

# Correlating accumulated cadmium and soil characteristics in wheat farm grain

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## Abstract

Cadmium (Cd) accumulation in edible crops is undesirable due to its hazardous influences on human health. The objective of this study was to evaluate grain Cd content and its relation with soil properties in 4000 km<sup>2</sup> wheat farms. A number of 255 soil (0-20 cm) and grain samples were taken in an irregular weighted sampling scheme, using a GPS apparatus. Cadmium concentrations in grain samples and some soil properties were measured. The results indicated that grain Cd was distributed in an approximately normal distribution. Skewness, kurtosis and range of grain Cd were 1.2, 1.7 and 0.15-1.75 mg/kg, respectively. The grain Cd concentrations in 95 percent of the samples exceeded the threshold of 0.27 mg/kg grain. There was a significant ( $p < 0.01$ ) correlation between grain Cd and organic carbon ( $r = 0.66^{**}$ ), CEC ( $r = 0.77^{**}$ ) and DTPA-extractable Cd ( $p < 0.05$ ) ( $r = 0.57^*$ ) of the soils. However, total Cd, soil pH and lime content (TNV) did not have significant ( $p < 0.05$ ) correlations with grain Cd in the whole study area. The grain and soil analysis revealed some pollution mainly at the east and west of the study area. Organic carbon and CEC were the effective factors controlling soil Cd availability for plants.

## Key Words

Cadmium, contaminated soils, soil characteristics, wheat farms

## Introduction

Cadmium (Cd) is a heavy metal, toxic to humans, animals and plants. About 75 percent of the Cd in food chain originates from cereals and vegetables (Wangstrand *et al.* 2006). Wheat (*Triticum aestivum*), especially durum wheat, can accumulate Cd in its tissues more than the other currently grown cereals. The European Community limit value for Cd in wheat grain is 0.2 mg/kg. Soil is the main Cd source for plant uptake. Cadmium phytoavailability in soils is related to soil properties such as concentration and form of metal, pH, organic matter, clay content, cation exchange capacity (CEC), soluble Cl, sulfur (S) and sodium (Na) (Wu *et al.* 2002; Sayyad *et al.* 2009). Cadmium is transported from soil to plant roots by convection, diffusion and interception (Ingwersen 2005). Some previous studies have evaluated the relationships between different soil properties and Cd uptake in cereals under field conditions. Cd accumulation in wheat grain was significantly affected by soil chemical characteristics and cultivar. Wu *et al.* (2002) showed that the variations of grain Cd and most soil properties ( $n = 124$ ) in a durum wheat field were strongly spatially dependent. Adams *et al.* (2004) reported that wheat grain Cd concentrations ( $n = 162$ ) could be predicted reasonably well from soil total Cd and pH using a model with 53 percent of the variance being accounted for. In this study, a large scale study was conducted to assess the correlations among grain Cd concentration and soil properties, as well as to determine the effects of soil properties on grain wheat Cd concentration.

## Methods

The study area was about 4000 km<sup>2</sup> based on the distribution of wheat fields in Khuzestan province, Southwest Iran. The fields were located from an east direction at 47°40' to 50°33' longitude and to a north direction at 29°57' to 30°00' latitude. This area included irrigated and dry land farms. Most dry land farms are located in the east of the province, while others are mainly under irrigation. Grain winter wheat and soil samples were collected from different regions using a weighing method, i.e., the more wheat grown in a farm area, the more grain and soil samples were taken. The required grain and soil samples (0-20 cm) were collected in mid May, 2008, from all 255 wheat farms. At this time, the wheat was near maturity. At each farm, a 1-m<sup>2</sup> quadrat was randomly placed in the field for sampling. A combined 0-20-cm topsoil sample (approximately 1 kg in weight and comprised of 10 cores) was obtained by manual coring within the quadrat area. A combined crop sample was collected at the same time by hand-cutting the crops near the ground level from all the quadrat areas.

Sub-samples of 0.2 g wheat grains were digested in HNO<sub>3</sub> and H<sub>2</sub>O<sub>2</sub> and distilled water. The solution was analyzed for grain Cd concentration by graphite furnace atomic absorption spectrometry. All soil samples were then air-dried and passed through a 2-mm sieve. Total Cd concentration was determined using concentrated HCl and HNO<sub>3</sub>, and the samples were analyzed by an atomic absorption spectrophotometer. Available cadmium was extracted using diethylenetriaminepentaacetic acid (DTPA) and analyzed by the graphite atomic absorption spectrophotometer. Electrical conductivity and pH of soil samples were measured in a saturated extract. Clay content was determined using the hydrometric method. Organic carbon was determined by wet oxidation and lime content was determined as the total neutralizing value (TNV) by titration with NaOH. Correlation analyses between total and DTPA-extractable Cd and soil parameters were done using the SPSS14 software.

## Results and discussion

Summary of descriptive statistics for Cd grain and topsoil properties are presented in Table 1. The results indicated that grain Cd was distributed in an approximately normal distribution. The calculated skewness, kurtosis and range of grain Cd data were 1.2, 1.7 and 0.15-1.75 mg/kg, respectively. Soil Cd<sub>t</sub> and Cd<sub>DTPA</sub> varied about 3-fold and 11-fold between their minimum and maximum, respectively. The mean concentration of 1.47 mg/kg for Cd<sub>t</sub> and 0.084 mg/kg for Cd<sub>DTPA</sub> are very close to the values for agricultural soils in central Iran reported by Amini *et al.* (2005).

**Table 1 The calculated statistics for grain Cd and some soil properties in the study area (n=255).**

| Variable <sup>(A)</sup> | Cd <sub>g</sub><br>mg/kg grain | Cd <sub>DTPA</sub><br>mg/kg soil | Cd <sub>t</sub> | pH   | CEC<br>cmol <sub>c</sub> /kg | OC<br>% | ECe<br>dS/m | TNV<br>% |
|-------------------------|--------------------------------|----------------------------------|-----------------|------|------------------------------|---------|-------------|----------|
| Mean                    | 0.70                           | 0.084                            | 1.47            | 7.40 | 13.75                        | 0.77    | 4.08        | 46.20    |
| SD                      | 0.31                           | 0.06                             | 0.26            | 0.26 | 4.00                         | 0.30    | 4.18        | 9.14     |
| CV%                     | 44.00                          | 71.00                            | 18.00           | 3.00 | 29.00                        | 39.00   | 102.00      | 0.20     |
| Maximum                 | 1.75                           | 0.35                             | 2.19            | 8.40 | 28.30                        | 1.71    | 24.30       | 75.00    |
| Skewness                | 1.20                           | 1.30                             | 0.03            | 0.04 | 0.60                         | 0.61    | 2.00        | -0.22    |
| Kurtosis                | 1.70                           | 2.40                             | 0.24            | 0.25 | 0.46                         | 0.33    | 4.70        | 0.85     |

<sup>(A)</sup> Cd<sub>g</sub>: concentration of Cd in grain; Cd<sub>DTPA</sub>: DTPA- extractable Cd; Cd<sub>t</sub>: total Cd; CEC: cation exchange capacity; OC: organic carbon; EC<sub>e</sub>: electrical conductivity in saturated paste extract; TNV: total neutralizing value respectively

The Pearson correlations between grain Cd and soil parameters were calculated. A significant correlation ( $p < 0.01$ ) was obtained between grain Cd and organic carbon ( $r = 0.66^{**}$ ). Also, the correlation between grain Cd and both CEC ( $r = 0.77^{**}$ ) and DTPA-extractable Cd ( $r = 0.57^*$ ) was significant ( $p < 0.05$ ). However, grain Cd was not significantly correlated with other soil properties such as EC<sub>e</sub>, pH, TNV and Cd<sub>t</sub>.

The correlation between grain Cd and CEC was the highest among soil properties. No significant ( $p < 0.05$ ) correlation was obtained between grain Cd and total Cd in all locations. This clearly indicates that the availability of Cd was controlled by other soil factors than total Cd concentration. It is common conception nowadays that the total concentrations of metals in soils are not a good indicator of phytoavailability, or a good tool for potential risk assessment, due to different and complex distribution patterns of metals among various chemical species or solid phases. Grain Cd in different regions was compared, using a one-way ANOVA method. Various soil and management systems in the regions caused significant differences ( $p < 0.05$ ) in grain Cd concentrations.

Grain Cd concentrations in 95 percent of the samples exceeded a concentration of 0.27 mg/kg. The greatest grain Cd concentrations were measured in the east regions with a range of 1.15 to 1.2 mg/kg. The lowest range was 0.32 to 0.63 mg/kg and it was distributed in different regions. Greater grain Cd contents were measured in regions with low Cd<sub>t</sub>, which confirms the results of some previous studies that showed no relationships between Cd<sub>t</sub> and grain Cd.

One reason for having such high Cd content in the grains at the east region can be attributed to the wheat cultivar. The durum wheat cultivar can accumulate more Cd in its grains than bread wheat. Another possible reason can be related to the dominant crop rotation system. In the east part the rotation is rice-wheat, while for the center and south it is wheat-wheat.

## Conclusion

Agricultural activities have significantly ( $p < 0.05$ ) increased Cd concentration in the topsoils and grains of the wheat farms in the study area. Also, in 95 percent of the grain samples, Cd concentration exceeded the 0.27

mg/kg limit. The organic carbon content, CEC, and DTPA-extractable Cd concentrations were significantly ( $p < 0.05$ ) correlated with the grain Cd concentrations. This indicated that the Cd availability for plants could be quantified by soil organic carbon and CEC. The results showed that some polluted samples were measured mainly in the east and west of the study area. Agricultural mismanagement due to overusing P-fertilizers seems to be the main reason for the increase in Cd concentration in the topsoils and grains of wheat grown in wheat farms in the study.

## References

- Adams ML, Zhao FJ, McGrath SP, Nicholson FA, Chambers BJ (2004). Predicting cadmium concentrations in wheat and barley grain using soil properties. *Journal Environmental Quality* **33**, 532-541.
- Amini, M, khademi H, Afyuni M, Abbaspour KC (2005). Variability of available cadmium in relation to soil properties and land use in an arid region in central Iran. *Water Air and Soil pollution Journal* **162**, 205-218.
- Ingwersen J, Streck T (2005). A regional-scale study on the crop uptake of cadmium from sandy soils; measurement and modeling. *Journal Environmental Quality* **34**, 1026-1035.
- Sayyad G, Mousavi SF, Abbaspour KC, Hajabbasi MA, Richards B and Schulin R (2009). Effects of cadmium, copper, lead, and zinc contamination on metal accumulation by safflower and wheat. *Soil & Sediment Contamination* **18**, 216-228.
- Wangstrand H, Eriksson J, Oborn I (2006). Cadmium concentration in winter wheat as affected by nitrogen fertilization. *European Journal of Agronomy*. *In press*.
- Wu J, Norvell WA, Hopkins DG, Welch RM (2002). Spatial variability of grain cadmium and soil characteristics in a durum wheat field. *Soil Science Society American Journal* **66**, 268-275.