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Note from the field

Solar water pumping system for water mining environmental control in a slate mine of Spain

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ABSTRACT

The location of mining areas is subject to the availability of resources and the capability to extract them. As these areas are usually isolated or of difficult access they lack any means of electric infrastructure as its installation can be rather costly. Therefore the use of local energy resources, such as solar energy, becomes relevant for the mine energy supply. This study carries out a solar pumping project in a slate mine in Galicia (Spain) related to automatic control systems in surface water management affected by waste from the extractive activity and thus abiding with environmental legislation.

1. Introduction

The technological revolution process at the end of the twentieth century developed into the current slate industry in Spain. This mining activity left behind the traditional production processes due to the necessity to satisfy the growing demand for ornamental stone in the European market (Oleynik, 2005). This development led to the mechanization of the production works, with more demanding strict environmental control systems to abide by the European Union legislation increasing demand on environmental preservation (European Commission, 2011).

According to the mining environmental legislation, the evaluation studies on impact for open-pit mines must include a vigilance and environmental control program, aimed at verifying and analysing the proper execution of all the operations involved in the mining project (prospection, installation, mining and restoration) (Azapagic, 2004; Paredes-Sánchez et al., 2013).

The usual approach to extracting the ornamental rock, slate in this case, is to remove the minimal amount of overburden from the mine, thus allowing good working progress. However, this mining structure is conditioned by the abundant water resources existing both on the surface and underground, which must be subject to special protection (Hilson and Murck, 2000).

This paper studies the use of autonomous mechanisms for environmental control of surface water in open-pit mining through solar water pumping systems, in a quarry located in A Fonsagrada area, Galicia (Spain). The importance of solar energy as a resource to be applied in industrial activities, has already been expressed in the works of González-González et al. (2014), Solangi et al. (2011), Şen (2004) and Varella et al. (2009).

2. Materials and methods

One of the most important Spanish areas for slate mining is Galicia, particularly A Fonsagrada. A Fonsagrada is located on the Central-East limit of the province of Lugo, on a wide eroded platform with river valleys, between quartzite ridges in a very rugged relief.

The climate could be considered mountainous with heavy rain and occasional snowfall and very cold winters. Summers are mild and humid with frequent showers. A Fonsagrada and San Martín de Oscos weather stations record rainfall values between 1754 and 1485 mm (Elías and Ruiz, 1979).

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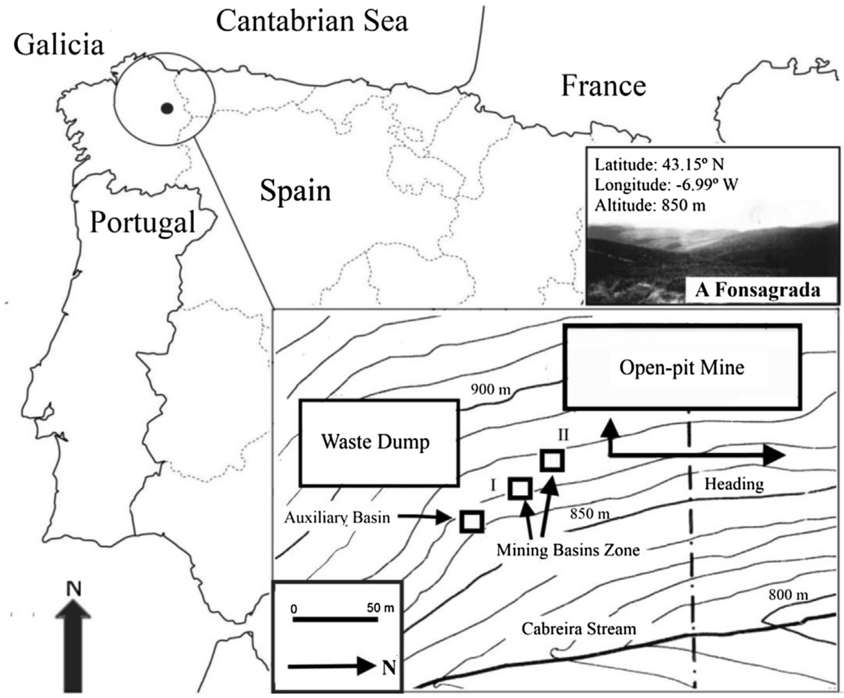

Fig. 1. Representation of the A Fonsagrada area, Galicia (Spain).

On average, most slate mines in this area are located over 700 m height on rough mountain slopes. The slate layers form an inwardly oriented cleavage known as "Pizarras de Luarca".

This study develops an automated solar water pumping system for hydrogeological environmental control in a slate quarry. Bouzidi (2011), Kaldellis et al. (2009), Jafar (2000) and Padmavathi and Daniel (2011) have also studied different examples of solar water pumping systems.

2.1. Hydrogeology

From a water flow and storage perspective, the underground hydrology in the region has a rift pattern, configured by its structural conditionings. The most deeply affected spots by tectonic factors, thrust faults, main faults, fold troughs, etc., could be suitable to serve as primary collectors, and eventually, subject to the topography and the variations in the piezometric levels, as water outlet lines to the exterior (Paredes-Sánchez and Martínez-Álvarez, 2004).

Rain water falls in the quarry dragging particles in suspension along its channelled course in trenches where small weirs are built to favour decantation. The mining process requires two mining basins with a surface of 18 m × 14 m and 1.5 m deep connected consecutively (I and II), where decantation of the solid particles takes place.

Rain water filtered in the waste dump is channelled and transferred into a settling basin called auxiliary basin, with a surface of 18 m × 14 m and 1.5 m deep, to cause the solid particles to decant.

Regarding the hydrology close to the quarry, the Cabreira Stream can be seen (Fig. 1).

To avoid possible flooding and to improve the decantation process due to space limitation, to the proximity to the stream and the gradient of the area, it is necessary to adopt specific environmental control measures, since the mentioned stream could act as a diffusion agent for liquid pollutants or for water derived from the mine into the hydrogeology of the area (Paredes-Sánchez et al., 2013).

Pumping is a complementary measure added to the traditional methods for calculating and designing settling basins for river water, aiming mainly to make the slate extraction works compatible with preserving the natural environment.

Thus, an automated solar water pumping system, fed by photovoltaic panels and batteries for electricity storage, is introduced. Therefore, in emergency situations caused by saturation of the water level in the auxiliary basin, the exceeding water runs into the exploitation basins to avoid overflowing in the waste dump in the pit of the quarry.

To ascertain the size of the solar water pumping system for that area, the PVsyst software has been used (PVsyst, 2004).

2.2. Methodology

To ensure an optimal design for the production and storage energy system, very precise information of the area is paramount. Geometrical, geographical and meteorological characteristics of the studied are required for a complete analysis of solar radiation. The integration of all those variables implies a complex process as expressed by Ertekin and Yaldiz (2000).

Table 1
Atmospheric data introduced in PVsyst.

Month	Horizontal global irradiation (MJ/m^2 day)	Temperature (°C)
January	5.43	5.8
February	7.94	6.9
March	10.87	8.4
April	12.12	9.6
May	14.63	12.3
June	15.88	15.2
July	16.72	17.7
August	17.56	18.0
September	13.37	16.1
October	10.45	12.4
November	6.68	8.8
December	5.02	6.9