Heavy Metal Content of Wheat Cultivated in Many Different Regions of Iraq

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ABSTRACT

Heavy metals (Fe, Cu, Cd and Pb) of wheat cultivated in many different provinces of Iraq were determined for their concentration within the limits recommended by Iraqi standardization and FAO/WHO. Wheat spike samples were gathered from different areas, such as near highway areas, near industrial areas, and rural areas. Wheat grains were peeled, milled and prepared for analyzes by Atomic Absorption Spectrophotometry (AAS). The results showed that the concentration of all the elements remained below the Iraqi standardization and FAO/WHO limits. The study also presented that the heavy metals concentrations varied in different provinces, whereby most metals were highest concentrated in Baghdad. Some metals (Fe and Cd) were higher in rural fields than in industrial nearby fields. In conclusion, all measured metals were permissible according to FAO/WHO and Iraqi standardization. Therefore, Iraqi wheat poses no health−risk in regard of the tested heavy metals, and it is safe for human consumption.

Keywords: Wheat, heavy metals, atomic absorption spectrophotometer, environment

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INTRODUCTION

Heavy metals are not biodegradable, persist long in a plant−available stage and account for health risks by accumulating in different organs of the human body. Plants are exposed to heavy metals either from polluted air, contaminated soils, and/or contaminated irrigation water (Elbagermi *et al*., 2012). Air or soils are polluted by heavy metals via emissions produced in different ways. Lead and cadmium emitted by burning transportation fuel are considered the most evenly distributed metals. In addition, cadmium emissions are related to non−ferrous metallurgy (Järup, 2003). Heavy metals have different effects on human and animals' health. For example, lead poisoning causes neurodevelopmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes beside headache, abdominal pain and irritability. Cadmium probably causes kidney damage, is carcinogenic by the inhalation route, while deaths and acute pulmonary are not common (WHO Drinking Water, 2011; Järup, 2003). Although iron, zinc, copper, magnesium and nickel are essential metals for human health, increasing their concentration more than their permissible limits probably causes toxic effects (Tegegne, 2015).

Wheat, rice and maize are the most important crops in the world (Shewry *et al*., 2002). Wheat is considered the leading grain used for human consumption because of its nutritional value, easy harvesting, storing and transportation, and processing compared to other cereal crops. Wheat consists of approximate 59.2% starch, 12.6% protein, 1.9% ash, 1.6% fat and 9% other carbohydrates, referred to a 14% moisture base (Kulp, 2000). Wheat and rice are the most important crops that serve as a staple food for most people in Iraq. Via Grain Board of Iraq (GBI), the Iraq government imported about 696,000 and 366,000 tons of rice and about 350,000 and 152,000 tons of wheat in 2015 and 2016, respectively (Data from GBI) in addition to domestically cultivated crops to distribute a monthly ration to Iraqi people. The Quality Control Department (QCD) in GBI is responsible for inspecting imported crops of wheat and rice. One of the safety assessments of these crops is heavy metal analysis (Cd and Pb), which is performed routinely for all the imported amounts of wheat and rice. In contrast, for the domestic cultivated wheat, heavy metal inspection has not been conducted by QCD during the acquisition of wheat from farmers. Therefore, the aim of this study is to detect the heavy metal content of wheat (grains) cultivated in different provinces of Iraq to determine the actual metal concentration as delimited by Iraqi standardization and FAO/WHO. This study is focusing on wheat cultivated in an industry area, near highways and some rural areas.

MATERIALS AND METHODS

Wheat cultivated in different provinces of Iraq was used. Copper standard, cadmium standard, iron standard, and lead standard (Sigma Chemical Co, St. Louis, MO, USA) 1000 mg/L were used. Hydrochloric acid (Qualigens Fine Chemicals, Dr. Annie Besant Road, Mumbai, India) and nitric acid (Gainland Chemical Company, Factory Road Sandycroft, Deeside Clwyd, U.K.) were purchased.

Study Area

The study area consists of seven provinces of Iraq, which covered middle, east, south, and north of Iraq. Figure 1 shows all the provinces that had been used to gather wheat spikes, which are Baghdad–Al Taji (north Baghdad), Babel, Wasit, Al Basrah, Al Najaf, Al Qadisiyah and Kirkuk.

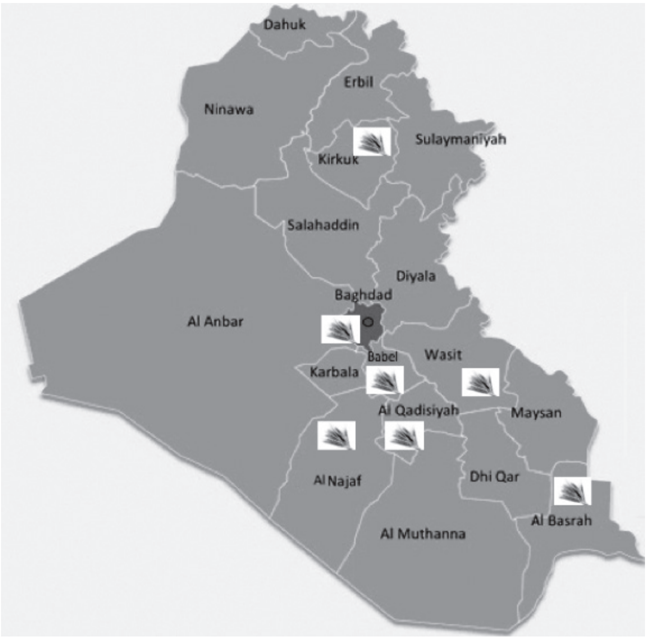

Figure 1 Provinces of Iraq marked with wheat spikes were used to collect wheat spike samples

Sample Collection

Wheat spikes were collected from different fields in provinces of Iraq during the harvest season (May and June) of 2017. Harvest season in Iraq starts in the south and ends in the north. Wheat spikes have been collected from one to several fields situated near industrial activity, around factories, or near a highway. Samples were collected from a wheat field in Al Taji (north Baghdad) that is close to a liquid gas industry (about 20 m far from the fence of the gas factory). Samples were taken from the first rows close to the factory and the other samples were taken from about 1 km far from the factory in order to know if the nearby area has an effect on the wheat heavy metal concentration. In Wasit, samples were collected in the immediate vicinity, and up to one km away, from a military station and an oil field. In Babel, one field was used to collect wheat spikes close to a highway (about 30m). In Al Basrah, two different positions in the same field were used to collect samples close to a highway and about 1 km distant of it. Samples from Al Najaf were collected from two different fields; one was close to a bricks factory (≈1 km) and the other was close to a military control point (≈30 m) where cars stop a while before getting a cheque. For Al Qadisiyah, two different fields were used; two samples were drawn in distances of about one and two km, respectively, from a rubber factory. The other field was in a rural area, and this field was considered a control compared with other fields. Three different varieties of wheat samples from Kirkuk were collected in a rural area. All collected samples were in triplicate.

Sample Preparations

The wheat grains were separated from the spikes manually and milled (device of Brabender® OHG, Duisburg, Germany) to produce a whole wheat flour. 10 g of ground flour was transferred to a clean crucible and placed in a muffle furnace (Hardening Furnace Heraeus MR 170, Dreieich, Germany). The temperature was increased to 600°C at a rate of 50°C/h, to be retained for 6 h. Crucibles were removed out of the furnace and left to cool; then 5 ml of HCl (6 M) were added and the samples were placed on a hot plate until the acid was evaporated. The residues were dissolved to 20 ml with 0.1 M HNO_3 and swilled to suspend all ash. Crucibles were covered, left standing for 1−2 hr. and the digestate was filtered before measuring by AAS (Jorhem, 2000).

Atomic Absorption Spectrophotometer Analysis (AAS)

Measurements of elements were done by using the AAS (AA−7000 Atomic Absorption Spectrophotometer, Shimadzu, Japan) at the QCD lab, and the device parameters of different elements are shown in Table 1. Standard solution of iron (Fe), copper (Cu), cadmium (Cd), and lead (Pb) were prepared from 1000 ppm stock solutions of each standard in 2N HNO_3. The r^2 values of Fe, Cu, Cd and Pb standard curves was 0.963, 0.997, 0.998 and 0.994, respectively. The blank was treated in the same way as the samples. Metal concentrations were calculated according to the formula:

$$c = \frac{(a + b) \times v}{m}$$

where c = metal concentration of the sample (mg/kg), a = metal concentration of the test solution, b = blank concentration, V = volume of the test solution and m = sample weight (Jorhem, 2000).

Table 1 Instrumental parameters of AAS used to detect heavy metals with Air−acetylene

Element	Wavelength (nm)	Slit Width (nm)	Lamp Current (mA)
Fe	248.3	0.2	12
Cu	324.8	0.7	8
Cd	228.8	0.7	8
Pb	283.3	0.7	10

Statistical Analysis

One−way analysis of variance (ANOVA) was performed for statistical analysis of data. Least Significant Difference (LSD) of means was implemented by using SAS version 9.0 (Cary, NC, USA). Significant differences were considered at $\alpha = 0.05$ level. All experiments were accomplished in triplicate.

RESULTS AND DISCUSSION

RESULTS

Iron

Table 2 demonstrates metals concentrations in grains from different fields of several Iraqi provinces. The Fe concentration in all tested samples was lower than the FAO limit. The highest concentration of Fe in Wasit was in the area close to the military station, and the concentration (60.45 mg/kg) was significantly higher than in other fields of Waist. In Al Qadisiyah, there was a significant difference in grain Fe concentrations from different fields, and unexpectedly, wheat samples of a rural field had higher Fe concentrations than wheat taken from a field close to the rubber industry.

Wheat samples from the vicinity of a control point in Al Najaf had higher Fe concentrations than near a bricks industry field. In Al Basrah, there was no significant difference in Fe concentrations between near and far street samples. In Baghdad, there was a vast and significant difference of Fe concentrations between samples taken from near (73.32 mg/kg) and far (36.52 mg/kg) from the gas industry. In Kirkuk, although the areas of taken samples were very close to each other, the Fe concentration was significantly different between different varieties and the highest was in Rasheed variety (64.89 mg/kg) (Table 2). Wheat samples from Baghdad areas had the highest Fe concentrations compared with other provinces (Table 3), however, the difference was only significant with Al Basrah wheat samples.

Copper

Copper concentrations of all grain samples were lower than the limit determined by FAO (Table 2). Copper concentrations of wheat samples in Wasit were significantly different in diverse fields ($P < 0.05$) and Cu concentration was higher in the area close to the oil field than near the military station. There were no significant differences in Cu concentrations of wheat samples in Al Qadisiyah, Al Basrah and Baghdad in different fields of each province. In Al Najaf, Cu concentrations varied significantly between samples from the field close to the control point than from the field close to bricks industry area. In Kirkuk, highest Cu concentration was in Adina variety compared to other varieties. The highest grain Cu concentrations were obtained from Baghdad, Al Qadisiyah and Al Najaf fields compared with those from other provinces and the lowest concentration was in samples of Kirkuk fields (Table 3).

Cadmium

Cadmium concentrations of wheat samples in all provinces were less than the limits given by FAO and Iraqi standard (Table 2). Cadmium concentrations were different in various fields of Wasit and the lowest concentration was found in samples drawn near the oil field (0.002 mg/kg) compared with the highest concentration (0.019 mg/kg) recorded in the field near the military station. In Al Qadisiyah, Cd concentrations were significantly lower in samples collected near the rubber factory than from other fields. There were no significant differences between wheat samples taken from different fields of Al Najaf, Al Basrah, and Baghdad. In Kirkuk, Rasheed variety had the highest concentration (0.019 mg/kg) compared with other varieties. Wheat samples from Al Qadisiyah fields and Baghdad had the highest Cd load compared with those from other provinces, and their amounts were significantly higher than in wheat samples of Al Basra, Babel and Kirkuk (Table 3).

Lead

Lead concentrations of all wheat samples were lower than delimited by FAO and Iraqi standard (Table 2). There was no Pb detected in the field nearby a military station in Wasit, while Pb was detected in the other samples. In Al Qadisiyah, unexpectedly, the rural area had the highest Pb concentration compared with the rubber industry areas. There was no Pb detected in Al Najaf and Kirkuk. In Baghdad, there were no significant differences between Pb concentrations of wheat samples obtained from near and far gas industry fields. Wheat samples of Baghdad field (Gas industry area) had the highest Pb amount compared with all other provinces (Table 3), and the concentration was significantly higher than in samples from Al Qadisiyah, Al Najaf, and Kirkuk. Grain Pb concentrations obtained from all other provinces did not significantly change.

DISCUSSION

Iron

Iron is a redox active and an essential element of living systems; its importance comes from its function of numerous enzymes, oxygen carriers and energy transduction mechanisms (Hider and Kong, 2013). Low level of iron causes anaemia, while iron overload affects major tissues including lipid and glucose metabolism (Fernández−Real and Manco, 2014). Iron concentrations of all the tested samples with 24−75 mg/kg (Table 2) were higher than those (10.64 mg/kg) of wheat in Ethiopia (Tegegne, 2015). They were also higher than those mentioned by Morgounov *et al*. (2007), which ranged between 25−56 mg/kg for sixty−six wheat samples of central Asia. Garnett and Graham (2005) mentioned that the concentration of Fe in the grain depends on the amount of metals that taken up by roots and the amount redistributed to the grain via the phloem. Moreover, the higher concentrations of Fe may indicate that most of the wheat samples were taken from contaminated areas such as control point −Al Najaf (75 mg/kg) and the gas industry region of Baghdad (73 mg/kg) (Table 2). Compared to other provinces, the highest concentrations of Fe with 65.19 mg/kg were found in grains from Baghdad (Table 3). Baghdad is the capital and the most crowded city in Iraq and may be more polluted than other regions.

Copper

Daily doses of about 1 mg of copper are an adequate amount of human needs (Prohaska, 2014). The major importance of copper in human health is related to its role in enzyme function. Copper toxicity is associated with inducing reactive oxygen species. Existing antioxidants such as ascorbic acid reduce Cu^{++} into Cu^{+}, and the latter is capable of catalysing hydroxyl radicals. Radicals cause lipid peroxidation and DNA damage (Gaetke *et al*., 2014). Copper concentrations of all tested wheat samples were less than the concentrations reported by Tegegne (2015), which is 1.7 mg/kg, and much less than the concentrations mentioned by Kumar *et al*. (2009), which is about 8.5 mg/kg. Garnett and Graham (2005) mentioned that the amount of Fe, Zn, Mn and Cu in the grain depends on the amount of metals that taken up by roots or via the phloem. Copper concentration differs depending on a soil type, for example, Cu concentrations were

120, 5.34 and 92.1 mg/kg in garden soil, marine clay, and river clay of Netherlands respectively (Novozamsky *et al*., 1993). Compared to other provinces, the highest copper concentration was with 0.55 mg/kg in wheat samples of Baghdad (Table 3).

Cadmium

Cadmium has been recognized as a health hazard substance for a long time, taken up with drinking water and crops such as wheat, rice, vegetables, etc. Toxic effects of Cd include kidney and lung damage if the exposure is occupationally, and fracture, osteomalacia, and kidney damage if the exposure via food (Åkesson *et al*., 2014). The maximum concentration of Cd was 0.035 mg/kg in wheat samples from near the gas industry of Baghdad, which is less than the Cd concentration (0.6 mg/kg) that reported Kirleis *et al*. (1984) for whole wheat flour. In the Tegegne (2015) study, Cd has not been detected in wheat. While in the Latare *et al*. (2014) study, Cd concentrations were 0.61 and 1.27 mg/kg of wheat grains and its straw respectively. The highest concentration of Cd was in Al Qadisiyah and Baghdad with 0.031 and 0.030 mg/kg, respectively (Table 3), and the concentrations were less than the limits of FAO and Iraqi standardization. Therefore, there are no potential health hazards related to Cd of wheat cultivated in Iraqi.

Lead

Lead is a health hazard metal that can originate from many resources such as gasoline, different kinds of pipes, paints and food cans (Batool *et al*., 2017). Lead can cause many chronic diseases, acting as developmental neurotoxicant due to occupational exposure (Grandjean and Landrigan 2014; Batool *et al*., 2017). Lone *et al*. (2006) stated that lead concentration of wheat leaves was variable and increased with the vicinity to a road site. Lead concentrations of wheat samples were between not detected to 0.191 mg/kg (Table 2), while Lone *et al*. (2006) quantified them between 33 to 2 mg/kg for 20 m and 820 m far from Vadhai road (Rawalpindi District, Pakistan), respectively. Latare *et al*. (2014) mentioned in their study, which was in India that lead has not been detected in wheat grain and in its straw. Tegegne (2015) reported that Pb concentration of wheat was 0.05 mg/kg, which is within this study range. The highest concentration of Pb (0.148 mg/kg) was in Bagdad compared to other provinces (Table 3). However, it was less than the standardization limits approved by this study, therefore, Iraqi wheat is safe in terms of Pb concentration.

Table 2 Heavy metal concentration of Fe, Cu, Cd, and Pb (mg/kg dry weight) of wheat grains cultivated in different fields of different provinces of Iraq

Position of Wheat Fields		Fe	Cu	Cd	Pb
Wasit	Near a Military Station	45.343 ± 1.38[b]	0.316 ± 0.02[ab]	0.019 ± 0.01[a]	ND
	Far from Military Station	40.752 ± 12.94[b]	0.278 ± 0.05[b]	0.018 ± 0.00[a]	ND
	Near an Oil Field	60.453 ± 1.94[a]	0.470 ± 0.10[a]	0.002 ± 0.00[b]	0.139 ± 0.07[a]
	Far from Oil Field	42.356 ± 0.59[b]	0.407 ± 0.11[ab]	0.017 ± 0.01[a]	0.191 ± 0.03[a]
Al Qadisiyah	Near a Rubber Industry	58.336 ± 3.63[a]	0.501 ± 0.11[a]	0.016 ± 0.00[b]	ND
	Far from Rubber Industry	42.284 ± 5.02[b]	0.573 ± 0.06[a]	0.033 ± 0.01[a]	ND
	Rural Area	62.817 ± 7.59[a]	0.432 ± 0.06[a]	0.031 ± 0.01[a]	0.017 ± 0.03[a]
Al Najaf	Near a Bricks Factory	55.083 ± 4.61[b]	0.478 ± 0.03[b]	0.022 ± 0.02[a]	ND
	Near a Check Point	75.300 ± 3.66[a]	0.496 ± 0.07[a]	0.012 ± 0.00[a]	ND
Al Basrah	Near a Highway	24.304 ± 6.52[a]	0.312 ± 0.043[a]	0.008 ± 0.01[a]	0.026 ± 0.05[a]
	Far from Highway	34.239 ± 5.38[a]	0.352 ± 0.01[a]	0.017 ± 0.00[a]	ND
Babel	Near a Highway	53.901 ± 3.07	0.447 ± 0.03	0.005 ± 0.00	0.023 ± 0.03
Baghdad	Near Gas Ind	73.323 ± 5.98[a]	0.533 ± 0.10[a]	0.035 ± 0.015[a]	0.122 ± 0.09[a]
	Far from Gas Ind	36.518 ± 0.74[b]	0.563 ± 0.06[a]	0.025 ± 0.00[a]	0.174 ± 0.14[a]
Kirkuk	Sham	29.265 ± 9.75[c]	0.235 ± 0.07[b]	0.009 ± 0.00[b]	ND
Rural Area	Adina	48.622 ± 2.25[b]	0.392 ± 0.03[a]	0.008 ± 0.00[b]	ND
	Rasheed	64.888 ± 0.55[a]	0.336 ± 0.02[ab]	0.019 ± 0.00[a]	ND
FAO[1]		425.50	73.30	0.20	0.30
IQ Stand[2]		–	–	0.06	0.50

Note: Values are expressed as a mean ± SD error from three independent experiments. Means with different letters within the same column and province are significantly different at $P < 0.05$

[1] Codex (2001), [2] Iraqi standardization (IQS, 1998) and ND: Not detected

Table 3 Heavy metal concentration of Fe, Cu, Cd, and Pb (mg/kg dry weight) of wheat grains cultivated in different provinces of Iraq

Position of wheat fields	Fe	Cu	Cd	Pb
Wasit	47.226 ± 9.724[ab]	0.358 ± 0.10[b]	0.0156 ± 0.01[ab]	0.066 ± 0.14[ab]
Al Qadisiyah	54.479 ± 10.060[ab]	0.492 ± 0.09[a]	0.0310 ± 0.01[a]	0.007 ± 0.02[b]
Al Najaf	54.921 ± 21.530[ab]	0.487 ± 0.05[a]	0.0170 ± 0.01[ab]	ND
Al Basrah	29.271 ± 7.530[b]	0.331 ± 0.04[b]	0.0120 ± 0.01[b]	0.026 ± 0.05[ab]
Babel	50.310 ± 9.930[ab]	0.447 ± 0.03[ab]	0.0050 ± 0.00[b]	0.023 ± 0.03[ab]
Baghdad	65.190 ± 9.930[a]	0.548 ± 0.08[a]	0.0300 ± 0.01[a]	0.148 ± 0.11[a]
Kirkuk	47.592 ± 16.271[ab]	0.321 ± 0.08[b]	0.0120 ± 0.01[b]	ND

Note: Values are expressed as a mean ± SD error from three independent experiments. Means with different letters within the same column are significantly different at $P < 0.05$

CONCLUSION

The level of Fe, Cu, Cd and Pb in wheat samples collected from the vicinity of industry fields and highway fields of different provinces of Iraq were found to be less than the limits approved by FAO/WHO and Iraqi standardization. This is an important result for human health, because wheat is an essential cereal and staple food in Iraq. Although all tested metals were less than the limit, the study revealed that Baghdad areas were more polluted than other tested provinces.

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REFERENCES

Åkesson, A., L. Barregard, I.A. Bergdahl, G.F. Nordberg, M. Nordberg and S. Skerfving. 2014. Non−renal effects and the risk assessment of environmental cadmium exposure. Environ. Health Perspect. 122(5): 431.

Batool, Z., N.A. Yousafzai, M.S. Murad, S. Shahid and A. Iqbal. 2017. Lead toxicity and evaluation of oxidative stress in humans. PSM Biol. Res. 2(2): 79−82.

Codex Alimentarius Commission. 2001. Food additives and contaminants. Joint FAO. WHO food standards programme. ALINORM. 1: 1−289.

Elbagermi, M.A., H.G.M. Edwards and A.I. Alajtal. 2012. Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya. ISRN Anal. Chem. Article ID 827645.

Fernández−Real, J.M. and M. Manco. 2014. Effects of iron overload on chronic metabolic diseases. Lancet Diabetes Endocrinol. 2(6): 513−526.

Gaetke, L.M., H.S. Chow−Johnson and C.K. Chow. 2014. Copper: toxicological relevance and mechanisms. Arch. Toxicol. 88(11): 1929−1938.

Garnett, T.P. and R.D. Graham. 2005. Distribution and remobilization of iron and copper in wheat. Ann. Bot. 95(5): 817−826.

Grandjean, P. and P.J. Landrigan. 2014. Neurobehavioural effects of developmental toxicity. Lancet Neurol. 13(3): 330−338.

Hider, R.C. and X. Kong. 2013. Iron: effect of overload and deficiency. pp. 229−294. *In*: Interrelations between Essential Metal Ions and Human Diseases. Springer, the Netherlands.

Latare, A.M., O. Kumar, S.K. Singh and A. Gupta. 2014. Direct and residual effect of sewage sludge on yield, heavy metals content and soil fertility under rice–wheat system. Ecol. Eng. 69: 17−24.

IQS: Wheat 2058. 1998. Central Organization for Standardization and Quality Control. Ministry of Planning, Iraq.

Järup, L. 2003. Hazards of heavy metal contamination. Br. Med. Bull. 68(1): 167−182.

Jorhem, L. 2000. Determination of metals in foods by atomic absorption spectrometry after dry ashing: NMKL1 collaborative study. J. AOAC Int. 83(5): 1204−1211.

Kirleis, A.W., L.E. Sommers and D.W. Nelson. 1984. Yield, heavy metal content and milling and baking properties of soft red winter wheat grown on soils amended with sewage sludge. Cereal Chem. 61(6): 518−522.

Kulp, K. 2000. Handbook of Cereal Science and Technology, 2nd edition. Marcel Darcel, New York, USA.

Kumar, R., N.K. Mehrotra, B.D. Nautiyal, P. Kumar and P.K. Singh. 2009. Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (*Triticum aestivum* L.). J. Environ. Biol. 30(4): 485–488.

Lone, M.I., S.H. Raza, S. Muhammad, M.A. Naeem and M. Khalid. 2006. Lead content in soil and wheat tissue along roads with different traffic loads in Rawalpindi district. Pak. J. Bot. 38(4): 1035.

Morgounov, A., H.F. Gómez−Becerra, A. Abugalieva, M. Dzhunusova, M. Yessimbekova, H. Muminjanov, Y. Zelenskiy, L. Ozturk and I. Cakmak. 2007. Iron and zinc grain density in common wheat grown in Central Asia. Euphytica 155(1−2): 193−203.

Novozamsky, I., T.M. Lexmond and V.J.G. Houba. 1993. A single extraction procedure of soil for evaluation of uptake of some heavy metals by plants. Int. J. Environ. Anal. Chem. 51(1−4): 47−58.

Prohaska, J.R. 2014. Impact of copper deficiency in humans. Ann. NY Acad. Sci. 1314(1): 1−5.

Shewry, P.R., N.G. Halford, P.S. Belton and A.S. Tatham. 2002. The structure and properties of gluten: an elastic protein from wheat grain. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 357(1418): 133−142.

Tegegne, W.A. 2015. Assessment of some heavy metals concentration in selected cereals collected from local markets of Ambo City, Ethiopia. J. Cereals Oilseeds 6(2): 8−13.

WHO Drinking Water. 2011. Guidelines for Drinking−Water Quality. 4th Edition. World Health Organization. Switzerland.