INTERNATIONAL CONFERENCE
CONTAMINATED SITES
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Ministry of Environment of the Slovak Republic
Slovak Environment Agency

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CONTAMINATED SITES 2022

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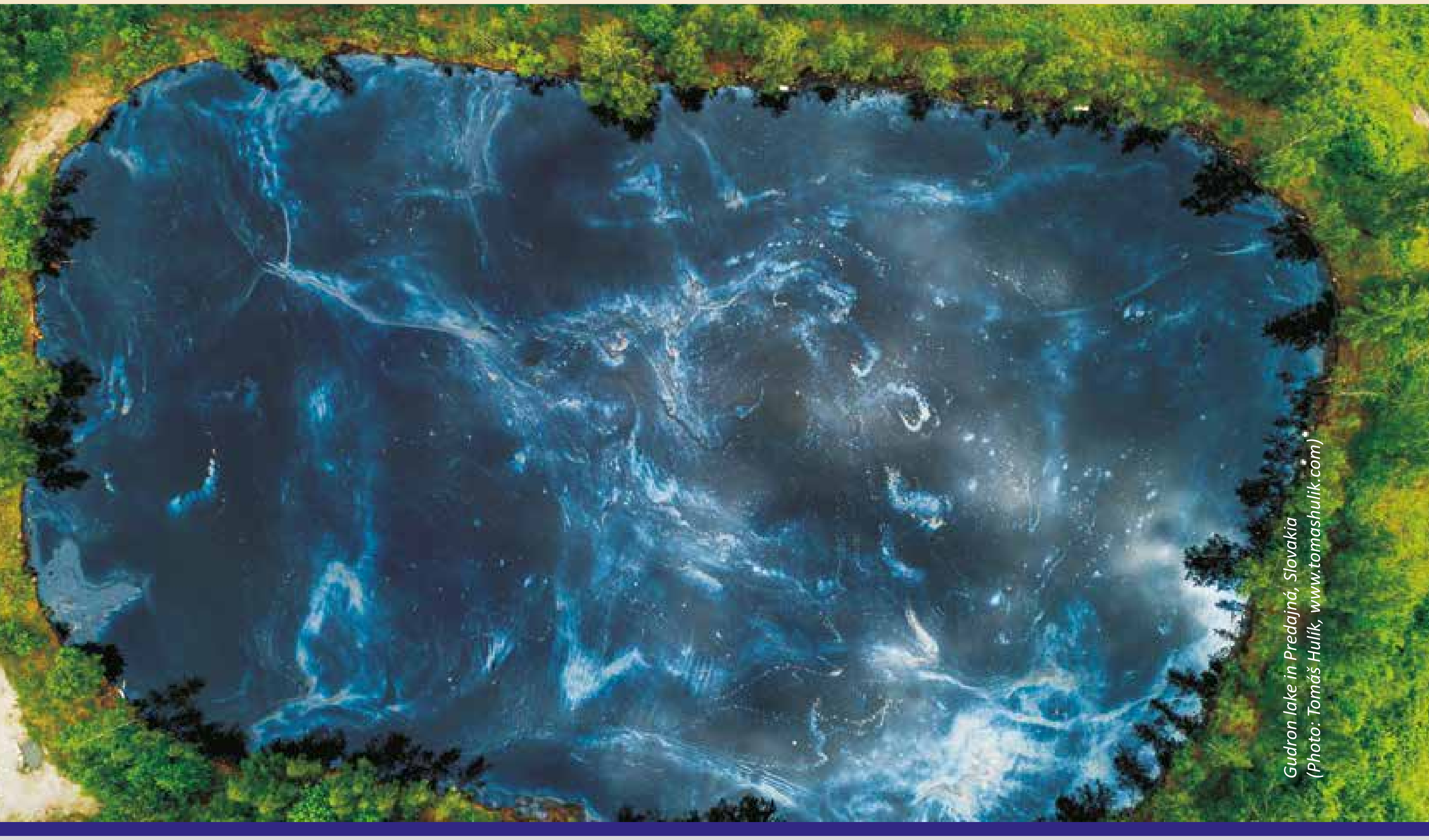

Gudron lake in Predajná, Slovakia (Photo: Tomáš Hulík, www.tomashulik.com)

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CONTENTS

STUDY OF THE VEGETATION COVER OF AN ENVIRONMENT CONTAMINATED BY HEAVY METAL SULPHIDES: STRATEGIES AND SPECIFIC DISTRIBUTION

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Sulphide metals pollution; plant colonization strategies; pioner plants; nurse plants

ABSTRACT
After the extraction of sulfide minerals such as galena, sphalerite and pyrite for decades, the abandoned minesites are a sort of mosaic of different substrates related with the different activities carried out on mineral management and processing. After the exploitation time, a slow but steady natural colonization starts by a select group of species, resilient enough to the very harsh conditions. The presence of high levels of heavy metals, acidic pH and a poor water retention are the key limiting factors. The list of the species and their specific role in the colonization strategies have been studied with the aim of determining the physiological or ecological mechanisms involved in overcoming the environmental restrictions. *Phragmites australis* can be considered as a pioner species, colonizing first the substrate and creating the necessary conditions for other species to stablish themselves in the area. This species creates a shallow network of rhizomes that allows the accumulation of resources (organic matter, finer mineral particles, etc.) that will ease the germination and growth of other species, specially *Retama sphaerocarpa*.
We have observed some interspecific strategies that lead to the improvement of edaphic conditions, increasing the organic matter content, favoring compaction, water retention and some enzymatic activities linked to microbial activity. This study draws predictions on the hypothetical ability to gerenate resources by plants and how different soil types alter plant strategies to achieve a sustainable plant cover, despite trenchant environmental constraints.The general objective of this study is to gather knowledge to understand the relationship between soil properties and species distribution in harsh environment.

SUMARY
An abandon mine area is an excellent site to study the processes used by plants to overcome environmental constraints. In our work we have analyzed and quantified the small scale spatio-temporal patterns of colonization and the phenomena involved in both the advance of the vegetation cover and in the increase in biodiversity. Having knowledge about soil properties, microbial activity and composition (Ailstock, 2000; Gallego et al, 2021) and plant cover patterns as well as changes in the relation and structure of coexisting species, is crucial in determining the functionality of the ecosystem and to identify opportunities for management of the degraded lands (Bradley 2014).
Our studies are focused on a galena and sphalerite mine, abandoned since the middle of the 20th century (Mina de San Quintín, Ciudad Real, Spain). Currently it is an area of approximately 1.5 km^2 that stands out as an interruption of the landscape patterns. The vegetation cover is characteristic of these Alcudian slate and greywacke substrates, generally of the dehesa type, with a clear predominance of holm oak (*Quercus ilex*), sporadic presence of broom, and the spontaneous vegetation generally associated with this ecosystem (Table 1). Surrounding the minesite we find oak-

scattered pastures dedicated to extensive sheep and cattle farming, alternated with cereal and olive plots and with a relative human presence. The minesite appears as a highly altered area with piles of rubble, mining tailings and scarce vegetation. Making a detailed study of the surface we identify the following areas (Fig 1):

TD: Totally Degraded areas. Characterized by the original soil has been totally removed or replaced by different materials.

Here we can find:

TDMG. Totally Degraded Mine Gangues: Large mounds of material several meters thick of sulphurous material extracted from the mine with ore richness lower than required to be extracted and processed (metallic sulphides around 2-5%). This material has ecological importance since they generate acid drainage due to the contact of sulfides with rainwater. Normally the acidic water percolates down to the impermeable base layers and then appears on the surface forming streams that end up affecting the surrounding area. Originally, a drainage channel was built to collect these runoffs and direct them to a nearby stream, characterized by a red color due to the presence of *Acidothiobacillus ferredoxidans* and the consequent ferric hydroxides. It is an area practically without vegetation with some isolated individuals of plants resistant to acidic substrate (Soil pH≈2.0) (**Table 1)**.

TDHT. Totally Degraded Heap of Tailings: With a surface of about 3000 m^2 this heap rises above the original level between 5 and 2 m. It is made up of a fine material coming from the grinding and subsequent extraction by physical decantation of the sulphide ores. The whole area consists of a deep substrate of fine material of silt and fine sand fractions, coming from the marly slates materials that surrounded the sulphurous veins. The resulting material is sulphides free. In this area a gradation of soil formation and compaction can be observed and studied. It has also been possible to observe the process of colonization of the lower parts through the years. *Phragmites australis* is the unique species homogeneously distributed throughout the whole covered area and it can be considered as a pioneer (Ait, 2004). The collaboration between the *Phragmites australis* and *Retama sphaerocarpa* species for said colonization has been studied.

PD: Partially Degraded areas. In this case, the soil has undergone gradual physical or chemical alterations but preserving its original composition and level. This alteration can be considered extreme, in the center of the mining area, or weaker, in the edge spaces. The disturbance may be due to the presence of non-native materials, mainly carried by the wind, contaminated liquid spills, acid drainage or soil compaction due to the continuous heavy hauling activity derived from mining processes.

We can find:

PDAD. Partially Degraded affected by Acid Drainage: It is an area affected by the acid drainage coming from the gangue deposits (**Fig. 2**). During the rainy season, the leached water from this material spreads over the flat and low-lying areas until it converges in a stream that empties into a nearby lagoon, outside the mining area. In the area affected by acid drainage we find very little vegetation and species that are very resistant to these conditions (**Fig. 3**). The vegetation is formed almost exclusively by patches of *Spergularia purpurea* and *Molineriella laevis*, perfectly associated and with a special location, leaving *S. purpurea* outside, in contact with acidic water (pH around 2.5). In places where conditions allow the formation of patches with a diameter greater than 1 m, the species *Micropirum tenellum* usually occupies the center.

PDLL. Partially Degraded Low-Level areas: Characterized by receiving materials from neighboring areas, specially, wind-borne fine material (clay and silk). A thin but impermeable layer is formed resulting harsh conditions for plant colonization. These areas flood in the wet season and dry up in summer. Due to these wet/dry cycles a salt crust appears in the surface. This area is colonized mainly by *Phragmites australis* and *Tamarix africana*, both of them resistant to high values of edaphic electric conductivity (10-16 dS/m). Processes closely linked to the evolution of natural ecosystems such as wind deposits of fine material, erosion by storm avalanches, colonization by pioneer species, etc, can be seen, measured and tracked. In general terms, the vegetal biodiversity is varied, and we can find species such as *Linum tenue, Retama sphaerocarpa*, *Centaurium eritraea, Hirschfeldia incana, Jasione montana* and *Thymus mastichina* among others.

PDCS. Partially Degraded Compacted Soil: Characterized by a deep alteration of the original substrate but keeping the original level. They are wide and irregular areas of gravel and loose sand, with a certain undulation with varied vegetation. Here we find a high incidence of therophytes, mainly *Molineriella laevis* and *Rumex bucephaloforus* as predominant species, accompanied by *Piptaptherum milliaceum* when edaphic conditions allow it. Allochthonous organic material, dumped in some areas, relieves the edaphic conditions and allows the appearance of new species such as *Holcus lanatus*.

PDME. Partially Degraded Marginal Edges: They are characterized by slightly disturbed soil. In these areas we find transitional vegetation with the most common ruderal species in the spaces surrounding the mining area. In this area, *Biscutella auriculata* and *Retama sphaerocarpa* are the most representative.

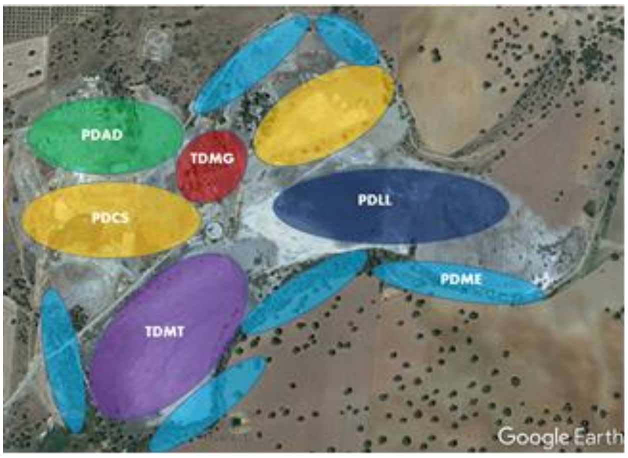

Fig 1. Defined areas.

Fig 2. Acid drainage, coming from the gangue piles, affect the lower areas. Only scattered patches of Spergularia purpurea and Molineriella laevis can be found on this zone.

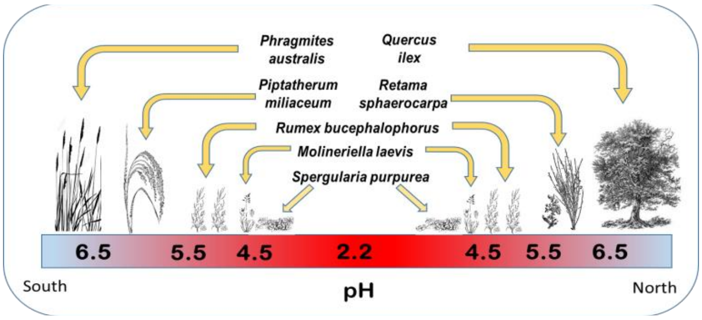

Fig 3. Plant cover transect across affected Acid Drainage zone (PDAD)

Table 1: Species distribution according with identified areas. TDMG: Totally Degraded Mine Gangues. TDHT: Totally Degraded Tailings Heap. PDAD: Partially Degraded affected by Acid Drainage. PDLL Partially Degraded Low-Level areas. PDCS: Partially Degraded Compacted Soil areas.PDME: Partially Degraded Marginal Edges areas. Presence: +++ abundant, forming tight communities; ++ dispersed individuals through a wide area; + isolate or rare individuals.

Species	TDMG	TDTR	PDAD	PDLL	PDCS	PDME
Aegilops triuncialis L.		+				
Asparagus acutifolius L.						+
Avena barbata Pott ex Link						++
Biscutella auriculata					++	+++
Bromus rubens L.		+		+	+	++
Campanula rapunculus L.						+
Carlina corymbosa L.						+
Carlina racemosa L.						+
Centaurium erythraea Rafin.		++		++	+	+
Cistus ladanifer L.						+
Crupina vulgaris Pers. ex Cass.						+
Daucus carota L.						+
Eryngium campestre L.				+	+	+
Helichrysum stoechas (L.) Moench.					+	++
Hirschfeldia incana (L.) Lagréze-F.	+	++		++	++	+
Holcus lanatus L.					+	
Jasione montana L.		+		+	++	++
Linum tenue Desf.		+		++		
Lomelosia stellata (L.) Raf.		+		+		++
Micropirum tenellum Link.			+		+	
Molineriella laevis (Brot.)			+++		+++	
Onopordum illyricum L.						+
Papaver roheas L.				+		+
*Petrorhagia nanteuilii (*Burnat)		+		+	+	++
Phragmites australis (Cav.) Trin.		+++		+++		
Piptatherum miliaceum (L.) Coss.			+	+	++	
Plantago coronopus L.					+	+
Quercus ilex L.						+
Retama sphaerocarpa (L.) Boiss.		+		+	+	++
Robinia pseudoacacia L.		+				+
Rumex bucephalophorus L.	+				+++	
Scabiosa atropurpurea L.		+		+		
Scrophularia canina L.		++				
Spergularia purpurea (Pers)	+		+++		+	
Serapias lingua L.						+
Tamarix africana Poir.				++		
Thymus mastichina (L.) L.		+		++	+	+

Species	TDMG	TDTR	PDAD	PDLL	PDCS	PDME
Thymus vulgaris L.		+				+
Trifolium arvense L.						+
Trifolium stellatum L.						+
Trifolium angustifolium L.						+
Trifolium campestre Schreb. in Sturm.						+

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