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# ASSESSING THE ENVIRONMENTAL IMPACT OF HEAVY METALS ON SOILS CAUSED BY AIR DISCHARGE ON SOIL: AN EXPERIMENTAL ANALYSIS OF CHROME AND CADMIUM ACCUMULATION IN CARROT CROP IN AN AIRPORT AREA

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## ABSTRACT

In the last years, the environmental impact of heavy metals on soil quality and food safety, has begun an important problem in peri-urban area. The present study is aimed at providing an experimental analysis of chrome and cadmium accumulation on an indicator crop (carrot) in four farms close to the "Leonardo da Vinci" International Airport of Rome (Italy). Carrot crop is an important and traditional agricultural resource in the studied area. High concentration of Copper and Chrome was observed in the carrot leaves and is considered a proxy for heavy pollution. The high leave concentration of Copper is linked to intense pesticides treatments while the Chrome high concentration is due to the fall out of gases and particulate from airplane traffic. Assessing heavy metal contamination of crop in peri-urban areas is particularly interesting in the light of food safety and the permanence of a viable agriculture around cities.

**Keywords:** Peri-urban area, fall-out, cropping systems, soil contamination, heavy metals

## 1. INTRODUCTION

The emissions of internal combustion engines contain heavy metals, among which the Chrome assumes particular importance. As produced by the propellant and the components of the vehicles, Chrome followed the processes of high temperature combustion in the engines being oxidized to $Cr_{VI}$ in volatile compounds contaminating the atmosphere and soil and

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being toxic to humans (Di Dio et al., 2001). The chromium content in the soil may vary from a few mg kg$^{-1}$ up to 300 mg kg$^{-1}$, although in some cases the soil substrate may concentrate even higher values. Once arrived at the level of the crop roots, the contaminant remains quite almost localized in the surface layer of the soil. The occurrence of $Cr_{VI}$ may decrease over time when high contents of organic matter and pH acids are present in the soil that favor the reduction to trivalent chromium, in such form Cr can be assimilated by the plant tissues (Anguissola Scotti and Silva, 1993). In general, plants have a low capacity for absorption and translocation of chromium, which tends to accumulate preferentially in the roots, in variable quantities depending on the species (Gunsé et al., 1991; Anguissolas et al., 1993). Another contaminant especially present in peri-urban areas such as airports, ports and other infrastructural installations is Copper, due to the use of cupric products for antiparasitic treatment. Cu plant requirement is quite modest (5-20 mg kg$^{-1}$). With high concentration of Cu plant toxicity is induced since Cu is competing with other elements, making them less available to plants, such as, Fe and Mn (Sequi, 1991). In addition, an excess of Cu in the soil seems to reduce metabolic activity of the microbial biomass (Rossi et al., 2001). Unlike the Cr, an excess of Cu does not involve important metabolic effects in humans, because, after intake, the element concentration is adjusted through homeostatic mechanisms. The accumulation of Cu in the soil can reach high concentrations due to inadequate agronomic practices in which takes place a continuous use of fungicides based on Cu. (Kabata-Pendias, 2001; Sacristàn D., 2015).

The characterization of heavy metals in soil is based on the determination of the content of total metals, even if the potential of toxic effects is related to the bioavailability of metals in the soil and in the plant. (Vacca et al., 2011; Violante et al., 2008). Organic pollutans and heavy metals are present in soil like a sink. (Pourang and Nori, 2014; Brunetti et al., 2009). The concentration of metals in the soil and is often used as indicator of the soil quality (Dolezalovà Weissurannovà et al., 2014; Ljung et al., 2006). The retention of high heavy metals concentrations in the soil induces toxic effects to the ecosystem (Sai Kachout, S.; Mishra and Tripathi 2008). Issues concerning the fall out of these two heavy metals as a result of airport traffic in the presence of an intense peri-urban agricultural activity are poorly assessed. Plants absorb heavy metals impacting food chain in a direct or indirect way. Carrots are a typical crop can accumulating heavy metals such as Cu and Cr, showing toxic effects on humans (Clemens et al., 2002; Yang et al., 2009). The consumption of crop growing in highly contaminated soils can impact negatively human health and animals (Roy and Mc Donald 2013, Morgan et al., 2013).

Based on these premises, the aims of this study are:

- to provide an experimental framework to assess the concentration of Cr and Cu in carrot crops in the immediate surrounding of an international airport, Leonardo da Vinci, Rome, Italy;
- to identify the causes of the presence of metals in different fractions of plants (from the soil and/or fall out pollution);
- to identify potential risk areas for the cultivation of carrot, along transects considering the direction of the prevailing winds and the inventory of airstrips and takeoff.

# 2. Materials & Methods

## 2.1. Sampling Procedures

The study was conducted at four farms located near the international airport "Leonardo da Vinci" in Rome, Italy (41.87774 N; 12.2138 E). In these farms are in place intensive cultivation of carrots (variety Nantaise cultivar Bolero), a winter harvest, characterized by an average production of 70-80 t/ha, which represent an important economic product in the area. The measurements were carried out on three transects 1 km long and 20 m wide oriented as follows (Figure 2):

- The first (T1) is perpendicular to the airport tracks 1 and 3, parallel to the runway 2 and having the same direction of the prevailing winds (south-west/north-east);
- The second (T2) is parallel to the runway 1 and distant from this way approximately 50 m.
- The third (T3) is the bisector of the angle formed by the tracks 2 and 3.

For each of the three transects considered, they were made 10 samples of soil (Ap horizon, 0-30 cm) and 10 vegetables (taproot and aerial part), roughly every 100 m along the same profile. The soils of the area are shallow, characterized by sandy texture, sub-alkaline pH, cation exchange capacity (CSC) average less than 15 cmol $kg^{-1}$ and an organic matter content of less than 1%. These soils have been categorized according to the Soil Taxonomy (Soil Survey Staff, 1975) in the group of Xeropsamment (Table 1).

**Table 1. Horizon Ap: chemical and physical values. Horizon Ap: averages of the main chemical-physical characteristics**

| Variable | Average |
|---|---|
| pH | 8.0 |
| Texture | Sand |
| sand (%) | 83.4 |
| Loam (%) | 11.6 |
| Clay (%) | 5.0 |
| SOM (%) | 0.8 |
| CSC (cmol $kg^{-1}$) | 12.5 |
| N tot (%) | 0.04 |
| $P_2O_5$ (mg $kg^{-1}$) | 121 |
| $K_2O$ (mg $kg^{-1}$) | 128 |

## 2.2. Chemical Analysis

The samples of soil, air-dried and screened to 2 mm, were determined: pH, texture, CSC, organic matter content in Cu and Cr in a total sample (Lindsay and Norwell, 1978; AA.VV., 1994;).The carrots were divided into aerial part and taproot, washed, dried at 80°C and ground, and they were treated with $HNO_3$ at 140°C, for the extraction of the metals considered. The determination of the amount of Cu and Cr in the extracts of soil and plants, was then carried out by plasma emission spectrometer (ICP-AES).The results were submitted to the analysis of variance and Pearson correlation. The contents of Cu and Cr detected along the three transects, were subjected to analysis of the spatial variability, using the Surfer geostatistical software.

## 3. Results and Discussion

The results relating to the total concentration of Cu and Cr detected in the soil investigated are shown in Table 2. The values of Cu content available to plant are shown in Table 3. All soil samples contained Cu and Cr, and total equivalent below the limits set for the sites considered not polluted (5-100 mg $kg^{-1}$ Cu, Cr 25-500 mg $kg^{-1}$) as proposed by a national workgroup called "heavy metal" (Ministry of Agriculture) for the revision of the Italian law 748/84. In particular, as regards the content of Cr available to plants, values were even below the limits of detection of the instrument. There were no statistically significant correlations between concentrations of Cu and Cr and soil attributed considered in the present study. A significant correlation was observed for the concentration of total Cr in the soil along the transect 3 ($R^2$ = 0.827) decreasing with the distance from the tracks 2 and 3 (Figure 1).

**Table 2. Total metals in the soils (Cu and Cr)**

| | Cu (mg kg $^{-1}$) | | | Cr (mg kg $^{-1}$) | | |
|---|---|---|---|---|---|---|
| L.748/84<br>*<br>** | 5-100<br>100-350 | | | 25-500<br>500-1000 | | |
| | T 1 | T2 | T 3 | T 1 | T 2 | T 3 |
| 1 | 8.0 | 8.5 | 5.0 | 19.5 | 16.5 | 25.5 |
| 2 | 6.0 | 8.0 | 10.0 | 15.5 | 17.0 | 25.0 |
| 3 | 11.0 | 7.5 | 8.0 | 17.5 | 15.5 | 23.0 |
| 4 | 8.0 | 8.0 | 11.0 | 19.0 | 21.0 | 24.0 |
| 5 | 7.0 | 7.0 | 17.5 | 19.0 | 17.0 | 20.0 |
| 6 | 6.5 | 8.0 | 15.5 | 18.5 | 15.0 | 20.5 |
| 7 | 8.0 | 7.5 | 13.0 | 18.0 | 16.0 | 22.0 |
| 8 | 6.5 | 8.5 | 12.0 | 17.0 | 20.0 | 20.0 |
| 9 | 7.5 | 6.5 | 15.0 | 19.0 | 18.0 | 19.0 |
| 10 | 9.0 | 8.0 | 16.0 | 17.5 | 17.0 | 18.8 |

* Ranges of concentration for soils considered non-polluted; ** Warning interval.

The values for the metals contained in the plant (taproots and leaves) are reported in Tables 4 and 5. By observing the values of the metals present in the taproots were detected concentrations below the danger threshold (30 mg $kg^{-1}$; Table 4) while in the leaves (Table 5) Cu values overpassed the toxicity limits prescribed by the national regulation cited above. The concentrations of Cr detected in the leaves however, were higher than 5/6 times the normal values (0.1-1 mg kg -1) reported in the literature (Channels et al. 1997; Chen et al. 1997). For this item a threshold of phytotoxicity has not yet been established. A concentration gradient for Cr present in the leaves was observed in transect 3 (Figure 3); the highest values are found in the proximity of the confluence of the tracks 2 and 3 ($R^2$ = 0.79) in line with what was observed for the total Cr content in the soil.

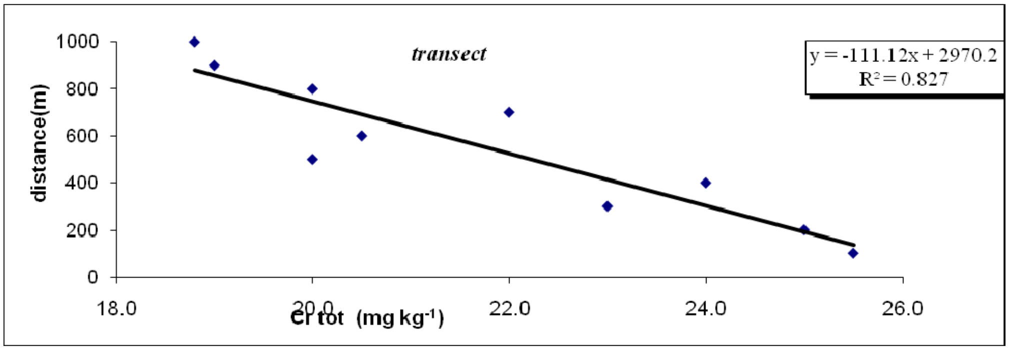


Figure 1. Performance of total Cr in soil in the transect 3.

**Table 3. Soil Cu content in soil**

| | Cu (mg kg $^{-1}$) | | |
|---|---|---|---|
| L.748/84<br>*<br>** | <br>6-13<br>15-35 | | |
| | T 1 | T 2 | T 3 |
| 1 | 1.4 | 1.8 | 0.6 |
| 2 | 1.2 | 1.8 | 2.0 |
| 3 | 1.6 | 1.7 | 2.5 |
| 4 | 1.4 | 1.7 | 4.0 |
| 5 | 1.2 | 1.6 | 5.7 |
| 6 | 1.5 | 1.5 | 4.8 |
| 7 | 1.2 | 1.8 | 3.0 |
| 8 | 1.3 | 1.9 | 4.0 |
| 9 | 1.5 | 1.8 | 3.2 |
| 10 | 1.4 | 1.8 | 0.2 |

* Ranges of concentration for soils considered non-polluted; ** Warning intervals.

**Table 4. Cu content in the taproot**

| | Cu (mg kg $^{-1}$) | | |
|---|---|---|---|
| L.748/84<br>*<br>** | <br>5-20<br>>30 | | |
| | T 1 | T 2 | T 3 |
| 1 | 5.0 | 8.5 | 11.5 |
| 2 | 5.5 | 11.0 | 6.5 |
| 3 | 5.5 | 8.0 | 7.5 |
| 4 | 6.0 | 9.0 | 8.0 |
| 5 | 7.0 | 8.5 | 9.0 |
| 6 | 5.0 | 9.0 | 7.5 |
| 7 | 6.0 | 8.5 | 8.3 |
| 8 | 7.5 | 7.5 | 6.4 |
| 9 | 4.5 | 8.0 | 8.0 |
| 10 | 5.2 | 9.0 | 9.0 |

* Normal Range for plant tissues; ** Threshold phytotoxicity.

**Table 5. Metals in the leaves**

| | Cu (mg kg $^{-1}$) | | | Cr (mg kg $^{-1}$) | | |
|---|---|---|---|---|---|---|
| L.748/84<br>*<br>** | <br>5-20<br>>30 | | | <br>0.1-1<br>--- | | |
| | T 1 | T 2 | T 3 | T 1 | T 2 | T 3 |
| 1 | 14.5 | 48.0 | 95.5 | 4.0 | 7.0 | 8.0 |
| 2 | 23.0 | 56.0 | 80.0 | 5.5 | 6.5 | 9.0 |
| 3 | 24.5 | 41.0 | 65.0 | 13.0 | 3.0 | 8.0 |
| 4 | 28.0 | 64.5 | 74.0 | 5.0 | 5.5 | 6.0 |
| 5 | 18.0 | 50.0 | 76.0 | 6.0 | 6.0 | 6.5 |
| 6 | 25.0 | 64.0 | 58.5 | 8.0 | 5.0 | 5.5 |
| 7 | 19.0 | 48.0 | 63.0 | 5.0 | 4.0 | 5.5 |
| 8 | 20.0 | 35.0 | 70.0 | 7.0 | 8.0 | 6.5 |
| 9 | 14.0 | 56.0 | 59.0 | 11.0 | 4.0 | 4.5 |
| 10 | 23.0 | 39.0 | 78.0 | 5.0 | 3.0 | 4.0 |

* Normal Range for plant tissues; ** Threshold phytotoxicity.

From the results obtained, it can be deduced that the presence of Cu above the toxicity limits of Cr and above normal limits found in the aerial part of the plants not to be attributed to the absorption of these metals at the level radical as the concentrations in the soil of Cu were below the limits set by current regulations and the content of Cr assimilable is below the limits of detection of the instrument. From this it can be assumed that the two elements come to the crop by means of deposition phenomena of different nature linked both airport activity than to that farm.

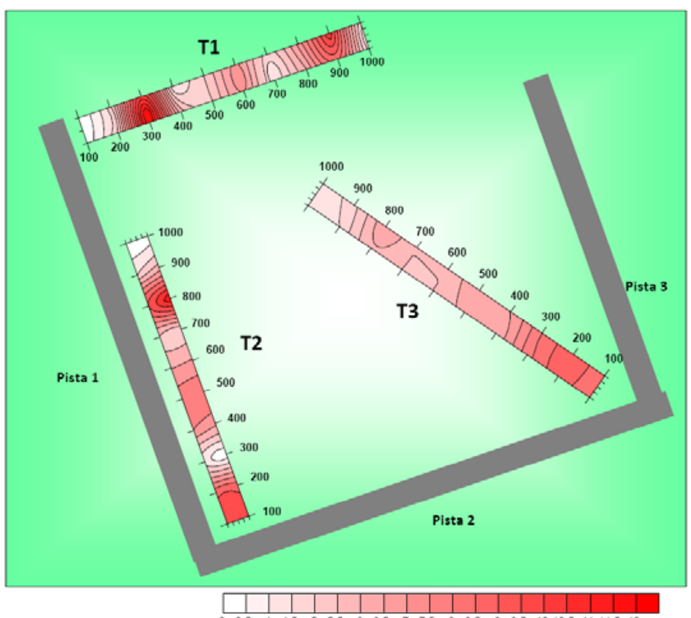


Figure 2. Spatial variability in the concentration of Cr (mg kg -1) in leaf tissue.

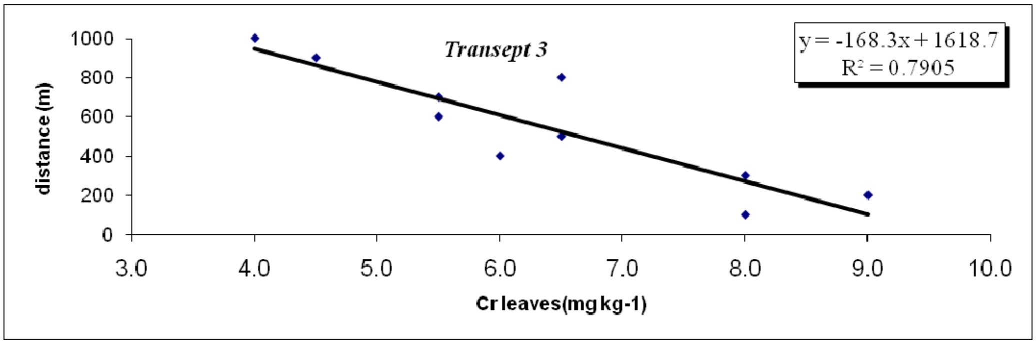


Figure 3. Cr content in carrot leaves in the transept 3.

## CONCLUSION

A high concentration of Cu and Cr in the leaf tissues of carrot can be considered an early warning environmental indicator of soil contamination for peri-urban agriculture. The Cu is made through some agronomic practices such as pesticide treatments carried out with cupric based products. The Cr is present in the fuel and solvents used for the cleaning of aircraft engines. Following the processes of combustion of the propellant Cr is oxidized to the hexavalent form, being particularly volatile and toxic. The aerial part of the plant therefore serves as a physical barrier for the soil and the underground part of the plant itself. Considering the results obtained it is appropriate to discourage the cultivation of leafy vegetables in agricultural areas subjected to fall out of unwanted elements while in the case of crops to bodies hypogea (such as the carrot) on sandy type soils, the risks of contamination are extremely reduced. The presence of these metals should be investigated also into the ground water because due to the type of weaving and the low organic matter content of these soils in periods when the crop is not in place. With species characterized by a reduced plant cover, the mobility of these metals along the profile of the soil itself can be strongly favored.

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