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Investigation of treatment process and treatment sufficiency of marble mine wastewater: a case study in Turkey

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Abstract

In this study, wastewater formed in marble mines operated as open mines with the aid of a cutting slope in the soil clarification tanks, which were made impermeable by using membranes and similar impermeable elements, was collected after the sedimentation process. The reusability of the water during the process was also investigated. In the marble mines where the study was carried out, an average of 25 m^3/day of water is used as the process water for cutting operations. It is thought that ~10 m^3/day of this water is evaporated or remains between the marble blocks. However, in the facility, 15 m^3/day of wastewater was collected in the clarification tank that was made impermeable with a plastic cover. The initial (I) and final (F) values for the suspended solid (SS), pH, colour (C), oil and grease (OG) and Cr^{6+} were determined as $SS_I = 106.5$ mg/l, $SS_F = 58.3$ mg/l, $pH_I = 8.06$, $pH_F = 7.93$, $C_I = 83.5$ (Pt–Co), $C_F = 47.5$ (Pt–Co), $(Cr^{6+})_I = < 0.05$ mg/l, $(Cr^{6+})_F = < 0.05$ mg/l, $OG_I = 8.7$ mg/l and $OG_F = 2.3$ mg/l. The fact that these values are below the required limits in the Water Pollution Control Regulation applied in Turkey indicates that the treatment is successful and that the clarification tank is working effectively. Therefore, this method can be used successfully in marble mines.

Keywords Wastewater treatment · Marble mine · Treatment sufficiency · Treatment process

1 Introduction

The rapid development in the construction sector has increased the production of natural stone and marble, one of the important inputs of the industry (Turgut and Algin 2007). This situation has increased the number of natural stone and marble plants that are generally operated as open mines and has made it possible to achieve a significant production volume (Turgut and Algin 2007). In marble mines, production is generally carried out by cutting with a diamond wire. In the method of cutting with a diamond wire, basically the

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horizontal and vertical holes connected to each other are drilled to the marble mass and the diamond wire is passed through these holes, with the marble mass remaining between the holes being cut. Water is used to prevent the heating of the special wires used during the cutting of the marble blocks (Barros et al. 2009). Water is supplied between the two marble blocks, and most of the used water is evaporated due to the heat of the cutting wire. Some of the used water is trapped between the marble blocks. The wastewater, remaining and originating from the process, is mixed with the marble dust and collected in the cutting area. If this wastewater is not properly treated, it can become an important source of pollutants for the natural environment, agricultural land and water resources (Collins 2001; Acosta et al. 2011; Kabas et al. 2012), particularly during rainy seasons. In the literature, it is reported in related studies that wastewater from marble cutting operations is transported great distances by mixing with surface water and underground water.

The collection of wastewater formed at marble mines and its treatment by transferring to a fixed reinforced concrete clarification tank are very difficult. The reason for this is that the depth and location of cuttings can change very quickly because of the constant change of the cutting area and characteristics and the location of removed stone. Therefore, the most practical and efficient method in practice is to collect the formed wastewater with the aid of the cutting slope in the impermeable stone area or clarification tanks made impermeable by using membranes, and after the sedimentation process, reuse the water after the process.

The aims of this study are to determine the sufficiency of clarification tanks used for the collection and treatment of wastewater from marble mines operated as open mines and to investigate the possibilities of reusing the treated water after the process.

2 Materials and method

In this study, the examined marble mines are located in Bilecik Province in the Marmara region of Turkey (Fig. 1a, b). This region has important potential for the production of natural stones and marble, and it has a large number of mines operated as open mines. The marble quality and the types of these mines in which block marble cutting is carried out are very diversified. Even the type and quality of the marbles found in different parts of

Fig. 1 **a**, **b** Open marble mine and cutting of marble blocks

the same mine can vary. This leads to a frequent change of the cutting site, and therefore, the transport of clarification tanks where wastewater formed from cutting is collected and treated.

The most practical solution in practice is the use of easy-to-install and transportable wastewater collection and clarification tanks. The location of these tanks is determined according to the wastewater flow direction determined by gravity. After the soil in the selected area is excavated according to the desired tank size, the soil is compressed and reduced after permeation. The tanks are made impermeable using a plastic cover or membrane (Fig. 2a, b).

In the marble mines where the study is carried out, an average of 25 m^3/day of water is used to prevent overheating of the wires during cutting. However, the amount of water used can vary depending on the size of the blocks to be cut and the cutting plan. Approximately 10 m^3/day of the used water evaporates due to the heat generated by the cutting process and remains between the marble blocks. The remaining 15 m^3/day of water mixes with the marble dusts and forms wastewater that reaches the clarification tank by the slope of the cutting area (Fig. 3).

In this study, samples were taken from the inlet and outlet of the clarification tank for the purpose of investigating the sufficiency of the clarification tank. In the samples, the desired parameters according to the Water Pollution Control Regulation (WPCR) applied in Turkey were investigated, including suspended solid (SS), pH, colour (C), oil and grease (OG) and Cr^{6+}. Standard methods were used in the analyses and are presented in Table 1. The heavy metal concentrations were determined by ICP-OES. Heavy metal measurements were made at pH values of the inlet (8.06) and outlet (7.93) water. All experiments in the study consisted of three replicates, and the averages are used.

3 Findings and discussion

Installing a drainage system consisting of ducts, pipes or gratings to collect the wastewater generated during the cutting of marble blocks in marble mines is very difficult. However, even if this system is installed, it will be blocked in a short time due to the high rate of

Fig. 2 **a**, **b** Construction and use of clarification tanks

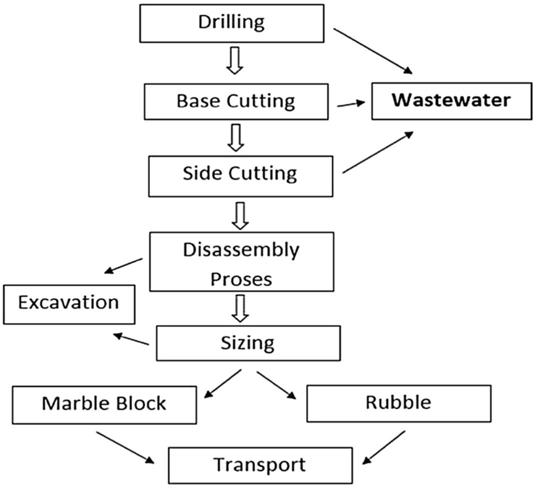

Fig. 3 Marble block production process and origin of wastewater

marble dust in the wastewater, and it will not be operated (Singh et al. 2009; Fernández-Caliani and Barba-Brioso 2010). In this study, the most important issue for the successful operation of the tested treatment system is the reaching of the wastewater to the clarification tank by the natural slope of the mine site. The location selection of the clarification tank and the topographic examination of the entire mine site were performed, and the slope characteristics of the site were determined. Using the determined slope characteristics, the paths followed by the wastewater to reach the lower elevations were determined. For this process, the coordinates and elevations of all topographic details in the mine area were determined by GPS.

These data were transferred to the computer program (NETCAD 7.6), and slope maps given in Fig. 4a, b are created. As seen in the slope maps in Fig. 4a, b, the most suitable intersection point of the paths that the water will follow depending on the slope in the mine site was chosen as the location for the clarification tank. In the area where the study was carried out, the wastewater reaches the clarification tanks from five different paths. The ground structure of these waterways occurring due to the slope is impermeable marble; therefore, most of the wastewater is deposited in the clarification tank by surface flow. However, the topographic characteristics of the mine site may change over time due to the performed cutting operations. In order to protect the waterways and to use the clarification tank functionally for a long time, it is important to protect these waterways at the cutting plans in the mine.

All of the wastewater in the examined marble mines is the result of mixing the water used as cooling water in the marble cutting process with the marble dust. Suspended solid values of marble mine wastewater are high. In some studies in the literature, it has been reported that the suspended solid values of natural stone and marble mine wastewater can be up to 2100 mg/l (Fahiminia et al. 2013).

However, this is also closely related to the character of the cut stone. Some natural stones cause high suspended solids in wastewater, since they produce more particles during the cutting process. The input suspended solid value of the analysed wastewater was determined as 106.5 mg/l (Table 2). This value is below the values given in the literature. The output suspended solid value was determined as 58.3 mg/l. In considering that one of the main functions of the clarification tank is to reduce the amount of suspended solids in

Table 1 Standard methods used in analyses (APHA 2017)

Analysis	Standard method number	Standard methods
Suspended solid	SM 2540 D	Standard method for the examination of water and wastewater. Total suspended solids dried 103–105 °C
pH	SM 4500 H^+ B	Standard method for the examination of water and wastewater. Electrometric method
Colour	SM 2120 C	Standard method for the examination of water and wastewater. Colour
Oil and grease	SM 5520 D	Standard method for the examination of water and wastewater. Oil and grease, Soxhlet extraction method
Cr^{+6}	SM 3500 Cr B	Standard method for the examination of water and wastewater. Hexavalent chromium, colorimetric methods

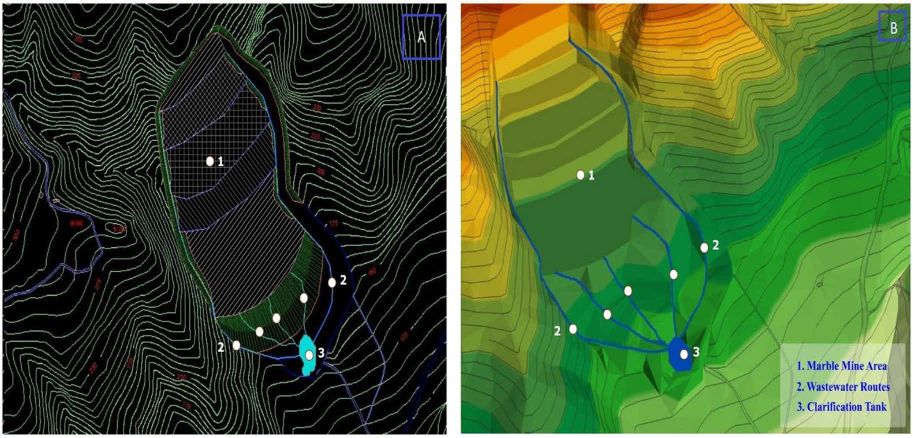

Fig. 4 **a**, **b** Topographic properties of marbel mine and clarification thank location

Table 2 Characterization of marble cutting wastewater and limit values of WPCR

Analysed parameters	Clarification tank input	Clarification tank output	WPCR limit values[a]
Suspended solid	106.5 (mg/l)	58.3 (mg/l)	100 (mg/l)
pH	8.06	7.93	6–9
Colour	83.5 (Pt–Co)	47.5 (Pt–Co)	280 (Pt–Co)
Oil and grease	8.7 (mg/l)	2.3 (mg/l)	10 (mg/l)
Cr^{+6}	< 0.05 (mg/l)	< 0.05 (mg/l)	0.3 (mg/l)

[a] Water Pollution Control Regulation applied in Turkey

the water, it appears that the clarification process reduced the suspended solids by half. It is known that various coagulants are used to treat marble mine wastewater with high suspended solid values (Arslan et al. 2005). However, the initial suspended solid value of the wastewater examined in this study is low and coagulant is not used in the clarification tank.

The decrease in the total suspended solid value also significantly affects the colour parameter. When the colour results in Table 2 are examined, it can be seen that the colour value of wastewater is 83.5 (Pt–Co) and it decreases after clarification to 47.5 (Pt–Co). The pH values of the wastewater samples taken from the clarification tank inlet and outlet were found to be 8.06 and 7.93, respectively. The oil and grease value in wastewater was 8.7 mg/l and 2.3 mg/l in effluent. The results of the Cr^{6+} analysis showed that the inlet and outlet water contained very low Cr^{6+} levels (< 0.05 mg/l).

The heavy metal contents of marble mine wastewater were investigated, and the results are presented in Table 3. The results show that the highest concentration of heavy metal was zinc in the marble mine wastewater (clarification tank input of 0.047 mg/l and output of 0.040 mg/l). The results of heavy metal analysis are consistent with similar studies in the literature. In the literature, it is stated that the main heavy metals in marble mine waters are zinc, cadmium and lead (Kabas et al. 2012). However, the heavy metal values in the input and output water were found to be very close to each other, indicating that the impact of the sedimentation pool on the heavy metal removal was limited.

Table 3 Concentrations of heavy metals in marble cutting wastewater

Heavy metals	Clarification tank input (mg/l)	Clarification tank output (mg/l)
Zinc	0.047	0.040
Copper	0.028	0.026
Nickel	0.025	0.025
Cadmium	< 0.004	< 0.004
Lead	0.025	0.025
Mercury	< 0.001	< 0.001
Molybdenum	< 0.05	< 0.05

This is an expected result, since it is known that the clearance removal efficiency of the clarification tanks is low even if a coagulant is used (Chang and Wang 2007). Therefore, if effective heavy metal removal is desired, techniques such as ion-exchange, adsorption and membrane filtration should be used. The clarification tank will provide suitable conditions for these methods (Plattes et al. 2007; Fu and Wang 2011).

It is noteworthy that water pollution control regulations in Turkey do not contain heavy metal limits for marble mine wastewaters. The purpose of the investigation of heavy metals is to determine the effect of the clarification tank used for the removal of heavy metals in wastewater. These data are also important in estimating the environmental impacts of overflows that may occur especially in periods of heavy rain.

When the results in Tables 2 and 3 are considered as a whole, it is seen that the results obtained from the water treated at the clarification tank is below the desired value of WPCR applied in Turkey. This shows that the clarification tank of the wastewater of the examined marble mine is effective and fulfils its function.

4 Results and recommendations

The wastewater of marble mines is an important source of pollution in terms of water resources and the natural environment if it is not treated and is discharged uncontrollably into receiving environment. However, since marble processing is a variable and complicated process, it is very difficult to collect wastewater and treat it in a fixed treatment plant. The best solution is to make easy-to-install and transportable clarification tanks. The results obtained in this study reveal that these clarification tanks can be used effectively in the treatment of marble mine wastewater. However, it is considered that it is important to design these clarification tanks taking into account extreme rainy weather conditions.

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