PHYSIOLOGICAL AND BIOCHEMICAL MARKERS IN THE PROCESS OF RESISTANCE OF HEAVY METALS IN THE ABANDONED MINING AREA OF SIDI KAMBER, SKIKDA, ALGERIA

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Mining activities produce large quantities of wastes which are highly contaminated with heavy metals. This can cause adverse effects on natural ecosystems, particularly on living organisms. The study reported here concerned the biomonitoring of pollution in the Sidi Kamber mining area, through the determination of various physiological mechanisms (bioaccumulation and translocation) and biochemical markers (chlorophyll (a) and (b), proline, total sugars and total proteins) active in resistance to heavy metals (Cd, Cu, Pb and Zn) contamination, using three plant species *Cistus monspeliensis, Rumex bucephalophorus* and *Verbascum sinuatum* as bioindicators. During the period of March-May 2015, soil and plant samples were collected from three different stations on and around the mine spoils and away from the mine in the study area. Soil and plant samples were systematically taken along a transect from the slope in the mining area, which included several extraction sites, depending on the altitude, biodiversity and distance from the mine. The total heavy metal fraction was determined by ICP-MS (Agilent, 7700X), whereas biochemical markers were determined by spectrophotometric techniques using a spectrophotometer *(Agilent, Cary 60)* using the following methods: Photosynthetic pigments determination (Lichtenthaler, 1987), Proline determination (Monneveux and Nemmar, 1986), Total proteins determination (Bradford, 1976) and Total sugars determination (Dubois et al., 1956). In addition, the translocation of heavy metals in different parts of the studied plants was measured by the calculation of the translocation factor (TF) according to the following formula: **TF**= Metal in leaves/Metal in roots.

The results revealed total contents of Zn, Pb, Cd and Cu higher than the regulatory limits of the European Union (EU-richtlinie 91/692/eWG.aBI eG. 31. dec. 1991 nr. l377. p.38). In addition, the bioavailable contents in plant tissues were found to be above normal values reported by Pugh et al., (2002) and Kabata-Pendias (2007), indicating that they may show signs of phyto-toxicity and therefore high soil pollution in this mining area. It was found that the studied plants are suitable for biomonitoring and phytoremediation of soils contaminated with heavy metals (HM). Nevertheless, despite these high HM levels, it appears that the plant species are not hyper-accumulators. The HM contents in the plants studied vary according to the plant species, the total metal content in the soil, and the bioavailability of metal as a function of soil physicochemical properties in the following order of abundance: $Zn \leq Pb \leq Cd \leq Cu$. It has also been found that *C. monspeliensis* accumulates more HM compared to *Cistus monspeliensis,* and *Verbascum sinuatum.* The TF of heavy metals Zn, Pb, Cd and Cu to the aerial parts of the plants proves to be a crucial indicator in the process of resistance to Zn and Pb. It has been found that *Cistus monspeliensis, Rumex bucephalophorus* and *Verbascum sinuatum* are better suited for the phyto-extraction of Cd and Cu and phyto-volatilization of Zn and Pb. In the case of Cu and Cd, a tendency to accumulate HM in roots and the ability to use plants in phyto-stabilization was also observed. The strategies of resistance of *Cistus monspeliensis, Rumex bucephalophorus,* and *Verbascum sinuatum* rely in large part on the action of biological molecules: chlorophyll, proteins, proline and total sugars as ligands for the disposal, accumulation or detoxification of HM pollution in different parts of plants. Obtained data showed also positive correlations (synergies) between Pb, Zn, Cd and Cu in plant tissues, which can be attributed to their common geochemical origin, similar behaviour and the human activities that introduce them into the medium. Negative correlations between Cu and Zn are attributed to antagonism and competition for active cell sites.

Key words: Biomonitoring, Biomarkers, Translocation Factor, Mining Area, Algeria