Chromium Ion Uptaken from Soil through Phytoremediation Using Zea Mays and Nicotiana Tabacum

تنظيف التربة من ايونات الكروم بواسطة الزراعة العلاجية وذلك بزراعة الذرة الشامية والتبغ

Murad Alhousani[1], Ahmad Abu-Obaid[*2], Husam Al-Said[3], Ayman Salah[4], Jamil Harb[5]

مراد الحوساني، أحمد أبو عبيد، حسام السيد، أيمن صلاح، جميل حرب

[1]Land Research Center, Halhul-Palestine. [2]Department of Chemistry, An-Najah National University, Nablus, Palestine. [3]Nakheel Palestine, Jericho, Palestine. [4]Palestine Polytechnic University, Hebron, Palestine. [5]Department of Biology and Biochemistry, Birzeit University, Birzeit, Palestine

Corresponding Author: obaid@najah.edu

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Abstract

Green technology “phytoremediation” approach was applied in WadiA lsamin in Hebron-Palestine to evaluate the plant efficiency in remediation of soil that is polluted with chromium (Cr). An open field controlled experiment was conducted to assess the efficiency of two plant species, namely corn (Zea mays) and tobacco (Nicotiana tabacum), in remediating the Cr-polluted soil. The concentration of Cr metal was determined in all plant parts (root, stem, leaf and fruit) for both plants using ICP-AES. The accumulation of Cr was higher in leaves than in the other plant parts for both plants with order of leaf>stem>root>fruit for corn plant and leaf>stem>fruit>root for tobacco.

Keywords: Heavy Metals, Corn, Tobacco, Phytoremediation, Palestine.

ملخص

تم تطبيق التكنولوجيا الخضراء (الزراعة العلاجية) في منطقة وادي السمن (الملوثة بعنصر الكروم) في الخليل لتقييم كفاءة وقدرة نباتات الذرة الشامية و التبغ على امتصاص وتخزين عنصر الكروم في مختلف أجزائهما من اجل تنظيف التربة من هذا العنصر. تم قياس تركيز الكروم في أجراء كلا النباتين (جذر وساق وأوراق وثمار) باستخدام جهاز مطيافية الانبعاث الذري في بلازما المقترنة بالحث (ICP- AES). ونتائج البحث أوضحت أن تركيز عنصر الكروم في نبات الذرة الشامية في الأوراق اعلي منه في الساق والساق أعلى منه في الجذور والجذور أعلى منه في الثمار أما نبات التبغ أعطى نتائج مختلفة فتركيز عنصر الكروم في الأوراق اعلي منه في الساق والساق أعلى منه في الثمار و الثمار أعلى منه في الجذور

الكلمات المفتاحية: معادن ثقيله، ذره شاميه، تبغ، الزراعة العلاجية، فلسطين.

Introduction

The problem of land pollution caused by raw wastewater which originated from remnants of wastewater and industrial part of Hebron-Palestine is the most serious environmental problem facing the region of south Hebron. The local wastewater stream known locally as “Wadi Alsamin” that is generated from domestic and industrial sources already destroyed thousands of hectares of agricultural land. The negative environmental impact of “Wadi Alsamin” wastewater increased progressively as it includes wastes of industrial area of Hebron city. The most devastating industrial entities are tannery factories and cutting stone plants, which discharged their raw wastewater without any treatment. In addition, Hebron district has no large-scale and operational wastewater treatment facilities, and consequently, pollution problems are becoming more complicated under wet flow conditions (e.g. Wadi Alsamin).It is well known that application of untreated wastewater to soil for years enriches soils with heavy metals to a concentration that may pose potential environmental and health risks (Carmina et al., 2003, p. 440). This is an ongoing problem that was born many years ago to the point that farmers abandoned their agricultural lands. Accordingly, these polluted lands need urgent remediation and restoration management. In this sense, the remediation approach has to be environment-friendly and also economically affordable, since conventional remediation approaches may not provide acceptable solutions (David et al., 1995, p. 468). A possible cost-effective, ecologically safe, and environmentally-sound solution is phytoremediation (Singh & Jain, 2003, p. 128). In this approach plants are used to remove or fix pollutants from the environment (Ilya, Robert & David, 1997, p.221). The phytoremediation technique can be used for pollutant stabilization, extraction, degradation, and/or volatilization (Elizabeth, 2005, p. 15; Shabir et al., 2012, p. 3991). However, the selection of plants for phytoremediation proved to be difficult, and depends mostly on their ability to accumulate moderate to high levels of metals – (Alireza & Farhang, 2010, p. 95). In this sense, corn (*Zea mays*) plant, which shows usually high growth rate, is one of the good candidates for phytoremediation (Akhionbare, Ebe, Akhionbare, & Ac-Chukwuocha, 2010, p. 993). It was reported that corn may absorb up to 0.1 mg. kg-1 of copper, cadmium, chromium, lead, nickel, and zinc; with such numbers corn may be considered as hyper accumulator (Akhionbare, Ebe, Akhionbare, & Ac-Chukwuocha, 2010, p. 993). In this respect, corn plants extract metals from contaminated soils and accumulate such metals in their shoots. Moreover, corn has a moderate bioaccumulation factor, which makes this plant a heavy-metal tolerant plant (Wuana, & Okieimen, 2010, p. 275). In addition to that, corns show high tolerance to heavy metals (Ulrich, 2003, p. 1939). In this sense, it was reported that corn plant effectively accumulated Cd and Pb (Amin, 2011, p. 17) and As, Cr and Cu (Grace, & Felix, 2011, p. 1). Concerning tobacco plant, previous studies indicated its usefulness as a hyper accumulator (Chitra, Sharavanan, & Vijayaragavan, 2011, p. 48; Houda, Mohamed, Mohamed, & Houda, 2009, p. 58). Furthermore, tobacco is considered as a potential candidate for sites contaminated with perchlorate (Sundberg, Ellington, Evans, Keys & Fisher, 2003, p. 505; Ellington et al., 2001, p. 3213), as these plants accumulate high levels of various metals (e.g. Zn, Pb and Cd) (Boonyapookana, Parkpain, Techapinyawat, Delaune & Juqsujinda, 2005, p. 117). Accordingly, the aim of this study is to assess the effectiveness of both corn and tobacco plants for the remediation of ‘Wadi AlSamin’ site that is highly polluted with chromium. The phytoremediation approach was chosen as an environment friendly that is economically affordable for local farmers.

Material and Methods

Site Selection and Location

Wadi Alsamin wastewater stream that located in the southern part of Hebron city in west bank of Palestine represents an open channel for the municipal raw wastewater with length of 44.3 km and width exceeding 70 m in some areas. The stream starts flowing from the industrial part of Hebron city (797 m above sea level) and passes through 18 Palestinian residential communities that are located on the stream bank and reaches Al Daherya area (396 m above sea level) (Figure 1). The wastewater stream is collected and treated in the wastewater treatment plant (Shouket) in Bersheva of area, and reused after that for agricultural purposes.

A part within wastewater stream with length of 5.3 km is served by transmission pipe since in 2004. The continuous flow of untreated wastewater rendered agricultural lands unproductive and hence abandoned by farmers. Our phytoremediation study was conducted in this part. The plot is divided into two sections: the first one is valley part where the soil is completely polluted by raw wastewater, and the second part is the sloppy area (out of wastewater stream).

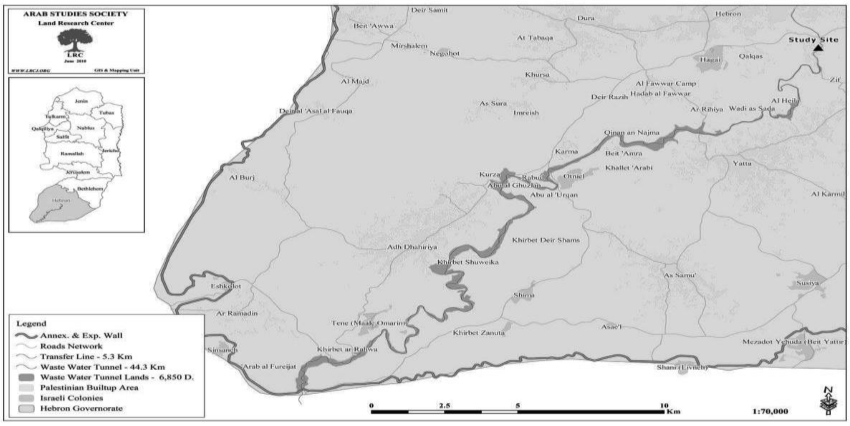

Figure (1): Wastewater Stream in Wadi Alsamin- Hebron. Source: Land Research Center - LRC, GIS and Mapping Unit, 2012.

Experiment Layout

The plot was divided to four sections, according to the distance from the wastewater stream: highly polluted (HP), medium polluted (MP), slightly polluted (SP), and ex-situ sections. Numbers of replicates were three for each level, and in each two plant species were cultivated. Consequently, the experiment layout (figure 2) includes 12 plots for each plant species, and the area of each plot was 9 m^2. The experimental design was completely randomized block design.

Plant Material

Two local plant species (corn and tobacco) were selected for this study, since farmers used to cultivate these two plants at commercial scale. Tobaccos were planted as seedlings, whereas corns were raised from seeds, and the planting density was 11 plants per m^2.

Sample collection and preparation

Composite soil samples were collected from each replicate plot before planting, and at the end of the growing season for both plant species. Each composite soil sample was collected from 5 positions from the top soil (the first 30 cm). All samples were air-dried and stored in plastic bags. After the end of the growing season from seed to seed

(March-October) with total period of 8 months, samples were collected also from plant parts (roots, leaves, stems and fruits). For each plant part a representative sample was prepared from three plants per each replicate. The number of leaves was counted and the three middle leaves were collected for analysis. Stem samples were collected at 20 cm height from soil surface. All plant samples were dried in an oven at 70 ºC for 4 hours.

Determination of soil pH and soil electrical conductivity (EC)

Soil pH was measured by direct method: through enough amount 5.0 g of soil into 25.0 ml of deionized water, the mixture was stirred for two hours and kept to set for overnight, the insoluble part was filtered out and aqueous residue was directly measured by (3540 pH & conductivity meter (JENWAY)) pH meter calibrated to trace HCl acidic calibrator 4, 9 acidic buffer, the same sample was subjected to microprocessor conductivity meter (EC) under identical conditions.

Heavy Metals measurement

A full description of soil profile in the study area was done to determine which heavy metals are needed for analysis. Out of eight heavy metals (Cr, Zn, Cd, As, Pb, Co, Ni and Mn) that were analyzed in the study area, five metals were detected (Cr, Zn, Ni, Pb and Mn) in the soil.

Dried samples of soil were sieved down to 0.2 mm in diameter, and plant samples were shredded to 2 mm size. After that, all samples were ignited at 600 ºC for 5 hours, and then cooled in desiccators to room temperature. The digested ash content of samples was mixed directly with concentrated nitric acid (69%) and hydrochloric acid (35%) with ratio 1:3 (HNO3: HCL) for 4 hours until solution is clear. Finally, the clear solutions were filtered through Wattman1 filter paper, and then diluted with distilled water to the required volume and analyzed by inductive couple plasma - ICP (Perkin Elmer-Optima 3000 R). The sample flow at ICP was 1 ml/minute in which the argon gas was used with plasma flow of 15 Liter/minute and nebulizer flow of 0.8 Liter/minute.

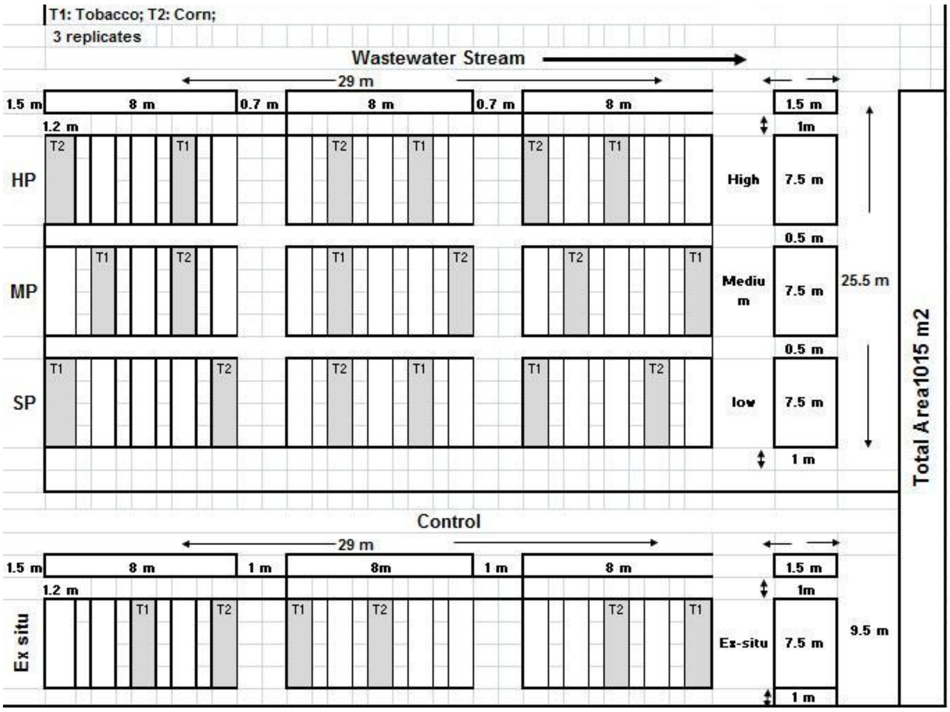

Figure (2): Experiment Layout, where the the polluted soil at valley soil was divided into (30 m width) for three levels, around 10 m per each level as illustrated at experiment layout. HP referred to highly polluted, MP to medium polluted, and SP to slightly polluted. T was referred to the type of cultivated plant as T1 for Tobacco and T2 for Corn.

Statistical Analysis

Statistical tests were done using SPSS software-15.0. The soil-plant data were analyzed by analysis of variance (ANOVA). They were evaluated at a 95 % confident level with Scheffe analysis.

Results and discussion

Soil pH

The soil pH ranged from 7.2 at the stream plot to 7.8 at the outer part. In addition, there are large difference between the ex-situ plot and the highly polluted level (pH) plot (Figure 3).The high soil pH of HP plot indicates that the untreated wastewater that has been discharged over decades possibly contains various chemical compounds, in particular Ca-compounds, which have alkaline reaction (Soon, Bates & Moyer, 1978, p. 269). The high soil alkalinity could also be due to the proximity of industrial sources of the wastewater to the study site, which already contains wastes that may raise soil pH such as tanneries and calcareous wastes from stone cutting (Delbert, Volk, Sheets & Wickliff, 1984, p.159; Emmanuel, 2008, p. 366; Sri, Khoirina & Rosich, 2012, p. 366; Shamshuddin & Fauziah, 2010, p. 1). On other hand, the soil in study area is considered as calcareous soil in which the CaCO3 content in soil is around 62% (Lu, Chien, Henao & Sompongse, 1987, p. 896). This soil pH is not optimal for most plants, although some plants prefer such high soil pH (Rafati et al., 2011, p. 961).

The EC values from wastewater stream; out-stream soil parts show no significant differences (figure 3). In this sense, such EC values fall within the tolerance range for plant growth and development (Rafati et al., 2011, p. 961). Taking into account that soil electrical conductivity is usually influenced by a combination of physio-chemical factors (Corwin & Lesch, 2005, p. 11), the slight and non-significant differences between polluted and control plots is most probably due to leaching and runoff of dissolved solutes, in particular in the last years following the construction of underground pipes in that area. In addition, the EC values correlate positively with the pH values of assessed soils. These results agree with previous studies (Ouhdai & Goodarzi, 2007, p. 109). Moreover, various researchers stated that electrical conductivity has a positive correlation with metals (Rana, Dhankhar & Chhikara, 2010, p. 513).

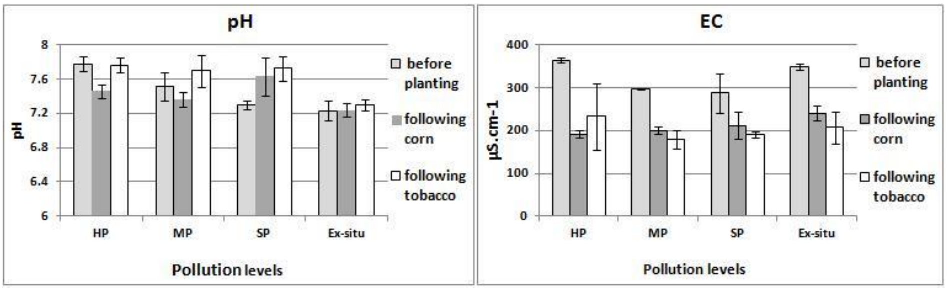

Figure (3): Changes in pH and electrical conductivity (EC) of soil after planting with corn and tobacco plants. HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: Outside Stream Area.

Chromium (Cr) Content in soil

The chromium level of the polluted soil averaged 147 mg.kg^{-1}, whereas the level of the outer part of stream averaged 101.3 mg.kg^{-1}. Such a difference was not significant (figure 4), which clearly indicated that over decades of discharging industrial untreated wastewater was highly polluted the whole soil along the valley, which resulted in the polluted of plots far from its current path. Such very high levels of Cr is not suitable for plant growth and development, as the Cr content in healthy soil is in the range of 10-50 mg.kg^{-1} (Adriano, 2001, p. 867). The high chromium level is directly related to the discharge of untreated tanneries wastes that originate from ten tannery factories of the industrial area of Hebron city. It is known that chromium salts, in particular chromium chloride, is widely used for tannery industry (Seema & Alok, 2011, p. 309). In this sense, chromium is the primary threat when tanning comes in practice (Alebel, 2010, p. 53). Therefore, the untreated tannery waste is considered the main pollutant source in Wadi Alsamin area.

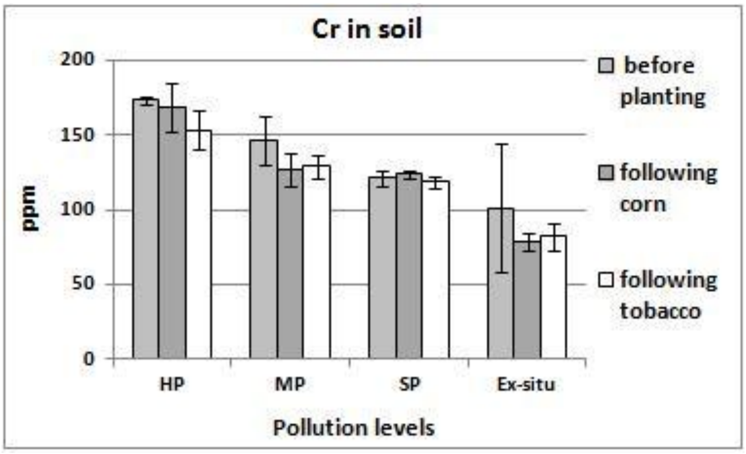

Figure (4): Chromium (Cr) content of soil before and after planting with corn and tobacco. HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: Outside Stream Area.

Chromium (Cr) content in corn and tobacco plants

The contents of Cr in plant parts are shown in figure 5. Fruits exhibited the least content, whereas the highest contents are recorded for leaves. Such trend is expected as the metals are translocated according to transpiration stream, and it is well known that leaves have much higher levels of transpiration compared to other plant parts.

A major trend noticed here is that Cr content of plants from HP plots is the lowest, which may indicate strong impairment of growth that retarded severely the uptake of that metal.

It is worth to mention here that uptake of heavy metals by plants is the function of their external concentrations and transpiration (Beauford, Barber & Barringer, 1977, p. 261). Moreover, the mechanisms of metal accumulation involve also extracellular and intracellular metal chelation, precipitation, compartmentalization and translocation in the vascular system (Ilya, PBA, Slavik & David, 1994, p. 285). Consequently, the accumulation and distribution of heavy metals in plant parts are dependent on various factors, including plant species, elemental species, pH, temperature, cation exchange capacity, dissolved oxygen, and secretion of roots (Shuiping, 2003, p. 335). However, transpiration rates remain the most important factor, and in the current study the observed Cr content sequence along plant parts agrees with the sequence documented in previous study (Wallace, Alexander, Chaudhry, 1977, p. 751; Mst & Sheila, 2012, p. 1). The extent of heavy metals accumulation in plant parts recorded here is higher than the typical trace element accumulations in vegetative parts that are reported by (Adriano, 2001, p. 867) which may signify the possible usage of these plants to remediate soils polluted with chromium.

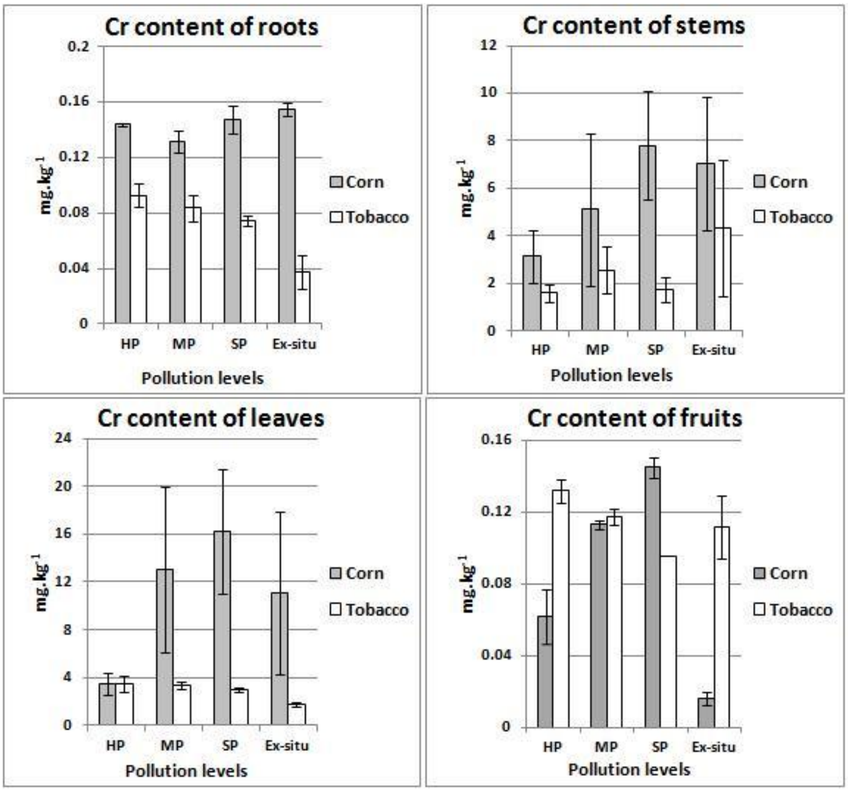

Figure (5): Chromium (Cr) contents of plant parts following cultivation. HP: Highly polluted MP; Medium polluted; SP: Slightly polluted, ex situ: Outside stream area.

Assessing of phytoremediation efficiency of polluted soil

The bioaccumulation factor (*f*) was calculated for corn and tobacco plants in order to evaluate the phytoremediation efficiency upon cultivation in polluted soils. The bioaccumulation factor (*f*) is the ratio of plant metal concentration divided by the total metal concentration in soil (Xingfeng, Hanping, Zhian, Ping & Bo, 2010, p. 2063; Marius, Ionel & Mihaela, 2009, p. 127; Vidya & Chandrasekaran, 2010, p. 60). *f* value of corn plant for Cr metal ranged from 0.04 - 0.29,while the *f* value of tobacco plant for arranged from 0.03 - 0.18 (figure 6).The higher *f* factor indicates the higher plant efficiency in phytoremediation. These *f* values are important since both corn and tobacco plants survived high pollution conditions. Therefore, on the long-term, these plants can be used to remediate polluted soils. Recent studies have considered corn as potential candidate for phytoremediation (Akhionbare, Ebe, Akhionbare & Ac-Chukwuocha, 2010, p. 993) with a measured bioaccumulation factor in contaminated soil of 0.33 (Vidya, Chandrasekaran, 2010, p. 60). (Marius, Ionel & Mihaela, 2009, p. 127). The *f* value for corn and tobacco obtained in this study were also higher than the *f* value for some ornamental plants such as Aptenia Cordofolia L. and Brassica Juncea L. with (f value = 0.1 - 0.88) which were recommended as phytoremediators (Fuat, Zeyneb & Nihal, 2011, p. 857).

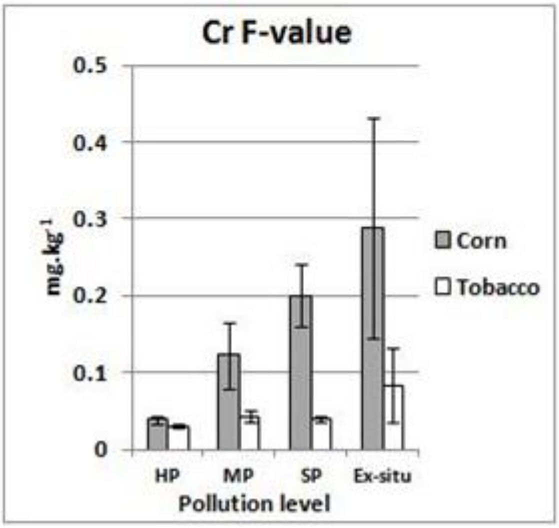

Figure (6): Accumulation coefficient of chromium (Cr) following cultivation. HP: High polluted MP; Medium polluted; SP: Slightly polluted, ex situ: Outside Stream Area.

Conclusion

Following heavy metals determination in soil, it was found that chromium exists at very high level, and can be considered as the main pollutant in that area. Both corn and tobacco plants were proven to tolerate such high levels, and accumulate relatively high amounts of Cr in their organs, particularly in leaves. Moreover, this study showed that the corn plant was more effective than tobacco for chromium remediation.

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