The status of lead and cadmium in soils of high prevalenct gastrointestinal cancer region of Isfahan

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Background: Cadmium and lead compounds are classified as human carcinogens by several regulatory agencies. Twenty five percent of all cancer-related deaths are attributed to gastrointestinal cancers (GI Ca). We investigated the levels of 2 different heavy metals (Cd and Pb) in the soils of the Lenjanat region, Isfahan province, Central Iran where intensive agriculture is surrounded by different industries like steel and cement-making factories and mining and gastrointestinal cancers are very common in this province. **Materials and methods:** Two hundred topsoil samples (0-20 cm depth) were collected from agricultural and non-agricultural soils of the region and were analyzed for heavy metals. The metal contents were determined by flame atomic absorption spectrometry. **Results:** The findings of this study showed that frequency of gastrointestinal cancers in the study area have been increased in the recent years. Results of soil samples in this region showed that the mean concentration of Pb and Cd were more than 16 and 1 mg kg^{-1}, respectively. The total Cd concentration in most of the samples exceeded the suggested Swiss thresholds (0.8 mg kg^{-1}) but the mean value of Pb concentration in soil was less than the threshold of 50 mg kg^{-1} set by Swiss Federal Office of Environmental, Forest and Landscape. Compared to the threshold values for heavy metals (Cd and Pb) in soils, data showed that the studied fields were contaminated especially by Cd. **Conclusion:** High heavy metals content in the soils seems to play an important etiological role in the carcinogenesis. Excessive accumulation of heavy metals in agricultural soils may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety. Thus, analyzing heavy metals content in crops, water and dust could provide us a better insight to solve the problem.

Key words: Gastrointestinal cancers, heavy metals, soil pollution

INTRODUCTION

Human health in towns and cities is strongly dependent on the status of urban soils.[1] In urban and industrial areas, chemical pollution sources are numerous.[2-12] Diffuse metal contamination of soil is caused mainly by atmospheric fallout from various sources, the most important being industrial and traffic emissions.[13-20,23]

Elevated soil metal concentrations are a serious and current concern for governmental and regulatory bodies for environmental and human risk assessment.[9-21]

Heavy metals such as Cd and lead present a risk for human health because they are non-degradable pollutants, having a large spectrum of effects (e.g., nervous or digestive system disturbances and carcinogenic effects), especially for young children who are more sensitive than adults.[10] Chiang *et al*., showed that areas having high some heavy metals content in the soil, from sources involving either anthropogenic or non-anthropogenic pollution, spatially correlates with regions of high male oral cancer mortality in Taiwan.[22]

Turkdogan *et al*., investigated levels of 7 different heavy metals in soil, fruit and vegetable samples of Van region in Eastern Turkey where upper gastrointestinal (GI) cancers are endemic. They reported the soil, the fruits and vegetables cultivated in this region possess potential carcinogenic risk factors which may be related to the high prevalence of the regional upper GI cancers.[38]

Hazards of cadmium and lead contamination on health

Cadmium

Cadmium is a highly toxic and carcinogenic metal used in metal plating, nickel-cadmium batteries, plastic stabilizers, and pesticides. Cadmium is also present as a pollutant in phosphate fertilizers. Cigarette smoking is a major source of Cd exposure.[3]

Food is the most important source of Cd exposure in the general non-smoking population in most countries.[24,43] Gastrointestinal absorption of Cd may be influenced by nutritional factors, such as iron status.[25] Cadmium exposure may cause kidney damage. The first sign of the renal lesion is usually a tubular

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dysfunction, evidenced by an increased excretion of low molecular weight proteins [such as β2-microglobulin and α_1-microglobulin (protein HC)] or enzymes [such as N-Acetyl-b-D-glucosaminidase (NAG)].[4] It has been suggested that the tubular damage is reversible, but there is an overwhelming evidence that the cadmium induced tubular damage is indeed irreversible.[4]

The International Agency for Research on Cancer (IARC) has classified cadmium as a human carcinogen (group I) on the basis of sufficient evidence in both humans and experimental animals.[8] Early data indicated an association between cadmium exposure and kidney cancer.[26]

Lead

The general population is exposed to lead from air and food in roughly equal proportions. Airborne lead can be deposited on soil and water, thus reaching humans *via* the food chain. Up to 50% of inhaled inorganic lead may be absorbed in the lungs. Adults take up 10-15% of lead in food, whereas children may absorb up to 50% *via* the gastrointestinal tract.[3] Lead in blood is bound to erythrocytes and elimination is slow and principally via urine. The symptoms of acute lead poisoning are headache, irritability, abdominal pain and various symptoms related to the nervous system.

IARC classified lead as a 'possible human carcinogen' based on sufficient animal data and insufficient human data in 1987. Since then a few studies have been published, the overall evidence for lead as a carcinogen being only weak, the most likely candidates are lung cancer, stomach cancer and gliomas.[27] Globally, a huge amount of this metal enters the soil due to human activities.[28] It is most toxic in its free (ionic) form which easily dissolves and moves through water, threatening groundwater supplies.[29]

Khorasani *et al*. showed that gastric cancer patients had a lower Zn level and a higher Pb level compared to healthy volunteers. Their study emphasizes the critical role of trace elements as a risk factor for development of cancer.[6] Wang *et al*., reported there is a direct relation between long-term environmental exposure to both cadmium and lead and an increased risk of mortality from all cancer, as well as from stomach, esophageal and lung-cancers.[30]

Lam *et al*. reviewed the studies which discussed the association between stomach cancer and lead exposure.[8] Two further studies on the general population in the United States have shown that U-Cd levels of 0.28 μg/g creatinine in men and blood Pb levels of 5-9 μg/dL could, respectively, significantly increase the risk of death from all cancer.[14-21,31,32] Nawrot *et al*. showed that the association between environmental exposure to cadmium and cancer. They found overall cancer risk was significantly associated with a doubling of 24-h cadmium excretion. They reported for lung cancer the adjusted hazard ratio was 1.57 for a doubling of cadmium concentration in soil.[18]

Cancer is a serious health problem worldwide, imposing a large economical and psychological burden, as well as loss of life and productivity. Cancer is the third most common cause of death in Iran, accounting for 14% of the total death toll.[17]

As both of the cadmium and lead are carcinogenic metal and may be related to Gastrointestinal Cancers (GI Ca)[6,23,29,30] and GI Ca are common in Isfahan,[15-19] we investigated the heavy metals levels in urban soils of Isfahan, Central Iran.

MATERIALS AND METHODS

Study area

The research included 150 km^2 of agricultural soils of urban and suburban areas of the Lenjanat and Falavarjan regions in Isfahan province, Iran. The total population of studied area is around 459,400 people. The area located between 51°14′29″ to 51°33′15″longitudes and 32°22′50″ to 32°37′30″latitudes. Isfahan is an industrial city in central Iran [Figure 1] in which intensive agriculture surrounded by different industries like steel and cement making factories and lead mining. The soils of this region are Aridisoils. The average annual rainfall and temperature of the region are 150 mm and 15.5°C, respectively.

The data of cancer during a 3-year period from 2006-2009 was obtained from Cancer Registry Center of Health Deputy.

Soil sampling

At each region, soils were randomly sampled from the surface horizon (0-20 cm) and bulked together to form a composite sample. Two hundred topsoil samples were collected and transported to the laboratory.[33]

Soil analysis

Soil samples were air-dried and sieved through a <2 mm mesh. Sub-samples were used to measure the physicochemical properties according to standard procedures. Electrical conductivity and pH of the soil samples were measured in a 1:2 soil to water ratio suspension. Soil texture was determined using hydrometer method. The organic carbon was determined using Walkley and Black's method.[33]

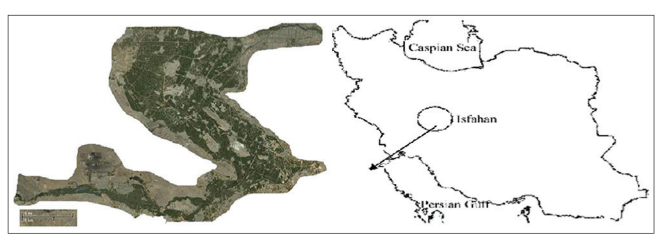

Figure 1: Location of the study area in Central Iran

For determination of Cd and Lead, 1 g of the dried samples was digested with 15 mL of 4 M HNO_3 at 80°C until a transparent solution was obtained.[34] The solution was then filtered through Whatman No. 42 filter paper and the solution was diluted to 50 mL with distilled water. The metal contents of these solutions were determined by flame atomic absorption spectrometry (FAAS).

Statistical analysis

Descriptive statistics variables including mean, variance, maximum, minimum, coefficient of variation (CV), skewness and kurtosis were calculated using STATISTICA 6.0 software.

RESULTS

During a 3-year period from 2006 to 2009, about 13527 new cases of cancer had been registered in Isfahan Cancer Registry Center. 52.8% of patients were male and 47.2% were female aged 59.8 ± 13.6 years (mean ± SD). The summary results of (GI Ca) in this region are given in Table 1. Nearly, 16.5% of all cancer cases in Isfahan province (13527) are related to gastrointestinal cancer. The findings of this study showed that frequency of (GI Ca) in the study area have been increased in recent years [Table 1]. According to results of Mokarian *et al*., during a 5-year period from year 2005 to 2010, 24,771 new cases of cancer have been recorded in Isfahan Cancer Registry Center.[15] Among different cancers; gastrointestinal system was reported as the most prevalent cancer. Frequency of cancers based on their topography is shown in Figure 2.

In Table 2 descriptive statistics for heavy metals (Cd and Pb) concentration in soil was presented. The frequency histograms of the data. The concentration of Cd showed a nearly normal distribution whereas concentration of Pb had a positive skewed distribution.

Among parameters, coefficient of variability (CV) is the most discriminating factors for describing variability. When CV is less than 10%, it shows low variability; while CV is more than 90%, it shows extensive variability.[24] The results in Tables 2 showed that the CVs of soil Cd and Pb were 44.81%, and 98.37% respectively; indicating soil Pb had high variability in the study area. The CV of Cd in this study indicates moderate variability.

Environmental standards in the ordinance of Swiss Federal Office of Environmental, Forest and Landscape.

DISCUSSIONS

There is no universally accepted safe level for assessing the state of Cd pollution in soils. Therefore, different levels are used in different countries.[5] In this study, the environmental standards based on Swiss Federal Office of Environmental, Forest and Landscape were used for the threshold values of heavy metals pollution in the soil (VBBo).

In Table 2, the mean value of Cd concentration in soil was higher than the threshold of 0.8 mg kg^{-1} set by VBBo[35] and also the maximum allowable limit (1 mg kg^{-1}) set by United Kingdom,[5] but the mean value of Pb concentration in soil was less than the threshold of 50 mg kg^{-1} set by VBBo.[35] Total concentrations of Cd in 80% of soil samples is more than 0.8 mg kg^{-1} and more than 1 mg kg^{-1} in 70% of the samples. About 8% of the data has more than 2 mg kg^{-1} Cd and more than 1% of samples have the Cd concentration higher than

Table 1: Summary results of gastrointestinal cancer, number in Isfahan province and the study region in different years

Sex	Frequency of gastrointestinal cancer in Isfahan province				Frequency of gastrointestinal cancer in the study area			
	2006-2007	2007-2008	2008-2009	2006-2009	2006-2007	2007-2008	2008-2009	2006-2009
Male	437	466	528	1431	35	48	55	138
Female	219	280	297	796	17	23	34	74

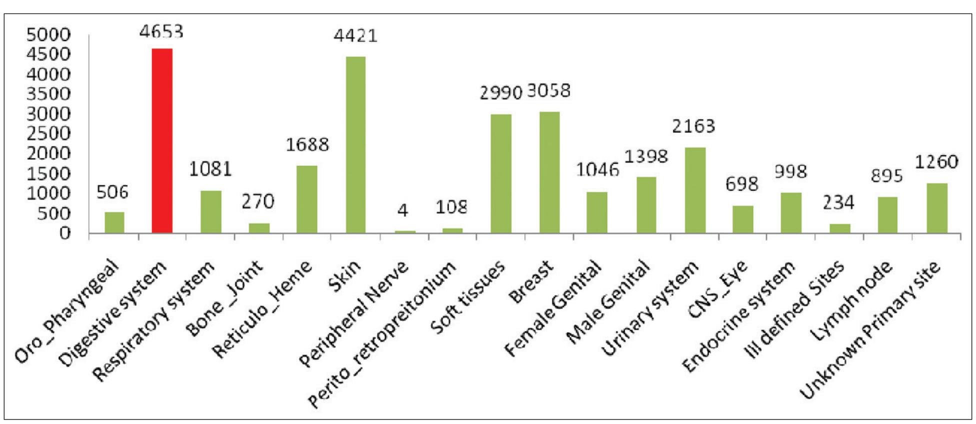

Figure 2: Frequency of cancers in Isfahan province (Mokarian *et al*.)[25]

Table 2: Descriptive statistics of heavy metals concentration in soils

Element	Sample number	Mean	Minimum	Maximum	Variance	Std.Dev	CV%	Skewness	Threshold[a] (mg kg^{-1})
Cd (mg kg^{-1})	200	1.27	0.18	3.12	0.33	0.5	44.81	0.72	0.8
Pb (mg kg^{-1})	200	16.02	1.8	115.75	248.44	15.76	98.37	3.73	50

Environmental standards in the ordinance of Swiss Federal Office of environmental; Forest and Landscape

3 mg kg^{-1}. Total soil Pb content ranged from 1.8 to 115.75 mg kg^{-1}, with a mean value of 16.02 mg kg^{-1}. About 5% of total Pb in soil samples is more than the threshold of 50 mg kg^{-1}.

Compared to the threshold values for heavy metals (Cd and Pb) pollution in soils, this investigation [Table 2] indicated that both the studied fields were contaminated especially by Cd. Similar results were also found in the previous studies in China.[16] Inhalation of cadmium fumes or particles can be life threatening, and although acute pulmonary effects and deaths are uncommon, sporadic cases still occur.[36]

The accumulation of Cd in fields may partly be due to the application of agrochemicals. For example some of the agrochemicals such as fertilizers contain Cd and Pb, which are 0.0005-0.5, 0.0008-0.93 mg kg^{-1}, respectively.[41] Therefore, the long-term application of agrochemicals may result in the accumulation of heavy metals in soils so that heavy metals concentrations in most soils exceeded the threshold values [Table 2]. Particularly, the average concentration of Cd was twice the threshold value. Alloway (1990) cited Cd deposition in the EU in urban areas of 3.9-29.6 gha^{-1} $year^{-1}$, and in rural areas of 2.6-19 g ha^{-1} $year^{-1}$. One of the other main sources of Cd emissions into the environment was an active different industries like steel and cement making factories and mining in the study area.

Automobile emissions are probably the major source of the elevated Pb content in Isfahan urban soils. Highest Pb concentrations were detected in soil samples collected from the border of the city motorway and also from streets, areas with high traffic flows.[36] The average concentration of Pb in the soils around the world is about 29.2 mg kg^{-1} with the range of <1 to 888 mg kg^{-1}.[37] Lead is toxic to humans, especially to young children, and to animals. Plant uptake of Pb is very limited. Therefore, soil containing Pb would need to be ingested in order for substantial exposure to occur. Thus, the primary route of Pb exposure to humans or animals from soil is by direct ingestion of soil particles or fertilizer rather than via food chain transfer. Two further studies on the general population in the United States have shown that urinary cadmium levels of 0.28 μgg^{-1} creatinine in men and blood Pb levels of 5-9 μgdL^{-1} could, respectively, significantly increase the risk of death from all cancers.[14-21,31,32]

In general, environmental toxins (heavy metals, radioactivity), dietary contaminants (nitrates, nitrites, polycyclic hydrocarbons, and aflatoxin) heavy metals and poor nutrition (like Se and Zn) seem to play important etiological roles in the carcinogenesis.[28] The need for further investigations on this subject is evident.

CONCLUSION

Based on the metal concentrations, about 80% of total Cd concentrations in soil samples are more than their background values and nearly 5% of total Pb in soil samples is more than the threshold of 50 mg kg^{-1}. The main pollution sources of the metals in this region are different. The sources of heavy metals in urban soils are mainly derived from traffic sources and industrial sources. However, the sources of heavy metals in agricultural soils are mainly influenced by mining, fertilization, pesticide application and atmospheric dusts.

In conclusion, high heavy metals content in the soils seems to play an important etiological role in the carcinogenesis. Excessive accumulation of heavy metals in agricultural soils may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, animals and thus affect food quality and safety. This food chain contamination is one of the important pathways for the entry of these toxic pollutants in to the human body. Although further research is required to explore the effects of multiple heavy metals on cancer risk based on cohort studies, our study provides useful new insights into the causes of several types of cancer mortality, so analyzing heavy metals contents in plant, water and dust of the region could provide us a better insight to solve the problem.

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