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Exploring Clayed Topsoiling for Heavy Metals Isolation in Central Nortern Chilean Copper Mining

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Abstract — Around the world, the typical tailing pond infrastructure only consider the construction of simple contention walls made by different gradient, and just in a few cases contain the material with a HDPE layer or as it is required by the local authorities. However, large number of active and abandoned tailing ponds doesn't have this isolation layer or any procedure to prepare and stabilize the soil before the installation of the dam. Some authors have suggested topsoiling as an alternative to protect the soil from pollution using clay as chemical immobilizer due it's molecular expandable structure; for this reason, the main purpose of this study is to explore the feasibility of use clay-sand topsoiling in the Central Northern Chile, due the natural availability, potential economical low cost and ecological efficiency.

Index Terms — Tailing Ponds, Mining Industry, Clay, Topsoiling, Heavy Metals Isolation, Impermeabilization, Groundwater systems, Central Northern Chile.

1 Introduction

In recent decades, Chile has established itself as the world's largest copper producer, moving from 14% of world production in 1960 to 32% in 2012, representing 13% of gross domestic product and 60% of foreign exports [1]. At present, the production of fine copper reaches 5,2 Mton, that to obtain it must process between 700 and 800 Mton of mineral. The rest, becomes part of the tailings, which accumulates in different types of deposits and over time the shape and technique of building deposits has been changing and increasing the size of these facilities [2]-[3]-[4].

According to [5], even some copper-mining operations, which use flotation processes, generate a total of approximately 100,000 Mtpd of tailings that need to be stored in a cost-effective, safe and environmentally friendly manner. It means ensuring optimal containment and preventing seepage from the impoundment through the dam and adjacent areas, for environmental protection and dam safety [5].

The main environmental problems associated with the mining sector of central Chile are: air pollution due to gas and particle emissions; water pollution by liquid effluents containing particulate matter, dissolved metals and acids; soil contamination; and risks caused by abandoned mining sites and tailing dams [6].

Tailings dams are some of the largest earth structures geotechnical engineers construct; their embankments are often built with steep slopes using the coarse fraction of the tailings thereby saving on cost. In order to keep such impoundments standing is one of the most challenging tasks in mine waste management [7].

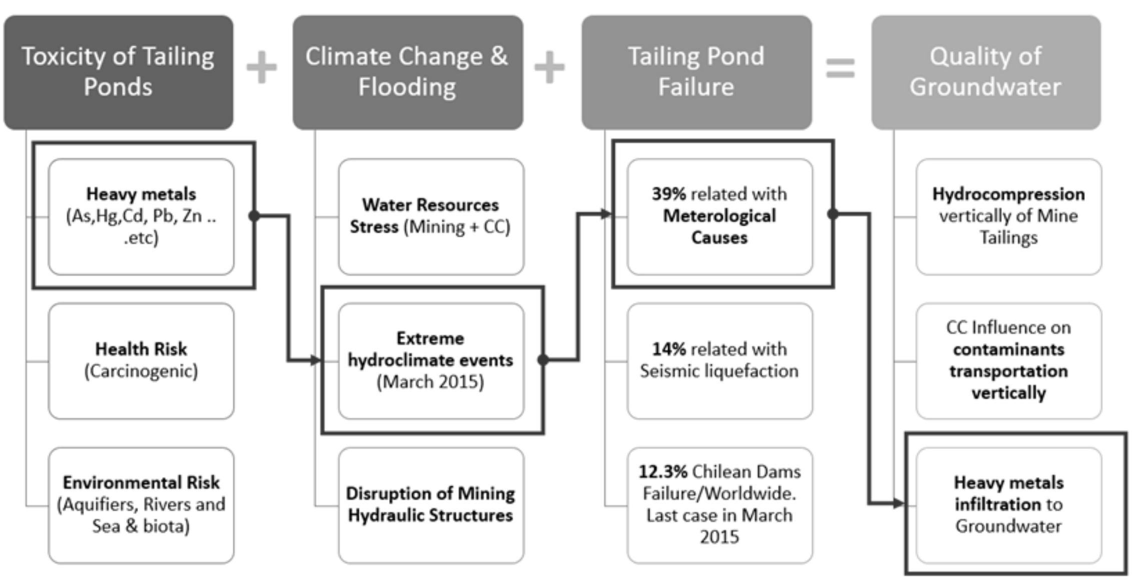

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Fig.1 Chilean Tailing Ponds Scenario Diagram [8]-[9]-[10]-[11]-[12]-[13]

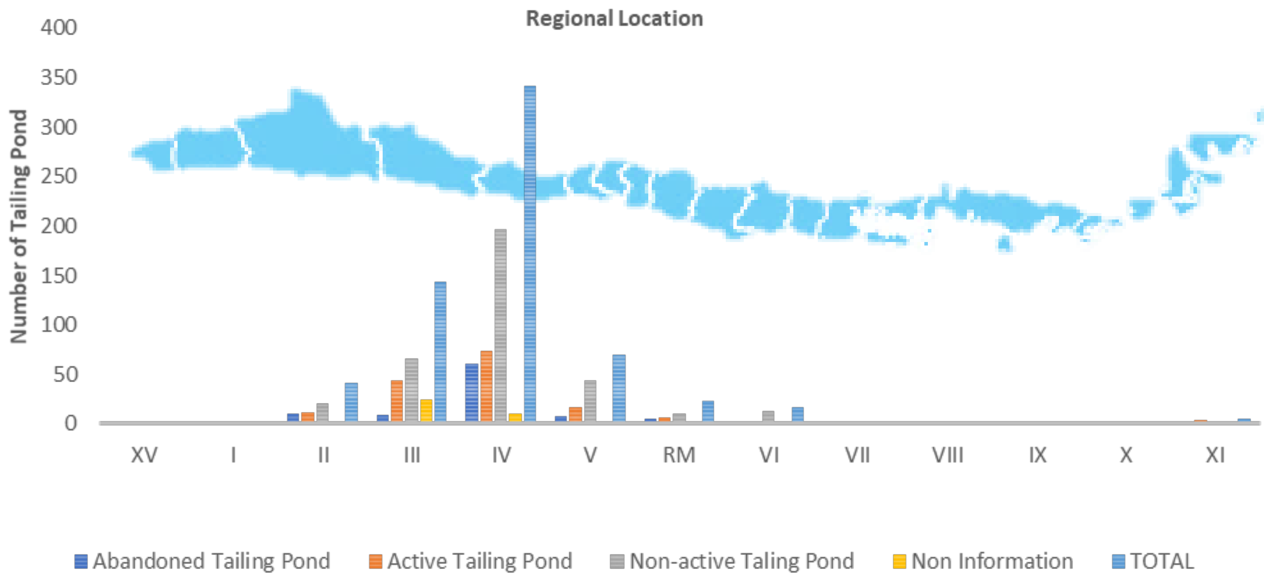

Fig.2 Chilean Tailing Ponds geographical distribution according to [4].

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According to Fig.1, 39% of the failures of Tailing Ponds correspond to meteorological causes (such as extreme precipitation processes), 14% with seismic liquefaction and the Chilean cases represents around a 12,3% of the worldwide cases.

The last case was during March 2015 due the extreme hydroclimate events in the northern Chile which made disrupt of mining structures. Around the world, the typical tailing pond infrastructure only consider the construction of simple contention walls made by different gradient and mostly by mixture of clay/sand, and just in a few cases where the company has more strict policies, they contain the material with a HDPE layer or as it is required by the local authorities [7].

2 Materials and Methodology

The following discussion is based on the Environmental Assessment Service from Chile public data (www.sea.gob.cl) related with Mining Projects approved during the period 2003-2017; which incorporates the construction and operation of a Tailing Pond from the Copper Industry. All projects consulted corresponds to Copper Mining Industry along the Northern and Central Chile.

In the consulted mining projects period 2003-2017, it was identified the most common soil characteristics. The interpreted data was extracted from the Environmental Impact Assessment reports and they are according to ASTM D5521-05 Standard Practice for Classification of Soils for Engineering Purposes [14].

By other hand, it was correlated the heavy metal geochemical content indicated by National Geology and Mining Service of Chile (NGMS) public database (www.sernageomin.cl) in Mining Projects, as well as the distribution of tailing ponds across the Chilean Territory.

3 Discussion

3.1 Distribution of Tailing Ponds in Chile

Based on [4], the distribution of tailing ponds across the Chilean Territory are concentrated in Central Northern Chile [4]-[6]-[15]-[16] (Regions III and IV) but mostly and an increase number of active and abandoned tailings are located in IV Region of Coquimbo mostly around Elqui River Basin (Fig.2).

The Elqui river basin in Chile extends between 29°27´– 0°34´S and 71°22´– 69°52´W, covering an area of around 9,700 km^2 [17].

According to Fig.2, around 52,9% of the total amount of tailing ponds along the Chilean territory is contained in IV Region of Coquimbo; from which ones 73 are considered in active operation, 197 non-active and 61 abandoned.

Despite the aridity and variable climatic conditions, the Elqui Basin has undergone important development in agricultural, agro-industrial, and mining activities. Mining is historically important: three mining districts in the Elqui basin, the Andacollo, Talcuna, and El Indio, are particularly important [17]-[18].

Currently there is a wide number of studies related with the local environmental evidences on the degration of the water and soil resources linked with mining development [19]-[20-[21]-[22]-[23].

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3.2 Geosynthetics in Tailing Ponds

Geosynthetic materials have become critical components in the design and performance of mining facilities [24]. Due to the nature and location of mining projects, the performance envelope of geosynthetic materials is often pushed beyond the limits making them susceptible to mechanical damage, and sensitivity to extreme climate conditions [5].

According to Fig.3 it is possible to identify the high frequency of use of geotextiles in starting wall (65%), in other infrastructure around 20% and just in 10% over foundations. Considering for several of those projects and the scare information that it is possible to obtain by EAS, only the isolated surface versus total tailing pond surface ratio reach 27,5% average; results an isolation gap which easily can allow the vertical infiltration to water table or any close aquifer.

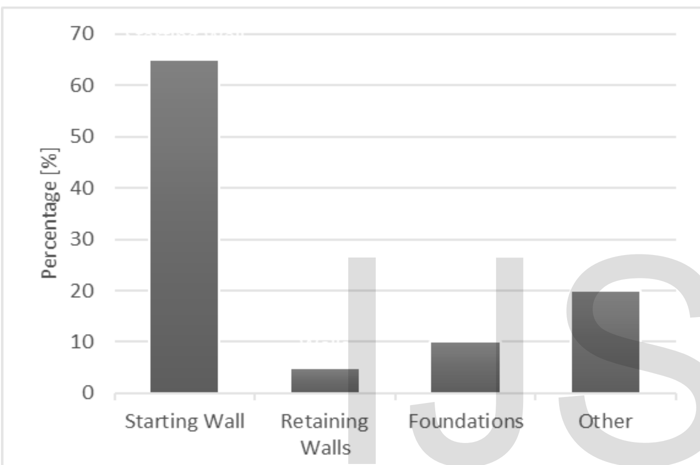

Fig.3 Preferred Impermeabilized Tailing Pond Parts in approved mining projects in Central Northen Chile 2004-2017.

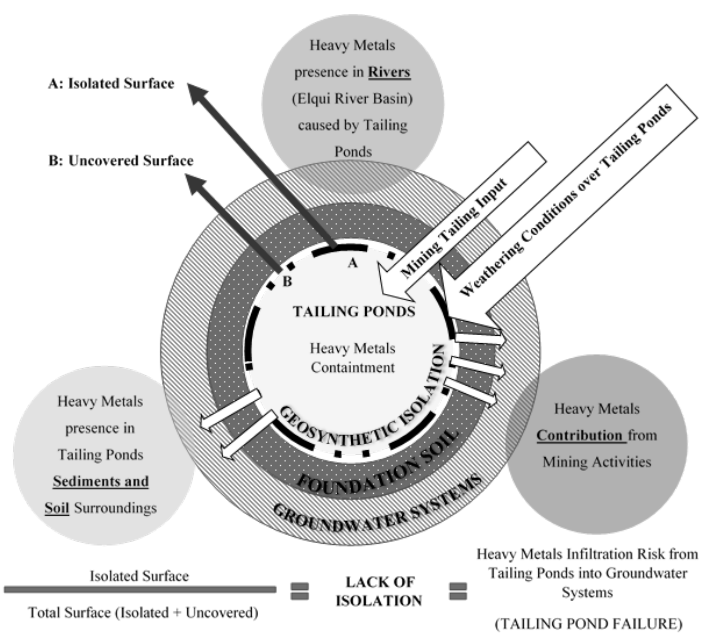

Fig.4 Central Northern Chile Tailing Pond Containment current situation.

As it is possible to see in the Fig.4, the current state of condition of several tailing ponds in Chile approved by the local authority allows us to have an impression of the isolation ratio in mining impoundments; the surface which is covered by geosynthetics technology (isolated surface) represents just a fraction of the total surface once the mining operations are in their full projected capacity.

3.3 Exploring Clay availability and uses as Topsoiling in Mining Projects of Central Northern Chile

Following the Fig.5, there are described the findings in several foundation soils of the consulted projects. The soils tend to be in most of the cases SC, SM and GP, which ones according to [14] corresponds to Clayed Sands (26,3%), Silty Sand (21,1%) y Clayey Gravel (21,1%).

Soil, peat, and clay minerals are most abundant natural barriers that can be suitable for soil protection in a supergene environment are physicochemical or, more precisely, sorption barriers [25].

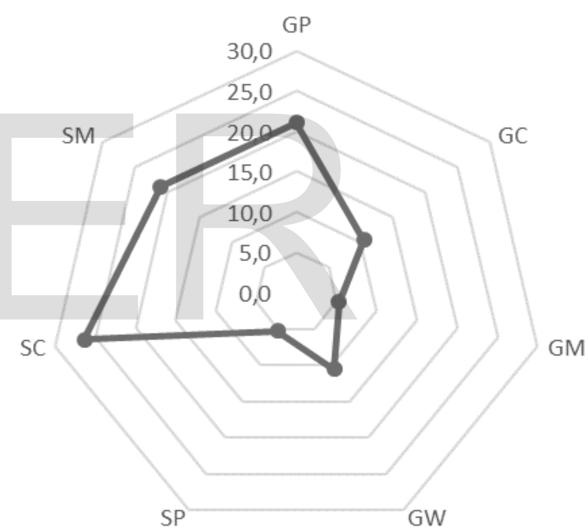

Fig.5 Percentage Distribution Soil Types presented in approved mining projects in Central Northern Chile 2004-2017

Particularly, the clayed fraction of soil is the most responsible for sorption by its mineral particles. There are two major types of clay minerals found in soils: 1:1 (kaolinite) and 2:1 (montmorillonite and illite [26]. The 2:1 type of clays have much higher total surface area than the 1:1 type has because of the existence of the internal surface area caused by the week van der Waals forces; which allows to be expandable and have higher cation exchange capacity [26]-[27].

Several clay studies related with heavy metals adsorption and ion exchange process has been reported by [27]-[28]; which indicates the important implications of the use of clay for future environmental impact assessment, mitigation efforts and remediation strategies.

Considering the low-cost of pumice and common clay for en-

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vironmental applications in small-scale mining industry, Kelm et al using batch methods, which demonstrated an excellent retention of Cu (>1100 to <0,05ppm), Fe (400 to >0,1ppm), Mo (0,7 to 0,3ppm) and As (174 to <5x10-4ppm)[27].

The clayed applications in the Copper Mining Industry in the Central Northern Chile it might be a potential good option due the natural availability of the resource, potential low costs and ecological efficiency.

The high ecological and economic efficiency of geochemical barrier implementation for environmental protection accents the potential of this research area and the possibility of its wide practical application, when creating new nature conservation technologies and ensuring environmental safety at mining sites [25].

4 Conclusions

Several studies have been performed in IV Region of Coquimbo related with the decrease quality of water and soil resources produced by the development of Mining Industry, mostly in Elqui River Basin. In consulted 2004-2017 Mining Projects located in the Central North Chile, the current state of geosynthetic surface in Tailing Ponds represents in average just a 27,5% of the total projected surface. The rest of the unconvered surfaces might be exposed directly to deposition of Tailings.

Higher costs and environmental stresses caused by difficult terrain and location makes them susceptible to mechanical damage and potential risk of infiltration in groundwater systems. However, the natural presence of clayed soils in mining surroundings with the clay expandable and ion exchange capacity allows to suggest the possibility to use it as topsoiling treatment in tailing ponds foundations for isolation improvement.

Further research lines might be useful to be incorporated the clayed application conditions, weathering variables and their effects on the vertical migration of heavy metals. This would be useful in order to foundament the potential effects of climatological constraints such as Climate Change over the Mining Industry and especially over Tailing Ponds Technologies.

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