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Phy2SUDOE

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RECOVERING CONTAMINATED SOILS THROUGH PHYTOMANAGEMENT
IN SOUTHWEST EUROPE

PRODUCT 3.1

STRATEGY FOR THE CONSERVATION OF NATIVE BIODIVERSITY IN MINING SITES CONTAMINATED WITH POTENTIALLY TOXIC METAL(LOID)S

GT3 - Identification and Conservation of endemic biodiversity of contaminated sites for potential exploitation in biotechnological applications

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"*Advancing in the application of innovative phytomanagement strategies in contaminated areas of the SUDOE space*"

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1. Introduction

Biodiversity refers to the variety of life forms found in a particular ecosystem, region, or the entire planet. It encompasses all living organisms, including plants, animals, and microorganisms, as well as the ecological systems and processes in which they interact. The richness and abundance of different species, along with their genetic variability, define the essence of biodiversity. Its significance lies in its role in sustaining the health and functioning of ecosystems, offering a multitude of benefits that include: i) ecological balance: biodiversity contributes to the stability and resilience of ecosystems, helping them withstand disturbances and adapt to changing environmental conditions; ii) climate regulation: ecosystems with high biodiversity play a vital role in carbon sequestration, helping mitigate climate change; iii) water and soil quality: healthy ecosystems, supported by biodiversity, contribute to clean water and soil through natural filtration and purification processes.

However, biodiversity is facing significant threats worldwide, primarily due to human activities such as industry and mining. Therefore, its conservation is of paramount importance, and it is crucial to outline strategies for its preservation.

Mining sites, namely those contaminated by metals and metalloids (hereafter metal(loid)s), exhibit varying degrees of biodiversity depending on the type and concentration of contaminants present, the duration of contamination, and the resilience of the affected ecosystems. Metal(loid)s contamination can cause physical-chemical changes in soil, water, and vegetation, resulting in habitat degradation. This degradation can further impact the availability of suitable habitats and resources for various organisms, leading to changes in biodiversity patterns.

Some organisms, including certain plant species, can endure contamination and present unique genetic traits and adaptations that allow them to thrive in metal(loid)-contaminated environments. Therefore, the conservation of these metal-tolerant species is crucial to ensure their survival and the maintenance of biodiversity.

The following sections will explore the importance of the biodiversity found in mining areas. Furthermore, effective strategies for conserving this biodiversity, namely metal-tolerant plants, in such environments will be discussed, highlighting the role of habitat restoration, reclamation, and the establishment of protected areas.

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2. The significance of biodiversity in metal(loid)-contaminated environments

Metal(loid)-contaminated sites typically exhibit a diminished species diversity, both in terms of the number of species present and the abundance of individuals. Certain species are more vulnerable to metal(loid) toxicity and therefore unable to thrive in these environments. Consequently, the species composition in these sites differs from that of uncontaminated areas, with a prevalence of tolerant or resistant species that can withstand metal toxicity, while sensitive or specialized species may be absent or occur in lower numbers. These metal-tolerant or metal-resistant species have adaptations that allow them to survive and reproduce in the presence of high metal(loid) concentrations.

The response of biodiversity to metal(loid) contamination is complex and can vary depending on local conditions, the specific metal(loid)s involved, and the resilience of the ecosystems. Understanding the specific biodiversity patterns in metal(loid)-contaminated sites is crucial for effective management and conservation strategies.

The conservation of biodiversity in mining areas is of paramount importance due to several reasons, including:

- **Ecosystem Functioning:** biodiversity is essential for the proper functioning of ecosystems, as each species plays a unique role, contributing to multiple processes such as nutrient cycling, pollination, seed dispersal, and pest control.
- **Ecological Resilience:** mining operations can disrupt the natural ecological balance, leading to the loss of native species and the invasion of non-native or invasive species. Preserving biodiversity helps maintain ecological resilience, allowing ecosystems to recover and adapt to disturbances, and reducing the vulnerability to future impacts.
- **Environmental remediation:** biodiversity conservation can contribute to environmental remediation efforts by promoting the establishment of plants and microorganisms that help in the removal/stabilization of contaminants.
- **Social and Cultural Value:** biodiversity has social and cultural significance. Many communities living in or near mining areas have strong cultural and traditional connections to the natural environment. Preserving biodiversity

allows for the continuation of these cultural practices, which can contribute to the well-being and identity of local communities.

Overall, preserving biodiversity in mining areas is essential for maintaining ecosystem health, protecting species, promoting environmental remediation and restoration, and contributing to sustainable development. It recognizes the interrelation of ecosystems, human well-being, and long-term environmental sustainability. Restoring native habitats and reintroducing native species can help rehabilitate degraded landscapes, enhance ecosystem services, and promote long-term ecological sustainability.

3. Importance of metallophytes and their conservation

Metal-contaminated sites are often characterized by the presence of metallophytic plant species (metallophytes), some endemic, that have adapted to thrive in such environments. These plants exhibit unique physiological and biochemical characteristics that allow them to tolerate and/or accumulate metal(loid)s in their tissues. Through specialized mechanisms such as metal ion exclusion, metal(loid) detoxification, and metal(loid) sequestration, metallophytes can survive and flourish in such high-metal concentration environments.

These exceptional plant species have evolved to endure and prosper in high-metal environments, demonstrating remarkable resilience and genetic adaptations. Safeguarding and conserving these metallophytes is crucial, not only for their intrinsic value but also for their potential contributions to phytoremediation and ecological restoration endeavors, as they contribute to the stabilization and reduction of metal pollutants in the soil. Moreover, metallophytes serve as a valuable resource for biodiversity conservation, as they support diverse ecological niches and provide habitats and food sources for other organisms in these challenging environments. Metallophytes also provide valuable opportunities for scientific research. Studying their adaptations to metal toxicity and understanding the mechanisms behind their tolerance can lead to new insights into plant physiology, biochemistry, and evolutionary processes. This knowledge can have broader applications in fields such as environmental remediation.

Metallophytes represent a valuable genetic resource for plant breeding and biotechnological applications. Their ability to tolerate high metal concentrations may provide genes or traits that can be transferred to crop plants, enhancing their tolerance to metal pollution or other environmental stressors.

Implementing conservation measures for metallophytes, including endemic species, in metal(loid)-contaminated sites requires a range of strategies that considers their distinct adaptations and ecological dynamics.

3.1. Conservation strategies for metallophytes

Metallophytes can be preserved through *in situ* and *ex situ* conservation approaches, to ensure their protection and long-term survival. *In situ* conservation involves the conservation of plants within their natural habitats and aims to protect and manage the ecosystems in which plants naturally occur. Some common *in situ* conservation practices for plants include:

1. establishing protected areas within metal(loid)-contaminated sites, which should be carefully delineated to minimize disturbance and prevent further contamination.
2. implementing habitat restoration techniques that include immobilizing the contaminants and improving soil quality.
3. conducting regular monitoring and research to assess the impact of metal(loid)s on plant populations and ecosystems. This information can guide conservation efforts and help develop tailored management strategies to enhance their chances of survival and reproduction.
4. collaborating with local communities living near plant habitats, involving them in conservation efforts, and promoting sustainable practices that benefit both people and plants.

Ex situ conservation approaches involve conserving plant species outside their natural habitats and typically comprise activities conducted in controlled environments such as botanical gardens, or specialized facilities. Some *ex situ* conservation practices include:

1. establishing seed, spores, or plant tissue banks, *i.e.*, germplasm banks for conserving plant genetic diversity in metal-contaminated sites. Seeds of endangered or rare plant species can be collected, stored, and maintained under controlled conditions to ensure their availability for future restoration and reintroduction programs.
2. cultivating and maintaining living specimens of endangered plants in protected environments such as greenhouses or fenced areas, can serve as *ex situ* conservation sites for metallophytes. These collections can house and

propagate endangered or threatened species, providing a safeguard against their potential extinction in the wild.

3. tissue culture techniques can be employed to propagate and multiply plants *in vitro* under sterile conditions, which is particularly useful for species that are difficult to propagate by traditional means, allowing the production of large numbers of plants for reintroduction purposes.

Both *in situ* and *ex situ* conservation approaches are important and often complement each other. *In situ* conservation aims to protect the natural processes and interactions within ecosystems, while *ex situ* conservation provides a safety net by preserving plants outside their native habitats and supporting their reintroduction efforts if needed.

However, specific conservation strategies employed will depend on the level and type of metal contamination, the characteristics of the plant species involved, and the overall goals of the conservation program. Expert knowledge and site-specific assessments are crucial for developing and implementing effective conservation approaches in metal-contaminated areas.

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4. Strategy for the conservation of native biodiversity in mining sites

Mining can have significant impacts on biodiversity. Developing a strategical plan to conserve native biodiversity, namely metallophytes, should follow several key steps, as follows:

1. Contamination Appraisal

- Identification of the specific metal(loid)s that are present and causing contamination.
- Evaluation of the extent of the contamination and its impact on the native biodiversity.
- Assessment of the existing biodiversity and ecological dynamics of the site.

2. Setting of Conservation Goals

- Definition of clear and measurable goals for the conservation of native biodiversity in the mining site, considering the specific characteristics of the site, such as its unique ecosystems and endangered species.
- Prioritization of the preservation of critical habitats and the protection of vulnerable species.

3. Implementation of Mitigation Strategies

- Identification and implementation of measures to mitigate the negative impacts of metal(loid) contamination on native biodiversity.
- Implementation of pollution control and remediation techniques to reduce the levels of toxic metal(loid)s in the environment.
- Exploration of natured-based approaches, such as phytoremediation or bioaugmentation.

4. Implementation of Conservation Actions

- Establishment of protected areas or conservation zones within the mining site to safeguard key habitats and species.
- Implementation of monitoring programs to track the recovery of native biodiversity and assess the effectiveness of conservation measures.

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- Promotion of sustainable land management practices that minimize disturbance and support the restoration of natural ecosystems.

5. Collaboration and Stakeholder Engagement

- Collaboration with relevant stakeholders, including mining companies, government agencies, local communities, and conservation organizations.
- Fostering partnerships to leverage resources, knowledge, and expertise for effective conservation efforts.
- Engaging with local communities in conservation initiatives, raising awareness about the importance of biodiversity, and involving them in monitoring and restoration activities.

6. Long-term Planning and Adaptation

- Developing long-term plans for ongoing monitoring, adaptive management, and continuous improvement of conservation strategies.
- Reviewing and updating the strategy based on scientific research, emerging technologies, and changing environmental conditions.
- Seeking opportunities for knowledge exchange and collaboration with other similar conservation projects to learn from their experiences and successes.

Each mining site and its biodiversity challenges are unique, so it is essential to adapt and tailor the strategy to the specific context and conditions of the site. Seeking guidance from experts in the field of conservation and environmental management is recommended.

To minimize the negative impacts on biodiversity, sustainable mining practices, environmental assessments, and comprehensive monitoring programs are essential. Implementing biodiversity conservation measures, adopting cleaner technologies, and restoring degraded mining sites can help mitigate the effects of mining on biodiversity and promote more environmentally responsible mining practices.

By implementing conservation measures, it is possible to strike a balance between mining operations and the preservation of valuable biodiversity, ensuring the long-term health and resilience of ecosystems.

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