Mine Water Management under Seasonal Rainfall Condition

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Abstract

Almost all hard coal mines of Vietnam are situated in Quang Ninh Coal Basin in the North East of Vietnam, near the coast of Ha Long Bay. Mine water discharged from coal mines has caused negative effects on Ha Long Bay's ecology as well as the quality of surface water resources. The primary reason is the seasonal mine water variation in both quantity and quality. Identifying a sufficient capacity for mine water treatment and managing the surplus volume of mine water during rainy season are two important solutions for designing mine water treatment plants (MWTPs).

Keywords: mine water, Quang Ninh Coal Basin, mine water treatment plant, seasonal mine water variation, rainy season

Introduction

Almost hard coal mines in Quang Ninh Coal Basin are under the management of Vietnam National Coal and Mineral Industries Holding Corporation Limited (VINACOMIN). Coal mining has been conducted by both open-pit (O/P) and underground (U/G) mining. Water running into mines is mainly surface water (rainwater) and groundwater.

Mine water is acidic and contains coal sludge (TSS), iron (Fe) and manganese (Mn) which are considered to be major pollutants (Kurtz 2009, Bilek et al. 2011, U+Ö 2015). The total volume of mine water is about 120 million m3 per year which is treated in 44 MWTPs (VITE 2014). The quality of treated mine water needs to meet The National Standard on Industrial Wastewater (QCVN 40:2011/BTNMT) which is pH = 5.5 – 9; TSS ≤ 100 mg/L; Fe ≤ 5 mg/L; Mn ≤ 1 mg/L accordingly. These values are adjusted further depending on the water supply purpose and volume parameters of the receiving water body and the wastewater flow (MONRE 2011).

There are four seasons in the North of Vietnam. However, a year can be divided into two main seasons for the mining industry regarding the rainfall: rainy season that lasts

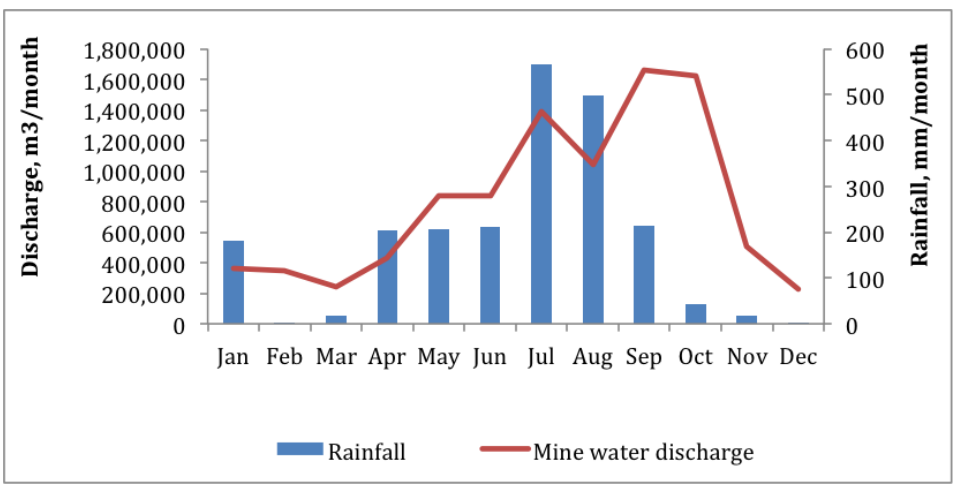

Figure 1 Diagram of the rainfall in Hon Gai area and the mine water drainage of Ha Tu O/P Coal Mine in 2016

from May to October and dry season that lasts from November to the following April. The annual rainfall in Quang Ninh varies from 2,200 mm to 2,400 mm and mainly concentrates in July, August, September. The variation of rainfall affects both the quantity (fig. 1) as well as the quality of mine water (Tran Mien 2017).

For U/G coal mines, the most important pumping time for mine water drainage in a year often coincides with the period of rainy season. For O/P coal mines, the mine water is accumulated in the pit bottom. The pumping time for mine water drainage concentrates in October, November and December in order to drain off water from the mining pit and to prepare the mining field for the following year. Due to the seasonal variation of mine water, the capacity of MWTPs is not stable as designed which leads to overflow in the rainy season and lack of inflow in the dry season as well as discrepancies from the technical norms in the discharged water. These are the biggest challenges for the mine water management of coal mines in Vietnam.

Before 2014, when designing MWTPs, two methods for determining the treatment capacity were used. Either the highest monthly average volume of mine water in a year was used with the aim to thoroughly complete the treatment of mine water ("full treatment" viewpoint) or in case of limited investment budget ("economical" viewpoint) the average annual volume of mine water was chosen. Both methods resulted in undesirable effects on the economic and technical efficiency of MWTPs. The performance survey among 34 MWTPs operating in the period of 2013 – 2014 in Quang Ninh Coal Basin shows that in 2013 up to 60% of them operated less than 75% of their designed capacity, 30% of them achieved their designed capacity; the corresponding figures in 2014 are 29% and 42% (VITE 2014). Those treatment plants which exceeded their design capacity produced low quality of treated water.

The cause of the above-mentioned problems originates in the decision of design capacity without considering the seasonal variation of mine water which means that the volume of mine water greatly decreases in dry season and contrary in rainy season. The feature of the seasonal variation of mine water requires a method to identify a sufficient design treatment capacity for MWTPs in order to ensure their cost-effectiveness as well as an effective management of surplus mine water volume in rainy season.

Methods

Seasonal mine water management for coal mines in Vietnam includes a set of following solutions:

- Identification of treatment capacity for the MWTP projects by taking the seasonal variation of mine water volume into consideration but keeping the investment costs at a suitable level and achieving conformance to national standards for industrial wastewater;
- Effective management of increased mine water volumes in rainy season;
- Installation and operation of the flexible multi-line treatment systems adjusted to mine water quantity at the operation time.

The identification of treatment capacity for MWTP projects by taking the seasonal variation of mine water volumes into consideration is based on the analysis of the seasonal variation of the mine water volumes (SMWA) in a number of consecutive years (3 years at minimum). The order of the steps is as follows.

Collecting, editing, analyzing the development of mine water drainage

Data of mine water drainage in coal mines can be managed and provided by some various relevant sections in the same mine depending on their respective management roles. Therefore, it is necessary to execute the verification, comparison, editing, correction and validation of data. The accuracy of data provided will determine the precision of MWTP designs.

Identifying capacity parameters

Data of mine water drainage in a year will be processed into 4 different volumes: i/ monthly average; ii/ quarterly average; iii/ (dry and rainy) seasonal average and iv/ annual average. Usually, the monthly average is the highest value and the annual average is the lowest. This is in accordance with the

methods of treatment capacity identification as used before, therefore the values will be used for reference. The quarterly average and the seasonal average (rainy season) are used for analysis and evaluation in accordance with SMWA. Depending on rainfall in the year, the value of seasonal average volume in rainy season is calculated according to the actual period of rain.

Verifying the capacity of mine water equalization in rainy season

The equalization of mine water in rainy season is an important factor which decides on the effective management of mine water of coal mines in Vietnam. This is realized by a reservoir system called "**equalizing reservoirs**".

In rainy season, parts of the mine water are stored in them. The volume of the equalizing reservoirs should be sufficient to store the surplus mine water after a rain event in order to prevent an overflow of untreated mine water into receiving water courses. At the same time, the reservoirs support settling of coal sludge in mine water during its retention time there (Tran Mien 2017).

In dry season, when the volume of mine water is greatly decreased, equalizing reservoirs are to collect and maintain its stable supply of mine water for treatment modules in correspondence with the volume of mine water at operation time.

The relevant parameters to be identified include: surplus mine water (increased mine water volume) in rainy season; available volume of equalizing reservoirs; real pumping time for storage meeting mine safety regulations, especially the ones for underground coal mines.

It is necessary to reuse available objects that are not used any more, such as sedimentation ponds of coal preparation plants, sections of abandoned stream for the establishment of equalizing reservoirs.

Identifying the appropriate number of parallel treatment modules in correspondence with the volume of mine water in season

As a design solution, parallel treatment modules are used to mobilize treatment capacity of a MWTP in accordance with mine water quantity existing at operation time. The number of parallel treatment modules is identified by the difference or ratio between the 3rd quarterly average volume or the rainy season average volume and the remaining other values of the same parameter in the same year.

Making the decision for a capacity alternative

A capacity alternative for any MWTP design will be decided based on analysis, evaluation and comparison of the above-mentioned factors. The capacity alternative chosen for the MWTP design is the lowest one among those and must satisfy the demand of full treatment of mine water volume in the year.

A decision on treatment capacity usually should be based on supplementary information such as: i) planned investment cost based on investment experiences from similar MWTPs which have been installed previously; ii) available conditions for design implementation (area, location of the area for equalizing reservoirs and other conditions related to the mines infrastructure).

SMWA method is currently used by VITE in making new MWTP designs and verifying the treatment capacity for MWTPs under operation.

Results

The results of SMWA method are shown in the verification of the treatment capacity for Ha Tu Open-pit (O/P) Coal Mine MWTP, Quang Ninh as an example.

Ha Tu MWTP treats mine water from mining field V.16 of Ha Tu O/P Coal Mine, designed with the capacity of 1,500 m3/h into two stages. In the 1st stage, the capacity of 300 m^3/h has been installed with 3 parallel treatment modules that have been put into operation in June 2013. In the 2nd stage, an additional capacity of 1,200 m^3/h has been installed with 2 parallel treatment modules that have been put into operation in January 2016. Their working regime is 300 days per year; 30 days per month; 3 shifts per day (or 20 operating hours per day). The total volume of 2 equalizing reservoirs is 25,000 m^3. Current status: Capacity of Ha Tu MWTP

is insufficient for treating its mine water volume in rainy season, therefore an overflow of untreated mine water into the receiving water course often occurs. It is necessary to verify its real capacity (for the year of 2018).

Figure 1 shows a resemblance between the developments of rainfall in Ha Long area and mine water drained from Ha Tu O/P Coal Mine.

Figure 3 shows the developments of treatment capacity in 2016, 2017, 2018 of Ha Tu MWTP. The volume of mine water increases from May to October and reaches its peak in July, August and September.

The performance of treatment in 2016, 2017 and 2018 is shown in table 1.

Figure 2 *Coal sludge from Ha Tu O/P Coal Mine in Lo Phong stream, Quang Ninh*

Development of verification:

Development of mine water drainage in 2018 is shown in table 2.

Results of calculation of capacity parameters are shown in table 3.

From the results of table 3, two capacity alternatives which have been offered to verify are the quarterly average volume of 2,400 m^3/h and the rainy season average volume of 1,800 m^3/h. The treatment capacity which has to be verified is the design capacity of 1,500 m^3/h.

Table 4 shows calculations of the developments of treatment capacity in accordance with the quantity of mine water supplied to Ha Tu MWTP in the year. The results of table 4 indicate the lack of treatment capacity in months of rain (- sign) and the surplus in months outside rainy season.

Table 5 shows the results of verification on treatment capacity in months after rainy season.

Conclusions from the results of verification:

The design capacity of 1,500 m3/h is insufficient for treatment demand during and after rainy season. Therefore, overflow of untreated mine water into receiving water

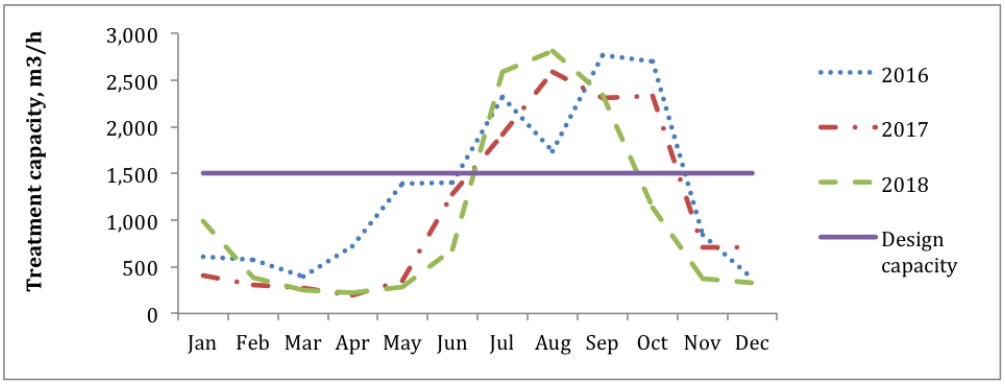

Figure 3 *Development of treatment capacity of Ha Tu MWTP in 2016, 2017 and 2018*

Table 1 *Performance of treatment in the period of 2016 - 2018*

	Drained volume, m^3	Treated volume, m^3	Overflow volume, m^3
2016	9,508,512	2,492,293	7,016,219
2017	8,009,430	6,927,644	1,081,786
2018	7,427,038	6,623,130	803,908

courses often occurs.

The capacity alternatives could be considered for Ha Tu MWTP are the quarterly average capacity of 2,400 m^3/h or the rainy season average capacity of 1,800 m^3/h, of which the rainy season average capacity follows the economic viewpoint while the quarterly average capacity is oriented towards high safety.

Between two these alternatives, the rainy season average capacity of 1,800 m^3/h is preferred because this alternative satisfies two prerequisite criteria which are i) its available capacity for the surplus of mine water volume higher than the same criteria of the capacity alternative of 2,400 m^3/h and ii) but with a lower investment scale.

Effective management of the surplus volume of mine water in rainy season is the accumulation of mine water in the pit bottom and treatment in the months after the rainy season.

The enlargement of capacity for Ha Tu MWTP needs to be considered.

Conclusions

The seasonal variation of rainfall in Vietnam has important effects on the management and the treatment of mine water. The management of surplus mine water in rainy season is an obligatory factor for reducing bad effects on the environment but, at the same time improving the economical and technical effectiveness of MWTPs at Quang Ninh Coal Basin.

SMWA method has being applied for designing MWTPs in coal mines under the management of VINACOMIN, as well as verifying the design capacities of existing MWTPs.

SMWA method together with the installation of equalizing reservoirs and parallel treatment modules have made up a set of solutions for the seasonal mine water management under the features of tropical rain in Vietnam (fig. 4).

SMWA method still has limitations due to the lack of data and their low confidence level. According to legal regulations of The

Table 2 *Development of mine water drainage in 2018*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Quantity, m^3/h	992	379	246	222	284	681	2,589	2,810	2,342	1,132	370	331

Table 3 *Capacity parameters*

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly avg.	992	379	246	222	284	681	2,589	2,810	2,342	1,132	370	331
Quarterly avg.		539			396			2,580			611	
Seasonal avg.			423				1,640					
Annual avg.						1,032						

Table 4 *Developmets of treatment capacity*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inflow, m^3/h	992	379	246	222	284	681	2,589	2,810	2,342	1,132	370	331
Treatment potential by alternatives:												
2400 m^3/h	*1,408*	*2,021*	*2,154*	*2,178*	*2,116*	*1,719*	*-189*	*-410*	*58*	*1,268*	*2,030*	*2,069*
1800 m^3/h	*808*	*1,421*	*1,554*	*1,578*	*1,516*	*1,119*	*-789*	*-1,010*	*-542*	*668*	*1,430*	*1,469*
1500 m^3/h	*508*	*1,121*	*1,254*	*1,278*	*1,216*	*819*	*-1,089*	*-1,310*	*-842*	*368*	*1,130*	*1,169*

Table 5 *Balance of treatment capacity in months after rainy season*

	Total of capacity needed for the surplus mine water volume, m^3/h	Total of capacity operated in months after rainy season, m^3/h	Total of available capacity for the surplus mine water volume, m^3/h
Alternative of 2,400 m^3/h	-599	4,174	3,026
Alternative of 1,800 m^3/h	-2,341	1,832	3,568
Designed capacity, 1,500 m^3/h	-3,241	1,832	2,668

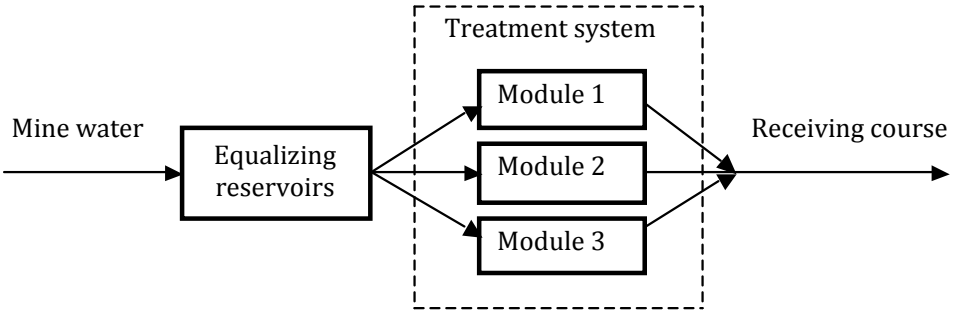

Figure 4 *Principle of seasonal mine water management system*

Government of Vietnam, since 2018 all MWTPs in Quang Ninh Coal Basin need to install an automatic monitoring system. For this reason, the confidence level of data will be ameliorated in the coming time.

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