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GARDENING WORK AND HEAVY METALS IN URBAN ENVIRONMENT

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Urban soil may be a source of occupational exposure to various pollutants in gardening and land cultivation. This paper presents data of a one-year follow-up of lead, cadmium, nickel, chromium, and vanadium in the environment of the city of Bologna. Samples of soil and leaves were collected at three locations; gardens from the inner-city high-traffic area, parks in moderate-traffic area, and parks in suburban, low-traffic area. The top and deeper layers of soil and leaves were mainly polluted by lead at all locations, which corresponded to the traffic density. Personal samplers recorded greater concentrations of airborne metals than did the area samplers but the values kept below the threshold limit established by the American Conference of Governmental Industrial Hygienists for the working environment. Due to cumulative nature and interactive effects of toxic metals with other toxic and essential elements, long-term exposure to metals in the urban environment may be a health risk for occupationally exposed gardeners.

Key words:
atomic absorption spectrometry, cadmium, chromium, health risk, lead, nickel, vanadium, occupational exposure

Human exposure to urban air pollutants and their possible health effects have recently attracted the interest of the scientific and medical community (1, 2). The role of the road traffic in the air pollution issues is well known (2, 3).

Geographically, there are three levels of air pollution which deserve serious concern: local/urban, continental, and global. Such pollution on the local and urban level

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is termed as the *vicinity pollution*. Several air pollutants are involved: sulphur dioxide, nitrogen oxides, carbon monoxide, particulate matter, organic compounds, photochemical oxidants, and heavy metals such as lead and cadmium. The effects of these pollutants have now come into the focus of investigation all over the world. The costs of the risk assessment and protection of the European cities are high and concern mainly public health and preservation of construction materials and buildings (for example, monuments and public buildings) from atmospheric agents. Pollution on the continental level takes the form of acid rain and photooxidant phenomena with consequent degradation of crops, forests, and buildings. Pollution on the global level is associated with global warming and depletion of the ozone layer, with consequent changes in climate and the rise of the sea level, and, eventually, with immense damage for nature and humanity.

Heavy metals such as lead and cadmium could be present in garden soil. Pollutants in most soils largely reflect atmospheric deposition patterns. Upon release from the atmosphere, metal particulates disperse and ultimately disappear from the air through wet and dry deposition and precipitation. In the urban environment, high atmospheric lead content resulting from the combustion of leaded gasoline in vehicles seems to be the main contributor to lead concentrations in soil. Another contributor to the accumulation of lead and cadmium in soil is the sewage sludge applied in agriculture and horticulture (4, 5).

While lead and cadmium are exogenous toxic elements which accumulate during the lifetime, chromium, nickel, and vanadium are believed to be essential trace metals for plants and animals (6). Chromium is found in all sorts of food with the highest concentration in shellfish. The only biologically active form of chromium is in oxidation state of trivalent form. This element is part of the organic complex known as glucose tolerance factor (7). Nickel affects enzymes in a variety of ways, apparently because it can be substituted, more or less adequately by other divalent ion, especially zinc. Nickel is an essential trace element for chicks, rats, and swine (8). Vanadium has been shown to be an essential trace element for rats and chicks, but its role is not yet known. It will probably be found essential for other inferior animals (9). In excessive physiological concentrations, chromium, nickel, and vanadium are rather toxic (10).

In the urban environment, gardening as an occupation may involve health risks through inhalation of dust raised by gardening tools such as lawn mowers, bush-trimmers, and fence-trimmers. The aim of our research was to determine the concentrations of airborne heavy metals, particularly of lead, cadmium, nickel, chromium, and vanadium on three locations with different road traffic density in the city of Bologna and to assess the occupational health risk of the exposed gardeners.

MATERIALS AND METHODS

Throughout the year 1996, save for the winter, samples from the top layer (ca 2 mm deep) and a deeper (ca 20 cm deep) layer of the soil were collected from gardens in the inner-city with dense road traffic (hereinafter, high-traffic area). Concurrently, leaves were taken from plants at about one metre from the ground and dry leaves were collected from the ground. Similar samples were collected from a park 100–200 metres away from a road with moderate traffic (hereinafter, moderate-traffic area) and from the outskirts of the city with low traffic density (hereinafter, low-traffic area). Winter has been omitted from the analysis as that period involves little gardening.

The gardeners' average daily exposure has been assessed in all three areas by means of personal and area samplers (Alpha 1 Tecora, Milan, Italy, flow 2 litres per minute, membrane filters of cellulose nitrate, pore size 0.8 μm, 25 mm diameter, MSA, Rozzano, Milan, Italy). The soil samples were dried at 105 °C and treated with a 1:3 solution of HNO_3 and HCl (11). The leaves were rinsed with a 5% HNO_3 in ultrasound bath for 30 minutes and then digested with a microwave (Milestone 2000) and concentrated HNO_3 and H_2O_2 (12). The sampler filters were treated in a similar way.

Metals were analysed using an atomic absorption spectrometer with graphite furnace and Zeeman correction (Perkin Elmer 5000) (13). The recovery from the samples varied between 96% and 106%. Relative standard deviations of the sample values were kept below 20%.

RESULTS AND DISCUSSION

Table 1 shows the results of the analysis of heavy metals in soil from three urban locations through different seasons. The highest values were found for lead in soil at all city locations and without differences between the top and the deeper ground layers. There were no differences in cadmium and nickel concentrations in the soils

Table 1 *Average concentrations of metals (mg/kg) in the soil in different seasons at three locations with different traffic density in the city of Bologna*

Season	Lead		Cadmium		Nickel		Chromium	
	*Top layer	Deeper layer	Top layer	Deeper layer	Top layer	Deeper layer	Top layer	Deeper layer
High-traffic area								
Spring	230.7	285.3	2.20	2.60	53.4	49.1	52.1	41.8
Summer	182.6	201.8	1.24	1.23	50.9	51.8	21.8	21.9
Autumn	142.3	124.4	0.60	0.50	43.7	47.1	37.3	35.7
Moderate-traffic area								
Summer	75.0	54.1	1.00	1.00	63.3	62.1	30.3	35.6
Autumn	66.6	61.1	0.50	0.34	50.9	51.6	37.3	37.9
Low-traffic area								
Spring	21.5	23.9	1.70	1.70	47.7	52.7	27.6	29.6
Summer	15.2	14.6	1.00	1.00	42.7	41.2	20.2	24.9
Autumn	6.0	10.0	0.10	0.20	39.5	39.2	23.0	28.0

No. of samples: 10–15; variability within 20%
*Top soil layer was ca 2 mm below the surface; the deeper soil layer was ca 20 cm below the surface

at different city locations. Some differences were observed for chromium between city and suburban areas. Vanadium concentrations in the soil were below the detection limit of the method (0.10 mg/kg).

Even lead concentrations found in the samples from the surface and deeper layers of the soil may be explained by the fact that the soil was cultivated, fertilised, and irrigated. Since the major source of lead in the atmosphere is the emission from motor vehicles, the tendency towards higher metal concentrations in spring may be explained by increased traffic in winter.

The differences in lead concentrations between the samples collected in the inner-city and in the suburban area closely relate to differences in traffic density. Lower concentrations of lead in the park soil of the moderate-traffic area suggest the so-called screen effect of the vegetation between the park and the road. High lead concentrations measured in the soil of the high-traffic area were comparable with the data of an investigation carried out seven years earlier in the city of Bologna with values ranging from 187 to 747 mg/kg (14).

Table 2 shows metal concentrations in leaves gathered in different seasons. The analysis of metals in washouts and digested samples of leaves was intended to distinguish metal deposition from the atmosphere and metal incorporation from the soil.

Table 2 *Average concentrations of metals (mg/kg) in leaves and leaf washouts in different seasons at two locations with different traffic density in the city of Bologna*

	Lead		Cadmium		Nickel		Chromium	
Season	**Washout**	**Digested leaves**	**Washout**	**Digested leaves**	**Washout**	**Digested leaves**	**Washout**	**Digested leaves**
High-traffic and moderate-traffic areas								
Spring	8.30	1.70	0.07	0.05	1.00	0.40	0.50	0.40
Summer	1.61	1.20	0.01	0.05	0.20	0.91	0.12	0.19
Autumn	1.81	0.71	–	–	–	–	0.37	0.31
Low-traffic area								
Spring	1.40	0.70	0.03	0.03	0.50	0.20	0.10	0.20
Summer	1.20	0.24	0.02	0.04	0.35	0.67	0.04	0.20
Autumn	0.25	0.24	–	–	–	–	0.09	0.07

No. of samples: 10–15; standard deviation variability within 20%

Leaf washouts showed higher lead concentrations than did the digested leaves. This was especially the case in spring when all metals were at their peak both in the high-traffic and low-traffic areas. This suggests substantial preponderance of metal deposition on vegetation from the atmosphere over incorporation of metals from the soil. As the concentrations of lead in leaves and the leaf washouts were similar in the high-traffic and moderate-traffic areas, the average values for the two locations are given together. This trend, different from what was observed for metals in soil, may be explained with labile depositions on the leaves which do not preserve or accumulate earlier depositions of the metal.

The results of an earlier study carried out in the city of Bologna (14) showed markedly greater lead concentrations in the leaves which ranged from 32 to 338 mg/kg, depending on traffic density. The comparison of the earlier and of the recent results with respect to lead in soil and leaves suggests that there is a trend of major reduction of lead dispersion in the environment. This is due to the increasing use of vehicles running on unleaded fuel and due to regulations of the European Union concerning motor vehicle emissions. In fact, in the highly industrialised European countries such as Italy, lead concentration in gasoline decreased from 0.7–0.8 to 0.1–0.2 g/L between 1978 and 1990 (15).

The analyses of the other metals often resulted in values below the detection limit established for the method used in the analyses. The determination of cadmium and nickel in autumn gave results at the detection limit level of the sensitivity of the method and therefore they are not reported.

Table 3 shows metal concentrations determined in filters of the area samplers and those measured with personal samplers in the high-traffic area in spring and autumn. Metal concentrations in the moderate-traffic and low-traffic areas were under the detection limits. Often in summer (and occasionally in spring) samplers gave results below the detection limit of the methods. This is why the summer data are not reported. Personal samplers detected higher values of metal concentrations than did the area samplers. Heavy metal concentrations determined in the air were in agreement with the data reported elsewhere (16). As far as airborne lead is concerned, we have observed an important reduction with respect to the previous study. At that time, lead concentrations ranged between 2.5 and 7.8 mg/m^3 and corresponded to the traffic density (14).

Table 3 *Average concentrations of metals (μg/m³) in filters of area samplers and personal samplers in two seasons in the the inner-city with high traffic density*

Season	Lead		Cadmium		Nickel		Chromium	
	Area sampler	Personal sampler	Area sampler	Personal sampler	Area sampler	Personal sampler	Area sampler	Personal sampler
Spring	0.3	1.8	0.04	0.21	0.10	0.70	0.10	1.00
Autumn	0.2	0.9	0.03	0.50	–	0.52	0.11	0.44

No. of samples: 10–15; standard deviation variability within 20%

It is well known that toxic metals may interact with each other and with other essential elements, and may affect human metabolism and organ functions (10, 17). Exposure to heavy metals may alter the concentrations of the essential elements through binding and formation of either complex or insoluble products. Simultaneously, however, essential elements may counteract the toxic effect of heavy metals. It is, therefore, important not only to include the search of other polluting substances in the analytical protocol, but also to investigate possible chemical interaction between toxic heavy metals and essential trace elements such as selenium, iron, and zinc (18).

Urban soil is an important source of environmental and occupational metal pollution. Health risk assessment of metal exposure in gardeners is a difficult and complex task involving such variables as different time of day and/or of the year, the atmospheric conditions, and the presence of various sources of emission. Furthermore, the absorbed doses sufficient to induce alterations in the organism depend on the route of exposure and on the general health of an individual.

For the past few years we have medically surveilled 22 gardeners, which comprised an evaluation of health in relation to specific sources of exposure, occupational history data, physical examination, and specific tests for evaluation of individual risk (spirometry, audiometry, haematological and toxicological analyses, electromyography and ultrasonography of upper limbs, etc.). The medical surveillance of the gardeners has been partly completed and has shown no health effects of urban environmental exposure (unpublished evidence).

It is interesting to compare gardeners with other workers occupationally exposed to urban environment, for example policemen controlling traffic. A previous study on the health surveillance of a group of urban policemen in the city of Naples showed that the average lead concentration in the air was 0.2 mg/m^3 (19), a value of the same order of magnitude of our data. The clinical-chemical analyses of the policemen showed normal blood and urine lead levels.

CONCLUSION

The average environmental concentrations of airborne heavy metals determined for the periods when gardeners are active were below the threshold limit values for the working environment established by the American Conference of Governmental Industrial Hygienists (ACGIH) (20). The actual threshold limit values – time-weighted average (TLVs–TWA) for metals (in mg/m^3) are: 0.05 for Pb, 0.01 for Cd; 0.5 for Cr, 1.0 for Ni, and 0.05 for V (in the form of V_2O_5). It is difficult to compare the concentrations of metals in the filters of area samplers and of personal samplers (in $\mu g/m^3$) with metal concentrations in soil and/or leaves (in mg/kg). The high values of lead concentrations in the last matrices could be explained by a phenomenon of metal deposition and accumulation on the ground surface and vegetation.

Our results confirm low-level exposure of gardeners to airborne heavy metals that more or less accumulate in the organism during the lifetime and interact with each other and with trace elements vital for body functions. Furthermore, health risk of low-level cumulative metal exposure comprises carcinogenic potential of certain metals such as cadmium which the International Agency for Research on Cancer (IARC) has classified as »probable human carcinogen« and nickel which is a »confirmed human carcinogen«.

To conclude, even at low-level pollution of the urban environment, gardeners are at higher risk for health effects of toxic metals and other environmental pollutants than the general population, as their occupation entails long-term environmental exposure.

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Sažetak

VRTLARSKI RAD I IZLOŽENOST TEŠKIM METALIMA U GRADSKOM OKRUŽJU

Gradsko tlo može biti izvorom profesionalne izloženosti različitim onečišćivačima u vrtlara, uključujući otrovne teške metale koji se talože iz onečišćenog zraka na tlo i lišće. U radu su prikazani podaci jednogodišnjeg praćenja koncentracija olova, kadmija, niklja, kroma i vanadija u talijanskom gradu Bologni. Uzorci tla i lišća skupljani su na tri mjesta s različitom gustoćom prometa; u središtu grada s velikom gustoćom prometa, u parkovima s umjerenim prometom u okolišu i u prigradskim parkovima sa slabim prometom. Na svim lokacijama gornji i dublji slojevi tla bili su podjednako onečišćeni ponajprije olovom i to je bilo u svezi s prometnom gustoćom. Koncentracije metala u zraku utvrđene u filtrima osobnih skupljača bile su više od koncentracija u skupljačima na tlu. Vrijednosti metala u zraku bile su niže od graničnih vrijednosti utvrđenih za radni okoliš od Američke konferencije vladinih industrijskih higijeničara (American Conference of Governmental Industrial Hygienists). Zaključeno je da vrtlari, u usporedbi s općim stanovništvom, i pri niskim razinama izloženosti u gradskom okolišu imaju povećan zdravstveni rizik za štetna djelovanja otrovnih metala i drugih onečišćivača okoliša zbog dugotrajne izloženosti u svezi s njihovim radom.

Ključne riječi:
atomska apsorpcijska spektrometrija, kadmij, krom, nikalj, olovo, profesionalna izloženost, vanadij, zdravstveni rizik

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