Determination of The Optimal Dosage of Chemical Compounds in the Wastewater Treatment Process in Trang Bach Coal Mine: the Laboratory Scale

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Abstract

The pH index of Trang Bach coal mine wastewater ranges from 2,8 to 6, meanwhile, the content of Fe, Mn, and turbidity & suspended solids (TSS) are rather high and it is impossible to discharge the wastewater directly to the environment. In order to achieve the requirement of QCVN 40:2011/BTNMT standard – The national standard for industrial wastewater quality after treatment of Vietnam and other purposes, the wastewater need to be treated by several methods such as coagulation-flocculation or sedimentation. In this article, we intend to find the optimal dosages of chemical compounds for the TSS, pH, Fe and Mn treatment process for Trang Bach coal mine wastewater in the laboratory modular.

Keywords: Trang Bach coal mine, laboratory modular, optimal dosage

Introduction

The Trang Bach coal mine is located in Dong Trieu district, Quang Ninh province, 80km far from Hanoi, the capital city of Vietnam (Institute of Mining Science and Technology, 2011). The wastewater in Trang Bach coal mine, which has the large amounts and high concentrations of pollutants, is formed through the processes of depositing and moving water in the expanding underground coal mine activities under the complicated physical and chemical conditions (Institue of Mining Science and Technology, 2011). A large amount of FeS2 and some of the major mineral ores of manganese are contained in coal. Due to the coal exploitation, there is a significant amount of sulfuric acid, sulfuric acid (Fe(OH)3) that have been released into the wastewater. As a result, Trang Bach coal mine's wastewater is highly acidic and contains many suspended solids.

In the rainy season, due to a large amount of diluted rainwater, the acidity and content of pollutants in wastewater are reduced (Institute of Mining Science and Technology, 2014). Therefore, the content of pollutants in wastewater in the rainy season is lower than the dry season.The components of mining wastewater effluent directly to the quality of surface water resources, polluting the water sources, changing the habitat of aquatic fauna and flora. Therefore, coal mine wastewater must be treated before discharging into surface water or further treated with advanced technologies for other demands (R. K. Tiwary, 2001). Due to the above mentioned characteristics, the principle of treating coal mine wastewater is to use alkaline chemicals, neutralize acidic environment, create precipitation medium of Fe and Mn metals, then use PAC - Poly Aluminium Chloride to increase the possibility of suspended solids deposition (Le Anh Tuan, 2005). After the treatment processes, the wastewater quality will be compared with the level B of QCVN 40: 2011 / BTNMT standard - The national standard for industrial wastewater quality after treatment of Vietnam. Thus, the main objective of the research is to observe the optimal dosage in the treatment of pH, Fe, Mn and TSS of Trang Bang coal mine in laboratory scale.

The wastewater treatment in Trang Bach Coal Mine

The wastewater sample was collected from the mine at the furnace door (location of effluent pumped out of the pit) in end of January 2016. It was the dry season in Vietnam. The sample was analyzed in The Water Quality Laboratory, Hydrogeology Department, Faculty of Geosciences and Geoengineering, Hanoi University of Mining and Geology, Vietnam (Tab.1).

In comparison with the QCVN 40:2011/BTNMT, the content of Fe, Mn, TSS and the value of pH is higher than the standard, therefore, the wastewater quality is not good enough to be discharged directly to the surface water. The applied treatment method in this coal mine is quite simple, they use mainly the deposition method. The data of the quality of mine wastewater after treatment in 2014, 2015, provided by The Department of Environmental Technology, Institute of Mining Science and Technology also shows that the pH, Fe, Mn and TSS concentration sometimes was not fully treated (Tab. 2)

Methodology

The concept of the treatment of the mine wastewater which contains low pH value and high concentration of iron, manganese and TSS is coagulation and sediment. We will use calcium oxide to increase the pH, in parallel with it, the ion Fe^{2+} will be hydrolysed and accumulated and due to the oxidation, the ion Fe^{2+} will convert into the ion Fe^{3+}, theoretically, it will be appreciated as a result of the chemical reaction:

$$4Fe(HCO_3)_2 + O_2 + 2H_2O + 4Ca(OH)_2 \rightarrow$$

Tab. 1. The quality of wastewater sample in comparison with the B level of QCVN 40: 2011 / BTNMT standard

	pH	Fe (mg/l)	Mn (mg/l)	TSS (mg/l)
Result	3.31	5.9	24.4	148
B level - QCVN 40:2011/BTNMT standard	5.5 - 9	5	1	100

Tab. 2. The quality of wastewater of Trang Bach coal mine after treatment in 2014, 2015 (Source: Institute of Mining Science and Technology, Vinacomin, Vietnam)

No.	Value	**2014**			**2015**			QCVN 40:2011 /BTNMT
		5-2014	8-2014	11-2014	5-2015	9-2015	10-2015	B level
1	pH	6.8	4.8	5.2	3	5.6	5.9	5.5-9
2	TSS (x10 mg/l)	1.1	6	5.3	3.4	2.7	1.8	10
3	Fe (mg/l)	0.81	5.95	3.91	5.71	5.05	5.52	5
4	Mn (mg/l)	0.56	0.71	0.64	0.96	1.25	1.46	1

$4\ Fe(OH)_{3\downarrow} + 4Ca(HCO_3)_2$

Although the precipitated ion Fe^{3+} can be easily removed from the wastewater, iron ion still presents in the form of suspension. In fact, due to the lack of oxygen during the pumping process that brings the wastewater from the underground mine into the surface, the chemical reaction happened in another way (Tran Tu Hieu, 2003):

$$Fe(HCO_3)_2 + Ca(OH)_2 \rightarrow FeCO_{3\downarrow} + CaCO_{3\downarrow} + 2H_2O$$

On the other hand, calcium hydroxide also decreases the ion manganese concentration:

$$Mn^{2+} + 2OH\text{-} = Mn(OH)_{2\downarrow}$$

With the aim to separate the suspension and the mine wastewater, it is necessary to use the flocculant to increase the precipitation abilities of TSS, heavy metal's ions. The popular flocculant is PAC - Poly Aluminium Chloride (Alm(OH) nCl3m-nxH_2O, with $m \leq 10$, $2 \leq n \leq 5$) (V.K. Gupta et al., 2009).

In order to achieve the goals of this study, 2 experiments method were used. The chemical compounds are CaO 70% and PAC (with the concentration of Al_2O_3> 30%), provided by Hydrogeology Department, Faculty of Geosciences and Geoengineering, Hanoi University of Mining and Geology, Vietnam. All the experiments were done in the Water Quality Laboratory, High-Tech Analysis Center, Hanoi University of Mining and Geology. Firstly, the pH value of the wastewater will be increased by using calcium oxide, with the Jar-test stirring standard - 100 round per min in the first 3 minutes, 30 round per min in the next 10 minutes and wait for 30 minutes (A.P. Black et al., 1957). We started the experiments with 5 mg calcium oxide and then increased the calcium oxide content by 5 mg for the next test. The experiment had been repeated until the pH value reach to the B level of QCVN 40:2011/BTNMT standard. Secondly, the wastewater will be fully treated by PAC with the Jar-test stirring standard in the constant condition of pH value. The content of PAC for the first test is also 5 mg, and we also increased the content of PAC by 5 mg for the next test and the experiment had been repeated until the concentration of iron, manganese and TSS reached to the B level of QCVN 40:2011/BTNMT.

Results and discussion

Table 3 shows the results of the wastewater quality after being treated by CaO 70%. At the value of 280 mg CaO 70%, the pH value reached to the B level of QCVN 40:2011/BTNMT standard, in parallel with it, the concentration of Iron, Manganese and TSS also decreased as well. We continued increasing the content of CaO 70% till 320 mg and the pH value increased positively as well as the concentration of ion Iron, Manganese and TSS decreased.

After the first experiment, the optimal dosage of CaO 70% to increase the pH value to more than 5.5 is 280 mg/l, the concentration of ion Fe, Mn and TSS are 0,29; 8,50 and 23 mg/l respectively (Fig.1). Calcium oxide not only increased the pH value but also decreased the concentration of ion Iron because the ion F^{e2+} were also oxidized into ion Fe^{3+}, presented in the form of insoluble iron hydroxide and precipitated due to the neutralization of pH in the wastewater (Fig. 2). As a result, the concentration of Iron also reached to the B level of QCVN 40:2011/BTNMT but the concentration of ion Manganese and TSS were still higher than the B level of the standard, it is necessary to perform the second experiment with PAC.

With the pH value is 5,53 and the content of CaO 70% is 280 mg/l, we need 125 mg/l PAC to fully treat the concentration of ion Manganese and TSS. The sampling time is in the dry season, when the wastewater is diluted by the surface water in the rainy season, the concentration of ion Iron, Manganese, TSS will decrease and the pH value will increase and as a result, the content of CaO 70% and PAC that we need to treat the wastewater will be lower than 280 mg/l and 125 mg/l respectively (Fig. 3).

We were not able to perform the experiments with the wastewater samples in the rainy season due to the lack of fund and the lack of information. In order to apply this idea to build a wastewater treatment model in industrial scale, the further studies are still required. On the other hand, the coal

Tab. 3. The pH value and concentration of Iron, Manganese and TSS in wastewater samples after being treated by CaO 70%

CaO (mg)	pH	Fe (mg/l)	Mn (mg/l)	TSS (mg/l)
0	3.31	4.90	24.40	148
10	3.31	4,9	23.10	124
15	3.38	4.82	22.90	111
20	3.39	4.75	22.30	100
25	3.40	4.73	21.50	98
30	3.40	4.72	20.90	94
35	3.42	4.60	18.10	89
40	3.43	4.53	17.50	83
80	3.52	4.35	16.10	79
120	3.56	4.23	16.10	56
160	3.84	1.23	12.70	46
200	4.64	1.08	11.20	32
240	4.94	0.45	9.50	27
280	**5.53**	0.29	8.50	23
320	**5.85**	0.20	8.20	21
B level of QCVN 40:2011/BTNMT standard	5.50	5.00	1.00	100

Tab. 4. The concentration of contaminant in wastewater sample after being treat by PAC at the pH value by 5.53

PAC (mg)	0.00	40.00	80.00	120.00	125.00	130.00
Fe (mg/l)	0.20	0.16	0.12	0.11	0.11	0.11
Mn (mg/l)	8.20	5.34	3.27	1.15	1.00	0.93
TSS (mg/l)	21.00	17.00	13.00	4.00	0.00	0.00

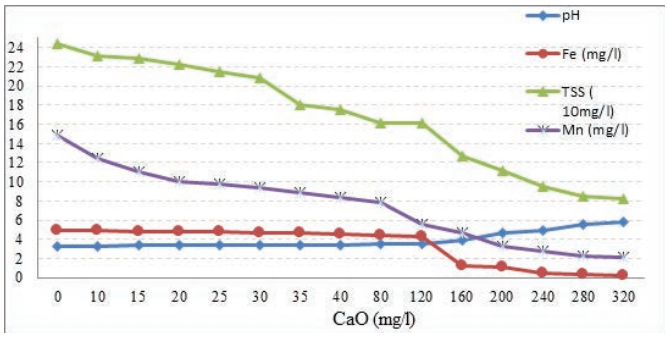


Fig. 1. The pH value and the concentration of ion Iron, Manganese and TSS after being treated by Calcium Oxide 70%

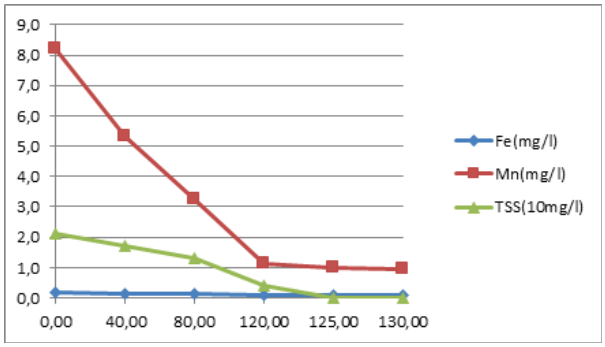
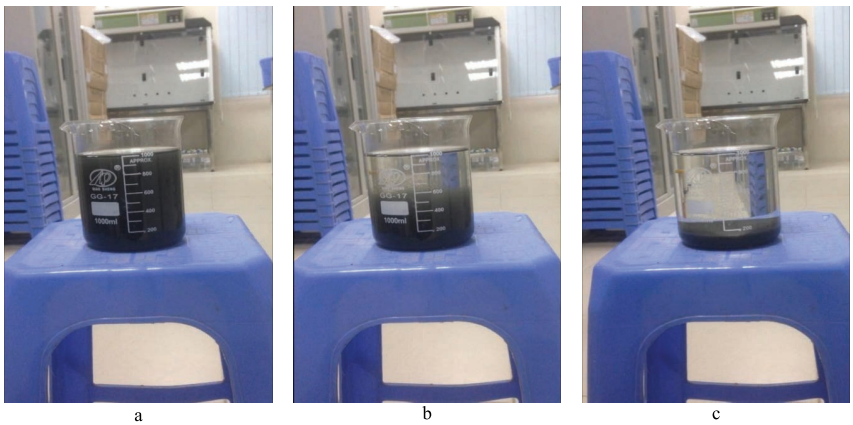


Fig. 3. The fluctuation of contaminants in the wastewater sample after being treated by PAC at the pH value by 5.53



a b c

Fig. 2. The precipitation process at the beginning (a), after 10 mintues (b) and after 30 minutes (c) of the wastewater sample after the first experiment with 280 mg/l Calcium Oxide 70% (Photo:Manh Ha Doan)

mines are located mostly in the North-West part of Vietnam, near several limestone mines so we have the potential to produce the chemical compounds for the industrial scale treatment locally.

Conclusion

The wastewater quality of Trang Bach coal mine is not good enough to be discharged immediately into the surface water. It contains the low value of pH, the high concentration of ion Iron, Manganese and TSS. In order to reach the B level of QCVN 40:2011/BTNMT – The national standard for wastewater quality after treatment of Vietnam, the wastewater need to be treated with 280 mg/l CaO 70 % and 125 mg/l PAC in laboratory scale.

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