# BIODIVERSITY CORRIDOR TO RECOVER THE AREAS AFFECTED BY ONE OF THE BIGGEST ENVIRONMENTAL CATASTROPHES REGISTERED IN SPAIN

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## Introduction

A biodiversity corridor was establish to recover the areas affected by one of the biggest environmental catastrophes registered in Spain. The accident took place due to the break of the open-air deposit in a mine located in the south-west of Spain. The studied area is along the Guadiamar river and close to the National Park of Doñana, important ecological reservation considered World Heritage and classified by the UNESCO as Biosphere Reservation. The deposit contained sedimented solids and water with diverse metallic contents in suspension, coming from the washing of the pyrite extracted and processed in the mine. The seriousness of this disaster was owed fundamentally to the nature and volume of the poured substances. A wide surface was affected, 4.500 hectares, being the quantity of toxic water spilled between 3 and 4 cubic hectometres and the volume of sludge and soil to remove about 2,25 cubic hectometres. It was also a highly polluting spillage, because there were waters and polluted sludges with toxic residuals of extreme sulfuric acidity and with a high content in ions of heavy metals as iron, magnesium and zinc, intermediate content in cadmium, lead and arsenic, and low content in copper, chromium and mercury. They are bio-accumulative products that produce important effects on the trophic chains in the long term. The spillage supposed a high risk and impact for the ecosystems of the Park, and affected directly to the marshlands that are in the area of influence of Doñana. To recover these damaged soils, first of all it was necessary to remove the sludges completely and to neutralize the acidity, getting the disminution of the ionic activity of the heavy metals and of the final dilution in the soil, until reaching some levels below those allowed. The establishment of vegetable species that cover the affected soils started after the sludges were removed. The Green Corridor along the whole basin of the Guadiamar river, was constituted by different arboreal, bushy and thicket species. All these species were perfectly adapted to the environment, so that the risks of problems that can arise were minimum. Simultaneously to the introduction of this vegetable corridor, a program for the soil recovery was developed, looking for the development and implantation of the vegetation that better adapted to the pedo-climatic conditions of the environment. Autochthonous species were used, adapted to the conditions of the soil and of the climate, with low hydric needs and that they allow to improve the ecological structure and landscape of this area. The establishment of vegetable species with capacity of extraction of metals, like the aromatic plants, allowed the covering of the soil that remains unprotected after the removal of sludges and subject to erosion processes.

## Characterization of the tailing sludges

Heavy metals that exist in mining sludges can have some very harmful effects as environmental pollutants because they cannot be eliminated through the biological degradation. They tend to accumulate in the environment, getting associated to the organic and inorganic matter by adsorption, complex formation and chemical combinations processes. There exist processes that can make that the metals immobilized in the silts are remobilized, what creates an important risk for the quality of the waters. To determine this quality it is fundamental to know the values of the contents in metals and the acidity of the waters during the different meteorological stations. In general, the margin of pH 6,5-9 is considered tolerant for the aquatic life. Analyzing the analytic results of different samples took along the riverbed, was deduced that the composition of the spilled materials was very homogeneous. The tailing sludge bulk density was 1900 $Kg*m^{-3}$. The composition of the sludges was related to the typical composition of the pyrite, although with less copper, lead and zinc, due to the flotation process (Table 1). With regard to the other metals is important to indicate that there were values smaller than 0.5% of manganese and smaller than 0.01% of cadmium, mercury and lead. The rest, approximately between a 35 and 45%, was constituted by sulfur, in the chemical form of sulphide and 10% by silicates. In general, it can be said that the fluvial silts contaminated by the sludge of pyrite had concentrations of some elements, three orders of magnitude higher to those of the natural fluvial silts. The zinc, lead, arsenic, copper, cobalt, talio, bismuth, cadmium and mercury were among these elements.

**Table 1:** Composition of the sludges in percentage

| Element | % |
|---|---|
| Iron | 34 at 38 |
| Copper | 0.1 at 0.2 |
| Lead | 0.8 at 1.2 |
| Zinc | 0.7 at 1.2 |
| Arsenic | 0.5 at 0.6 |

**Establishment of the Green Corridor**

When choosing the different vegetable species that were implanted along the Green Corridor it was fundamental to analyze their capacity of extraction of the underground waters, that is to say, to what level on the water height of the phreatic layer the plant can be as maximum, so that their appropriate use can be definitively assured (Table 2). The Guadiamar basin was occupied by a typical vegetation of riverside (Figures 1 and 2). In the farthest part of the riverbed elm trees or ash trees could settle down, depending on the soils being more basic and eutrophic or sandier, respectively. Next, occupying the areas that are usually covered when floods take place, big poplar groves were located and could be alternated with different species of arboreal willows. These trees were bound with diverse climbers, as the wild vine or the sarsaparilla, giving this way a bigger covering to the soil. Much more near the riverbed, where there is a bigger availability of water and light, the characteristic bushy formation would be constituted by willows and tamarix, which would settle down fundamentally in more saline areas, where the variations between the big avenues and the droughts are very accented along the year. At the end of the riverbed, reedbeds, cattails and other types of taken root aquatic plants will grow and will complete the pursued image that will serve as final link between the river and the external natural medium. Inside the riverbed small islands will be formed that will be occupied by bushy species like willows, tamarix and oleanders. Wrapping the whole Green Corridor, it was advisable the installation of a forest system constituted by mediterranean typical vegetation, like holm-oak wood and cork-oak wood, depending on the soil type. Next to these two main species, others were settled down as wild olive tree, algarroba tree, palm, strawberry tree grove, lentiscus, broom, kermes oak, thyme, rosemary, greater asparagus, spurge laurel and honeysuckle. They were joined with more or less intensity depending on the hydric and pedological characteristics of the area. In the intermediate fringe between the high part of the basin and the marshlands area, ash trees, elm trees and poplars will be mainly included, depending on the characteristics of the land and of the phreatic layer depth. In marshlands area will be species adapted to conditions of salinity like tamarix, cattails, rushes and bulrush.

**Table 2:** Distribution of the different vegetable species of the Green Corridor in function of the depth, in meters, of the exploited waters, being the depth Z=0 the corresponding to the soil surface.

| | | Vegetable Formations | Depth (m) |
|---|---|---|---|
| | | Elm tree grove, Ash tree grove | +3 ♦ +2 |
| | Hygrophyllic | Poplar grove, Willow grove, Osier, Bramble patch, Vine arbor | +2 ♦ +1 |
| Hygrophytic | (Soil moisture) | Willow grove, Osier, Tamarix, Reedbed | +1 ♦ 0 |
| Vegetation | | Oleander field, Tamarix, Willow Grove, Poplar Grove, Ash tree Grove | Small islands |
| | Hydrophyllic | Reedbed, "Bodonal", Rush | 0 ♦ -0,5 |
| | (Free water) | (Aquatic communities), Broadleaved Pondweed, Bassinet | < -0,5 |

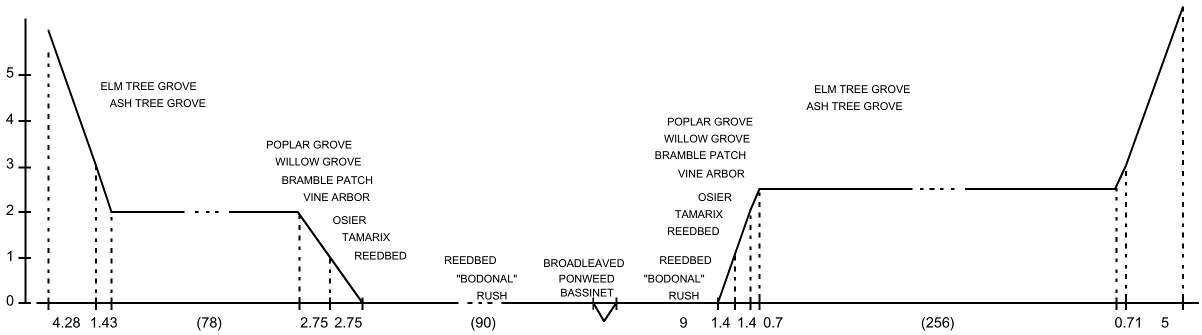


**Figure 1:** Section of the high part Guadiamar river basin showing the different vegetable species distribution of the Green Corridor as function of the exploited waters. Z=0 corresponds to soil surface. All measurements are in metres. (Measurements in brackets are not at scale)

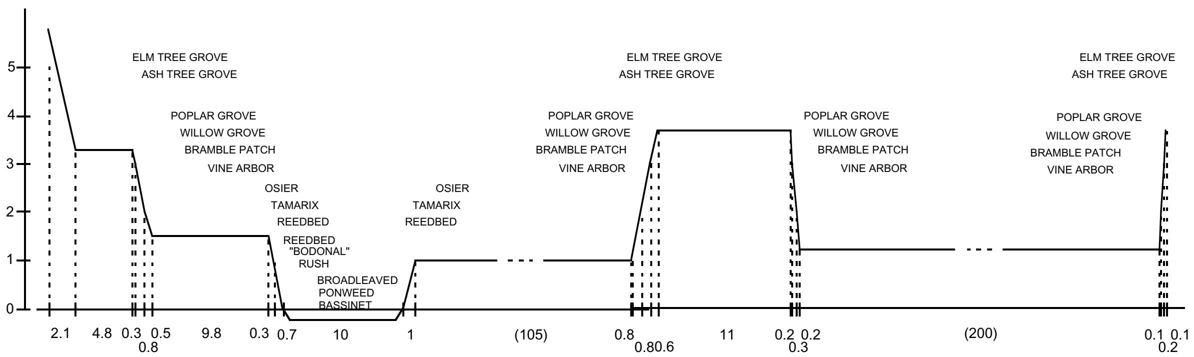


**Figure 2:** Section of the low part Guadiamar river basin showing the different vegetable species distribution of the Green Corridor as function of the exploited waters. Z=0 corresponds to soil surface. All measurements are in metres. (Measurements in brackets are not at scale)

With the establishment of the Green Corridor was carry out the restoration of the water contributions, in quality and quantity, necessary to recover the traditional dynamics of the marshlands of Doñana.

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