Assessment of Lead Levels in Dust and Date Palm (*Phoenix dactylifera* L.) in 6–10 Year-old School Children Environment in Riyadh City, Saudi-Arabia

M. BOUNESSAH*, S.M. AL-SHAYEB, K.M. AL-GHEFAILI and B. ABDULFATAH
Department of Chemistry, Riyadh College of Technology, P.O. Box 42826 Riyadh-11551, Saudi Arabia

To assess lead levels in the school environment of 6–10 year-old children in Riyadh City, swept-dust, soil and date palm (*Phoenix dactylifera* L.) leaflets were obtained from 55 schools located in a 35 km section passing through the city centre. The study area was divided into eastern, central, western and rural sections, the central area (city centre) being the section where the impact of environmental lead pollution is known to be the highest. Swept-dust samples were obtained from the inside and outside of school buildings in order to assess the extent of lead migration from streets into classrooms. Hence, samples were collected from school entrance (SCL1), school playground (SCL2), first floor (SCL3) and second floor (SCL4) of each school building. Soil and date palm (*Phoenix dactylifera* L.) leaflets were taken from the inside perimeter of each school. The leaflets were divided into washed (LFWS) and unwashed (LFUW) subsamples. Soil samples were collected from the top 5 cm of soil (SLA) and also at a depth of 30 cm, close to the date palm trees (SLB). After digestion with concentrated nitric acid at 80°C, the samples were analysed for lead by flame atomic absorption spectrophotometry.

The results showed that lead distribution is a reflection of traffic density and pollution from automotive emissions. Analysis of variance showed that mean lead concentrations for all variables in the city centre, were significantly different from those of the eastern and western sections. The dust-Pb means were found to be the highest in the city centre, *i.e.*, 367 $\mu g\ g^{-1}$, 273 $\mu g\ g^{-1}$, 253 $\mu g\ g^{-1}$ and 214 $\mu g\ g^{-1}$ (from SCL1 to SCL4). These are higher compared with the eastern section (131 $\mu g\ g^{-1}$, 103 $\mu g\ g^{-1}$, 117 $\mu g\ g^{-1}$ and 130 $\mu g\ g^{-1}$) and the western section (164 $\mu g\ g^{-1}$, 135 $\mu g\ g^{-1}$, 129 $\mu g\ g^{-1}$ and 135 $\mu g\ g^{-1}$). Lead pollution in the city centre was also reflected in unwashed (east = 20 $\mu g\ g^{-1}$, centre = 40 $\mu g\ g^{-1}$, west = 27 $\mu g\ g^{-1}$, rural = 15 $\mu g\ g^{-1}$) and washed leaflets (east = 9 $\mu g\ g^{-1}$, center = 18 $\mu g\ g^{-1}$, west = 11 $\mu g\ g^{-1}$, rural = 7 $\mu g\ g^{-1}$). Lead levels in unwashed leaflets showed a significant correlation with washed leaflets (0.77) but a poor correlation with SLB (0.32), suggesting metal absorption from the atmosphere. From this study, it is concluded that in spite of the dilution of windblown inhalable particulates and the reduction of Pb levels in gasoline, undue pollution from this metal is shown to exist in the 6–10 year-old schoolchildren environment in Riyadh city centre.

INTRODUCTION

Dust is an important pathway to lead exposure and in particular for children which are the most susceptible to contamination from the environment due to many reasons[1]: their behaviour (playing outdoors, hand-to-mouth contact, etc.) which increases exposure, better gastroinestinal absorption and increased susceptibility to the effects of lead. Childhood lead poisoning is considered to be an important chronic health condition and it is known to be associated with significant adverse effects on vital organs. It adversely affects children's growth and their renal, hematopoietic and neurological systems[2]; it negatively affects their cognitive development as shown by their poor performance on IQ tests and in schools[3]; it also increases the rate of their behavioural problems[4].

Many studies were carried out as regards lead pollution in the Riyadh area. Ahmed and Al-Swaidan[5] found Pb averages of 208 $\mu g\ g^{-1}$ in surface dust in industrial areas and 106 $\mu g\ g^{-1}$ in rural areas. Their results also showed an increase of Pb levels with car traffic density. Ahmed *et al.*[6] analysed Pb in dusty streets and car parks and found exceptionally high mean concentrations (389 $\mu g\ g^{-1}$ in car parks; 1344 $\mu g\ g^{-1}$ in city centre). In another study, El-Shobokshy *et al.*[7] found high lead levels in atmospheric inhalable particulates (5 $\mu g\ m^{-3}$) which was attributed to vehicle direct emissions as the principal cause of this metal. However, in a comprehensive study of lead contamination in schoolchildren in Saudi Arabia, Ahmed *et al.*[8] concluded that hair-Pb and blood-Pb levels are within the normal range and do not exceed the threshold value (100 μg/L). Lead pollution in Riyadh was also investigated using washed and unwashed leaflet samples of date palm (*Phoenix dactylifera* L.). The work of Al-Shayeb and Seaward[9] showed significant high mean-Pb levels in the urban area relative to the rural area.

The city of Riyadh is an open city with constant blowing winds and wide streets, the wind acting as a diluting medium for dust particulates[7]. In Riyadh, leaded gasoline is still in use, and lead phasedown was begun in the mid-eighties with the aim of lowering Pb content in gasoline from concentrations as high as 0.8 g/L. This paper assesses lead levels in swept-dust, soil and date palm (*Phoenix dactylifera* L.) leaflets in 6–10 year-old schoolchildren environment from Riyadh city. These levels are compared among schools falling in a northeastern section, passing through Riyadh city centre and spanning over a wide range of environmental lead impact.

EXPERIMENTAL

Riyadh is the capital city of the kingdom of Saudi Arabia with an estimated population of over 2 million people compared to 100 thousand in 1950. It is located in the middle of the country in the Arabian Desert, 1000 km east of the Red Sea and 400 km west of the Arabian Gulf. The climate in Riyadh is mainly dry and hot, characterised by a long dry season and short wet season (November-February) with temperatures reaching 45°C during summer and as low as

7°C during winter. The city stands on a 600 m high plateau, surrounded by sandy hills and dunes.

The study area consists of 55 schools for 6–10 year-old children, located along a 35 km long and 2 km wide northeastern section passing through Riyadh city centre. It was divided into 4 sections: east (21 schools), centre (18 schools), west (11 schools) and rural (5 schools), the city centre being the most exposed to lead environmental pollution. The study area was chosen such as to include samples from rural, suburban (eastern and western sections) and urban sections central section) characterised by a variable degree of metal dispersion. Samples taken from the rural area were for control purposes and where the impact of environmental lead pollution is thought to be insignificant.

Sample preparation and analysis: Swept-dust, data palm (*Phoenix dactylifera* L.) leaflets, and soil samples were collected from each school. Swept-dust samples were obtained form 4 different locations distributed in the school environment: school entrance (SCL1), school playground (SCL2), first floor (SCL3), and second floor of the school building (SCL4). The samples were swept from the surface of the ground by means of a brush and a plastic dustpan, collected in a plastic bag and labelled. The samples were then air-dried overnight to remove moisture, sieved with stainless steel sieves and the smallest particle sizes (< 30 μm) were chosen for digestion, because previous studies showed that the highest heavy metal contents are borne by the smallest particles[10]. In the rural section, only one type of swept-dust sample (DSRL) was collected (at school entrance).

Soil samples were taken close to the date palm trees, using a stainless steel trowel, from the top five centimetres of soil (SLA) and at 30 cm depth (SLB). The samples were then air-dried and sieved in a stainless steel sieve to pass 2-mm mesh size using a mechanical shaker. 1 g sample was then ashed at 450°C for 24 h in a muffle furnace to remove organic matter.

The leaflets were obtained from date palm (*Phoenix dactylifera* L.) trees having the same trunk width in order to minimize age variation and therefore variation in environmental exposure period. At each site, a composite sample was collected from middle-aged leaves as explained by Al-Shayeb and Seaward[11] using a pair of stainless steel secateurs. Each sample was then divided into two subsamples; one was washed with deionised (LFWS) water to remove dust particles and the other remained untreated (LFUW). The subsamples were then oven-dried at 105°C for 24 h and milled in a stainless steel grinder. 1 g sample was then ashed in a muffle furnace at 450°C for 24 h and weighed.

1 g samples from the swept-dust, soil and ashed leaflets were digested in 10 mL concentrated nitric acid (AR grade) at 85°C in a sand bath for 4 h and then made up to the mark with deionised water in 10 mL volumetric flasks. After filtration, the samples were analysed for Pb by the Pye Unicam SP9 series flame atomic absorption spectrophotometer. The detection limit for Pb was 0.1 $\mu g\ g^{-1}$. The average precision expressed as the relative standard deviation was found to be below 20% based on 10% replicate samples of the total number of samples. The accuracy of the results was checked by the inclusion of 2 reference standard materials in every batch.

Statistical analysis: Descriptive statistics were obained for SCL1, SCL2, SCL3, SCL4, DSRL, SLA, SLB, LFUW and LFWS. To investigate the normality of data, the Shapiro-Wilk's test and cumulative probability plots were used showing that the Pb concentrations do not follow a normal distribution but fit much better a log normal distribution. Lead values were therefore log-transformed (base 10) in statistical tests. The correlation between variables was evaluated using the Pearson product moment correlation. Comparison between Pb means in the eastern, central and western sections was conducted using the one-way analysis of variance. The assumption of equal variances was carried out with the Levene's test. To investigate differences between each pair of means among all groups, the data were subjected to the least significant difference (LSD) multiple-comparison test as described elsewhere.

RESULTS AND DISCUSSION

Lead concentration in swept-dust: The highest Pb levels were found in the city centre in the four sampled sites at each school with the school entrances showing the highest concentrations (Fig. 1). The mean Pb values for SCL1, SCL2, SCL3 and SCL4 were: 367 μg g^{-1} (± 109.7 SD), 273 μg g^{-1} (± 146.5), 253 μg g^{-1} (± 177.5) and 214 μg g^{-1} (± 132.1) respectively. In eastern and western sections, average Pb concentrations were closer to each other but much lower than in the city center. Average Pb concentrations from SCL1 to SCL4 were: 131 μg g^{-1} (± 36.1), 103 μg g^{-1} (± 50.1), 117 μg g^{-1} (± 52.2) and 130 μg g^{-1} (± 35.4) in the eastern section; and 164 μg g^{-1} (± 42.7), 135 μg g^{-1} (± 64.0), 129 μg g^{-1} (± 45.8) and 135 μg g^{-1} (± 60.3) in the western section (Table-1).

TABLE-1
SUMMARY STATISTICS FOR SWEPT-DUST Pb (μg g^{-1}, DRY WEIGHT) IN 6–10 YEAR-OLD SCHOOLCHILDREN ENVIRONMENT IN RIYADH CITY

Sample type	East		City centre		West		Rural	
	m	SD	m	SD	m	SD	m	SD
SCL1	131	36.1	367	109.7	164	42.7	–	–
SCL2	103	50.1	273	146.5	135	64.0	–	–
SCL3	117	52.2	253	177.5	129	45.8	–	–
SCL4	130	35.4	214	132.1	135	60.3	–	–
DSRL	–	–	–	–	–	–	89	10.8
SLA	33	9.4	77	21.9	32	12.1	24	8.5
SLB	19	8.0	41	16.9	27	6.4	18	4.9
LFUW	20	9.6	40	6.4	27	4.0	15	4.3
LFWS	9	2.9	18	4.0	11	4.4	7	1.5

m = mean; SD = standard deviation; SCL1 = school entrance; SLC2 = school playground; SCL3 = first floor; SCL4 = second floor; DSRL = rural area; SLA = surface soil; SLB = 30 cm deep soil; LFUW = unwashed leaflets; LFWS = washed leaflets.

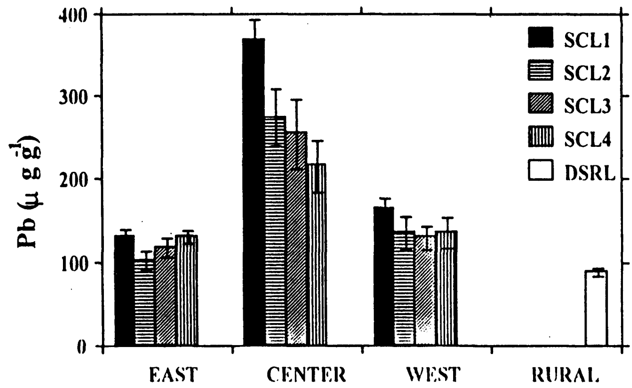

Fig. 1. Variation of mean swept-dust Pb (µg g^{-1}, dry weight) among 6–10 year-old school-children environment in eastern, central, western and rural sections of Riyadh city. SCL1: school entrance; SCL2: school playground; SCL3: first floor; SCL4: second floor; DSRL: rural area.

Lead Concentrations in Soil and Date Palm (*Phoenix dactylifera* L.) Leaflets

Fig. 2 shows the distribution of average lead concentrations is soil and date palm (*Phoenix dactylifera* L.) leaflets among the eastern, western, central and rural sections. Soil samples (SLA and SLB) showed the highest Pb mean levels in the city centre (SLA = 77 µg g^{-1} and SLB = 41 µg g^{-1}). Lead concentrations in the eastern and western sections were approximately 2 times lower for both types of soil samples. Compared with levels from the control area, Pb values in the other localities are much higher.

Average Pb levels in washed and unwashed leaflets were also the highest in the central section (LFUW = 40 µg g^{-1}, LFWS = 18 µg g^{-1}). LFUW and LFWS concentrations showed no significant correlation with those of SLA and SLB.

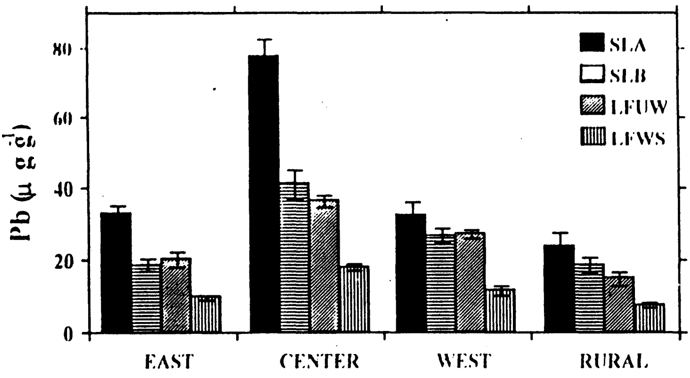

Fig. 2. Variation of mean-Pb (µg g^{-1}, dry weight) in date palm (*Phoenix dactylifera* L.) leaflets and soil among schools from the eastern, central, western and rural sections of Riyadh city. SLA: surface soil; SLB: 30 cm deep soil; LFUW: unwashed leaflets; LFWS: washed leaflets.

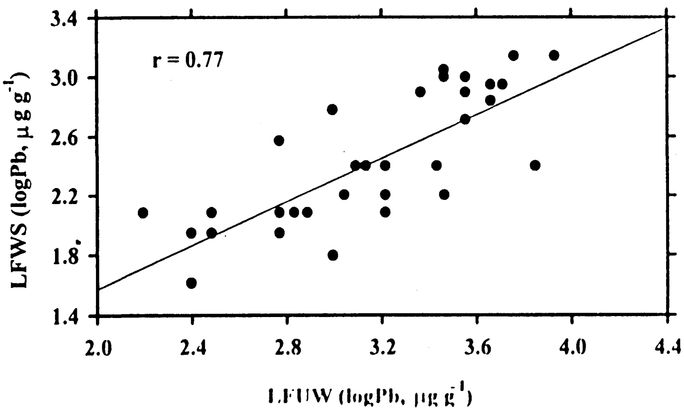

Fig. 3. Correlation between log Pb concentrations (μg g^{-1}, dry weight) in washed (LFWS) and unwashed (LFUW) date palm (*Phoenix dactylifera* L.) leaflets in 6–10 year-old schoolchildren environment of Riyadh city.

However, log Pb values for LFUW and LFWS were significantly correlated ($r = 0.77$, $p = 0.0004$) in samples from the whole study area (Fig. 3). Correlation between log SLB and log FLWS was not significant ($r = 0.32$, $p > 0.05$).

Comparison between Eastern, Central and Western Sections

The one-way analysis of variance was applied to log-transformed Pb for the dependent variables SCL1, SCL2, SCL3, SCL4, LFUW, LFWS, SLA and SLB of the eastern, central and western sections. Lead mean concentrations differed significantly among the 3 sections (Table-2) implying the difference between eastern, central and western sections to be genuine and not due to any chance or random factor. This test, however, did not show which sections were different. To elucidate this, the LSD multiple comparison method was conducted. Results showed that SCL1, SCL2, SCL3, LFUW, LFWS, SLA and SLB in the central section differed significantly from those of the eastern and the western sections

TABLE-2
RESULTS OF ANOVA FOR COMPARISON BETWEEN MEAN-log Pb LEVELS IN SWEPT-DUST, SOIL AND DATE PALM (*Phoenix dactylifera* L.) IN EASTERN, CENTRAL AND WESTERN SECTIONS OF 6–10 YEAR-OLD ENVIRONMENT IN RIYADH CITY

	SCL1	SCL2	SCL3	SCL4	SLA	SLB	LFUW	LFWS
df between groups	2	2	2	2	2	2	2	2
df within groups	29	29	29	29	27	27	27	27
F	34.51	9.40	4.97	3.19	27.65	10.10	13.11	17.18
P	0.000	0.001	0.014	0.056	0.000	0.001	0.000	0.000

SCL1 = school entrance; SLC2 = school playground; SCL3 = first floor; SCL4 = second floor; SLA and SLB = soil samples; LFUW = unwashed leaflets and LFWS = washed leaflets of date palm (*Phoenix dactylifera* L.) df = degree of freedom

(Table-2). However, SLC4 did not show a significant difference (p = 0.056) as confirmed by the Levene's test for homogeneity of variance. Finally, the LSD test showed that not all pairs of means between the eastern and western sections were significantly different.

RESULTS AND DISCUSSION

The levels of lead found in swept-dust, date palm (*Phoenix dactylifera* L.) and soil are a reflection of the environmental lead introduced by the exhaust fumes and also a reflection of traffic density. The highest Pb average concentrations were found, in all sample types, in the city centre where traffic density is at its highest. The high Pb levels in playgrounds and indoor samples from the city centre suggest a migration of lead-polluted dust from the streets into the school buildings by means of shoes and winds. The highest Pb concentrations were found in indoor dust (SCL3 and SCL4) collected from Ibn Kais (mean = 435 $\mu g\ g^{-1}$) and Tidhkaria Schools (mean = 593 $\mu g\ g^{-1}$). This may be explained by the location of these schools; Ibn Kais school is located near a railway station whereas Tidhkaria school is located near heavy car traffic in the city centre. Moreover, the Tidhkaria school is known to be the oldest one in Riyadh which may explain the high indoor Pb, as studied elsewhere showed that old buildings could be the source of high Pb concentrations due mainly to paint[12, 13]. The high Pb levels in Ibn Kais and Tidhkaria schools confirm the high concentrations found by Ahmed *et al.*[8] in hair-Pb and blood-Pb of 6–10 year old schoolchildren in these schools compared with schools nationwide.

Our data compare favourably with Pb averages reported by Al-Rajhi and Seaward[10], for indoor dust of rural and suburban areas but compared to the urban area, our results showed lower concentrations. However, for outdoor dust-lead, the averages were much higher since their samples were exclusively collected from industrial zones and motorways. Also compared with results from Ahmed *et al.*[6], which reported 106 $\mu g\ g^{-1}$ and 208 $\mu g\ g^{-1}$ in outdoor dust from rural and industrial areas respectively, the mean Pb values showed much higher values in all schools in this study. This may be explained by the fact that they analysed the whole sample. Lead levels obtained in this study are however low in comparison with dust samples collected from petrol stations, motorways and car parks[5, 6, 9, 10]. This suggests that only a fraction of the lead emanating from automobile emissions reaches the schools, since a study by Bounessah and Al-Shayeb[14] showed high lead concentation in swept-dust at 50 petrol stations from Riyadh city centre (mean = 2098 $\mu g\ g^{-1}$). It is known that heavy metals settle down very quickly on roads[15]. Moreover, the city of Riyadh is an open city with constant blowing winds and wide streets, the wind acting as a diluting media for lead-dust particulates[7].

The distribution of average lead levels in the date palm (*Phoenix dactylifera* L.) among the eastern, central and western sections indicates a pollution from environmental exposure and in particular in the city centre. This confirms the results of Al-Shayeb *et al.*[9] which concluded that date palm (*Phoenix dactylifera*

L.) accumulates heavy metals and may be used as a biomonitor. However, the lead levels in this study are lower than those reported by Al-Shayeb *et al.*[9]. This is probably due to the location of the schools in the present study as these are not always located near heavy traffic. The process by which this accumulation occurs in the leaflets is not known. An investigation is being carried out by Bounessah and Al-Shayeb[16] in order to understand the mechanism by which lead is absorbed into leaflets. Preliminary results suggest that lead is introduced into leaflets not through the polluted soil but absorbed from the atmosphere into the leaflets, characterised by a large specific area. This explains the significant correlation between the washed and unwashed leaflets in the study area ($r = 0.77$, $p = 0.004$). Moreover, the extremely arid climate in Riyadh city suggests the unlikely absorption of lead from soil through the roots.

It is concluded that in spite of wind dilution of dust particulates and the reduction of lead content in gasoline, undue environmental lead pollution in 6–10 year-old school environment in Riyadh city centre is shown in this study. Lead-polluted dust tends to migrate into schools probably by means of wind and shoes or is due to the location or age of school buildings. This study also confirms the use of date palm (*Phoenix dactylifera* L.) leaflets as a biomonitor for lead in an arid environment. Finally, due to the accumulative effect of lead in the body, it is suggested that lead content in gasoline should be further reduced.

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(*Received:* 25 April 2001; *Accepted:* 23 July 2001) AJC-2393