Drainage Pollution

Pollutant	Unit	Tuuow I	Turow II	Adamow	Konin Surface Mine		Belchatow
					Kazimierz Open Pit	Jozwin Open Pit	
BOD_5	$mg0_2/dm^2$	2-60	1.3-38	1-40	-	-	1.3-4.1
Oxygen consumption	$mg0_2/dm^3$	3.2-82	12-35	64-390	10-55	-	0.9-30
Chlorides	$mgC1/dm^3$	12-100	16-39	20-100	up to 14	up to 13	12-50
Sulphates	$mgS0_4/dm^3$	23-465	264-585	50-150	up to 10	up to 18	14-80
Soluble matter	mg/dm^3	633-979	782-1020	up to 600	up to 500	up to 600	250-500
General suspended matter	mg/dm^3	8-928	134-808	60-2800	73-370	up to 350	30-500
pH	-	1.8-8.9	5.6-8.4	7.0-8.1	7.6-8.3	7.0-8.0	7.3-8.1
Total iron	$mgFe/dm^3$	0.02-4.12	1.9-4.1	0.0-5.0	up to 1.0	up to 0.7	0.5-1.5

Table 3

Characteristic Parameters of Some Sedimentation Ponds

It.	Open pit	Max. Volume of dirty waters	Area of sedimentation pond	Present day capacity of pond	Present day average depth	Theoretical retention time	Suspended solids concentration at inlet	Suspended solids concentration at outlet	Efficiency
		m^3/min.	ha	thous.m^3	m	days	mg/dm^3	mg/dm^3	%
1.	Lubstow	9.0	1.3	22.1	1.7	1.7	2.900	223*)	92
2.	Jozwin	70	10.9	185.3	1.7	1.8	200	30	85
3.	Belchatow	180	25.2	215.8	1.65	1.6	200	20	85

*) further treatment in a chamber with grass filter

shown most important changes in the sedimentation rate. The dependence of sedimentation accelerating effect on the absorbed dose was conformable with theoretical expectations because, with the same absorbed doses, the radiolysis of water should be the same, and the radiothermal processes should intensify as the dose increases.

The irradiation inconsiderably changes "zeta" potential values of colloidal particles suspended in the water. These changes are difficult to be explained, and they probably depend on both the absorbed dose, dosing rate and chemical composition of irradiated water. To sum-up it one can say that the radiative treatment of lignite mine drainage gives favourable results beginning from the absorbed dose of 500 kRad. A value of 1000kRad should be considered as an optimum dose. Though the doses of more that 1000kRad, any up to 2000kRad, bring about further increase in the sedimentation rate still they result in capacities incommensurable with the applied power.

MINE DRAINAGE TREATMENT BY FLOCCULATION

The flocculation processes for mine water treatment were examined in the laboratory and field scale.

Eighteen (18) American and Polish-made flocculants were analysed in view of their efficiency, including anion, cation and non-ion polyelectrolites. The effects of flocculation were controlled by measuring the colour, turbidity, reaction alkalinity and oxygen consumption. In some cases, the determinations of hardness and iron content were also made. In addition, the process was controlled by measuring the electrokinetic potential. The tests have shown that for mine waters of turbidity up to 100 NTU and average suspended solids content up to 200 mg/dm^3 (Konin, Adamow Open Pits) good effects were obtained using cationic flocculants, from which US - made Calgon M-502 and M-503 and Polish-made Rokrysol WF-5 proved the best. The optimum doses of Calgon and Rokrysol amounted to 0.1-3.0 mg/dm^3 and 10-20 mg/dm^3 , respectively. The reduction of turbidity reached 99 percent. In case of hard-to-treat water containing large amounts of fined suspended solids (Turow Open Pit)), the treatment using flocculants not always gave satisfactory results. For those waters, the traditional coagulants have proved better, and the lime first of all.

The tests have not shown any substantial influence of water temperature within 0-23°C on the treatment effect. Also, was found any substantial influence of pH on the treatment effects within 6.5 - 8.5. Nothing but changes in pH above 9 resulted in the improved process of suspended matter reduction.

For the field tests special experimental station was established along with flocculants reperation and dosage plant, mixing facilities and sedimentation pond. The tests aimed at a check of laboratory results and determining, to a semi-commercial scale, main relationship needed in planning and designing mine drainage treatment plants. Particularly, the dependences of treatment effects upon type of flocculant, dose, mixing method, retention time in the sedimentation pond.

For testing, two cationic flocculants were used, namely American Calgon M-502 and Polish Rokrysol RF-5. The operating effects of sedimentation pond were measured, first of all by the reduction of turbidity, suspended solids content and oxygen consumption. In some cases, the determinations of full water composition were made at the inlet and outlet of the basin.

The tests have shown that turbidity reduction in natural sedimentation in retention time 70 minutes was 51 percent. Addition of Calgon in the ration 0.5 mg/dm^3 resulted in the increased reduction to 60-65 percent. The increased rate of flocculant up to 1 mg/dm^3 brought effect up to 75 per cent. The dose of 1.5 mg/dm^3 enabled to

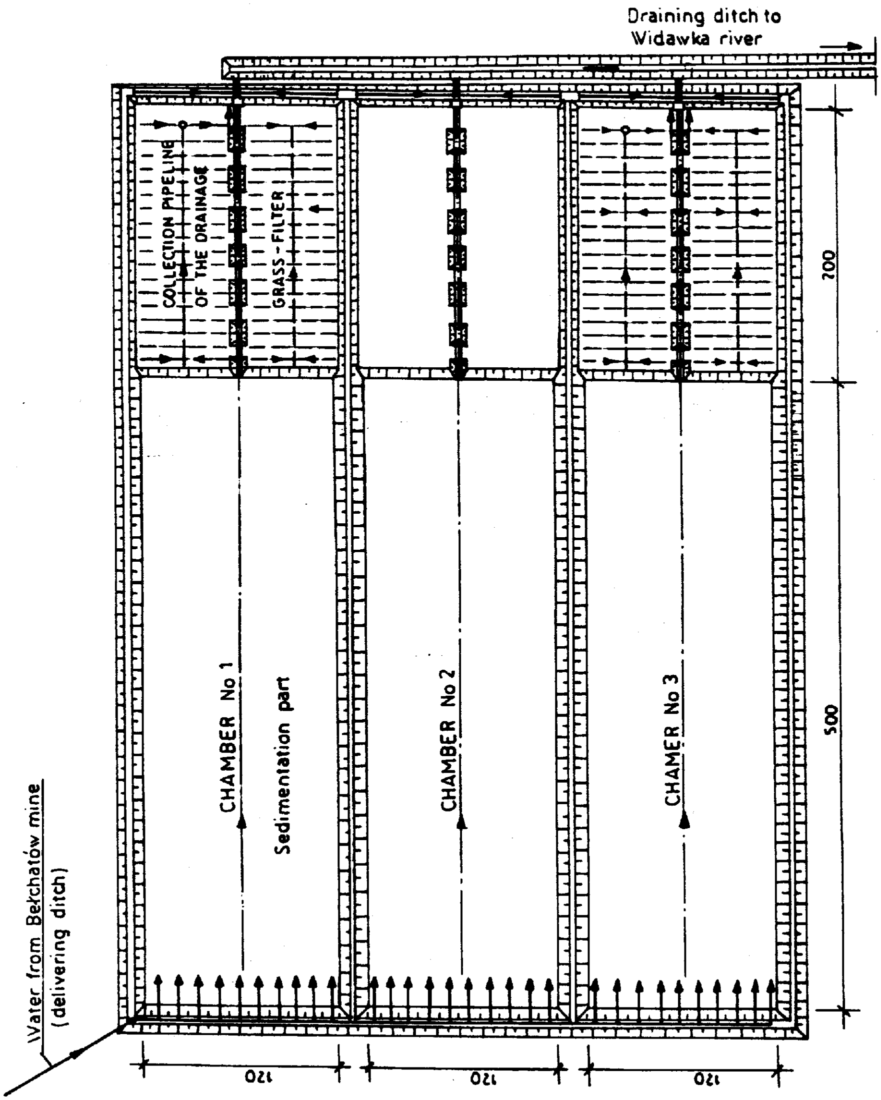

Figure 1 **Sedimentation basin at the Bełchatów mine**

reduce some 77 percent of turbidity at a max. retention time of 15 hours. Further increase up to 2 and 4 mg/dm^3 was not of any substantial effect.

The addition of flocculant resulted in a clearly visible increase in the reduction of turbidity and suspended solids, especially at short retention times below 5 hours.

Basing on the above results it could be concluded that practical optimum dose of flocculant Calgon M-502 is 1.0 - 1.5 mg/dm^3 . However depending on the water quality and quick mixing method in use, this dose can be decreased or increased within 0.75 - 2.0 mg/dm^3.

The size of sedimentation chamber should provide a real water retention time within 3-8 hours. When using the optimum dose of flocculant further increase in the retention time improves treatment effects to an inconsiderable extent only. The tests have shown that essential reduction in suspended solids contents took place in the first half of sedimentation pond. In most cases, the turbidity reduction within this areas was 70-80 percent of total reduction.

To sum up one can say that the results from examination of the applicability of flocculation processes have shown that it is possible to achieve a high suspended solids reduction rate when using cationic flocculants. This technique requires, however, a servicing personnel to attend flocullant delivery, storage, transportation, preparation and dosage facilities. So, it is labour-consuming and expensive process and, therefore, the mine operators do not like it.

MINE DRAINAGE TREATMENT WITH THE USE OF GRASS FILTER

The mine drainage treatment with use of grass filter was investigated on the experimental and commercial scale. The experimental research was carried out in a specially designed three sedimentation ponds (Figure 1). Two ponds were implanted with different types of vegetation to form so called grass filters consisting of different species. The third, sedimentation pond was free from the vegetation.

The tests have shown a favourable effect of the grass filter consisting of mixed bog plants on the reduction of suspended solids, turbidity and other impurities. The differences in the outlet concentrations of suspended solids reduction in particular chambers was always most favourable in the chamber with mixed vegetation. The favourable effect of vegetation on the reduction of some chemical impurities could be mainly seen for the iron, maganese, oxygen consumption, BOD_5, and some nitrogen compounds.

On full scale, the test were carried out in sedimentation pond constructed at the Belchatow Lignite Open Pit. The pond size was 120 x 700 m, where length of separated inelt sedimentation portion and outlet portion with grass filter was 500 m and 200 m, respectively. The depth of natural sedimentation portion was 1.65 m, and the retention time was about 16-20 hours at medium inflow rate. The depth in the vegetation portion was 0.2 - 0.4 m. The filter vegetation has developed from seeds and rhizomes introduced to the basin along with the peat soil. Hence, an incidental composition of filter vegetation. In the latter part of first growing season, the filter surface was overgrown 60 - 70 percent, and in the second season, the filter surface was overgrown 60 - 70 percent, and in the second season - 100 percent.

The prevailing species were bog plants. The treatment efficiency was mainly examined by measuring the turvidity and suspended solids content at the inlet to the sedimentation and grass filter portions and at the pond outlet. Some other chemical components content were also measured. The mine water flowing to the sedimentation basin had suspended solids content up to 1000 mg/dm^3. The other impurities were insignificant only iron, maganese, sulphate content, oxygen consumption and pH were found to be quite high.

The results of investigation have testified to the treatment effects obtained in the experimental sedimentation pond. The grass filter caused the reduction of finest suspended solids, thus increasing the total treatment effect by about 5-6 percent, which enabled to achieve final reduction of about 95 percent and average concentration of suspended solids less that 15 mg/dm^3 at the pond outlet.

The chemical characteristics of water have shown the reduction of iron, manganese, oxygen consumption, nitrogen compounds and partly, hardness and sulphates.

The observations of treatment effects in the sedimentation pond carried out till 1990 have confirmed its high efficiency and obtaining average yearly suspended solids concentration at outlet of less than 20 mg/dm^3.

CONCLUSIONS

1. The main frequently, the only one impurity of waters from Polish surface mines of lignite now in operation are the suspended solids and resultant water turbidity and colour. The concentrations of suspended solids and their sedimentation ability are different at individual open pits and show a high variation in time.

2. The water treatment technology in use is mainly based on the natural sedimentation process in large settling ponds. From the observations made until now, it results that this technology makes it possible to clean the water from suspended solids to concentrations 30-60 mg/dm^3.

3. If increased treatment effects should be obtained it is necessary to use other techniques based on the water flow through a set of bog plants, i.e. so called grass filter, or on the flocculation or coagulation processes. These techniques when used according to recommendations based on individual research allow to reduce the suspended solids down to less than 20 mg/dm^3.

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