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A research on Treating and Recycling Wastewater from Mine Tunnels at 790 Coal Mine, MTV 790 Ltd. Company

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Abstract: Large amount of water is used and wastewater is created in coal mining industry. Coal mining wastewater treatment by reusing it for production and domestic purposes is then essential. Coal pit No 790 of Dong Bac Coal Corporation locates in the area of Mong Duong district, Quang Ninh province. Wastewater after treatment is within the limitation specified in the column B in QCVN 40:2011/BTNMT on industrial wastewater. The process effectiveness of treating turbidity, iron and Mn reaches the maximum level of83%, 30% and 40% (after Arkal filtering disc); 88%, 71% and 87% (after Media Filter); and 57%, 78% and 84% (after UF membrane filter) respectively.Those above indicators have met regulations for domestic water under QCVN 01:2009/BYT. However, the Coliform has insignificantly decreased after treating by Arkal filter which are hundreds to thousands of CFU/100ml. The amount of Coliform have decreased to 12 ÷ 51 CFU/100ml (after Media Filter) and from 1 to 18 CFU/100 ml (after through UF), respectively. The wastewate has been required for further treatment for purpose of domestic water supplying for workers and local people.

Key words: wastewater, Dong Bac coal, recycling, media filter, UF

1. Introduction

Wastewater is now one of the main polluting sources in coal exploitation at MTV 790 Ltd. Company. In addition, the demand for supply of water and water pumping at the height of +150 and +180 from sea level are urgent issues. This comes from the fact that the water needed for workers' daily use, about 700-1,000 workers on average directly working at one mine (around 250 liters/person/day) for production and dust mitigation. Currently, the source of water supplied for production of the corporation is mainly bought from local water supply system [3]. In fact, the water supply for production, dust mitigation and firefighting is not required at good quality but good quality of water is needed workers' drinking, cooking and bathing/washing.

Research finds that an overall solution of treating wastewater from mine tunnels to be recycled and reused in daily activities and production should be appropriate and urgent, which satisfies the criteria of appropriate and economic water resource, at the same time, protecting the environment.

2. Research Objectives and Methods

2.1 Objectives

The author investigated and assessed the quality of wastewater from mine tunnels of MTV 790 Ltd. Company by comparing concentration of TSS, Fe, Mangan, Coliform and etc. before and after being treated (the treatment method is disc filter technology in combination with media filter, UF membrane filtration) and compared those above indicators with Vietnam Technical Regulations (QCVN). Based on

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that result, the technology for wastewater retreatment from mine tunnels after the first level of treatment will be proposed.

2.2 Research Methodology

2.2.1 Synthesizing and Analyzing Information, Document and Statistics Method

Document collecting method was used to gather necessary information and related statistics such as technology, treatment capacity and efficiency about wastewater treatment systems which were built in 790 coal mines.

2.2.2 Sample Collection and Analysis Method

Wastewater samples after being treated by Arkal disc filter, Media filter and UF membrane filtration from May to July, 2014 reduced time of collecting samples (5-3-1 day/collecting time). The procedure for sample collection, maintenance and transferation should follow (Vietnam National Standard-TCVN) TCVN 5999:1995 – Water quality – Sampling – Guidance on samples of wastewater. Wastewater sampling follows TCVN 6663-3:2008 (ISO 5667-3:2003) – Water quality – Sampling – Part 3: Guidance on the preservation and handling of water samples. Instruction for maintaining and treating samples: each sample was put into 02 brown glass bottles with ground stopper and of 500 ml volume. 1 bottle was added 1.5 ml acid of HNO_3 (d = 1.42) to analyze Fe and Mn and another bottle was not added any chemicals. Before sampling, both bottles were rinsed three times with the wastewater collected.

Table 1 Methods and facilities used in analyzing wastewater samples.

No	Indicator	Methods and facilities
1	Turbidity (TSS)	TCVN 275 : 2014, cut off point from 0 ÷ 4000 NTU, error < ±5%
2	Total Fe	TCVN 6177:1996 (**UV – VIS spectrograph**, cut off point from 0.01 ÷ 5 mg/l)
3	Mn	TCVN 6002:1995 (**UV – VIS spectrograph**, using formal doxim as reactant, cut off point from 0.01 ÷ 5 mg/l)
4	Coliform	TCVN 6187-1:2009 (Membrane filter method, transplant and count the number of colonies)

After sampling, the samples were preserved in specialized tanks at 4°C and sent for analyzing within one day at Receiving house (VILAS 176), Center for Applying Scientific and Technological Development, QuangNinh Department of Science and Technology. Each sample was analyzed in terms of 4 indicators: turbidity (TSS), total Fe, Mn and Coliform.

2.2.3 Comparison Method

The analyzing results of wastewater samples were compared to the current environmental technical regulation of Vietnam (QCVN 40:2011/BTNMT[1], QCVN 02:2009/BYT[2] and QCVN 01:2009/BYT) to assess the pollution of wastewater from mine tunnels and the effectiveness of treatment technologies.

2.2.4 Synthesizing and Processing Data Method

Microsoft Word and Excel were used to process information and collected data. Results of wastewater quality were presented in form of tables, diagrams, charts and etc. After that, they were synthesized and assessed.

2.2.5 Expert Interviewing

Experts specialized in environment, mining, chemistry, water supply were consulted in order to select and develop appropriate technology to retreat wastewater from mines after being treated at level 1. The treated wastewater was then recycled and reused for living purposes and production (level 2)

3. Results and Discussions

3.1 Technology Assessment And Effectiveness of Mine Tunnels Wastewater Treatment (Level 1) at 790 Coal Mine

Wastewater from coal mining at 790 Coal mines was pumped to a wastewater treatment station with the

[1] BTNMT: Ministry of Natural resources and Environment.
[2] BYT: Ministry of Health.

capacity of 2600 m^3/day. This station has operated since 2012. Wastewater treatment system (level 1) at the elevation +48 (coal Barrier -150) belonging to Mong Duong mine area of the company 790 (Northeast Coal Corporation - Ministry of Defence) are processed primarily by means of flocculation — settling with lime, PAC (Poly Aluminium Chloride) and flocculation auxiliaries of PAM (polyacrylamide) Cationic.

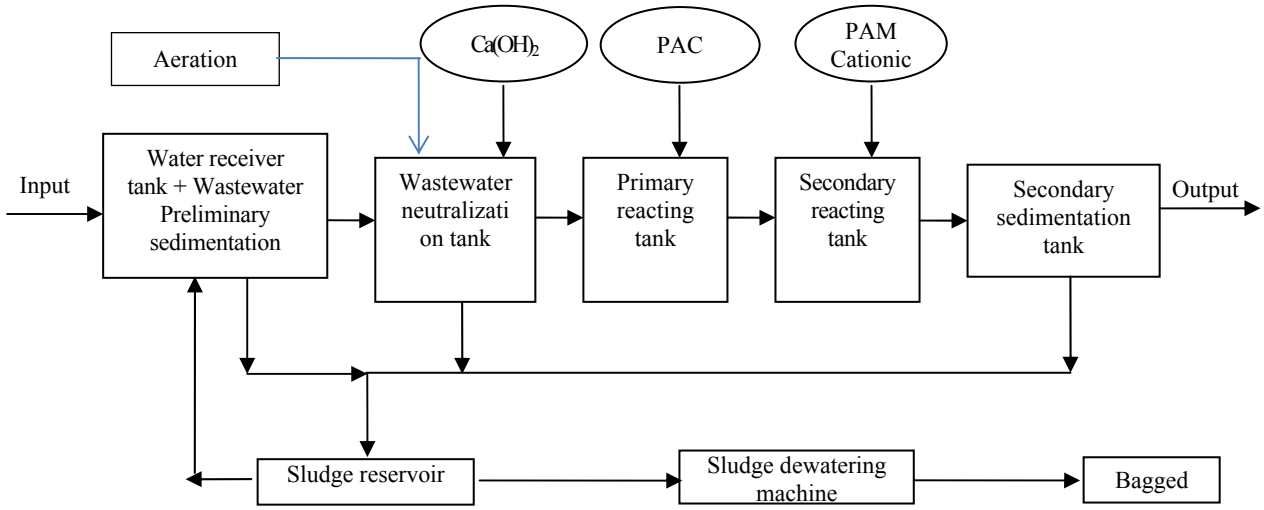

Fig. 1 Diagram of current wastewater treatment technology at MTV 790 Ltd. Company.

Table 2 The quality of post treated wastewater at 790 Coal mine in different sampling.

No	Indicator	Unit	05/11/2013	05/02/2014	06/05/2014	06/08/2014	QCVN 40: 2011 (B)
1	pH	-	4	3.5	4.5	5,0	**5.5 ÷ 9**
2	TSS	mg/l	520	460	690	765	**100**
3	BOD_5 (20^oC)	mg/l	20	35	44.5	32.1	**50**
4	COD	mg/l	250	274	85.3	75.6	**150**
5	Pb	mg/l	0.006	0,004	0.003	0.002	**0,5**
6	Cu	mg/l	0.46	0.81	0.38	0.42	**2**
7	Total Fe	mg/l	7.22	8.51	6.34	5.87	**5**
8	Cd	mg/l	KPH	KPH	KPH	KPH	**0,1**
9	Mn	mg/l	4.51	5,23	2.65	1.87	**1**
10	As	mg/l	KPH	KPH	KPH	KPH	**0,1**
11	Hg	mg/l	KPH	KPH	KPH	KPH	**0,01**
12	Ammonia	mg/l	2.17	3.51	1.26	1.14	**10**
13	Total Phosphor	mg/l	0,36	0.82	0.51	0.26	**6**
14	Total coliform	MPN/100 ml	1800	3500	2730	2650	**5000**

Note: KPH: Unidentified; GHCP: is $C_{max} = C \times K_q \times K_f$. in which: C_{max} is the maximum values of pollution parameters in industrial wastewater; C is the value of pollution parameters in industrial wastewater specified in Section 2.3 of the QCVN 40: 2011/BTNMT - National Technical regulations on industrial wastewater. Column B identifies the quality of wastewater being discharged into water sources but not used for supplying water for daily use. K_q is flow coefficient/volume of the receiving wastewater sources ($K_q = 1$). K_f is flow coefficient of the discharge source equivalent to the total wastewater source of the production unit when discharging into receiving wastewater sources ($K_f = 1$)

Wastewater is directly pumped into the neutralization tank. In this tank, the solution of lime $Ca(OH)_2$ is pumped in and mixed with wastewater to neutralize H_2SO_4 in wastewater in order to raise the

pH to the environmental standard. At the same time, the air from the compressor is aerated into the neutralization tank to oxidize most Fe, part of Mn and aid the process of mixing the lime liquid. Wastewater from the neutralization tank flows directly into the flocculation tank where flocculation PAC solution and PAM Cationic are pumped into and mixed with wastewater by stirring process and then flows into the secondary sedimentation tank. At this stage, PAC is added in order to reduce viscosity, increase the attraction among small particles to form larger ones. PAM Cationic then is used to enhance convergence of the particles when exposed to each other to form a large coagulation and increase the settling velocity. In the secondary sedimentation tank, the suspended solids gather into large sludge mostly settling down to the bottom. At the bottom of the tank, sludge suction pipe is connected to the sludge pump. Sludge is periodically pumped into sludge tank then pumped into sludge dewatering equipment for compression.

Water from the secondary sedimentation tank flows directly into the water receiver tank, and is pumped by pressure pumps to the Mangan filter tank. It then flows through the pipeline to the clean water tank. At this tank, clean water flows into streams through the pipeline which is partly reused for industrial hygiene purposes and watering roads to reduce dust. Wastewater treatment station is controlled semi-automatically. Treated wastewater is able to be discharged into the surface water class B according to QCVN 40: 2011 — National Technical Regulation on industrial wastewater. It is also discharged into the western drainage to flow into Lep My stream and into Mong Duong River. Sludge is sucked into the tank periodically, gone through the sludge dewatering equipment to reduce its weight before being transferred to the deck [1].

Meanwhile, the demand for water supply at the coal mine are very high at about 420 m^3/day.

Recently, this total amount of water has been purchased from supply water system of Cam Pha city by the company at the price of 6,000 VND/m^3. The company would save 153,300 m^3 of clean water, equal to 918,000,000 VND each year if wastewater has been collected and treated for living purpose and manufacturing. So it is necessary to find a reasonable solution, a better process (Handling level 2) to reduce concentration of the pollutants such as Fe, Mn, TSS and coliform to recirculate water for other purposes.

Table 3 Water supply demand at Mine No. 790.

Demand	Value (m^3/day)
Water for domestic purposes	230
Water for dust suppression and road spraying	150
Water demand for diluting chemicals in wastewater treatment	40
Total	420

3.2 Recirculation Wastewater Treatment Technology Using Arkal Disc Filtration Combined with Pressure Filter and Media Filter

The authors and company Vietnam - Singapore has designed a treatment system after wastewater treatment station of 790 Coal mine company with a capacity of Q = 40 m^3/h to meet QCVN 02:2009/BYT since 2013. This aims to supply clean water for daily purposes, washing of workers, spray dust suppression and industrial hygiene on site.

3.3 Research on Further Wastewater Treatment Using Membrane Filtration to Supply Water for Drinking and Cooking Purposes

3.3.1 Model and Process of Research on Membrane Filtration Model Placed at Site

The filter used is UF tube fiber made by Mann-Hummel, Germany. UF tube fiber has the following characteristics: the pore size is from .01 to 0.1 μm, filtration area: 48 m^2, the water flow capacity through the filter: 11-72 l/m^2.h (at 25°C); the maximum inlet pressure: 241 kPa and maximum filtration pressure: 55 kPa.

The process works as follows:

- Filtration process

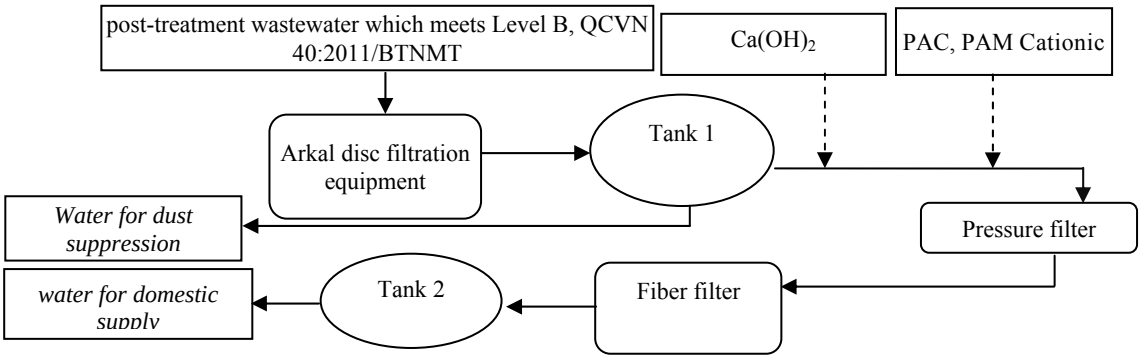

Fig. 2 Diagram of continuing wastewater treatment at MTV 790 Ltd. Co. using Arkal disc filtration system and pressure filter, fiber filter (Media Filter) installed by the Viet-Sing Company.

Because the amount of suspended solids in post-treatment wastewater at wastewater treatment station of MTV 790 Ltd. Company is large, the input wastewater of the model is taken from tank 1 after filter system using Arkal disc. Firstly, water runs through the preliminary purification equipment (the pore size of 100 µm, can be backwashed and mounted on a base). The water will then be distributed evenly over the pipe into the filter module. A flow regulator valve allows water flow to maintain at stable levels. Water will be filtered through a UF membrane. After a certain time, the membrane surface will be dirty, the valve at this moment opens automatically to increase the input pumping pressure to maintain water flow at stable parameters which is identified when designing. A part volume of water will be recirculated to the water tank or back to the inlet water flow with the help of the valve adjustment at the upper end of the membrane. This amount of recirculation water is always maintained stably to minimize dirt concentrated on the filter surface.

- Regular membrane wash process

Periodically, filters will be backwashed by a combination of aeration and use of filtered water to remove particles adhered on the surface of the membrane. Backwash system is connected to filtered water tank and backwash pump or rinse pressure process. Filtered water is pumped back to the process of backwashing. Backwash pump is connected to an inverter equipment to maintain backwash speed according to preset parameters. Water for backwash taken from the top in combination with compressed air from the bottom will make the filter vibrate strongly to loosen the dirt and separate it from the fiber surface membrane. The amount of wastewater from backwash is discharged.

- The periodical fiber membrane cleaning

This is the process of cleaning the fiber membrane with chemicals to enhance the removal of dirt adhesion from the membrane. This process consists of 2 steps: cleaning by sodium hydroxide/hypochlorite and then by acid. Time for each cleaning cycle with chemical is about 3 hours. Kinetic pressure and water flow filtered through the fixed membrane are 20 kPa and 20 $l/m^2.h$, respectively.

3.3.2 The Quality of Treated Wastewater after Treatment Level 2

After being treated at wastewater treatment station of MTV 790 Ltd. Company, wastewater is treated further in Arkal disc filters to separate the remaining crude insoluble solids dispersion. The wastewater turbidity after this process reduces significantly from 58-70 NTU to 10-14 NTU before and after treating at Arkal disc, respectively. The turbidity after treatment in sand and fiber filtration systems drops from 1.2 to 4.2 NTU which is within the allowed standards for supply domestic water (turbidity: 5 NTU) according to QCVN 02:2009/BYT. After the UF process, the turbidity of the output water falls from 1.1 to 1.8 NTU, which meets regulations for drinking and cooking

water (turbidity: 2 NTU) by QCVN 01: 2009/BYT.

The Fe concentration after treating at the Arkal disc reduces negligibly. After the filter process, the Fe concentration in water meets the regulation for Fe in domestic water (less than 0.5 mg/l) according to QCVN 02:2009/BYT. After going through UF membrane filter, the iron concentration meets the requirement for Fe in drinking and cooking water under the QCVN 01:2009/BYT which stands from 0.03 to 0.09 mg/l.

Like iron, manganese concentration in the wastewater going through Arkal disc filter reduces insignificantly. After the sand filter and fiber filter, the manganese concentration in water is from 0.052 to 0.45 mg/l. After going through UF membrane filter, the manganese concentration in water is from 0.045 to 0.072 mg/l which fully meets the requirements for Mn concentration in drinking and cooking water according to QCVN 01: 2009/BYT (less than 0.3 mg/l).

The number of coliform after Arkal disc filtration treatment reduces slightly, remains at hundreds to thousands of CFU/100 ml. Once going through the sand filter and fiber filter tank, the number of coliform reduces to tens (from 12 to 51 CFU/100 ml). Although most of the samples have the remaining coliform quantity of less than 50 CFU/100 ml, there are still a number of water samples after processing systems that exceeds the standards of QCVN 02:2009/BYT in terms of coliform indicator. After going through UF membranes, number of coliform in water is between 1 and 18 CFU/100 ml. Thus, in order to supply water for drinking and cooking purpose, water after UF membrane filtration system must continue to be disinfected with appropriate methods.

The wastewater treatment cost is 6,230 VND/m^3 (which includes equipment depreciation cost, labour cost, power and chemicals expense). Thus, recent cost for wastewater treatment is higher than the cost of buying supply water. However, the Company will save the amount of 218,376,000 VND/year from paying for environmental protection fee if it installs the wastewater treatment and water re-circulation system. This case will be feasible in the term of cost [2].

4. Conclusion and Recommendations

4.1 Conclusion

Research results show that:

- The current post-treated water at coal mines meets the allowable limits specified in column B of QCVN 40:2011/BTNMT on quality industrial wastewater before being discharged into the environment.

After further treatment through Arkal disc filtration systems - pressure filter, fiber filter (Media Filter) and UF membrane filter: the turbidity reduces from 58-70 NTU to 10 ÷ 14 NTU (after Arkal disc filter), from 1.2 ÷ 4.2 NTU (after Media filter) and from 1.1 ÷ 1.8 NTU (after UF membrane filtration); Fe concentration decreases respectively from 0.5 ÷ 1.2 mg/l to 0.35 ÷ 0.9 mg/l (after Arkal disc filter), from 0.1 ÷ 0.4 mg/l (after Media filter) and from 0.03 ÷ 0.09 mg/l (after UF membrane filter); Mn concentration decreases from 0.55 ÷ respectively 1.5 mg/l to 0.4 ÷ 0.9 mg/l (after filtering Arkal disc), from 0.052 ÷ 0.45mg/l (after Media Filter) and from 0.045 ÷ 0.072 mg/l (after UF membrane filtration) to meets regulations for Mn concectration in drinking water under the QCVN 01:2009/BYT. Particularly the number of coliform after Arkan disc filtration process insignificantly reduces which remains from hundreds to thousands of CFU/100 ml; falling from 12 ÷ 51 CFU/100 ml (later Media Filter) and 1 to 18 CFU/100 ml (after UF membrane filter). Therefore, water needs to continue being disinfected further before suppling for daily purposes of workers.

- The wastewater treatment cost is 6,230 VND/m^3. This case should be feasible in the term of cost.

4.2 Proposal of Technonoly Systeme

Based on the above results, the authors propose installing the treatment system Level 2 in order to supply clean water for workers' showering, cooking and drinking purposes at 790 Coal mine. The

operation principles of treatment system are as follows:

Wastewater from wastewater tank which meets standard at B level in QCVN 40:2011/BTNMT after treatment, is pumped to supply for Arkal disc filtration. The Arkal disk filtration has 4 parallel columns that allow water to be pushed simultaneously into Arkal filtration columns and through tightly spaced filter disc. The pore size of Arkal disc is 20 μm and the diameter is 3" which hold all sediments greater than 20 μm in the water before the water goes to tank 1.

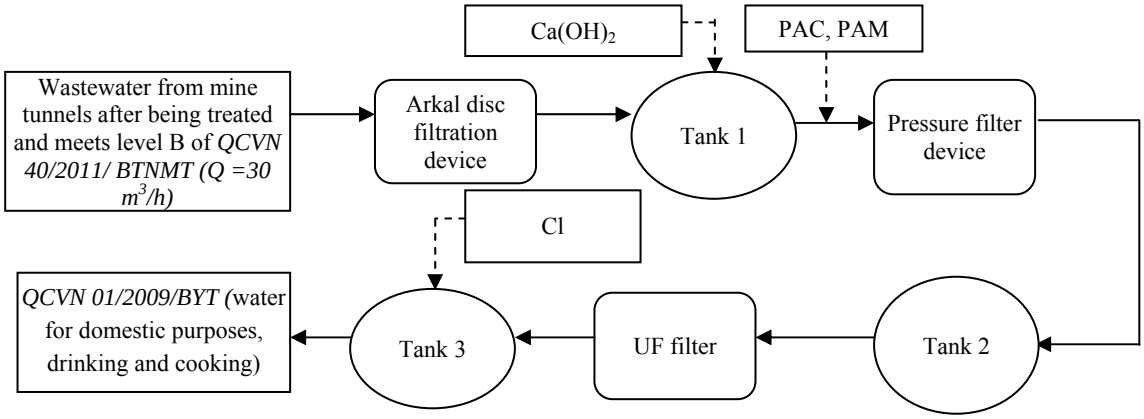

Fig. 3 Map of wastewater treatment technology level 2 to supply water for domestic purposes like drinking and cooking.

At tank 1, metering pump system will suck and quantify the amount of chemicals into the water to raise the pH of the water to ensure satisfaction for domestic supply. Pressure pumps continue pumping water from tank 1 into 02 units of pressure filter to perform filtering process that removes metals, organics and etc. Each unit of pressure filters consists of 03 filter columns installed in series. Each filter column contains a specific material with different processing capability. The first column contains a sand MnO_2 filter which is capable of removing Mn and a part of Fe. The second filter column contains Zeolite Diatomit versatile filters ore, light density, and the main ingredient is SiO_2 with high adsorption properties which is capable of removing Fe, F, Cl, organic chemicals, mineral oil, Sulphate radicals and etc. The third filtration column contains activated carbon, which can adsorb colored particiles, deodorize and purify water. Pumps just create pressure in the first filter column and automatically push water to the next filter columns to carry out the filtering process. After going through the third filter, water is pushed back to tank 2.

Pumps continue sucking water from tank 2 and push into fiber filters. In these filters, there are filter cores with the diameter of 5 μm and the length of 40". These 5 μm filter cores will keep the water residue with the size larger than 5 μm on the surface of filter cores and clean water will pass through filtering fiber layer and then is collected and flows to tank 3. In tank 3, there is equipment which quantifies disinfection chemicals. When water flows out, it meets the standards of QCVN 01:2009/BYT in terms of physics, chemistry and microbiology indicators.

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