Reclamation and Landscape Design Suggestions for a Mine Tailing in Cartagena, SE Spain

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Abstract: In order to bring out a functional and sustainable land use in a highly contaminated mine tailing, firstly environmental risks have to be reduced or eliminated by suitable reclamation activities, then landscape design have to be created according to the new conditions of the area. Excavation and backfilling works in these areas are not suitable for sustainable reclamation and development strategies, because of the high amount of pollutants and the big volume of polluted soil. Preventing the spreading of pollutants to the surrounding land and water, creating a new ecological condition, erosion control and improving the soil conditions can be combined in the use of native vegetation which can make phytostabilization. This study explores the issues related to the landscape design suggestions in a mine tailing which can be combined with the use of phytostabilization as a reclamation technique. Introducing the more economic, painless and as far as natural reclamation solution in a new land use is important to provide the sustainability and to get the acceptance of society.

Key-Words: Landscape design, reclamation, phytostabilization, mine tailing, available metals.

1 Introduction
Mining activities in southeast Spain have generated high amounts of sterile materials accumulated in pyramidal structures called tailing ponds characterized by strong acidification processes, high salinity, accumulation of metals and scarce or null vegetation [1]. Reintroduce of a vegetation cover can fulfil the objectives of stabilization, pollution control, visual improvement and removal of threats to human beings [2]. In the initializing of plant colonization, incorporation of organic amendments into contaminated mine soils has also been proposed as feasible, inexpensive and environmentally solution practise, as generally such wastes can improve soil properties [3]. Besides, vegetation itself may contribute to metal immobilization processes through biological activities in the production of organic matter [4], which is seen an emerging technology called phytostabilization. Phytostabilization is described as the use of metal tolerant plant species to immobilize heavy metals through absorption and accumulation by roots, adsorption onto roots, or precipitation within the rhizosphere, but not in plant tissues.

There is a growing evidence that phytostabilization can facilitate the restoration of mining degraded land [5]. Because in so heavily contaminated soils, like in Sierra Minera Cartagena-La Unión, removal of metals using plants would take an unrealistic amount of time, so that phytostabilization can change metals to a less bioavailable form; exposure of livestock, wildlife and human can be reduced [6]. Phytostabilization needs to use native plant species in which the mine tailings are found, appropriate to the harsh climate of semiarid environments. Also these species can prevent the introduction of non-native and potentially invasive species that may result in decreasing regional plant diversity [7]. For creating a self-sustainable landscape in post-mining areas, utilization of natural plant species, is also important, thus, new ecological conditions can be created in the area.

While this study explores the issues related to reclamation and new land use of a mine tailing, on the other hand integration of these components in a recreation area is trying to be provided in a landscape conceptual design.

2 Materials and methods
2.1 Case study description
The study area is in countryside close to newly emerging resorts in a scenery location and covers a
2.5 ha of El Lirio mine tailing in Sierra Minera Cartagena-La Unión, southeast Spain. Environmental problems and public safety concerns resulting from unvegetated structure of the tailing, made this area a critical case of study, where the resolution advisories has to be brought out immediately in the frame of ecological and sustainable considerations.

2.2 Procedure

Natural, cultural, physicochemical, biological geochemical characteristics of the landscape were analyzed. These characteristics are all important for reclamation process, for giving a new function to the area and for creation of a landscape design. One of the main important issues for plantation design in a metal-mining area in order to combine it with landscape design is to know the distribution of available heavy metals. Heavy metals available for plants constitute one of the most important factors which directly effects plant growing. According to the distribution of the pollution, the places which can be opened for the use of the visitors and the places which will be focused on reclamation activities can be determined.

After analysing and evaluating these characteristics [8, 9, 10] which were held on the area between 2004 and 2009, the effects of different amendments on plant colonization and their successful results such as recuperation of some soil properties were assessed; application of marble mud and pig slurry and development of phytostabilization techniques was suggested in order to make the reclamation of the area and to create a new landscape design.

The areas which are thought to make phytostabilization were chosen after the assessments that are mentioned above. Besides plantation for phytostabilization, the use of native ornamental plant species was suggested in non contaminated areas for several aims such as increasing attraction, redirecting of visitors, preventing the entrance to the places which are forbidden for visitors, etc.

Due to the priority of plantation because of reclamation efforts, after choosing the contaminated areas for reclamation objectives, suggestions have been made in terms of landscape design for the rest of the area, related to its new land use.

3 Results and Discussion

Figure 1 shows the distribution of available heavy metals in El Lirio tailing. It is possible to see 9 different level polluted areas according to their context for each element (Zn, Pb, Cd).

With respect to the soil plant toxicity levels that are showed in Table 1 [11], Zn is not toxic in the 1 level of the area and is partially acceptable in 2 level, but in the rest of the mine tailing, Zn is approximately from 1.8 to 19 times toxic for plants. Pb is not toxic in the 1, 2, 3, 4 and 5 levels of the area. However, Pb toxicity from 6 to 9 levels of the area reaches until 3 times more than index. With respect to Cd amount, it is not toxic in 1, 2 and 3 levels of the area, is partially acceptable in 4 level, while in the rest Cd toxicity is ranging from 2.5 to 8.3 times for the plants.

In regard to these gradually changes of available heavy metals density of phytostabilization measures can be separated into graded ranks and the areas which will serve to public use can be determined. In Figure 2 toxic amount distribution of metals and the parts under toxic limits can be seen.

Figure 1- Spatial distributions of available metals (Arcview 3.2)
In the plot experiment which is mentioned above related to the effects of different amendments on plant colonization, marble mud (CaCO$_3$) was used for immobilising metals, removing them in a mineral form such as oxi-hydroxides and carbonates, and creating better conditions plant development. In order to add nutrients, organic matter and nitrogen; pig manure and sewage sludge were applied and according to the results of the experiment the better conditions was obtained from soil amended with pig slurry. This initial incorporation of organic matter has promoted the microbial activity and establishment of vegetation, which remains after 5 years of application. This vegetation cover includes some native species of the area: *Zigophyllum fabago*, *Piptatherum miliaceum*, *Dittrichia viscosa*, *Phragmites australis*, *Helichrysum decumbens*, *Sonchus tenerrimus*. Eventhough these spontaneous species colonized the ponds after amendments applications without seeding, some plant species are suitable for phytostabilization process. In order to observe their effect on soil characteristics, we suggest establishing experimental trial in the most polluted parts of the tailing pond. Figure 3 shows the proposed design of the experimental areas which are inspired from Mel Chin's Revival Field [12, 13]. Revival Field is an example which shows that public art can also serve as a venue for experimental installations. It is an art-science work that explores how plants can safely remove compounds from contaminated soils and was the first replicated field test conducted as an art installation in the US. Chin selected plants to remove toxins from degraded land and arranged them into a bulls-eye shape, surrounded by industrial fencing. At the time, little was known about the effectiveness of phytoremediation, and both research efforts and money were scarce. The project helped to confirm the effectiveness of the technique. By the help of these experimental areas the phytostabilization technique which is suggested to use in the area can be diversified such as the places only with amendments without seeding, the places with amendments and with seeding, different plant species, etc.

The aim is to reduce or eliminate the negative effects on environmental and public health of the metal-mining area by creating a new functional and sustainable landscape as shown in the Figure 4 which presents the ideal concept design for El Lirio mine tailing.
According to the design only the area in which the toxicity level under limits was opened to the visitors. Visitors are not allowed to enter to the phytostabilization areas because of the maintenance requirement of phytostabilization process. Surroundings of these areas were closed by using fences and in several places with native ornamental plants, which are naturally grown in the area. In the most contaminated areas of the tailing phytostabilization experimental areas are located in order to make investigations related to the improvement of the technique. Through on the both sides of the walking path, design process of the mine tailing and phytoreclamation explanation panels will take place. Parallel to this path also there will be a bidirectional bicycle path which is separated from the pedestrians’ with a plant cover border in order to provide the safety of both pedestrian and cyclist. At the end of both paths, which they reach to the most scenic place of the area, sitting area will be located. In order to provide shadow in this area, pergolas and/or gazebos can be used.

4 Conclusions
The present work shows that if the environmental risks can be reduced or eliminated, recreational activities can be developed in a mine tailing. Integration of reclamation efforts and recreational activities, based on the safety of both environment and public, can be realized by the help of landscape design suggestions.
Use of amendments and phytostabilization plant species can reduce the environmental risks of the area, by immobilizing heavy metals, preventing erosion and their spread to the surroundings. After these conditions are obtained, educative value of the experimental area can be used to improve the knowledge of the visitors; on the other hand, a new investigation opportunity or in other words environmental education tools can be given to the academic institutions.
Instead of creating new recreational areas, a waste land can be returned to a new functional and sustainable area which can serve for the requirements of the public.

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