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The Date Palm (*Phoenix dactylifera* L.) Fibre as a Biomonitor of Lead and Other Elements in Arid Environments

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The fibre of date palm (*Phoenix dactylifera* L.) has been tested as a possible biomonitor of lead and other metal pollution in Riyadh City, Saudi Arabia. The content of (Pb, Zn, Cu, Ni, Cr and Li) was determined for washed and unwashed fibre samples collected from three different sites with different degrees of metal pollution (urban, rural area with sludge amended soils and rural "control" area). Differences between washed and unwashed samples revealed that the large amount of metal pollutants exist as superficial contaminants, which varied according to the metal source. However, *P. dactylifera* fibres were found to be suitable biomonitor for metal pollution in Riyadh and similar arid and semi-arid environments.

INTRODUCTION

During the last decades heavy metal pollution has considerably increased in the environment. Automobile exhaust emissions is regarded as one of the major sources of heavy metal contamination in urbanised areas. This is due to the combustion of leaded gasoline and the consequent discharge of lead particles. Other metals such as Zn, Cu, Ni, Cr and Cd which are associated with vehicles are released to the environment due to wear and tear. Due to their presence in the atmosphere the metals reach the soil and the plant by precipitation[1].

In Riyadh, automobiles, power stations, oil refinery, cement plant and the industrial activities are the suspected sources of air pollution. However, among these, the automobile is considered the major contributor to air pollution. This is due to the very high numbers of vehicles which is increasing every year, *e.g.*, automobiles increased by a factor of 843% during the period 1973–1983. There is a very little information about the environmental pollution by heavy metals in Riyadh city. The average lead concentrations in two locations in Riyadh were found to be (5.5 $\mu g\ m^{-3}$) and (2.5 $\mu g\ m^{-3}$).[2] These concentrations reflect the heavy and light traffic areas respectively. Both values are exceeding the WHO guideline, *i.e.*, (0.5–1.0 μg Pb m^{-3}).[3] Copper also was reported to have a high level in Riyadh environment, *i.e.*, (6.4 $\mu g\ m^{-3}$).[4]

Therefore, monitoring the metal levels in the atmosphere became an important task. This can be done by using filtering equipment. However, this method has disavantages; due to the relatively high cost associated, only few sites within the

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study area usually selected for the availability of power supply and safety from vandalism, rather than for scientific purpose. On the other hand, biological monitors provide relatively simple, quick, cheap and continuous method. Among these biological monitors are trees and particularly tree trunks. They are of considerable value because they are widely distributed and remain in a fixed known location over long period of time.

The tree rings and bark were used to monitor the metals in the environment by many researchers. The tree rings were used as historical monitors of heavy metal atmospheric pollution. Ault *et al.*[5] analysed annual rings of a red oak (*Quercus rubra*) in New Jersey, to study lead pollution of the environment. They found a pronounced increase in lead concentration from the inner stem towards the outermost rings. There are three pathways by which metals enter into trees: through the leaves, through the bark, and uptake from the soil through roots[6]. Other studies were conducted using the tree rings as monitors of heavy metals in the environment include[7–9].

Tree bark remains in the environment for many years. Therefore it records very precisely any changes occurring in this environment. A detailed comparison of the most commonly used material leads to the conclusion that mosses and lichens and, to a lesser extent, tree bark are the most suitable monitors of heavy metals in the atmosphere[10]. Ward *et al.*[11] found that the lead content of tree bark samples from Avenue, New Zealand, was ten times greater than that of those taken from background trees. Barnes *et al.*[12] have used pine bark to monitor atmospheric metal pollution. They found lead concentration in tree bark to be sensitive to the traffic flow. Also they found lead, zinc and copper in the tree bark decreased with increased distance from the road and with height above the ground. Laaksovirta and Alakuijala[13] studied the lead contents of lichen (*Hypogymnia physodes*) and its substrate (bark of *Pinus sylvestris*) along a busy four-lane highway on the coast of southern Finland. In their study they found pine bark to be a better indicator than lichens of lead emission from motor vehicles. Analysis of cedar bark samples in the Nagatsuta area, Yokohama, Japan, shows that there is contamination by heavy metals, Cr, Zn, Cu and Pb (Nyangababo and Ichikuni). They suggeted that this contamination occurs primarily by aerial deposition. Bruin and Hackenits[10] studied the relations between concentrations of 20 trace elements in epiphytic lichens and in the substrate (bark). They found for most elements, a significant correlation between the concentrations in the lichen and the concentrations in the outer and inner bark. They suggested that the risk of interference by uptake by lichens from the substrate can largely be reduced by using transplants consisting of pieces of bark with lichens from clear areas. The levels of heavy metals deposited on bark of 29 trees of five different species in Benin city, Nigeria, were studied by Ademoroti[14]. It was found that the rougher the tree bark, the higher the deposit for each species.

The date palm (*Phoenix dactylifera*) meets many of the requirements of a good biomonitor. It is widely distributed in the study area (Riyadh city), easily identified, and has already been tested as a biomonitor by leaves[15].

In noticing a date palm tree, a central columnar trunk will be found. Around its sides the older leaves are fastening the stem with their broad-sheathed bases.

Closely wedged between these are dozens of sheets of very tough, coarse-matted fibre. The real trunk of the date tree is inside of these and is greatly strengthened and protected by them. At the line of leaf attachment to trunk sheets of this fibre encircle the tree. If a date palm be dissected, cutting away leaf after leaf till we get toward the bud, we find leaves with their original structure entire and the margins of the wide base of the rib thinning out to a continuous mat of brown fibres, which forms a complete sheath encircling all the younger growth. As the area of active growth is approached, near the centre this sheath will be yellowish white, soft, and succulent, not more than 2 or 3 inches in diameter, and 8 inches or a foot in length. In a large tree the sheath may be 20 inches or more in length. On the opposite side from the rachis the margin of the sheath has an upward expansion into a broad lingua, with coarsely incised margins and a blunt-pointed or an acuminate apex, which sometimes protrudes several inches against the enclosed leaves and which varies in a manner somewhat characteristic of different varieties. The diagonal arrangement of the fibres allows the sheath to expand a good deal, but the continual pushing upward of new leaves from within and the expansion of the trunk finally rupture it or tear it loose from the sides of the tip. Its lower margin remains attached to the trunk, so that this wrapping of old sheath fibre may persist for many years[16].

Therefore, due to the above mentioned features of the sheath fibre of the date tree (*Phoenix dactylifera*) it was the major aim of this study to investigate the possibility of using it as a biomonitor of the atmospheric metal pollution in Riyadh and other semi-arid environments.

EXPERIMENTAL

Sampling and samples treatment

Fibre samples were collected from date trees from urban and rural (control) areas. Other samples were collected from an area flooded with treated sewage water (Alhaire). For the purpose of comparison leaf samples were collected as well from the same area.

To study the vertical variation of the metal contents along the trunk of the date palm, fibre samples were obtained from different heights from the ground (0.5, 1.0, 1.5, 2, 2.5, 3, 3.5, 4 and 4.5 m). Three date trees comparable in height were chosen in three urban areas namely Al-Jameah street, Al-Shemasea street and Al-Matar street.

Both fibre and middle age leaf samples were collected at comparable height of 1.5 m using stainless steel secateurs. Each sample was then divided into two subsamples. One was thoroughly washed with running distilled water to remove dust particles, the other remained untreated. The samples were then oven-dried at 80°C, milled in a micro-hammer cutter, and fed through a 1 mm sieve. Each plant sample was stored in a clean self-sealing plastic bag.

Extraction method

1 g samples of dry milled plant material were ashed in an electric muffle furnace at 480°C for 24 h. The weighed ash was digested in 10 mL AR

concentrated HNO_3, evaporated to near dryness on a hot-plate and made up to volume with 1% HNO_3.

Element concentrations were measured by an atomic absorption spectrophotometer (Perkin-Elmer model 1100, micro-computer controlled with integrated CRT screen and keyboard function). The precision of the results was checked by duplicating 20% of the samples chosen randomly. In order to ascertain the accuracy of the method employed, two reference materials were included with every batch (SRM 1547 Peach leaves and CRM 281 Rye grass).

RESULTS AND DISCUSSION

Metal levels in date palm fibres from different sites

Table-1 shows the average metal values for fibre samples taken from urban, rural and another rural area with sludge amended soils (Al-Hayer). Figure 1 shows mean values for metal contents in washed and unwashed fibre samples taken from these three areas at a height of about 1.5 m. The influence of urbanisation and traffic exhaust emission in depositing heavy metals becomes apparent when the results obtained from the urban area compared with those from the rural area.

The mean lead content in unwashed fibres from the urban area was found to be 821.70 $\mu g\ g^{-1}$, which is much higher than those levels found in fibres collected from the rural area (6.90 $\mu g\ g^{-1}$). Although, the lead level in washed fibres from the urban area was about 2.5 times less than its level in unwashed ones (333.9 $\mu g\ g^{-1}$), it is still much higher than that collected from the rural area (3.36 $\mu g\ g^{-1}$). This shows that both washed and unwashed fibres can be used to monitor the atmospheric deposition of this metal. Lead content in unwashed fibres collected from rural area with sludge amended soils (Al-Hayer) was shown to be about three times higher than those from the other rural area with an average value of 18.44 $\mu g\ g^{-1}$, whereas the lead content in wahsed fibres was comparable in both rural areas.

Figure 1 shows zinc and copper levels in washed and unwashed fibres to be exhibiting the same trend shown by lead. In the urban area, the mean zinc content in unwashed fibres was 82.80 $\mu g\ g^{-1}$, which is about eight times greater than that of those taken from the rural area (10.80 $\mu g\ g^{-1}$). The zinc content in washed fibres from the urban area was more than two times less than unwashed ones, but on the other hand it is about four times greater than that of those collected from rural area.

The mean copper content in unwashed fibre samples collected from the urban area was 38.49 $\mu g\ g^{-1}$, which is more than four times greater than for those taken from the rural area. The copper content of washed fibre samples was about two times less than for unwashed ones with an average value of 18.61 $\mu g\ g^{-1}$ but it is still about three times greater than the copper content in washed fibres from the rural area. Enhanced levels of zinc and copper were shown to be present in unwashed fibre samples collected from the rural area with sludge amended soils (Al-Hayer) with mean values of 28.0 $\mu g\ g^{-1}$ and 16.24 $\mu g\ g^{-1}$, respectively, compared with the other rural area.

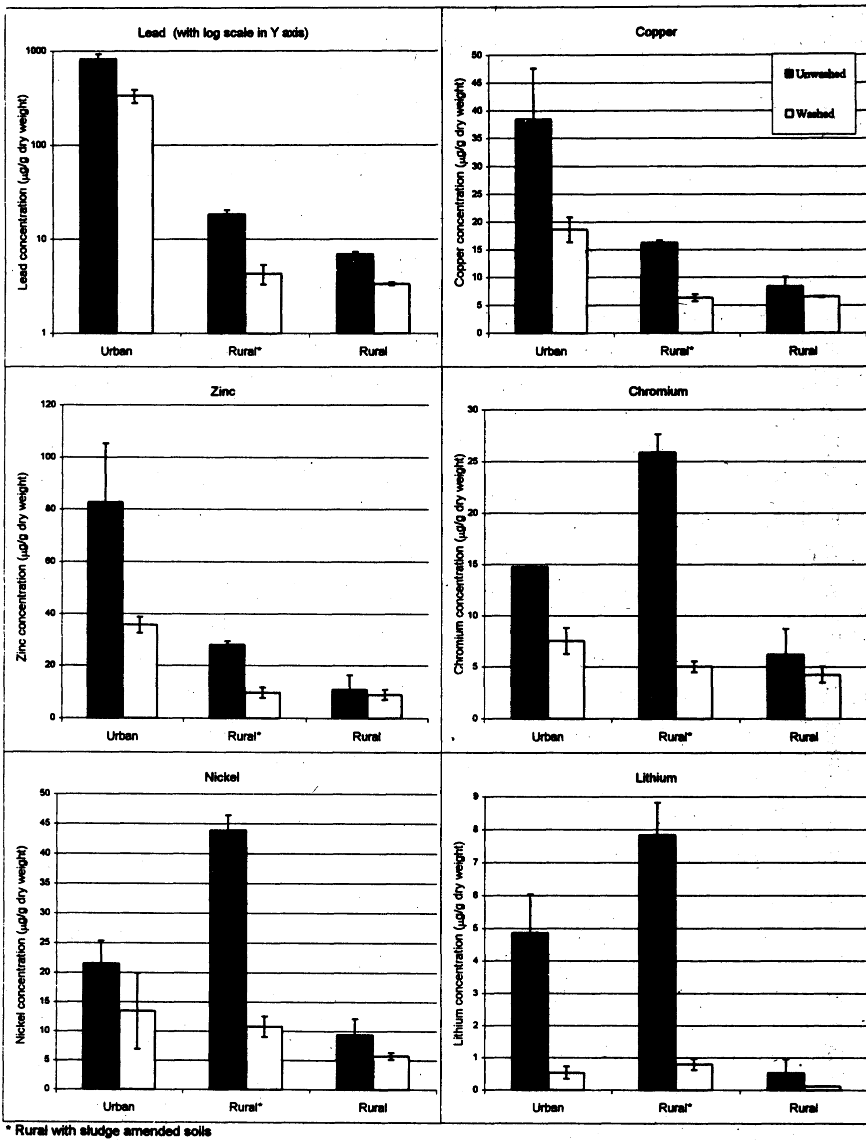

Fig. 1. Metal concentrations in washed and unwashed *P. dactylifera* fibres collected from different areas in Riyadh city (mean and SE error bars)

TABLE-1
METAL VARIATION IN *P. dactylifera* FIBRES (μg/g DRY WEIGHT) FROM DIFFERENT AREAS OF RIYADH CITY

Element	Urban		Rural		Al Hayer*	
	Unwashed	Washed	Unwashed	Washed	Unwashed	Washed
Pb	821.70 ± 107.57	333.90 ± 53.38	6.90 ± 0.42	3.36 ± 0.12	18.44 ± 1.94	4.32 ± 1.01
Zn	82.80 ± 22.44	35.70 ± 3.11	10.80 ± 5.64	8.88 ± 1.92	28.00 ± 1.44	9.72 ± 2.05
Cu	38.49 ± 9.11	18.61 ± 2.29	8.40 ± 1.68	6.60 ± 0.12	16.24 ± 0.40	6.36 ± 0.62
Li	4.86 ± 1.17	0.54 ± 0.20	0.54 ± 0.42	0.12 ± 0.01	7.84 ± 0.97	0.80 ± 0.17
Cr	16.35 ± 1.60	16.83 ± 9.31	6.24 ± 2.52	4.26 ± 0.78	25.88 ± 1.76	5.04 ± 0.52
Ni	21.51 ± 3.88	13.44 ± 6.51	9.42 ± 2.70	5.76 ± 0.60	43.92 ± 2.48	10.80 ± 1.77

TABLE-2
METAL VARIATION IN *P. dactyiifera* FIBRES (μg/g DRY WEIGHT) FROM DIFFERENT AREAS OF RIYADH CITY

Element	Urban		Rural		Al Hayer*	
	Unwashed	Washed	Unwashed	Washed	Unwashed	Washed
Pb	136.79 ± 23.87	29.94 ± 8.42	3.70 ± 0.41	1.85 ± 0.12	5.12 ± 1.05	2.40 ± 0.14
Zn	20.85 ± 2.38	11.71 ± 1.50	8.18 ± 0.50	6.65 ± 0.65	9.00 ± 0.43	7.44 ± 0.36
Cu	5.71 ± 0.73	3.41 ± 0.31	3.34 ± 0.41	2.59 ± 0.24	4.40 ± 0.20	3.40 ± 0.38
Li	2.01 ± 0.33	1.24 ± 0.33	1.42 ± 0.02	1.06 ± 0.23	2.32 ± 0.28	1.36 ± 0.11
Cr	7.28 ± 2.05	3.61 ± 0.85	2.47 ± 0.13	2.66 ± 0.34	10.40 ± 0.64	8.72 ± 1.94
Ni	8.25 ± 1.95	4.41 ± 1.08	4.27 ± 0.22	3.74 ± 0.36	11.84 ± 2.07	7.88 ± 1.08

*Rural area with sludge amended soils

This shows the possibility of using both washed and unwashed fibre samples to monitor the atmospheric deposition of these metals in the studied areas.

Nickel and chromium levels in washed and unwashed fibres showed the same trend. Their levels in unwashed samples collected from the rural area with sludge amended soils (Al-Hayer) were higher than levels in both urban and rural areas with average values of 43.92 and 25.88 μg g^{-1} respectively. Their mean values in unwashed fibres in the urban area were 21.51 and 16.35 μg g^{-1} respectively, which were higher than their mean values from those in rural area, 9.42 and 6.24 μg g^{-1} respectively. This emphasised the influence of the sludge amendment of the soil.

Comparison between metal levels in date palm fibres and leaves

The metal concentrations in the corresponding washed and unwashed leaves samples collected from the above-mentioned three areas are shown in Table-2. Figure 2 shows the metal levels in unwashed fibre and the corresponding leaflet samples collected from the three areas. However, metal levels in unwashed fibre samples were shown to be higher than those in leaflet samples in the three areas, but metal levels in the latter exhibited the same trend shown by the former; for example, the mean lead concentration in unwashed leaves from the urban area was 136.79 μg g^{-1}, which is about six times less than lead levels in unwashed fibres. Furthermore, the lead content in washed leaves was 29.94 μg g^{-1}, which is more than ten times less than the lead content in washed fibres from the urban area.

Although the mean zinc level in unwashed leaves in urban area (20.85 μg g^{-1}) was about two times greater than that in rural area (9.00 μg g^{-1}), but both values were more than three times less than their corresponding values in fibre samples. The mean copper content in unwashed leaves in urban area was 5.71 μg g^{-1}, which is about seven times less than its mean content in unwashed fibres. These high differences between the metal content in fibres and leaves are attributed to the unique structures of the fibres which enable them to retain large amounts of atmospheric deposited dust. The differences in the exposure periods between fibres and leaves can also contribute in this difference.

Figure 3 shows the metal content in washed fibres and their corresponding leaflet samples for a particular tree in the studied three areas. All metal levels proved to be higher in washed fibres than in leaflets, except nickel in the rural area with sludge amended soils (Al-Hayer), which showed the opposite. Lithium levels were higher in washed leaflets than in fibre samples. From these results, washed date palm fibres can be effectively used to monitor these metals in the atmosphere.

Metal levels in fibre at various tree heights

Standardisation of sample orientation in relation to the prevailing wind direction and height above ground are important requirements in biomonitoring with date palm fibres in order to obtain comparable results from trees of different sites.

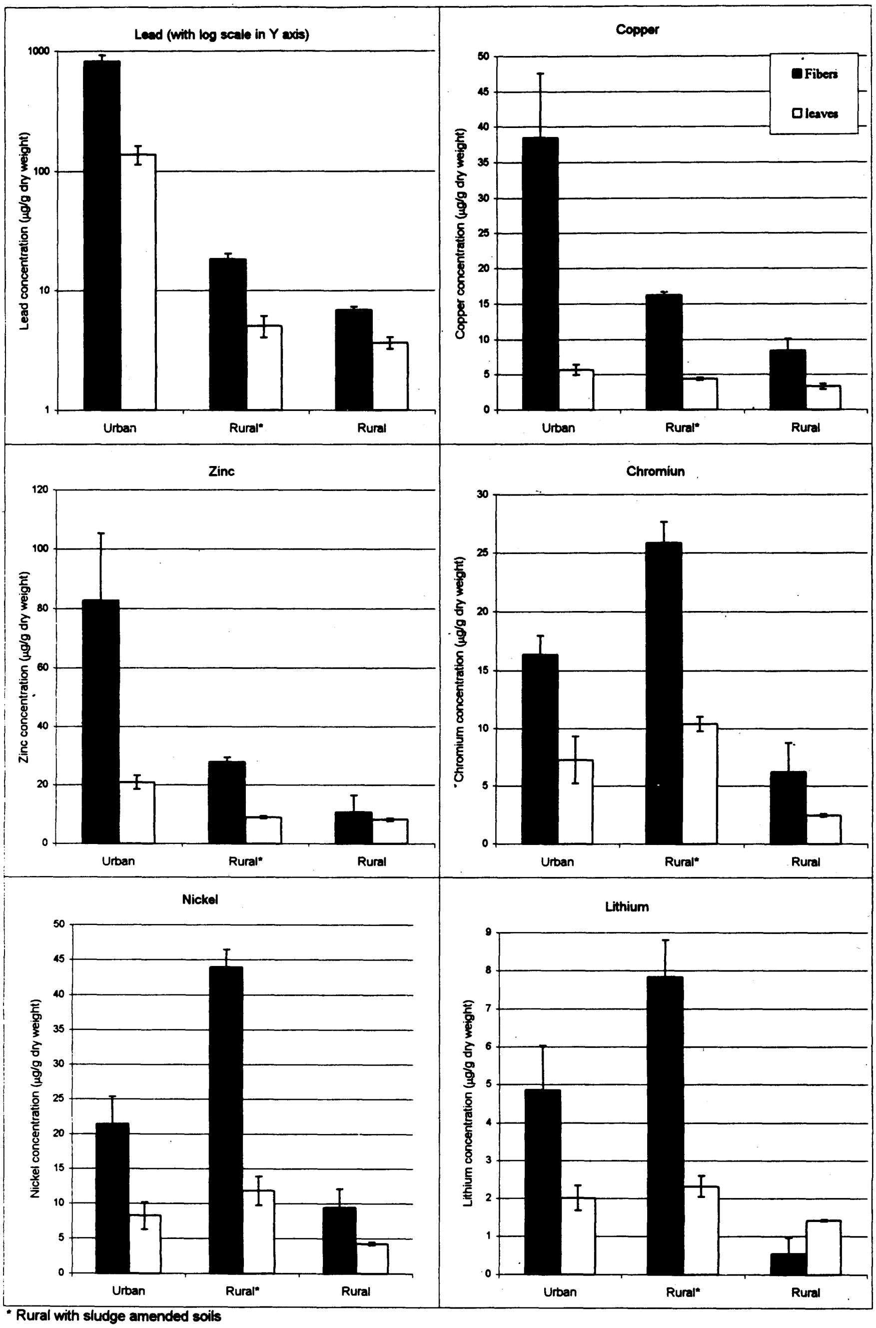

Fig. 2. Metal concentrations in unwashed *P. dactylifera* fibres and leaflets collected from the same areas in Riyadh city (mean and SE error bars)

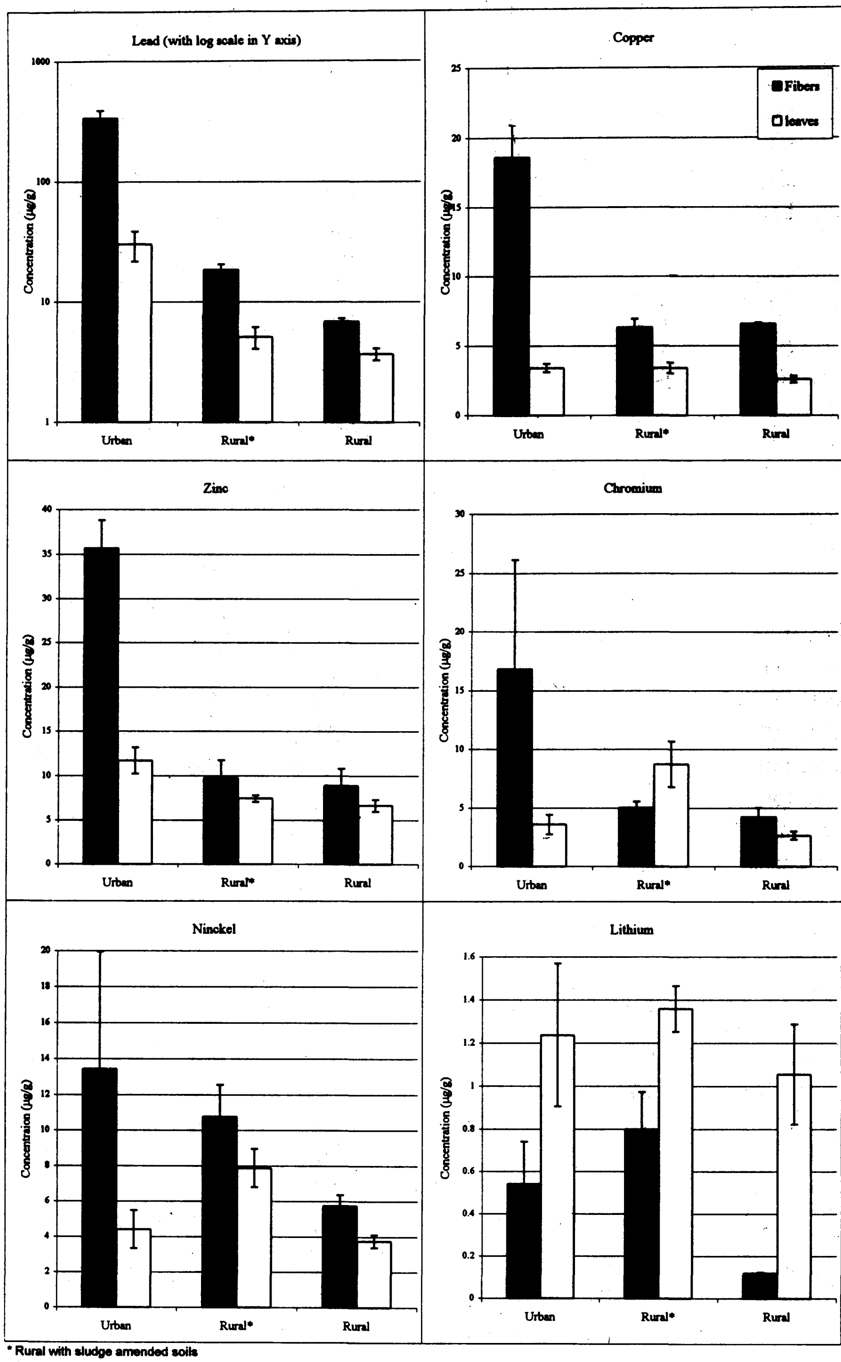

Fig. 3. Metal concentrations in washed *P. dactylifera* fibres and leaflets collected from the same areas in Riyadh city (mean and SE error bars)

Having established that metal concentrations in fibres were remarkably high, it was decided to examine the vertical distribution of metals in samples at various heights above the ground. Table-3 and Fig. 4 show the metal content of washed and unwashed fibre samples collected at various heights.

The concentration of all metal studied in washed and unwashed fibres generally decreased with height, the maximum concentrations usually being found between 0.5 and 1.5 m from the ground (Fig. 4), but there is a clear pattern of increase from 0.5 m up to a height of about 1 m; then the levels decrease, These observations conform to a pattern of emitted lead leaving the vehicle at a height of about 0.25 m and rising to strike the fibres of the date palm at about 1 to 1.5 m above ground.

From Figure (4) it is obvious for lead, zinc, copper and lithium that a large proportion of metal levels in fibre samples is only superficial and can be removed by washing procedures. The reduction in metal concentrations with increasing height of fibre sampling can be attributed to differences in exposure periods.

Conclusions

It was shown by the results of this work that the metal levels in the fibre were correlating with their sources. Furthermore, they show the ability of *P. dactylifera* fibres to retain deposited metals, enhanced by their special structure as dozens of sheets of very tough, coarse-matted fibre and, moreover, their long growing period and long life-span during which metals can be deposited from the atmosphere and retained by the fibers.

Although the results of washing the fibres showed that considerable amounts of metal perticulate are present as removable surface contamination, but the differences between the metal content in washed fibres from different areas show the ability of the fibre to retain these types of pollutants.

The results of the comparison show that fibres can retain the metal pollutants more than the leaflets in both washed and unwashed samples.

The levels of all metals studied in washed and unwashed fibres generally decreased with height, with a maximum concentrations usually found between 0.5 and 1.5 m from the ground.

From the data presented in this work, it may be concluded that *P. dactylifera* fibers can be used to monitor polluted sites. Therefore, regular monitoring of the metal levels on, as well as in, fibres could be used as an inexpensive and simple biomonitor of atmospheric metal pollution.

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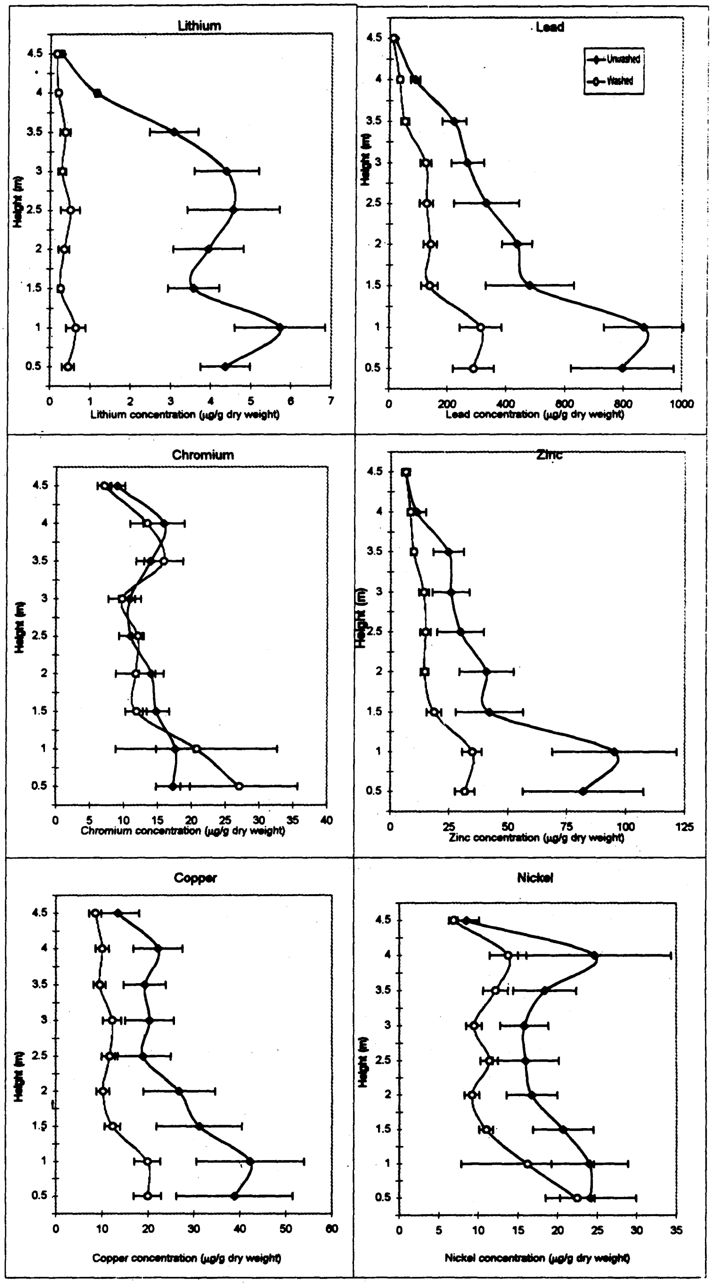

Fig. 4. Metal concentrations (µg/g dry weight) in washed fibres of *P. dactylifera* as a function of height as from 0.5 metre from the ground (mean and SE error bars)

TABLE-3

METALS CONCENTRATION (μg/g DRY WT.) IN WASHED & UNWASHED FIBRES OF *Phoenix dactylifera* AS FUNCTION OF HEIGHT FROM GROUND

Height (m)	Pb		Zn		Cu	
	Unwashed	Washed	Unwashed	Washed	Unwashed	Washed
0.5	797.47 ± 175.69	289.15 ± 69.52	81.97 ± 25.55	31.80 ± 4.15	38.83 ± 12.67	19.91 ± 2.98
1	869.60 ± 136.22	312.93 ± 72.16	95.20 ± 26.45	34.80 ± 4.21	42.24 ± 11.74	19.83 ± 2.81
1.5	480.13 ± 150.74	137.32 ± 28.53	42.13 ± 14.28	18.47 ± 3.15	31.14 ± 9.27	12.28 ± 1.74
2	436.13 ± 51.01	139.48 ± 23.34	40.87 ± 11.49	14.50 ± 1.69	26.79 ± 7.81	10.23 ± 1.43
2.5	331.49 ± 111.25	126.16 ± 23.48	29.77 ± 9.97	14.89 ± 2.21	18.88 ± 6.04	11.67 ± 1.74
3	267.31 ± 55.61	124.00 ± 18.56	25.75 ± 7.89	14.17 ± 2.14	20.28 ± 5.31	12.17 ± 2.01
3.5	220.88 ± 40.99	52.49 ± 14.19	24.67 ± 6.52	9.81 ± 1.19	19.23 ± 4.62	9.44 ± 1.34
4	87.55 ± 16.10	34.34 ± 9.24	11.17 ± 3.92	8.32 ± 1.19	22.17 ± 5.35	10.04 ± 1.47
4.5	17.60 ± 2.76	10.36 ± 2.33	6.38 ± 1.77	6.22 ± 1.11	13.46 ± 4.62	8.52 ± 1.30

Height (m)	Cr		Ni		Li	
	Unwashed	Wahsed	Unwashed	Washed	Unwashed	Washed
0.5	17.29 ± 2.51	27.05 ± 8.66	24.19 ± 5.72	22.49 ± 2.20	4.37 ± 0.61	0.46 ± 0.15
1	17.61 ± 2.80	20.76 ± 11.94	20.04 ± 4.85	16.20 ± 8.34	5.72 ± 1.13	0.64 ± 0.24
1.5	14.78 ± 1.96	11.84 ± 1.58	20.70 ± 3.81	10.97 ± 0.89	3.56 ± 0.64	0.26 ± 0.07
2	14.05 ± 1.82	11.75 ± 2.92	16.73 ± 3.21	9.16 ± 0.94	3.94 ± 0.88	0.34 ± 0.14
2.5	10.99 ± 1.71	12.08 ± 0.84	15.97 ± 4.17	11.37 ± 1.09	4.55 ± 1.15	0.49 ± 0.24
3	10.86 ± 1.63	9.66 ± 1.96	15.79 ± 3.03	9.43 ± 1.00	4.38 ± 0.81	0.29 ± 0.10
3.5	13.90 ± 2.14	15.85 ± 2.88	18.39 ± 3.95	12.15 ± 1.57	3.07 ± 0.60	0.36 ± 0.13
4	15.87 ± 3.08	13.39 ± 2.48	24.68 ± 9.68	13.74 ± 2.32	1.16 ± 0.05	0.19 ± 0.05
4.5	9.00 ± 1.12	7.06 ± 1.02	8.48 ± 1.63	6.84 ± 0.56	0.28 ± 0.05	0.15 ± 0.05

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