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CASE STUDY

Mitigation of environmental impacts in ornamental rock and limestone aggregate quarries in arid and semi-arid areas

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ABSTRACT

BACKGROUND AND OBJECTIVES: Open-pit mining is an important activity to obtain mineral resources that supply society with raw materials to improve people's quality of life. However, this extractive activity causes negative environmental impacts and, it is therefore necessary to identify and evaluate these impacts in order to design preventive and control measures to reduce them and thus safeguard the environment and natural resources. In the Region of Murcia, in Spain, as well as other Mediterranean areas with similar climatic conditions, there is a great deal of mining activity linked to the building sector, in which mainly ornamental rock (marble and marble limestone) and limestone aggregates are used. All of this has given rise to numerous active and abandoned mines, where no restoration process has been carried out, generating strong impacts on the environment.
METHODS: In this study, 8 environmental impact assessments studies of ornamental rock and aggregate quarries in the Region of Murcia were analysed to identify the negative impacts on the abiotic and biotic environment, landscape, socio-economic and socio-cultural environment, and infrastructures and analysing preventive and control measures.
FINDINGS: According to the environmental impact assessment studies analysed, the importance of the most significant environmental impacts has been calculated, indicating whether the impacts are critical, severe, moderate or compatible, and based on it, preventive and corrective measures are proposed together in an impact mitigation management system based in flow charts that will serve to more easily apply and control these measures, in order to prevent them from causing significant or irreversible damage to the environment. Analysing these measures, it has been observed that 90% of the measures applied to control the different negative environmental factors in this type of quarry are the same.
CONCLUSION: Open-pit mining extraction systems have a series of similar characteristics that allow a systematic approach to be established when analysing the impacts. With the use of flowcharts, it becomes easier to apply measures to reduce environmental impacts and in addition, these diagrams, allow at the same time the easy incorporation of updates due to changing regulations.

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INTRODUCTION

Open-pit mining have been considered as an activity that represents a social and economic benefit for the regions and improve the quality of life of the inhabitants, thus constituting an important element for development. However, quarrying, like other mining-related works, causes negative impacts on the environment and strong ecological changes in the affected ecosystems (Sheoran *et al.,* 2010; Sort and Alcañiz, 1996). The level of destruction caused by open pit mining is ten times greater than that caused by other types of mining (Zhou *et al.,* 2018). It is important the identification and assessment these risk in order to design strategies that avoid, mitigate and compensate for these impacts (Luna, 2015). The increase in human capacity to transform the natural environment has led to an imbalance between the damage caused and the capacity of the environment to recover from it. It is clear that this type of exploitation cannot be dispensed with, as it supplies society with the raw materials necessary to improve its quality of life (Parrota and Knowles, 2001). The abandonment of open-pit quarries, without any kind of rehabilitation or recovery of their initial state, is the main source of impacts (Darwish *et al.*, 2010; Khabali and Kamal, 2013). Open-pit mining negatively affects the environment in a variety of ways, from exploration and blasting, transport and disposal of waste rocks (Lad and Samant, 2014). In addition, the exploitation of open-pit quarries causes other environmental impacts: affectation and disappearance of vegetation, fauna, soil and landscape degradation; disruption of animal habitats; changes in air quality, dust pollution; increase of particulate matter in the air; loss of water resources due to degradation of aquifers, diversion of underground streams, changes in the water table and water pollution; contamination of rivers; diversion and blockage of natural drainage systems; production of large volumes of highly polluting waste; noise and vibration; landscape alteration, visual pollution of waste dumps and degradation of large areas that take thousands of years to restore; land use conflict (Maponga and Munyanduri, 1998; Stehouwer *et al.,* 2006; Fierro, 2012; ; Karbassi and Heidari, 2015; Karbassi, and Pazoki, 2015). Moreover, it can also affect the health conditions of the surrounding population. Today, awareness of the limitation of natural resources, as well as that of the various elements which constitute ecosystems, makes it necessary to solve the problems for the demand of raw materials in accordance with the conservation of nature, in such a way as to safeguard the environment and natural resources in order to be able to pass them on to future generations (Montes de Oca and Ulloa, 2013). To achieve greener mining with fewer impacts, it is necessary to improve the pollution produced by activities in the air and water and those produced by noise, as well as the need to recover the land and its uses after the activities on the exploitations (Zhou *et al.,* 2020). For all these reasons, Spain created the Law 21, (2013), on environmental assessment, amended by Law 9, (2018), which states that an environmental impact assessment is essential for the protection of the environment. This is an adaptation of the national legislation to the existing legislation in the European Union. It facilitates the incorporation of sustainability criteria in strategic decision-making and guarantees adequate prevention of the specific environmental impacts that may be generated, while at the same time establishing effective mechanisms for correction or compensation of the damage. In Spain, the mining activity achieve account 3,280 million euros (M€) in 2017 (MET, 2018). In the Region of Murcia, the exploitation of geological resources has always been linked to the extraction of minerals and rocks. Specifically, it is represented by the extraction of marble, marble limestone and limestone aggregates, which are used by building companies in multiple applications, ranging from the production of concrete, mortar and asphalt agglomerates, to the construction of bases and sub-bases for roads, ballast and sub-ballast for railway tracks, or breakwaters for the defence and construction of ports. The consequence of obtaining them is linked to the damage caused to rural areas and the natural environment during the different phases of exploitation, concerning for the correct development, conservation of the environment and, obligations under legislation have evolved over the years (Casas, 2018). Quarries are found in all the territories of the Region of Murcia, but the Norwest area and the Mula basin stand out due to their great variety of ornamental rock, and the Fortuna-Abanilla area due to its large production of limestone aggregates. The aim of this study is to create an impact mitigation management system based in flow charts with corrective and preventive measures that can be easily applied in ornamental rock and aggregate quarries in arid and semi-arid areas. To this end, several environmental impact assessment (EIA) studies of quarries in the Region of Murcia have been analysed, the importance of the impacts they produce has been calculated and the measures used to mitigate these impacts have been taken into account. The conventional methods used to mitigate impacts are characterized by being a cumbersome, slow and expensive process. So, in this study, a decision support system is proposed that minimizes these problems. This study has been carried out in the Region of Murcia, Spain during 2020-2021.

European and national legal framework

The evolution of the regulations up to the current situation implies the need to study and define a systematic methodology for impact assessment and mitigation. The environmental assessment is a well-established instrument that accompanies mining development, ensuring that it is sustainable and inclusive. At the international level, environmental assessment regulation is under the Espoo Convention, (1991), and it's Protocol on Strategic Environmental Assessment, (UN, 2003). In the European Unión, it is regulated by Directive 42, (2001), by Directive 92, (2011), and by Directive 52, (2014). At the national level, in Spain, it is regulated by Law 21, (2013), on environmental assessment, modified by Law 9, (2018). This regulation includes the obligation to carry out an EIA of the projects. The EIA, aims to incorporate environmental aspects in decision making and seeks sustainable development and environmental protection (Enriquez-de-Salamanca, 2021). In addition, it is considered as an instrument to support decision making (Retief *et al.*, 2020). According to Pchalek (2019), the objective of the EIA is to point out suitable alternatives, minimizing and compensating impacts. According to Glasson and Therivel, (2019), the EIA is a process in which the possible environmental impacts of a project are evaluated in a phase prior to decision-making to promote healthy environmental management. Therefore, the minimization of environmental impacts is a standard procedure in mining operations (Falck, 2016). Environmental management is the key to sustainability in mining (Yildiz, 2020), it is necessary to carry out a sustainable management of natural resources to create the minimum negative results on the environment (Elvan, 2013). Mining has an important role in the sustainable development of natural resources, given by the important environmental and social impacts that it can generate (Ghorbani and Kuan, 2017). Directive 52, (2014). This indicates that EIA has to identify, describe and assess the significant effects of a project on the following factors: population and human health; biodiversity, paying particular attention to species and habitats protected under Council Directive, (1992) and Directive 147, (2009); land, soil, water, air and climate; material assets, cultural heritage and landscape; and the interaction between the factors referred previously. In addition, Law 9, (2018) makes compulsory to carry out an environmental impact study in the ordinary EIA. The EIA study is intended to prevent possible natural damage, establishing corrective measures and ensuring the possibility of compatibility of the extractive activity with the conservation of the environment and developing methods of recovery and monitoring of impacts on soil and water (Casas, 2018). The objective of EIA in mining is to identify, predict and prevent environmental alterations caused by extractive activities, from research and mining exploitation to the processing of the minerals to be processed (Astorga *et al.*, 2003). The main objective is to ensure that environmental considerations are explicitly expressed and included in the decision-making process and to anticipate and avoid, minimise and compensate for negative effects on the environment (Mora-Barrantes, 2016). Among the main objectives are: to ensure that environmental considerations are explicitly expressed and included in the decision-making process; to anticipate and avoid, minimise and compensate for significant negative biophysical, social and other relevant effects of the development proposal; to protect the productivity and capacity of natural systems and their ecological processes; to promote sustainable development by optimising the use of resources and management opportunities (Johnson and Bell, 1975). In addition to the EIA, a complementary environmental assessment must be carried out in accordance with the "Methodological Guide for Environmental Impact Assessment in Natura 2000 Network" (MET,2019), for Sites of Community Interest (SCI) and Special Areas of Conservation (SAC), which are protected areas integrated in the Natura 2000 Network (RN2000) designated for hosting an area of one or more types of natural Habitats of Community Interest (HIC) and/or habitats of the species listed in Law 42, (2007), modified by Law 33, (2015), which transposes the Habitat Directive of the European union.

MATERIALS AND METHODS

In order to know the environmental impacts and the measures to mitigate them, a methodological procedure is used to identify mining actions, such as environmental impacting components and environmental factors susceptible to receive impacts. The environmental impacts were identified, characterised, assessed and evaluated. In this way, premises are established to ensure that quarries carry out environmentally friendly mining operations. In order to identify impacts, it is necessary to analyse the different environmental factors that undergo variations. In most studies for the identification and assessment of impacts, the impact assessment method of Conesa *et al.* (2010) is used, this is an *ad hoc* method described in their book "Methodological guide for environmental impact assessment". However, this methodology predates the latest legislative amendments. Nevertheless, it provides a solid basis on which to develop EIA studies. Castelo *et al.* (2019), after having analysed various methodologies to assess risks in open pit mining, has verified that evaluating these risks depends on a number of data that are difficult to obtain or on general quantitative methods or the data are of uncertain reproducibility, in addition, they depend on multiple occasions of the evaluator and their experience and if more reliability is required, experienced teams or expensive processes are needed, so there is no method to respond quickly and that is reproducible and reliable to date. So, following the method described above, the project actions that may cause impacts are identified, and then the impacts are assessed in a qualitative manner, characterised by a series of attributes such as synergy, effect, accumulation, periodicity and recoverability. This technique is based on the cause-effect matrix method, which according to Garmendia *et al.* (2005) is the most widely used tool for determining impacts, derived from the Leopold matrix (Leopold, 1971) with qualitative results. This matrix is based on relating project actions with the environmental factors of the project, identifying the magnitude and importance of the potential effects on a certain environmental factor and the one generated for a certain project action. Once the impacts have been identified in the impact identification matrix and their causes, each of the impacts identified are evaluated according to a series of parameters to determine their importance in an impact assessment matrix. The importance will take values between 13 and 100 depending on the scores given to each parameter. The definition of these impacts together with their importance is shown in Table 1 and it will be concluded in the EIA study whether the development of the project is acceptable or not.

The methodology followed in this article is based on the analysis of EIA studies by several authors (Handjaba, 2012; Khabali and Kamal, 2013; Luna, 2015; Gómez, 2016; Villalba, 2017; Miñarro, 2018; Casas, 2018; Moreno, 2021), in order to apply techniques to mitigate and reduce the negative effects caused by the extraction of ornamental rock (marble and marble limestone) and limestone aggregates in open-pit quarries and their abandonment without any type of restoration. In this study the EIA studies of 8 quarries found in the Region of Murcia, which is an arid and semi-arid region, have been analysed. To identify

Table 1: Classification of impacts and its importance

Classification of impacts		Importance
Compatible	It is the one whose recovery is immediate after the cessation of the activity and does not require preventive or corrective measures.	13-25
Moderate	It is one whose recovery does not require intensive preventive or corrective measures and in which the achievement of the initial environmental conditions requires a certain amount of time.	25-50
Severe	It is one in which the recovery of the environmental conditions requires the adoption of preventive or corrective measures, and in which, even with these measures, recovery requires a long period of time.	50-75
Critic	It is one whose magnitude is higher than the acceptable threshold. It results in a permanent loss of the quality of environmental conditions, with no possibility of recovery, even with the adoption of preventive and corrective measures.	75-100

the most significant impacts on these quarries, the importance of each activity in the different phases of a quarry with respect to the different environmental factors has been calculated. For this, the lowest and highest data have been collected on the importance that each mining activity can take in each of the different phases of exploitation in relation to each environmental factor in each of the 8 analysed quarries. The components usually considered in this inventory are the abiotic and biotic environment, the perceptual environment, the socio-economic environment and the socio-cultural environment and infrastructures. The different phases in a quarry are: phase I, of preparation, in which the roads and accesses are adapted and the clearing of the vegetation and the drainage and sewers are carried out; phase II, of operation, in which the start-up is carried out by loading and blasting, the transport of materials, the creation of fissures, the auxiliary and processing operations and the maintenance of machines, an occupation and change of use is carried out of the land, the fencing and enclosure of the quarry and spills and dumps are generated; and phase III, of restoration, in which in which remodelling and revealing is carried out and there is vehicle traffic. Once the most important impacts that occur in quarry operations have been obtained, preventive and control measures are proposed to reduce or eliminate these impacts based on the different components of the environment (these measures have also been obtained from impact studies analysed) and flow diagrams are created to facilitate the application of corrective and preventive measures with respect to the pollutants existing in the quarries (dust, noise, oils and lubricants, reject materials and other quarry waste). In addition, a diagram will be created to control the topsoil, another to improve the environment and human health and one to improve the health and safety of workers and another to improve the surfaces altered by the quarrying activity and reduce the impact on the landscape, fauna and flora. This detailed study establishes a methodology that can be applied generally in other regions and open-pit mining operations, facilitating systematic monitoring and the proposal of impact mitigation measures.

Study area

The Region of Murcia is located in the Southeast of the Iberian Peninsula, and forms part of the eastern part of the Betic Mountain Range. The area, according to the National Geographic Institute (IGN, 2020), is structurally divided into two zones: External Zones, subdivided into the Prebetic and Subbetic domains, and the Internal Zone, which is divided into three domains that rode on top of each other but were later transformed into extensional detachment faults. These domains are, from bottom to top, Nevado, Filábride, Alpujárride and Maláguide. All these domains are represented in the Region of Murcia. In addition to the materials of the Betic Mountain Range linked to the main tectonics, there are other post-orogenic materials that are well developed in the inner depressions and alluvial valleys: the tertiary basins of Campo de Cartagena, Mula, Fortuna, Calasparra syncline, Moratalla, Lorca and Rambla de Tarragoya stand out, and among the latter, the Plio-Quaternary valley of the Guadalentín-Segura. Mining in Murcia is mainly represented by the ornamental rock and aggregate sector. According to the Mining Service of the Autonomous Community of the Region of Murcia (CREM, 2019), the number of existing mines in the Region of Murcia is 227, all of them carried out by open-pit mining methods. Of these, 98 are still active. Fig. 1 shows the municipalities in which there are ornamental rock quarries and the most representative ones in which there are aggregate quarries.

There were 122 ornamental rock quarries in the Region, of which 42 are active (CREM, 2019). Specifically, these ornamental rocks are different varieties of marble and marble limestones. Their location is shown in Table 2, which shows the type of ornamental rock that exists in each municipality. The ornamental rock, in the Northeast and the Altiplano, is associated with the Jurassic layers of the Subbetic and Prebetic Eocene, large thicknesses of limestones and dolomites, with a wide variety of colours: creams, browns and reds. Marbles, strictly speaking, appear in the Betic alignments of the Alpujarride of the Cabezo Gordo in Torre Pacheco. Aggregate quarries are distributed throughout all the districts of the Region, there are 74 quarries and 32 of them are active. The most representative limestone aggregate quarries are located in the Fortuna-Abanilla district and in the district of the metropolitan area of Murcia, in Santomera, with 44 percent (%) of production, and in the district of Campo de Cartagena, in Fuente Álamo,

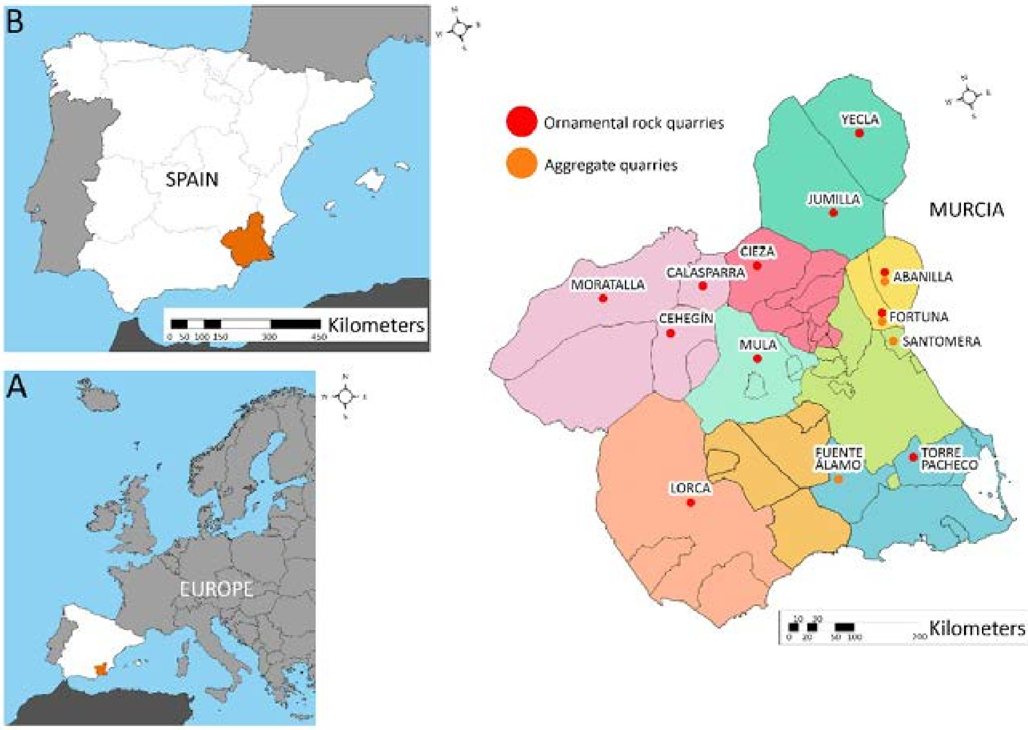

Fig. 1: Geographic location of the study area in the most representative municipalities in the Murcia region of Spain with ornamental rock and aggregate quarries

with 14% of production. Of the total production in quarries in the Region, approximately 74.8% corresponds to the aggregate extraction subsector.

The Region of Murcia has a Mediterranean climate with arid features: hot, dry summers, mild winters, although with frequent frosts in the interior, and rainfall in spring and autumn. The general characteristic of this climate is its scarcity of rainfall, concentrated in a few days of the year, with maximum rainfall in autumn. These rains, usually torrential, are produced when a mass of warm, humid air from the Mediterranean Sea enters the area and, on colliding with the coastal mountain ranges and rising, comes into contact with another mass of cold air and precipitates. These rains must be considered precisely because of the high erosive power they can unleash when it comes to recovering mining areas. According to Köppen's climate classification, (Köppen, 1936), the following climate types can be distinguished in the region: warm semi-arid (BSh), cold semi-arid (BSk) and Mediterranean (Csa). In the BSh climate, the mean annual temperature is above 18 degrees Celsius (°C) and precipitation is low, solar evaporation exceeds precipitation, it is a hot and dry climate; in the BSk climate, the mean annual temperature is below 18°C, precipitation is also low and evaporation, like BSh, also exceeds precipitation, this climate is cold and dry; in CSa, the average temperature of the coldest month is below 18°C and above -3°C and that of the warmest month is above 10°C, the temperature of the warmest month is above 22°C and average temperatures above 10°C occur in less than four months of the year. Precipitation exceeds evaporation and there is seasonal rainfall. The summer is dry, so the minimum rainfall is quite marked and coincides with the period of highest temperatures. The rainiest season is not necessarily winter. Table 3 shows the average annual temperatures, in ºC, and rainfall, in litres per square meter (l/m²), for 2019 in the study sites, the table is based on data obtained from the Murcia regional statistics portal (CREM, 2020). With regard to the winds, the west/northwest-south/east orientation (WNW-SE) of the great Betic relief lines channels the winds from the Atlantic, while the winds

Table 2: Types of ornamental rock currently exploited in the Region of Murcia and their geographical distribution. Source: own elaboration according to data obtained from the Ministry of Business, Industry and Spokesperson of the Region of Murcia

District	Municipality	Ornamental rock
Region of Lorca	Lorca	Oolitic limestones Crinoid limestones
Campo de Cartagena-Mar Menor	Torre Pacheco	Greyish-white or greyish-white limestones, with white and ochre veining
Mula basin	Mula	Light and grey massive dolomites White to pinkish coloured limestones Reddish nodular limestones Limestones with Nummulites Limestone with algae Limestones with large Nummulites
Northwest	Calasparra	Dark brown dolomites Greyish and brown dolomites
	Caravaca and Moratalla	Greyish limestones White and cream massive limestones Massive sandy limestones Calcarenites Cream-coloured massive limestone
	Cehegín	Brecciated and massive limestones varying from red to dark grey
Vega del Segura	Cieza	Brown dolomites White limestone
Abanilla-Fortuna basin	Fortuna and Abanilla	Reddish massive limestone Tertiary limestone
Altiplano	Jumilla and Yecla	Dark-coloured massive dolomite Honey-coloured dolomite White limestone

from the north/northwest orientation (N-NW), which predominate during the winter, are dry and cold due to their long route. The Mediterranean squalls associated with convection phenomena give rise to a regime of easterly winds, with humid characteristics on the eastern flank of the region, which gradually dry out towards the interior. This situation predominates in spring and summer, extending into autumn. Wind speed is generally moderate, except on the coast, where it is higher due to its exposure to easterly winds. Relative humidity varies according to proximity to the sea. Inland it varies between 52 and 63% and on the coast between 71 and 76%. These climatic characteristics create a high rate of evapotranspiration which results in a permanent water deficit. This situation is generalised throughout the Region of Murcia.

The Region of Murcia is the most arid area of the Iberian Peninsula and is part of the Segura Hydrographic Basin. The drainage network of the Region is structured around the Segura river and its tributaries, the Guadalentín, the Argos and the Quipar. Groundwater comes from the fraction of precipitation that infiltrates due to the action of gravity. The Segura basin has been one of the first in the exploitation of groundwater, which has allowed unirrigated areas to be transformed into irrigated areas. There are currently ten different aquifer systems in the Region: Jumilla-Yecla, Calasparra, Cieza-Abanilla, Mula-Aledo, Caravaca-Moratalla, Bullas-Coy, Puentes-Valdeinfierno, Segura-Guadalentín, Cartagena and Mazarrón-Águilas (SITMURCIA, 2019). In general terms, in the Region of Murcia, there are more than two thousand plant species, which represents approximately 33% of the total number of species on the Iberian Peninsula, giving rise to a wide regional spectrum and making it one of the richest in Spain. The area occupied by crops exceeds 50% of the total and the rest is dominated by scrubland and tree species. With regard to scrubland, there is noble scrubland, with species such as Pistacia, Quercus, Rhamnus, Chamaerops, Arbutus, etc., and the characteristic scrubland of regressive stages such as rosemary (*Salvia imantopus*), esparto grassland

Table 3: Average annual temperature and annual rainfall by region with quarries

District	Municipality	Approximate annual average temperature 2019 (ºC)	Approximate annual rainfall in 2019 (l/m²)
Region of Lorca	Lorca	17,5	318
Campo de Cartagena-Mar Menor	Torre Pacheco and Fuente Álamo	18,6	419,5
Metropolitan area of Murcia	Santomera	18,5	523,9
Mula basin	Mula	18	455
Northwest	Calasparra, Caravaca, Moratalla, Cehegín	15,4	493,2
Vega del Segura	Cieza	17,3	475
Fortuna-Abanilla	Fortuna and Abanilla	18,8	575
Altiplano	Jumilla and Yecla	16	430

(*Stipa tenacissima*), thyme (*Thymus*), etc. From the coast to the inland mountain ranges, in a south-east-north-west direction, the wooded area increases and, therefore, the diversity of forest systems. The tree formations consist of frugal species, such as pines, junipers and xerophytic oaks. The wooded hills are made up of conifers and the broadleaved forests are mainly composed of kermes oaks, although they also appear in mixtures with other broadleaved and resinous species. The mid-mountain and foothill areas in the centre, north-west and north-east of the Region, include quercines (*quercus*), although these areas are highly altered. The intensive use of vegetation cover has led to significant deforestation, accentuated by climatic conditions. The fauna presents a very heterogeneous territory with a great variety of habitats, which contributes to maintaining a significant biodiversity of species such as Phartet (*Aphanius iberus*), Great Bustards (*Otis tarda*), Otters (*Lutrinae*), Shelducks (*Tadorna*), Vultures, Birds of Prey, Salamanders (*Caudata*), etc. Linked to the forest ecosystems, there are unique species such as the mountain goat (*Capra pyrenaica*), the Trompet Bullfinch (*Bucanetes githagineus*) and Dupont's Lark (*Chersophilus duponti*), as well as other species included in the annexes of the Habitats Directive and the Birds Directive, especially bats. There are also 51 species of mammals, both terrestrial and marine, many of them threatened or under some kind of conservation status. On the other hand, there are not many reptile and amphibian species, there are only 20 reptile species and 11 amphibian species and they are decreasing due to several negative factors that are influencing the region such as the aridity of the area, the use of water resources, the intensive agriculture, the introduction of invasive species, etc. Regarding to birdlife, there are almost 300 species, only one third of which are sedentary. According to the Council Directive, (1992), 42% of the regional area is classified as HIC (SITMURCIA, 2019).

RESULTS AND DISCUSSION

Main impacts from ornamental rock and limestone aggregate quarries in the Region of Murcia

In EIA studies, the description of the Environmental Inventory must take into consideration the components of the environment that intervene or may potentially be affected by the activities of the project to be environmentally assessed (Garmendia, 2005). The following tables show the most significant impacts that are usually produced by ornamental rock and limestone aggregate quarries in the Region of Murcia, in arid and semi-arid areas, according to the EIA studies analysed (Table 4, 5 and 6). These tables indicate the values that the impacts usually take, these values are previously defined in table 2 according to the classification of the impact. The impacts represented in Tables 4, 5 and 6 are those that generate a negative impact.

Analysing this phase, it is obtained that the environmental factors that can cause a severe impact on quarries in arid and semi-arid areas are noise and vibrations in the phase of adaptation of roads and accesses, the loss of soil quality in the clearing of the land, the loss of water quality when creating drains and aquifers, the alteration of flora and vegetation in the adaptation of roads and accesses and the clearing of vegetation and a visual impact on the creation of roads and accesses. In the elimination of the existing vegetation to carry out work in the

Table 4: Importance of the most significant environmental impacts in ornamental rock and aggregate quarries in the Region of Murcia in Phase I of preparation

Environmental factors			Phase I preparation		
			Adequacy of roads and accesses	Drains and sewers	Vegetation clearing
Physical environment	Atmosphere	Noise and vibration	35-55		
		Air quality	35-40		15-30
	Terrestrial environment	Soil quality	25-30	25-40	35-55
		Geomorphology	20-35		
	Water	Water quality		45-60	30-40
		Hydrogeology		35-45	
Biotic environment	Flora and vegetation		45-60		25-60
	Fauna	Biotypes	25-50		
		Species of interest	25-50		25-30
Perceptual environment	Landscape	Intrinsic quality	40-50		25-40
		Visual impact	45-60		25-40
Socio-economic and socio-cultural environment	Productive use	Agricultural forestry and livestock	40-45		

quarry; the surrounding vegetation is affected by the dust particles generated on the exploitation, these particles are deposited on the stomata, interfering with the chlorophyll function and intervening in growth. High concentrations or long exposures of nitrogen oxides (NOx) from vehicles and machinery cause leaf pigmentation, necrosis and reduced growth. The high concentration of sulfur dioxide (SO_2), released from the fuels used, prevents an assimilable transformation for the metabolism of the vegetation and initiates a cellular rupture (Villalba, 2017). With the elimination of the vegetation the habitat of some species is destroyed, which leads to the emigration of the fauna, and the edaphic fauna is also eliminated. The rest of the impacts are moderate (with values of the importance between 25 and 50) or compatible (with the importance between 13 and 25) and in the gaps in which there is no importance it is because they are insignificant.

In this phase, there may be a critical impact on the activity of occupation and change of land use, since it creates a modification of the landscape and a qualitative visual impact. There may also be severe impacts (with values of importance between 50 and 75) such as noise and vibrations to the atmosphere produced by the use of heavy machinery and in drilling, blasting and mechanical preparation of the raw material. Loss of air quality caused by emissions of polluting substances due to the use of heavy machinery, the use of explosive substances for blasting, and the use of fuels and lubricants for machinery. Among the polluting substances that are released are nitrogen oxides (NOx), which contribute to the generation of photochemical smog and acid rain and, in addition, in areas where there is surface water, can cause eutrophication. Another polluting substance is carbon dioxide (CO_2), which increases the greenhouse effect, in addition, it also contributes to the loss of air quality, the generation of dust in extraction operations, drilling, blasting, accumulation, charging, transport, crushing and classification of the resource and that produced in the creation of accesses to the quarry (Villalba, 2017; Jiskani, 2021). Another severe impact would be the alteration of the geology and the loss of the quality of the soil when carrying out the work in the quarry. There is also the risk of groundwater contamination due to accidental discharge of polluting substances such as oils or other substances from vehicles and machinery used. The voids generated in the quarries, in addition, can create irreversible contamination in the water table due to the creation of tailings, especially if these voids occur in karst areas with a high degree of cracking and in which the waters flow rapidly, without being by filtration processes, reaching more or less deep aquifers (depending on the topography) with their respective discharge and catchment areas (Khabali and Kamal, 2013). With regard to surface waters, there may be contamination of rivers due to erosion by rainwater currents and

Table 5: Importance of the most significant environmental impacts in ornamental rock and aggregate quarries in the Region of Murcia in Phase II of exploitation

Environmental factors			Phase II of operation						
			Blast start and charge	Transport of materials	Auxiliary and processing operations	Creation of fissures	Occupation and change of land use	Landfill of tailings, waste rock dumps	Fencing and enclosures
Medium physical	Atmosphere	Noise and vibration	35-65	40-55	45-60			45-50	
		Air quality	20-25	50-55	40-50	40-45		40-50	
	Terrestrial environment	Soil quality		25-30		40-60	40-45		
		Geology	25-35			25-60			
		Soil science	25-35			25-30	25-30		
		Geomorphology	30-35			30-40			
	Water	Water quality	30-35	30-40		35-45		30-55	
Biotic environment	Flora	Plant formations		40-50			25-30		
		Species of interest					25-35		
	Fauna	Biotypes		35-40			25-30		40-45
		Species of interest	25-35	30-40	30-35		45-50		35-45
Medium perceptual	Landscape Visual impact		50-55				55-90		40-45
Socio-economic and socio-cultural environment	Recreational use: Tourism, hunting and sporting activities						35-50		25-30
	Productive use: Forestry, agriculture and livestock						40-50		
	Human health and safety			50-65					
	Communication routes: mobility			40-50					
	Land use					40-45	45-50		

Table 6: Importance of the most significant environmental impacts in ornamental rock and aggregate quarries in the Region of Murcia in Phase III of restoration

Environmental factors			Phase III restoration		
			Vehicle traffic	Remodelling	Revegetation
Medium physical	Atmosphere	Noise and vibration	45-55	25-30	
		Air quality	35-45	25-35	
	Terrestrial environment	Soil quality	45-50	40-50	40-45
		Geomorphology		30-35	
	Water	Water quality	45-50		
Medium biotic	Flora	Plant formations	30-40	25-35	25-30
		Species of interest	45-50	30-40	25-35
	Fauna	Biotypes		30-35	40-45
		Species of interest	45-50	30-35	30-40
Medium perceptual	Landscape	Intrinsic quality	45-50		25-30
		Visual impact	35-45	30-40	30-35
Socio-economic and socio-cultural environment	Productive use: Forestry, agriculture and livestock				25-30
	Human health and safety		40-50	30-40	
	Communication routes: mobility		45-50		
	Land use		40-45		

the wind, since they can carry substances from the vehicles and machinery used and can lead to the loss of ecosystems. Due to the noise, vibrations and dust produced in the quarries, fauna is displaced and redistributed and habitats can be altered due to the possible contamination of groundwater and rivers. In the generation of holes and slag heaps, the visual quality of the landscape is lost and, in addition, visual intrusion occurs due to the use of machinery. The emission of noise, vibration, dust and water pollution can cause harmful effects on workers, those generated cause eye irritation, congestion and lung diseases and SO_2 and dust particles in suspension, produce allergies and infections in the respiratory system. The rest of the impacts are moderate (with values of the importance between 25 and 50) or compatible (with the importance between 13 and 25) and in the gaps in which there is no importance it is because they are insignificant.

In this phase, all the impacts obtained would be moderate, except for the noise and vibrations produced by vehicle traffic, which could become severe. The rest of the impacts not indicated would be compatible or insignificant. In this phase, the contribution of land is of interest, which can generate occasional air pollution due to suspended particles generated by the unloading of trucks. Dust has a negative impact on air pollution in the atmosphere, but also on water and land resources, as it interrupts the natural processes of flora and fauna and causes irreversible effects on human health (Timofeeva and Murzin, 2020). Reducing the noise and vibrations produced in many operations such as removal of the surface soil, drilling, blasting, excavation, crushing, handling and transport and other operations with machinery is important to the health of people and their well-being and that of the ecosystem, as high levels negatively influence species by increasing stress levels, modifying their habitat and masking other sounds they need for their survival (Jain *et al.,* 2016). Another factor that negatively influences the environment is mining waste, because if they are not treated properly they contaminate the water, the atmosphere, the soil and the occupied land. (Chen *et al.,* 2020).

Preventive measures to control and mitigate environmental impacts

Once the impacts that usually occur in ornamental rock and aggregate quarries in the region of Murcia have been obtained and analysed, the measures that are usually applied to control and reduce these impacts have been analysed on the basis of the environmental impact studies studied and it has been found that 90% of the measures that are applied to control the different negative environmental factors are always the same. These measures are described below, and in relation to them, flow diagrams will be proposed to simplify their control and application in the quarries. In order to control the visual impact

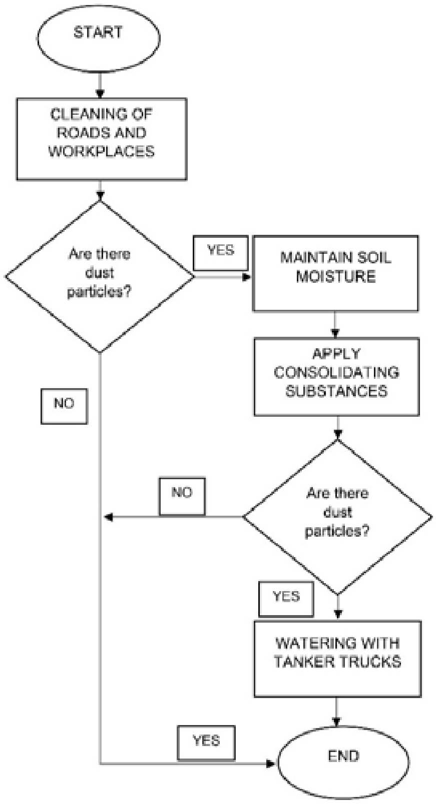

Fig. 2: Flowchart to reduce dust on roads and workplaces

and the modification of the landscape, the original forms of the accesses that are not essential for access to the restoration of the land must be restored by means of disabling and environmental recovery. In addition, as work on the slopes is completed, a slope ageing product should be applied that simulates the chromatic characteristics of the environment. Efforts should also be made to work in areas of low visibility from main roads and urban centres. The measures that are usually applied to reduce dust are: clearing land and opening roads, as far as possible, on days when the force of the wind does not imply a high risk of suspension of materials; carrying out effective maintenance of access roads to avoid the formation of dust and the accumulation of mud on the roads due to the transit of lorries; maintaining tracks and squares with a sufficient degree of humidity to avoid the dust deposited on them becoming suspended, using, if necessary, substances that consolidate and maintain the humidity of the soil. Another option is to irrigate with water tankers, as water is not normally available in mining areas and rainfall in the Region of Murcia is scarce; workplaces should be kept clean to prevent the accumulation of dust that can later be put into suspension. When there are accumulations of dust in different parts of the quarry, these shall be removed as soon as possible; in addition, the provisions of Order ITC 2585, (2007) on protection of workers against dust, in relation to silicosis, in the extractive industries. The suspension of dust in vehicle and machinery transit operations must also be controlled by irrigation, paying special attention to the quarry site, access tracks and unpaved areas, in order to affect human beings and the surrounding flora and fauna as little as possible. In order to make it easier to control dust, a flow chart has been drawn up with some proposed measures (Fig. 2).

To control noise and vibrations in quarries, the engines of machines that are going to be on standby for long periods of time should be switched off, the noisiest operations should be planned so that they do not coincide in time to avoid a large amount of noise and vibrations, and noise should be made on working days and intermittently. Except in emergency situations, work should not be carried out at night. The machinery used must comply with the permitted noise emissions, in this case regulated by Royal Decree 212, (2002). Blasting must be carried out in the middle of the day. In addition, to reduce the effect of air waves and vibrations from blasting, bottom-loading cartridges should be primed with non-electric detonators, detonating cord should not be used in the open air and the connection and sequencing between blast holes on the surface should be done with non-electric connectors so that the sequencing time is different from one another. In addition, if mechanical preparation plants are present, noise protection screens should be provided. The correct operation and commissioning of the vehicles on the operation must be checked, carrying out the corresponding gas emission controls and equipment checks established by the manufacturers. This will reduce noise and the emission of polluting gases, as well as reducing the risk of breakdowns and potential accidental spillage of polluting liquids. Periodic inspections of machinery must comply with Law 34, (2007), with respect to air quality and protection of the atmosphere and with Decree 1439, (1972) with respect to noise. In order to control oil and lubricant spills, the use of vehicles should be optimised to allow for the maximum

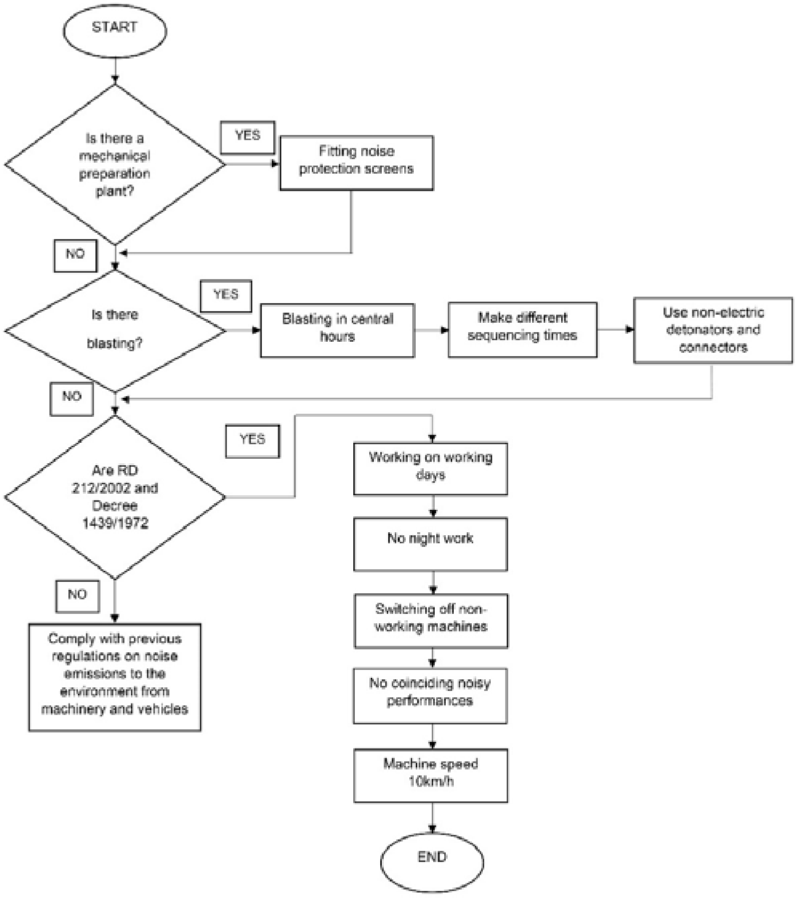

Fig. 3: Flow chart to reduce noise and vibrations in mining

operationally possible fuel savings. Equipment and vehicles must be more efficient and less polluting, more efficient vehicles and heavy equipment produce less pollution and reduce greenhouse gas emissions since their engines are cleaner, so older equipment must be replaced (Jiskani *el al.,* 2021). Repairs or oil changes of machines should be carried out in specialised workshops. In the event of accidental spillage of these materials, they must be cleaned and collected, deposited in containers for subsequent removal by an authorised waste manager, so that they do not affect runoff water or water that may infiltrate. Used oils and any other waste qualified as such from the exploitation must be compulsorily removed by an authorised hazardous waste manager. To reduce SO_2, CO_2 and NOx emissions as far as possible, the speed of machinery will be reduced to 10km/h in the area, in addition to choosing machinery that is equipped with catalytic converters that reduce emissions as much as possible, and the days on which the atmospheric phenomenon of thermal inversion occurs will also be taken into account so that accumulations of emissions do not form in the area due to a lack of ventilation (Villalba, 2017). To make it easy to implement these measures, a flow chart for noise and vibration reduction (Fig. 3) and a flow chart for fuels and lubricants (Fig. 4) have been developed.

A simple flow chart (Fig. 5) is proposed to control topsoil. The measures to be applied for this would be as follows: the topsoil should be removed, stockpiled and adequately maintained for later use in restoration. This removal must be carried out with care to avoid its deterioration by compaction and thus to preserve the soil structure, the existence of microorganisms, etc. For this reason, the passage of machinery over this soil should be avoided. During storage, it must

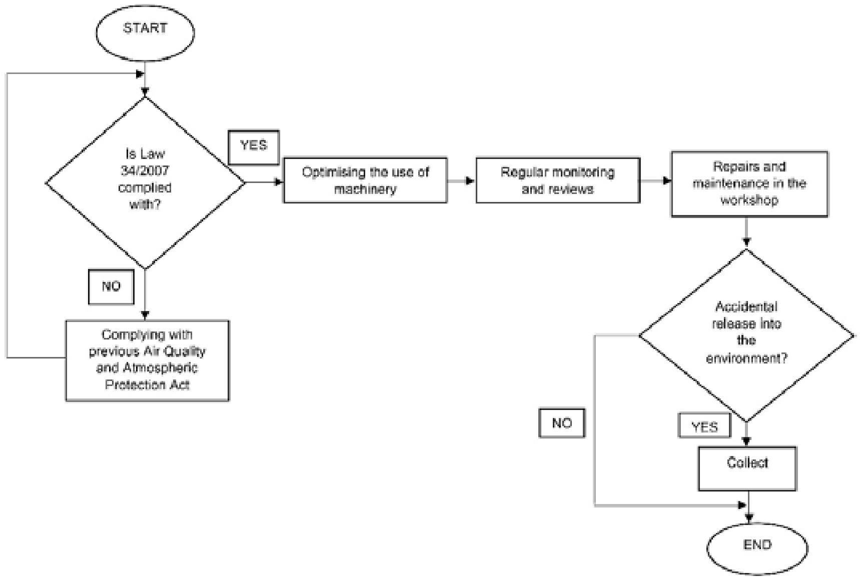

Fig. 4: Flow chart for reducing fuels and lubricants in mining

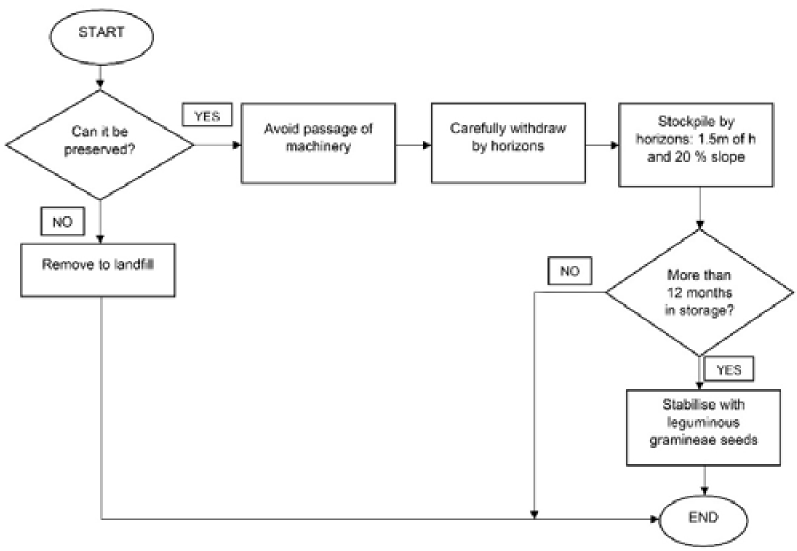

Fig. 5: Flow chart to control topsoil in mining

be protected from wind, water erosion and pollutants that alter the vegetative capacity. Stockpiles should not exceed 1.5m in height and slope gradients should not exceed 20º to avoid erosion (Casas, 2018; Moreno, 2020). The removal and stockpiling should be done differentiating the different soil horizons in order to be able to restore them in the restoration with the same original arrangement. Where feasible, the original soil flora will be preserved, in order to try to maintain a fertile layer on the surface to facilitate vegetation growth and control runoff erosion in the short term in sloping areas. If topsoil is to be stockpiled for more than 12 months, it should be stabilised with a mixture of leguminous and grass seeds to protect it from erosion and preserve its soil characteristics.

In order to control waste material in quarries, an inner spoil heap must be created to deposit the tailings generated in the exploitation, which will progress as the exploitation pit progresses. The pit must be filled to the level of the surrounding ground surface with the tailings from the limestone rejects. The topsoil, previously removed and reserved, shall be spread over the tailings from the rejects located inside the shaft, in order to subsequently proceed with the revegetation of the land. If there is no topsoil from the mining activity, a topsoil with similar characteristics to the existing one must be placed. When work is finished in the mining areas or work is stopped for more than one year, all types of material, machinery, waste and remains that may be left in the area must be collected and taken to a landfill site, leaving the area in a perfectly clean condition. Revegetation should be attempted with native and fast-growing species. Exotic species should be avoided, as they are susceptible to becoming invasive. Planting will include, when the soils require it due to insufficient stockpiles or inadequate quality, topsoil, fertilisers and amendments, and of course, the necessary tillage. When the revegetation work is completed, care of the topsoil has to be carried out, including replacing dead plants during the following years, installing protective structures to prevent trampling and additional foot watering. A simple flow chart has been proposed to control the reject material (Fig. 6).

In quarries there are reject materials that must be removed from the work areas so that they do not contaminate the environment; these can produce, among other things, water, soil and atmospheric pollution. For this purpose, the most common measures that are usually applied are shown together with a flow chart (Fig. 7) to make it easier to control them. Solid waste should be disposed of in controlled landfills. Leftover materials and non-hazardous waste should be deposited in authorised landfills. If there is a layer of debris prior to the removal of usable soil, this should also be taken to authorised landfill sites or put to an appropriate use. Perimeter channels can be planned to prevent water from the outside from entering exploitation. Small mammals and other vertebrates that may fall into ditches or holes created

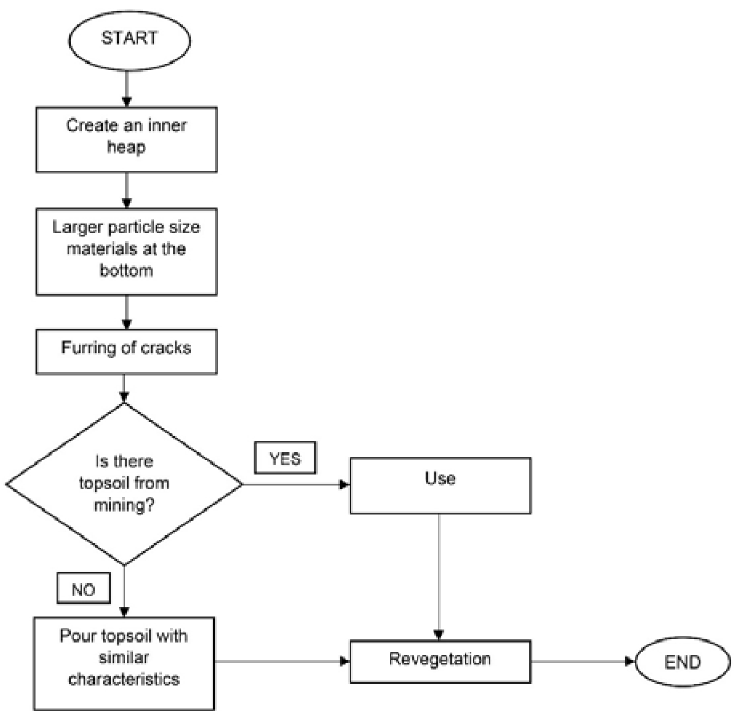

Fig. 6: Flow chart for controlling reject material from mining

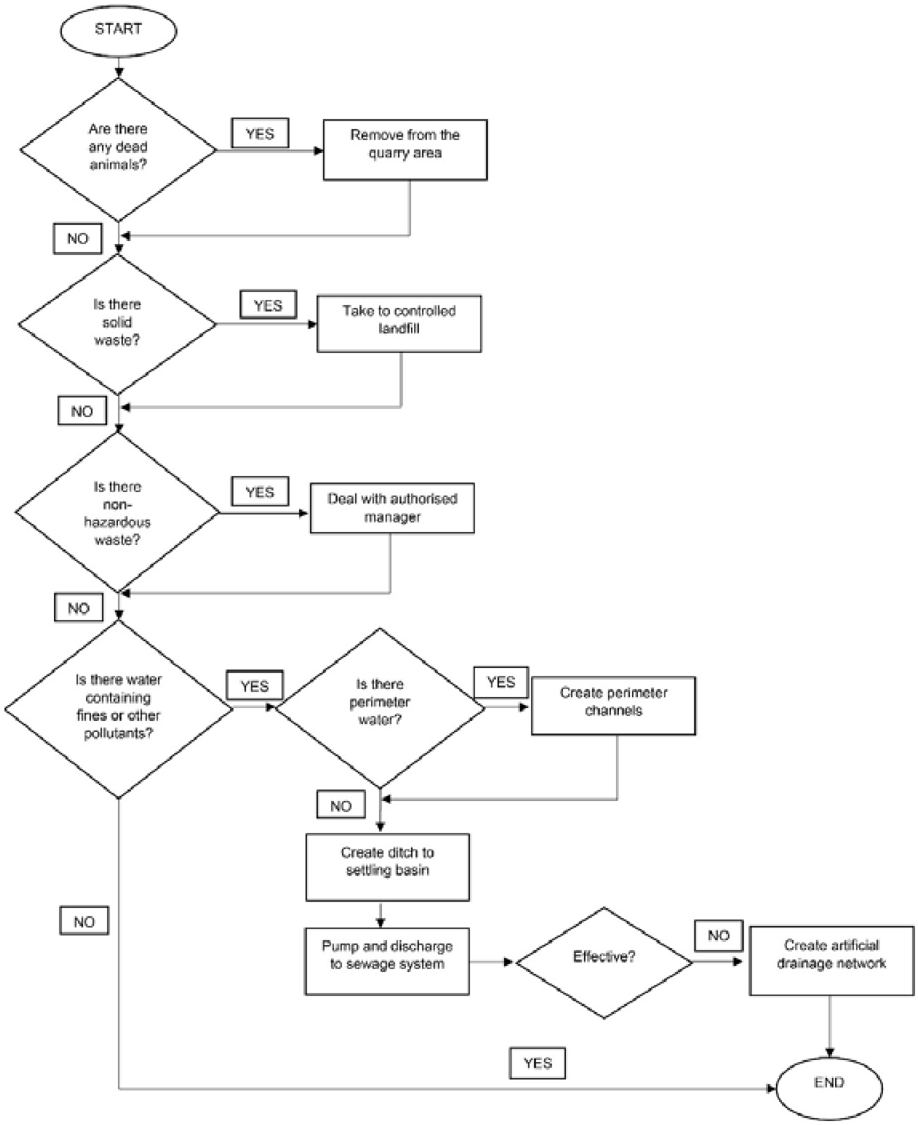

Fig. 7: Flow chart to control and reduce other quarry waste in quarries

on the exploitation must be released after daily checks prior to the start of exploitation work. For the collection of water from the interior, a ditch can be built to collect the water in a settling basin, so that the water laden with fines does not reach the natural drainage network. The clean water from the settling basin will be pumped and discharged directly into the drainage network. If the water table is below the excavation level and with the above measures, the mining activity will not affect the drainage network or any aquifer. If necessary, an artificial drainage network must be created to ensure trafficability and to channel the resulting runoff. The processing and use of waste, in addition to not polluting the environment, serves to compensate for the scarcity of resources, which means that I have great social, environmental and economic benefits. In addition, there is a strategic commitment to the circular economy that supports waste minimization (Jiskani *et al.,* 2021).

It is crucial to consider the environmental and human health, one to improve the health and safety of workers for which the measures given below are usually used and based on them a flow chart has been created for easy application (Fig. 8) and another to improve the surfaces altered by the quarrying activity and reduce the impact on the landscape, fauna and flora for which other measures also described below have been established and have been collected in Fig. 9. Beacons and barriers must be placed indicating danger zones on the site, access points, speed limits, etc. Workers must wear the appropriate work clothes and personal protective equipment necessary for the performance of their tasks. The collaboration of forestry agents must be ensured so that the works are carried out with the least possible risk of fire. The evolution of the slopes must be monitored as the work progresses. The bottom layer of the backfill must be made up of the materials with the highest granulometry, in order to favour the stability and drainage of the whole deposit. No people or material should be in the vicinity of the working slope during the removal of the material. Fire must not be used in

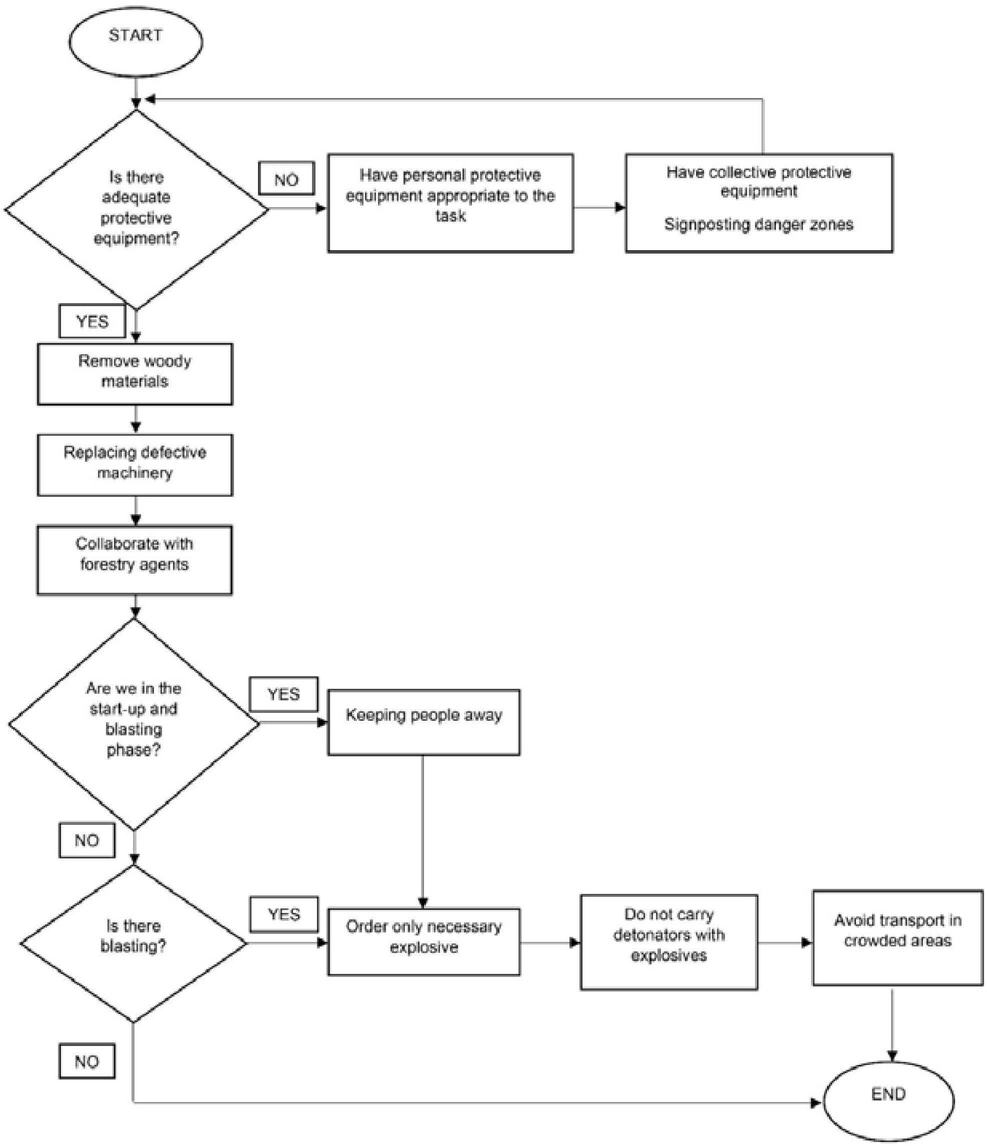

Fig. 8: Flow chart for improving the health and safety of workers in quarrying

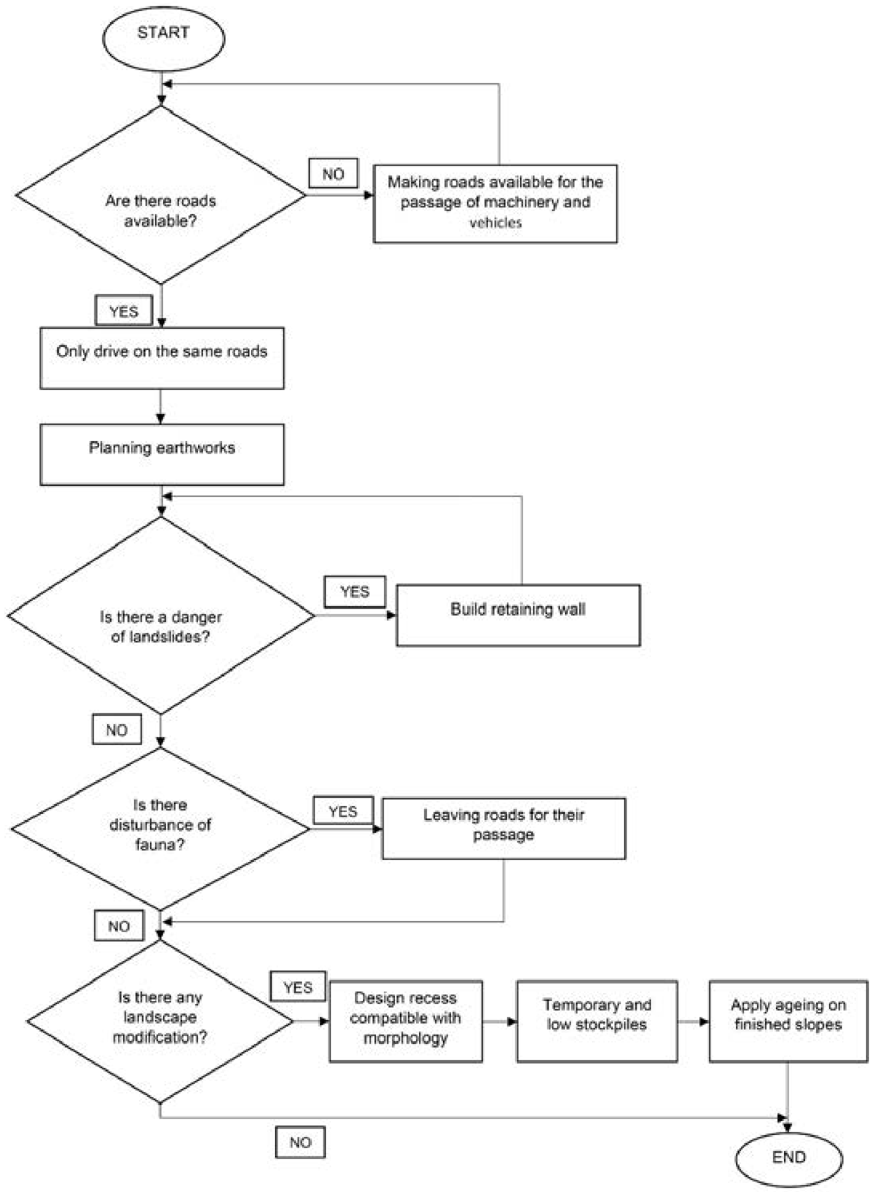

Fig. 9: Flow chart to improve disturbed areas in mining and reduce the impact on landscape, fauna and flora

the area during the mining phase. Woody materials from the opening of roads and tracks must be removed so that they do not pose a fire risk once dry. In addition, to avoid sparks, malfunctioning machinery must be replaced. The necessary extinguishing media must be provided to prevent the spread of fire. Non-flammable species should also be selected from among the species suitable for revegetation in this area.

For the preservation of the fauna, the roads must be used by both vehicles and people and not use areas not designed for traffic. In order for the fauna species to gradually adapt to the changes in their habitat, the removal of soil and vegetation must be done progressively and slowly. Every day before work begins, it must be checked that there are no animals in the ditches or holes. If an area is to be enclosed, small mammals must be allowed to pass through at points where areas with natural vegetation are interconnected. Design of a hollow compatible with the morphology of the environment both during the exploitation phase and in the final phase of restoration. In order to foster natural regeneration over time, conservative as well as preservative actions must be carried to protect biodiversity through the greening of areas (Jiskani *et al.,* 2021). Existing roads and tracks should be used, opening new roads only if strictly necessary. It is important to plan earthworks to reduce disturbed areas. If necessary, retaining walls should be built to prevent soil slides and possible landslides.

The use of this flow charts, which can be widely applied in open-pit mining activities, allow to reduce the impacts of this activity. Moreover, they serve as tools before starting the exploitation and aid to prevent possible effects.

CONCLUSION

Open-pit mining extraction systems have a series of similar characteristics that allow a systematic approach to be established when analysing the impacts. Many authors use different methodologies to assess, prevent and mitigate risks, so there is no single and simple method to respond quickly and that is easy to reproduce and reliable to date, so an impact mitigation system has been presented that allows evaluating the impacts of quarries in arid and semi-arid areas (most of the time the impacts are the same in areas with similar climatic conditions), but at the same time it includes proposals established through the use of flow charts that allow the development of actions to mitigate the negative effects of the exploitation during the active phase and once it finishes. In addition, the use of these charts before starting mining allows to prevent some possible environmental impacts. In this study, were found that 90% of the preventive and corrective measures applied in environmental impact studies in quarries in arid and semi-arid zones are the same. Several environmental impact studies have been first analysed to create these charts, taking into account the importance of the most significant environmental impacts in this type of quarries in the different exploitation phases (preparation, operation and restoration) in order to identify the impacts, the negative effects that they produce. The flow charts propose in a simple way measures to reduce dust on roads and workplaces, noise, fuels and lubricants in mining activities, measures to control topsoil and reject materials in open-pit mines and measures to control other wastes. In addition, some measures have been created to improve the safety and health of workers in quarrying and to improve disturbed areas affected by mining, reducing the impact on landscape, fauna and flora. In this study, a number of preventive and corrective measures have been taken in order to avoid or, when appropriate, moderate the impacts indicated above, considering the components of the environment that intervene o could potentially be affected by mining: physical and biotic environment, perceptual environment, socio-economic and socio-cultural environment. However, as it can be deduced from the preliminary analysis of the legislative framework, the mitigation of environmental impacts is subject to possible new modifications that will have to be incorporated into the methodological framework of the EIAs. In this sense, the establishment of flow charts allows their easy incorporation and updating in a simpler way, as well as their subsequent application and evaluation during and after exploitation. Moreover, future actions will achieve the development of a software, modelling the environmental impact studies based on the framework established by these flow charts. Another future action is to establish the Environmental Surveillance Plan (ESP), since in it, it is about establishing a system that guarantees compliance with the indications, preventive and corrective measures, it tries to define the fundamental elements that must be controlled to meet its objectives. In this specific case, the function of the ESP is to establish a control system, that is, to monitor during the preparation, exploitation and restoration phases of the project.

AUTHOR CONTRIBUTIONS

M.A. Peñaranda Barba performed the literature review, experimental design, analysed and interpreted the data, prepared the manuscript text, compiled the data and manuscript preparation and manuscript edition. V. Alarcón Martínez compiled the data and manuscript preparation, helped in the literature review and manuscript preparation and helped in the manuscript text. J. Navarro Pedreño performed the literature review, manuscript edition, helped in the literature review and manuscript preparation and helped to prepared the manuscript text. I. Gómez Lucas helped in literature review and helped to prepared the manuscript text.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

ABBREVIATIONS

BSh	Warm semi-arid
BSk	Cold semi-arid
CREM	Statical portal of the Region of Murcia
CO_2	Carbon dioxide
Csa	Mediterranean
EIA	Environmental impact assessment
ESP	Environmental Surveillance Plan
HIC	Habitats of community interest
IGN	National Geographic Institute
l/m^2	Liters per square meter
MET	Ministry for Ecological Transition
M€	Million euros
N-NW	north/northwest orientation
NOx	Nitrogen oxides
RN2000	Natura 2000 network
SAC	Special areas of conservation
SCI	Sites of community interest
SITMURCIA	Territorial information system of the Region of Murcia
SO_2	Sulfur dioxide
WNW-SE	west/northwest-south/east orientation
ºC	Degrees Celsius
%	Percent

REFERENCES

Astorga, A.; Aguilar, G.; and Hernández, G., (2003). Manual técnico de EIA: lineamientos generales para Centroamérica. IUCN, San José, CR.

Casas, L., (2018). Estudio de impacto ambiental de la cantera "La Esperanza". Master´s Thesis, Polytechnic University of Cartagena, ES.

Castelo, J.; Rebbah, R.; Duarte, J.; Baptista, J.S, (2019). Risk Assessment in the Open Pit Mining Industry. Stud. Syst. Decis. Control. 202: 13-21 **(9 pages)**.

Chen, J.; Jiskani, I.M.; Jinliang, C.; Yan, H, (2020). Evaluation and future framework of green mine construction in China based on the DPSIR model. Sustain. Environ. Res. 30: 1-10 **(10 pages)**.

Conesa, V.; Conesa, L.; and Conesa, V., (2010). Methodological guide for environmental impact assessment. Mindi-Prensa, Madrid, ES.

Council Directive, (1992). on the conservation natural habitats and wild fauna and flora, Off. J. Eur. Communities. 206: 7-50 **(43 pages).**

CREM., (2019). Evolution of the main features of the mining sector. Department of business, Industry and Spokesperson of the Region of Murcia. Murcia, ES.

CREM, (2020). Climatology. Department of business, Industry and Spokesperson of the Region of Murcia. Murcia, ES.

Darwish, T.; Khater, C.; Jomaa, I.; Stehouwer, R.; Shaban, A.; Hamze, M., (2010). Environmental Impact of Quarries on Natural Resources in Lebanon. Land. Degrad. Develop. 22: 345-358 **(14 pages)**.

Decree 1439, (1972)., on the approval of motor vehicles with regard to the noise produced by them. Boletín Oficial del Estado, Madrid, ES. 138: 10215-10216 **(2 pages)**.

Directive 42, (2001)., of the European Parliament and of the Council, of 27 June 2001, on the assessment of the effects of certain plans and programmes on the environment. Off. J. Eur. Communities. 197: 30-37 **(8 pages)**.

Directive 147, (2009)., of the European Parliament and of the Council, of 10 November 2009, on the conservation of wild birds. Off. J. Eur. Union. 20: 7-25 **(19 pages)**.

Directive 92, (2011)., of the European Parliament and of the Council, of 13 December 2011, on the assessment of the effects of certain public and private projects on the environment. Off. J. Eur. Union. 26: 1-21 **(21 pages)**.

Directive 52, (2014)., of the European Parliament and of the Council, of 16 April 2014, amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment, Off. J. Eur. Union. 124: 1-18 **(18 pages)**.

Enríquez de Salamanca, A., (2021). Project justification and EIA: Anything goes? Environ. Impact. Assess. Rev. 87: 1-4 **(4 pages)**.

Elvan, O.D., (2013). The legal environmental risk analysis (LERA) sample of mining and the environment in Turkish legislation. Resour. Pol. 38(3): 252–257 **(6 pages).**

Espoo Convention, (1991). Convention on Environmental Impact Assessment in a Transboundary Context. Espoo, FI.

Falck, W.E., (2016). Social was licensing in mining—between ethical dilemmas and economic risk management. Min. Econ., 29: 97–104 **(8 pages)**.

Fierro, J., (2012). Políticas mineras en Colombia. ILSA, CO.

Garmendia, A.; Salvador, A.; Crespo, C.; Garmendia, L., (2005).

Environmental Impact Assessment. Pearson Educación, S.A., Madrid, ES.

Ghorbani, Y.; Kuan, S.H., (2017). A review of sustainable development in the Chilean mining sector: past, present and future. Int. J. Min. Reclamat. Environ. 31(2): 137–165 **(29 pages)**.

Glasson, J.; Therivel, R., (2019). Introduction to Environmental Impact Assessment. 5th ed. Routledge, London.

Gómez, I., (2016). Propuesta metodológica para la evaluación del impacto ambiental en la explotación a cielo abierto "cantera Begoña" Final Project Thesis. Department of Agrochemistry and Environment, The University Miguel Hernandez of Elche, ES.

Handjaba, J., (2012). Estudio minero-ambiental de la cantera El Cacao. Cien. Futuro., 2(4): 49-58 **(10 pages).**

IGN, (2020). Geology and tectonics of the Betic Cordillera. Ministry of Transport, Mobility and Urban Agenda, Madrid, ES.

Jain, R.K.; Cui, Z.C.; Domen, J.K., (2016). Environmental Impact of Mining and Mineral Processing. Elsevier Inc., Boston, USA.

Jiskani, M.I.; Cai, Q.; Zhou, W.; Shah, S.A., (2021). Green and climate-smart mining: A framework to analyze open-pit mines for cleaner mineral production. Resour. Policy., 71: 1-13 (**13 pages**).

Johnson, F.; Bell, D., (1975). Guidelines for the identification of potential environmental impacts in the construction and operation of a reservoir. Department of Forestry, Agricultural Experiment Station, University of Illinois at Urbana-Champaign, Illinois, US.

Karbassi, A.R.; Heidari, M., (2015). An investigation on role of salinity, pH and DO on heavy metals elimination throughout estuarial mixture. Global J. Environ. Sci. Manage., 1(1): 41-46 **(6 pages)**.

Karbassi, A.R.; Pazoki, M., (2015). Environmental qualitative assessment of rivers sediments. Global J. Environ. Sci. Manage., 1(2): 109-116 **(8 pages)**.

Khabali, H.; Kamal, EK., (2013). Quarrying in coastal Kenikra and its area of influence: environmental impact study. Est. andaluces., 30: 1-26 **(26 pages).**

Köppen, W., (1936). The Geographical System of Climates. Borntraeger Science Publishers, Berlin, DE.

Lad, R.J.; Samant, J.S., (2014). Environmental and social impact of stone quarrying- a case study of Kolhapur District. Int. J. Curr. Res. 6(3): 5664-5669 **(6 pages)**.

Law 34, (2007)., of 15 November, on air quality and atmospheric protection. Boletín Oficial del Estado. Madrid, ES. 275: 46962-46987 **(26 pages)**.

Law 42, (2007)., of 13 December, on Natural Heritage and Biodiversity. Boletín Oficial del Estado, Madrid, ES. 299: 51275-51327 **(53 pages)**.

Law 33, (2015)., of 21 September, which amends Law 42/2007, of 13 December, on Natural Heritage and Biodiversity. Boletín Oficial del Estado, Madrid, ES. 227: 83588- 83632 **(45 pages)**.

Law 21, (2013)., of 9 December, on environmental assessment. Boletín Oficial del Estado, Madrid, Spain. 296: 98151-98227 **(77 pages)**.

Law 9, (2018). 5 December, amending Law 21/2013, of 9 December, on environmental assessment, Law 21/2015, of 20 July, amending Law 43/2003, of 21 November, on Forestry and Law 1/2005, of 9 March, regulating the greenhouse gas emission allowance trading scheme. Boletín Oficial del Estado, Madrid, ES. 294: 119858-119905 **(48 pages)**.

Leopold, L.; Clarke, F.; Hanshaw, B.; Balsley, J., (1971). A Procedure for Evaluating Environmental Impact. Geological Survey Circular 645, Washington, US.

Luna, JA., (2015). El impacto Ambiental por la actividad de explotación de canteras en la localidad de Usme y sus principales medidas de manejo. Master´s thesis, Military University Nueva Granada. Bogotá, CO.

Maponga, O.; Munyanduri, N., (2001). Sustainability of the dimension stone industry in Zimbabwe - challenges and opportunities. Nat. Resour. Forum. 25: 203-213 **(11 pages)**.

MET, (2018). Estadística Minera de España 2017. Ministry for Ecological Transition. Madrid, ES.

MET, (2019). Methodological Guide for Environmental Impact Assessment in Natura 2000 Network. Madrid, ES.

Miñarro, A., (2018). Estudio de impacto ambiental de la cantera "La Chica". Final Project Thesis. Department of Mining, Geological and Cartographic Engineering, Polytechnic University of Cartagena, ES.

Montes de Oca-Risco, A.; Ulloa-Carcassés, M., (2013). Recovery of areas damaged by mining in the Los Guaos Quarry. Revista Luna. Azul., 37: 74-88 (**15 pages**).

Mora-Barrantes, J.; Molina-león, O.; Sibaja-Brenes, J., (2016). Application of a method for the environmental impact assessment of university construction projects. Tecnol. Marcha., 29(3): 132-145 (**14 pages**).

Moreno, M.A., (2021). Estudio de impacto ambiental de una cantera de calizas en el valle de Escombreras. Master´s Thesis, Polytechnic University of Cartagena, ES.

Order ITC 2585, (2007)., of 30 August, approving Complementary Technical Instruction 2.0.02 "Protection of workers against dust, in relation to silicosis, in the extractive industries", to the General Regulations on Basic Standards for Mining Safety. Boletín Oficial del Estado, Madrid, ES. 215: 36828-36833 **(6 pages)**.

Parrota, J.A.; Knowles, O.H., (2001). Restoring tropical forests on lands mined for bauxite: Examples from the Brazilian. Ecol. Eng. 17: 219-239 (**21 pages**).

Pchalek, M., (2019). The legalization of unpermitted projects in the light of requirements of the EIA directive. Eur. Energy. Environ. Law. Rev. 28(3): 101–106 **(6 pages)**.

Retief, F.P.; Fischer, T.B.; Alberts, R.C.; Roos, C.; Cilliers, D.P., (2020). An administrative justice perspective on improving EIA effectiveness. Impact. Assess. Proj. Apprais. 38(2): 151–155 **(55 pages)**.

Royal Decree 212, (2002). 22 February 2002, regulating noise emissions in the environment due to certain outdoor machinery. Boletín Oficial del Estado, Madrid, ES. 52: 8196-8238 **(43 pages)**.

Sheoran, V.; Sheoran, A.S; Poonia, P., (2010). Role of hyperaccumulators in phytoextraction of metals from contaminated mining sites: A Review. Crit. Rev. Env. Sci. Technol. 41(2): 168-214 (**47 pages**).

SITMURCIA, (2019). Advance of the territorial management plan for mineral resources in the Region of Murcia. Regional Ministry of Employment, Universities, Enterprise and Environment, Murcia, ES.

Sort, X.; Alcañiz, J.M., (1996). Contribution of sewage sludge to erosion control in the rehabilitation of limestone quarries. Land Degrad. Dev. 7(1): 69-76 (**8 pages**).

Stehouwer, R.; Day, R.; Macneal, E., (2006). Nutrient and trace element leaching following mine reclamation with biosolids. J. Environ. Qual. 35: 1118-1126 **(9 pages)**.

Timofeeva, S.S.; Murzin, M.A., (2020). Assessing the environmental risk of mining enterprises by the integral indicator of dust emission. Earth. Environ. Sci. 408: 1–5 **(5 pages)**.

UN, (2003). Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context. United Nations. Kiev, UA **(28 pages)**.

Villalba, V., (2017). Estudio de Impacto Ambiental de un proyecto de rehabilitación de una cantera en el término municipal de Alfarp (Valencia). Master's thesis. Department of Road, Canal and Port Engineering, Polytechnic University of Valencia, Valencia, ES.

Yildiz, T., (2020). The impacts of EIA procedure on the mining sector in the permit process of mining operating activities & Turkey analysis. Resour. Pol. 67: 1-17 **(17 pages)**.

Zhou, W.; Yin, W.; Peng, X.; Liu, F.; Yang, F., (2018). Comprehensive evaluation of land reclamation and utilisation schemes based on a modified VIKOR method for surface mines. Int. J. Min. Reclam. Environ., 32: 93-108 **(15 pages)**.

Zhou, Y.; Zhou, W.; Lu, X.; Jiskani, I.M.; Cai, Q.; Liu, P.; Li, L., (2020). Evaluation Index System of Green Surface Mining in China. Min. Metall. Explor. 37: 1093-1103 **(11 pages)**.

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