ARTICLE IN PRESS
Arabian Journal of Chemistry (2012) xxx, xxx–xxx

King Saud University
Arabian Journal of Chemistry
www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Assessment of toxic metals in wheat crops grown on selected soils of Khyber Pukhtoon Khaw, Pakistan, irrigated by different water sources

Zeid A. Al-Othman [a], Rahmat Ali [a,*], Abdulaziz M. Al-Othman [b], Jawad Ali [c], Mohamed A. Habila [a]

[a] *Advanced Material Research Chair, Department of Chemistry, College of Science, Building-5, King Saud University, Riyadh, Saudi Arabia*
[b] *Department of Community Health Sciences, College of Applied Medical Science, King Saud University, Riyadh 11433, Saudi Arabia*
[c] *Institute of Chemical Sciences, University of Peshawar, Peshawar 25120, Pakistan*

Received 24 December 2011; accepted 7 April 2012

KEYWORDS
Heavy metals;
Soil pollution;
Irrigation water;
Wheat crop

Abstract We describe a comparative study of the concentration of different metals (e.g., Cd, Pb, As, Ni, Cu, Zn, Mn, and Cr) in various parts of wheat plants (e.g., roots, stem, leaves and seeds) collected at several locations in Khyber Pukhtoon Khaw, Pakistan. The wheat crop in these areas was irrigated using different irrigation sources, including rain, tube well, river, and canal. In wheat samples, the concentration of metals was analyzed using an atomic absorption spectrophotometer. Among the various parts of the plant, the roots had the highest levels of heavy metals, followed by the vegetative parts. By comparison, the seeds and grains had the lowest levels of heavy metals. The levels of heavy metals in all of the studied areas were not significantly localized to any particular area. The general order for the accumulation of studied metals in wheat was found to be Mn > Zn > Cu > Ni > Cr > As > Pb > Cd.

* Corresponding author. Tel.: +966 560467434.
E-mail address: rahmat_chemistpk@yahoo.com (R. Ali).

Peer review under responsibility of King Saud University.
http://dx.doi.org/10.1016/j.arabjc.2012.04.006

Production and hosting by Elsevier

1. Introduction

The world is focusing on the problem of pollution, which is an undesirable change in the physical, chemical and biological characteristics of air, water and soil that affects the lives of humans and animals (Misra and Mani, 1991; Jamal et al., 2002; Al-Othman et al., 2012a). All over the world, industrialization has resulted in the degradation of environmental quality, resulting in long-term, adverse health effects (Vander

Gaag et al., 1991). Soil is a mixture of a variety of inorganic, organic, gaseous and liquid substances, so it acts as a sink for these pollutants, to varying degrees (McLaren and Crawford, 1973; Evans, 1989; Schnitt and Sticher, 1991). Identified routes for the introduction of heavy metals into the human body include direct inhalation of contaminated air, ingestion of contaminated water, and direct ingestion of soil and consumption of food plants grown in metal-contaminated soil (Dudka and Miller, 1999; Bhagure and Mirgane, 2011). In addition, studies have indicated that crops grown in metal-contaminated soil have higher concentrations of metals than those in uncontaminated soil (Dowdy and Larson, 1975). Certain trace metals are essential for plants, playing important roles in plant metabolism and biosynthesis, both as cofactors for enzymes and as metabolic products (Rattan et al., 2005). For example, Zn, Fe, Cu, Cr, and Co are essential nutrients but become toxic at high concentrations. By contrast, Pb and Cd have no known beneficial effects in plants and are exclusively toxic (Radojevic and Bashkin, 1999; Mohamed and Ahmed, 2006). Thus, plants grown in a polluted environment can accumulate trace elements at high concentrations and may serve as a main pathway for transferring metals into the food chain. These plants then pose a serious risk to consumers (Alloway et al., 1990).

Heavy metal accumulation is one of the most serious environmental concerns of the present day, not only because many of these metals are toxic to the crops themselves, but also because of their potential harm to animals and humans. Metals are non-biodegradable and are considered major environmental pollutants resulting in cytotoxic, mutagenic and carcinogenic effects in animals (More et al., 2003; Al-Othman et al., 2011). The accumulation of heavy metals in plants occurs both in roots and aboveground tissue, so monitoring of the bioavailable pool of metals has attracted a lot of interest (Rattan et al., 2005; Rajurkar and Daman, 1998).

Wheat is one of the main crops and an integral constituent of the national diet. It plays a vital role in human growth by providing carbohydrates, proteins and certain inorganic micronutrients (Anita et al., 2010). Consumption of grain is safe when accumulation of metals is under the permissible limits (Das, 1990; Khan et al., 2008). However, when accumulations exceed the permissible limit, it exerts toxic effects and may produce a variety of diseases in human (Nariago, 1990; Melamed et al., 2003; Al-Othman et al., 2012b). In the past, the study of heavy metal pollution focused primarily on certain industrialized regions. In the present investigation, we focused on both polluted and unpolluted areas of Khyber Pukhtoon Khaw, Pakistan, that were irrigated with different water systems (canal, river, tube well and rain). The data collected helped us to understand the distribution of heavy metals in the studied areas. The study was important for assessing the suitability of irrigation system and for increasing public awareness of the threat of heavy metal pollution. The present investigation was carried out with the following objectives.

- To determine the quality of our irrigation system being used for the irrigation of crops.
- To evaluate the distribution of metals in the sampling area.
- To determine the concentration of different metal ions in the irrigated crops.
- To track the movement of heavy metals across different plant parts.

2. Experimental

2.1. Collection of samples

Wheat plants and respective soil samples were collected from twelve areas of Khyber Pukhtoon Khaw which included Swabi, Shergarh, Dir, Takhtbai, Mardan, Batkhela, Swat, Bara, Kohat, Karak, Nowshera and Peshawar, where the fields were irrigated with different water systems (canal, river, tube well and rain). Soil samples were stored in glass containers for further study, while the plant samples were subjected to further processing. Specifically, the plants were rinsed with deionized water, dried in the shade and then in an oven at 110 °C for 2–4 h. The roots, stem, leaves and seeds were then separated and crushed to powder. The dried and powdered samples were subsequently stored in bottles for further study. During all these steps, necessary measures were taken to avoid any loss of sample or contamination of the sample with heavy metals.

2.2. Sample preparation

One gram of crushed, powdered plant parts was weighed in crucibles and heated in a furnace for 5 h at 550 °C. The content of the crucibles was then cooled under desiccating conditions. Next, 2.5 ml of 6 M HNO_3 was added to dissolve the samples (AOAC, 2000). All the required glassware was first washed with standard detergent followed by tap water, soaked in an acid bath (30% nitric acid) and placed in a fume hood to dry. Thereafter, glassware was rinsed first with tap water and then with de-ionized water (Robert, 1981). The sample solution was then filtered, transferred to 20 ml volumetric flasks, diluted to the mark and examined by atomic absorption spectrophotometer.

2.3. Analysis of metals

Concentrations of Cd, Pb, As, Ni, Cu, Zn, Cr, and Mn in the plant samples were measured by an atomic absorption spectrophotometer (Vario 6, Analytic Jena), operated in single-beam mode. The instrumental parameters are listed in Table 1. All the chemicals used were of analytical grade (Merck). The deionized water used in the analysis had an electrical resistivity of 10 MΩ/cm. The reference materials (commercial standards) used were from CPA Chem. Ltd., Bulgaria. Calibration with a linear regression value (R^2) of 0.999 was established for each element.

Maximum care was taken to minimize random and systematic errors. Calibration curves were obtained and the tests were carried out in duplicate to establish confidence in the accuracy, reproducibility and reliability of the data. Health and safety measures were also observed.

2.4. Soil characterization

The soil samples collected from different locations were characterized by pH and by soil moisture, as % weight, to aid in