Hair lead concentration in the Lebanese population: phase 1 results

P. Salameh,[1] N. Bouchy[1] and A. Geahchan[1]

تركيز الرصاص في شعر السكان اللبنانيِّين: نتائج المرحلة الأولى

باسكال سلامة، نرمين بوشي، عزيز جهشان

الخلاصة: هدفت المرحلة الأولى من هذه الدراسة المستعرضة إلى مقارنة تراكيز الرصاص في الشعر ووضع محددات لمستوياته لدى 149 من المتعرضين للرصاص لأسباب مهنية، ومقارنة ذلك مع 177 من الشواهد ممن لم يتعرضوا للرصاص لأسباب مهنية من السكان اللبنانيِّين. وقد استخدم الباحثون استبياناً معيارياً وقاسوا تركيز الرصاص بمقياس الطيف الضوئي، ووجدوا فرقاً يصل إلى 5–6 أضعاف لدى المتعرضين مما هو عليه لدى غير المتعرضين (23.60 مقابل 4.33 جزء بالمليون) وقد أبدى المتعرّضون بسبب المهنة ولاسيما العاملين في تكرير البترول ومحطات الوقود الحد الأقصى من الترابط مع التعرض للرصاص. أما لدى غير المتعرضين فإن الترابط الأعلى كان بين التراكيز المرتفعة من الرصاص وبين الذكورة والجنسية غير اللبنانية والعمل في مواقع حضرية.

ABSTRACT Phase 1 of this cross-sectional study aimed to compare hair lead concentrations and establish the determinants of hair lead levels in 149 occupationally exposed individuals versus 177 non-occupationally exposed controls in the Lebanese population. In addition to a standardized questionnaire, lead concentration was measured by atomic spectrophotometry. A 5–6-fold difference in hair lead concentration was found between occupationally exposed and non-exposed individuals (23.60 ppm versus 4.33 ppm). Professional exposure, particularly working in petrol refining and gasoline stations, had the highest correlation with lead exposure. In non-exposed individuals, male sex, non-Lebanese nationality and urban worksite correlated with higher hair lead concentration.

Contrentration de plomb dans les cheveux : résultats de la première phase d'une étude menée dans la population libasnaise

RÉSUMÉ La première phase de cette étude transversale visait à comparer la concentration de plomb dans les cheveux de 149 sujets exposés sur leur lieu de travail à celle de 177 témoins non exposés sur leur lieu de travail, choisis dans la population libanaise, et à établir les déterminants de ces concentrations. Un questionnaire standard a été utilisé et la concentration en plomb a été mesurée par spectrophotométrie atomique. La concentration de plomb dans les cheveux des sujets exposés sur leur lieu de travail était 5 à 6 fois plus élevée que dans ceux des sujets non exposés (23,60 ppm contre 4,33 ppm). L'exposition professionnelle, notamment dans les raffineries de pétrole et les stations-service, présentait la corrélation la plus élevée avec l'exposition au plomb. Chez les sujets non exposés, le sexe masculin, la nationalité non libanaise et le lieu de travail urbain étaient corrélés avec une concentration de plomb dans les cheveux plus élevée.

[1]Faculty of Pharmacy, Lebanese University, Beirut, Lebanon (Correspondence to P. Salameh: pascalesalameh@yahoo.com).
Received: 04/01/06; accepted: 07/05/06

Introduction

Lead poisoning is a global health problem, particularly in developing countries that persist with leaded fuel [*1,2*]. However, even in developed countries with stricter controls, sources of lead are still numerous [*1,2*]. In fact, lead remains an important problem for poor, inner-city, ethnic minority children, with a particular emphasis on lead paint and dust [*3*]. In houses built before 1980, paint crumbles and mixes into house dust and soil, where it may be unwittingly ingested by young children. Airborne lead can also be generated during renovation work, when paint is often sanded or burned into fine inhalable particles [*4*].

Careful longitudinal cohort studies have shown that children with elevated lead exposure are at risk for deficits in IQ, balance, hearing and growth [*5*]. In adults, chronic lead exposure has led to kidney, gastrointestinal, haematological, nervous system and rheumatologic problems. Women have an increased risk of stillbirths, miscarriages and decreased birth weights, and men often develop abnormal sperm counts and morphology leading to sterility [*6,7*]. Occupational lead exposure can also cause a decline in cognitive function over the course of time [*8*].

The Centers for Disease Control and Prevention guidelines define elevated blood lead levels as $\geq$ 10 µg/dL for children [*9*]. However, evidence is now emerging that even levels $<$ 10 µg/dL can cause neurological damage [*1*]. The effects of lead may thus be more deleterious than currently thought. For occupationally exposed adults, the maximum allowable blood lead that requires medical removal remains the existing Occupational Safety and Health Act standard of 50 µg/dL. Below these levels, however, nervous, gastrointestinal, and musculoskeletal symptoms begin to be increased in individuals with blood leads between 30 and 39 µg/dL and possibly at levels as low as 25–30 µg/dL for nervous system symptoms [*10*].

In Lebanon, close to 90% of vehicles were operating on leaded gasoline until early 2002 when leaded gasoline was banned [*11*]. In addition to ambient air lead and passive and active smoking, the population in Lebanon may be exposed to lead through other sources, such as tap water delivered by lead-soldered pipes, paint and kohl (traditional eyeliner rich in lead) [*12*]. Despite the presence of a national study on all groundwater sources used in Lebanon that reported non-detectable lead content, or lead concentrations that were within international standards [*13*], lead content has not been assessed in households, or within the old water distribution network, which has been maintained or replaced only recently [*12*].

A study has been performed on working men in Lebanon at low occupational hazard for lead toxicity in Beirut [*14*], and another on children aged 1–3 years old [*12*]. However, to our knowledge, no study has been carried out across all Lebanese regions, particularly using hair concentration as an indicator of lead exposure, nor has a study been performed in Lebanon to compare occupational and non-occupational exposures to lead from gasoline and other sources and its determinants. The objective of the first phase of our study, which was carried out before lead was banned from fuel in Lebanon, was to compare hair lead concentrations in occupationally exposed individuals versus non-occupationally exposed controls in the population across Lebanon, and to look at determinants of hair lead levels in both occupationally exposed and non-exposed individuals. With the announcement of the new law, a

second phase was designed to compare its results with those of phase 1, allowing us to confirm whether there had been a decrease in exposure, to find out the new determinants of lead exposure in Lebanon, and to come up with new recommendations for further decreases in lead exposure. Phase 2 of our study is expected to finish by the end of 2008. In this article, the results of phase 1 are presented.

Methods

This was a cross-sectional comparative study that compared hair lead concentration from individuals occupationally exposed to lead versus individuals not occupationally exposed in the Lebanese population.

Sample

The study took place between January and September 2001, before lead was banned from Lebanese gasoline in 2002. Occupationally exposed individuals were selected by convenience non-random quota sampling from individuals working in sectors known to be exposed to lead, with equivalent distribution of residence in all Lebanese regions. The sectors involved were: traffic flow controllers, taxi drivers, gasoline station staff, pipe soldering workers, glass industry workers, battery recycling workers, oil refinery workers and lead-containing pigments industry workers.

Non-exposed individuals were workers who had never worked in these sectors, selected by non-random quota sampling, distributed by sex and region of residence according to the Central Administration of Statistics in Lebanon [*15*]. Furthermore, the numbers were weighted to take account of the distribution of the general Lebanese population by region, sex, nationality and age group [*15*].

Data collection

In every region, people were approached at their worksite. Previously trained, independent interviewers briefly explained that they were carrying out a health study. Individuals gave oral consent to give a hair sample and answer a questionnaire.

Questionnaire

A standardized questionnaire was used, where the dependent variable was hair lead concentration and the independent variables were professional exposure to lead, age, sex, nationality, region of residence, region of work, smoking and frequency of fish consumption. Occupational exposure to lead was determined according to the description of the actual job (for employment of 6 months and over). Regions were determined according to the official distribution of Lebanese governorates, and primary residence was considered as the region of residence. Smoking details included frequency of cigarette smoking during the last 6 months. Fish eating was introduced because of the proven accumulation of heavy metals in seafood; however, no studies were available concerning the lead levels in Lebanese coastal fish.

Lead analysis

Results from other studies support the hypothesis that hair lead levels can be considered an indicator of relative exposure of populations to lead pollution [*16–18*]. It is in the occipital region that hair growth is least affected by age and sex. In order to limit variable factors, a standardized technique was used: 50–100 mg of hair (about 30–50 hairs) were cut at 1 cm from the base of the occipital region. This proximal hair sampling is expected to maximize the correlation with blood levels, with a correlation coefficient $r = 0.70$, and a correlation equation being

log(blood Pb in μg/L) = 0.3445 log(hair Pb in ng/g) + 0.7385 [*19*]. Hair samples were preserved in plastic bags and transported to the laboratory.

A 1100B model Perkin Elmer spectrophotometer was used, equipped with a deuterium lamp for correction of basic signal, a hollow cathode lamp and a HG-400 graphite oven. The experimental conditions were as follows: cathode lamp λ = 283.3 nm, bandwidth 0.7 nm, intensity 10 mA; argon vector gas; atomization conditions as shown in Table 1. Controls at 0, 10, 20 and 30 μg/L of lead were analysed according to the same atomization procedure. Detection limit of the method is 0.05 μg/L.

Sweat, sebum and other environmental organic pollutants were removed to decrease false positive results. Hair samples were washed with distilled water 3 times, then with acetone 3 times, then again with distilled water 3 times, followed by desiccation at 60 °C for 2 hours.

Hair solubilization was performed with 5 mL of 65% supra-pure nitric acid and 1 mL of 110 V hydrogen peroxide for every 50–100 mg of washed and dried hair. Digestion was done in an incubator at 50 °C for 2 hours. The final volume was adjusted to 10 mL with distilled water. Analysis was then done by spectrometry. Concentrations are expressed in parts per million (ppm) or μg of lead/kg of dry hair.

Table 1 **Atomization conditions for hair lead analysis**

Step	Temp (°C)	Ramp (s)	Hold time (min)	Argon flow (mL)
Desiccation	150	15	20	300
Combustion	1100	15	10	300
Atomization (reading)	1600	0	3	0
Cleaning	2500	1	3	300

Temp = temperature.

Data analysis

Data entry and analysis was performed using SPSS, version 12.0. Statistical tests used included chi-squared test for bivariate analysis of categorical data and Student or Mann–Whitney rank sum test for continuous variables when applicable. A *P*-value of 5% was taken as significant. Multivariate analysis was also performed using a step-by-step backwards linear regression procedure, with the independent variables: professional exposure, age, sex, nationality, region of residence, region of work, fish consumption and smoking. The dependent variable was lead concentration.

Results

The sample size was 326. There were 177 (54.3%) non-occupationally exposed individuals versus 149 (45.7%) individuals occupationally exposed to lead.

Background characteristics

The mean age of the whole group was 34.15 [standard deviation (SD) 15.40] years; for non-exposed individuals it was 35.47 (SD 17.49) years and for exposed individuals 32.58 (SD 2.35) years (not significant; $P <$ 0.09).

There were some significant differences in the baseline characteristics of the 2 groups. The exposed group was composed of a higher proportion of males (99.3%), aged between 19 and 40 years (71.1%), residing almost equally in all Lebanese regions, and working mainly in Beirut (40.9%) (Table 2). They also included a majority of smokers (61.7%), with a higher percentage of non-Lebanese (29.5%) and those working on urban sites (77.9%). The

Table 2 **Sociodemographic characteristics of individuals occupationally exposed to lead sources and individuals not exposed**

Characteristic	Non-exposed (n = 177)[a] No.	%	Exposed (n = 149)[a] No.	%	P-value	Total (n = 326)[a] No.	%
Sex					< 0.001		
Male	88	50.0	148	99.3		236	72.6
Female	88	50.0	1	0.7		89	27.4
Age (years)							
≤ 18	19	10.8	8	5.4	0.001	27	8.3
19–40	88	50.0	106	71.1		194	59.7
> 40	69	39.2	35	23.5		104	32.0
Residence region					0.01		
Beirut	19	10.7	30	20.1		49	15.0
Mount Lebanon	71	40.1	41	27.5		112	34.4
North Lebanon	36	20.3	21	14.1		57	17.5
Bekaa	22	12.4	29	19.5		51	15.6
South Lebanon	29	16.4	28	18.8		57	17.5
Work region					< 0.001		
Beirut	15	8.5	61	40.9		76	23.4
Mount Lebanon	81	45.8	39	26.2		120	36.9
North Lebanon	33	18.6	20	13.4		53	16.3
Bekaa	18	10.2	7	4.7		25	7.7
South Lebanon	29	16.4	22	14.8		51	15.7
Smoking (packs/day)					0.001		
Non-smoker	104	58.8	57	38.3		161	49.4
< 1	54	30.5	59	39.6		113	34.7
1–2	15	8.5	24	16.1		39	12.0
> 2	4	2.3	9	6.0		13	4.0
Fish consumption (times/month)					0.10		
1	55	31.1	33	22.1		88	27.0
2	54	30.5	39	26.2		93	28.5
3	32	18.1	39	26.2		71	21.8
> 3	36	20.3	38	25.5		74	22.7
Nationality					< 0.001		
Non-Lebanese	12	6.8	44	29.5		56	17.2
Lebanese	165	93.2	105	70.5		270	82.8
Residence					0.82		
Urban	64	36.4	56	37.6		120	36.9
Rural	112	63.6	93	62.4		205	63.1
Worksite					0.002		
Rural	68	38.4	33	22.1		101	31.0
Urban	109	61.6	116	77.9		225	69.0

[a]*Data missing for some items.*

non-occupationally exposed group had 50% females, 50% of 19–40 years, mainly residents and workers of Mount Lebanon (40.1% and 46% respectively), 58.8% non-smokers, 6.8% non-Lebanese, and 61.6% with urban worksite. Fish consumption and urban residence were similar between the 2 groups ($P = 0.10$) (Table 2).

Hair lead concentration

There was a 5–6-fold difference in hair lead concentration between occupationally exposed and non-exposed individuals: 23.60 ppm versus 4.33 ppm ($P < 0.001$). In non-exposed individuals male sex, older age, North Lebanon, Beirut and Bekaa residence and working regions, smoking, non-Lebanese nationality, urban residence and urban worksite were all associated with higher lead concentrations (Table 3).

Of the occupationally exposed workers, 9 (6%) were petrol refinery workers, 40 (27%) gasoline station staff, 42 (28%) traffic flow controllers, 31 (21%) taxi drivers, 12 (8%) pipe soldering workers, 3 (2%) glass industry workers, 11 (7%) battery recycling workers and 1 (1%) lead pigments industry workers. Petrol refining workers had the highest concentrations (30.92 ppm), along with gasoline station attendants (28.29 ppm), followed by traffic flow controllers (22.73 ppm), taxi drivers (21.76 ppm) and pipe soldering workers (21.08 ppm). Workers in the glass industry, battery recycling and lead-containing pigments industry had lead levels of 15.17, 14.61 and 14.10 ppm respectively. These differences were statistically significant ($P < 0.001$).

In Table 4, we present a multivariate analysis of lead concentrations. In non-exposed individuals, age, male sex, non-Lebanese nationality and urban worksite were correlated with higher hair lead concentration (adjusted $R^2 = 0.44$). In the total population, professional exposure was the factor with the highest correlation with lead concentration, along with the same other factors (male sex, non-Lebanese nationality and urban worksite), except that age that was not retained in the model (adjusted $R^2 = 0.79$).

Discussion

In this study, we found a 5–6 fold difference in hair lead concentrations between occupationally exposed and non-exposed individuals. Occupational exposure to lead sources, particularly working in petrol refining and gasoline stations, was the most strongly correlated with lead exposure. In non-exposed individuals, male sex, non-Lebanese nationality and urban work-site were correlated with higher lead concentrations. Individuals with higher lead exposure are expected to present all kinds of symptoms and diseases associated with high lead exposure, such as neurological, nephrological and gastrointestinal health effects [*5–8*]. Again, the banning of lead from fuel in our country is expected to affect those individuals beneficially because lead in engine fuel is the most important source of lead exposure in urban regions, despite the fact that this utilization constitutes only 2.2% of its global utilization [*20*]. This is expected to decrease the exposure level of all individuals, and thus their lead-associated health risks.

Gasoline exposure constituted the most important source of lead in our study, and other exposed professions had lower lead concentrations although still higher than the general population. This is in line with the results of other studies, where the hair lead concentration of workers occupationally exposed to lead was significantly higher than that in persons not exposed to the metal (7.6 µg/g for exposed workers versus

Table 3 **Mean hair lead concentrations of occupationally exposed and non-exposed individuals in parts per million (ppm)**

Characteristic	Non-exposed Mean lead level (ppm)	Non-exposed SD	*P*-value	Exposed Mean lead level (ppm)	Exposed SD	*P*-value	*P*-value[a]
Sex			< 0.001			0.34	
Male	5.85	2.90		23.62	7.16		< 0.001
Female	2.80	1.84		16.70	0		< 0.001
Age (years)			< 0.001			0.25	
≤ 18	1.52	0.91		21.80	8.12		< 0.001
19–40	3.91	2.52		24.24	7.59		< 0.001
> 40	5.65	2.93		21.96	5.16		< 0.001
Residence region			< 0.001			0.05	
Beirut	5.29	2.40		23.73	7.46		< 0.001
Mount Lebanon	3.28	1.92		26.32	8.26		< 0.001
North Lebanon	6.31	3.65		23.22	6.05		< 0.001
Bekaa	5.17	3.19		22.37	5.98		< 0.001
South Lebanon	3.16	1.98		20.90	5.92		< 0.001
Work region			< 0.001			0.08	
Beirut	6.52	0.57		23.97	6.48		< 0.001
Mount Lebanon	3.52	2.30		25.37	8.80		< 0.001
North Lebanon	6.09	3.65		23.44	6.12		< 0.001
Bekaa	4.82	3.45		21.89	6.80		< 0.001
South Lebanon	3.16	1.98		19.94	5.69		< 0.001
Smoking (packs/day)			0.001			0.45	
Non-smoker	3.66	2.90		23.69	7.21		< 0.001
< 1	5.32	2.34		24.22	7.10		< 0.001
1–2	5.64	3.35		21.57	6.74		< 0.001
> 2	3.21	1.39		23.92	8.46		< 0.001
Fish consumption (times/month)			0.07			< 0.001	
1	4.72	2.48		20.67	6.58		< 0.001
2	4.18	2.96		23.72	6.74		< 0.001
3	3.26	3.02		28.08	7.59		< 0.001
> 3	4.90	2.97		21.31	5.24		< 0.001
Nationality			< 0.001			0.02	
Non-Lebanese	7.25	2.58		25.64	7.79		< 0.001
Lebanese	4.12	2.78		22.71	6.72		< 0.001
Residence			< 0.001			0.15	
Urban	4.95	2.91		24.23	7.51		< 0.001
Rural	3.23	2.46		22.48	6.44		< 0.001
Worksite			< 0.001			0.20	
Urban	5.08	2.87		23.97	7.08		< 0.001
Rural	3.12	2.43		22.16	7.33		< 0.001
Total	4.33	2.87		23.60	7.15		< 0.001

[a]*Exposed vs non-exposed.*
SD = standard deviation.

3.2 µg/g for non-exposed workers and 2.6 µg/g for randomly selected controls, $P < 0.05$) [*17*]. The results we obtained for non-occupationally exposed individuals are below the threshold for hair lead (5 µg/g) suggested by Maimulov et al., especially for individuals below 18 years of age [*21*]; higher allowable limits of 9 µg/g were even suggested by Revich [*22*] and by Esteban [*23*]. However, lead may still be a problem for selected individuals. Nuwayhid et al. found for children 1–3 years old that those whose fathers worked in occupations with potential exposure to lead, and whose families used kohl, glazed pottery for food preparation or hot tap water for milk preparation, might be at a higher risk for lead exposure [*12*]. In the study performed in Moscow, by Revich the highest lead concentrations among urban children were found among those who lived near a copper smelter (18.2 µg/g), a lead–cadmium plant (31.1 µg/g) and a storage battery factory (48.3 µg/g), exceeding the control group values by up to 5 times [*22*]. Our phase 2 study is expected to provide further insight regarding high-risk subgroups.

In our study, smoking was found to be a factor that affected hair lead level in the bivariate analysis; however, when tested as an independent factor, it was not retained in the final multivariate model as a source of lead. In fact, the quantity of lead absorbed from 1 pack of cigarettes is estimated to be 0.68 µg to 1.35 µg [*24*], which is a relatively small quantity compared to occupational exposure. Even in non-occupationally exposed individuals, smoking was not found to correlate with hair lead level. One explanation for this finding is that there may be sources of exposure to lead in these populations that are more important than smoking; another explanation would be an information bias. This contrasts with Nuwayhid et al.'s findings that smoking was related to higher blood lead levels in workers of Beirut, whether or not they were occupationally exposed to lead [*14*]. Further studies are necessary to clarify this issue. Fish consumption also did not show any correlation to lead exposure in our study. In fact, it has been demonstrated that seafood contains less lead than other heavy metals such as mercury [*25*].

Given that lead poisoning is a preventable condition, these findings add urgency to the call for effective implementation of governmental policies that help to prevent lead poisoning [*3*]. The results we found could be extrapolated to neighbouring developing countries where lead is still used in gasoline, demonstrating the urgency of acting to solve this issue by public health decision-makers in these countries. However, this is not sufficient to prevent all health risks of lead in the population. Vigilance in countries where leaded fuel has been banned should also be applied; it could be assisted by broadening community awareness, by enforcing stricter controls over use of products known to contain lead, as well as stricter surveillance and testing of goods [*2*]. In Lebanon, further research is needed to assess the decrease in lead exposure and its determinants, with the ultimate aim of acting to diminish lead concentrations to no-effect levels.

In this study, the following systematic errors are possible: residual confounding may persist despite the fact that potential confounding variables were taken into account in the multivariate analysis. A selection bias is also possible since sampling was non-random, particularly for non-exposed individuals. However, we do not expect these possible biases to affect our results except towards the null.

Table 4 **Multivariate linear regression analysis of hair lead levels in the total sample and in non-exposed individuals**

Variable	Non-exposed		Total	
	β (95% CI)	*P*-value	β (95% CI)	*P*-value
Professional exposure	n/a	–	17.17 (15.82 to 18.53)	< 0.001
Male sex	2.15 (1.03 to 4.07)	< 0.001	2.60 (1.10 to 4.11)	0.001
Lebanese	–2.02 (–3.37 to –0.66)	0.04	–2.41 (–3.97 to –0.85)	0.003
Urban worksite	1.37 (0.70 to 2.04)	< 0.001	1.44 (0.22 to 2.66)	0.02
Age	0.05 (0.03 to 0.07)	< 0.001	n/r	–
Adjusted R^2	0.44		0.79	

Adjustment was made for smoking status, fish consumption, age, sex, nationality, work region, urban worksite, residence region and urban residence.
CI = confidence interval; n/a = not applicable; n/r = not retained in the model.

Conclusion

In conclusion, high levels of lead were found in the hair of occupationally exposed people. In addition, non-occupationally exposed individuals also had measurable lead concentrations in their hair, and are thus exposed to its harmful effects. The resolution of the problem has begun by banning lead-containing fuel from the Lebanese market. This is expected to decrease hair lead levels, and comparison with the current results will be performed in phase 2 of the current study. Future results are expected to inform decision-makers about the appropriateness of the policy they applied and further steps to be taken to promote the health of at-risk populations.

References

1. Gavaghan H. Lead, unsafe at any level. *Bulletin of the World Health Organization*, 2002, 80(1):82.
2. Mangas S, Fitzgerald J. Exposures to lead require ongoing vigilance. *Bulletin of the World Health Organization*, 2003, 81(11):847.
3. Rabito F, Shorter C, White LA. Lead levels among children who live in public housing. *Epidemiology*, 2003, 14:263–8.
4. Hu H, Brown MJ. Effectiveness of environmental health policies: a new frontier for epidemiologists. *Epidemiology*, 2003, 14(3):257–8.
5. Markowitz M. Lead poisoning: a disease for the next millennium. *Current problems in pediatrics*, 2000, 30:62–70.
6. Nomiyama K et al. Lead induced increase of blood pressure in female lead workers. *Occupational and environmental medicine*, 2002, 59:734–9.
7. Brewster U, Perazella M. A review of chronic lead intoxication: an unrecognized cause of chronic kidney disease. *American journal of the medical sciences*, 2004, 327(6):341–7.
8. Schwartz B et al. Occupational lead exposure and longitudinal decline in

neurobehavioral test scores. *Epidemiology*, 2005, 16:106–13.

9. *Preventing lead poisoning in young children: a statement by the Centers for Disease Control*. Atlanta, Georgia, United States Department of Health and Human Services, Centers for Disease Control and Prevention, 1991.

10. Occupational exposure to lead. Attachments to the preamble for the final standard. Book 2. *American federal register*, 1978, 43(225):54353–616.

11. Chaaban FB, Nuwayhid I, Djoundourian S. A study of social and economic implications of mobile sources on air quality in Lebanon. *Transportation Research Part D: Transport and environment*, 2001, 6(5):347–55.

12. Nuwayhid I et al. Blood lead concentrations in 1–3 year old Lebanese children: a cross-sectional study. *Environmental health*, 2003, 2(1):5.

13. Jurdi M, ed. *Survey of the quality of potable water in Lebanon*. Beirut, Lebanon, Ministry of Hydraulic and Electrical Resources and UNICEF, 1998 (WATR/00/1998/002).

14. Nuwayhid I et al. Determinants of elevated blood lead levels among working men in Greater Beirut. *Lebanese medical journal*, 2001, 49:132–9.

15. *National Study of Household Living Conditions in 1997*. Beirut, Lebanon, Central Administration of Statistics, 1998.

16. Katz SA. The use of hair as a biopsy material for trace elements in the body. *International laboratory*, 1979, 5:181–9.

17. Strumylaite L, Ryselis S, Kregzdyte R. Content of lead in human hair from people with various exposure levels in Lithuania. *International journal of hygiene and environmental health*, 2004, 207(4):345–51.

18. Sanna E et al. Blood and hair lead levels in boys and girls living in two Sardinian towns at different risks of lead pollution. *Ecotoxicology and environmental safety*, 2003, 55(3):293–9.

19. Stupar J, Dolinsek F, Erzen I. Hair-Pb longitudinal profiles and blood-Pb in the population of young Slovenian males. *Ecotoxicology and environmental safety*, 2007, 68:134–43.

20. *Phasing lead out of gasoline: an examination of policy approaches in different countries*. 1999. Paris, Organisation for Economic Cooperation and Development/United Nations Environment Programme, 1999.

21. Maimulov G, Patsiuk NA, Baskovich GA. Gigienicheskaia otsenka vluianiia khimicheskogo zagriazneniia okruzhaiushchei sredy megapolisa na sostoianie zdorov'ia detei [Hygienic evaluation of the large city environmental chemical pollution influence on children's health status]. *Gigiena i sanitaria*, 2004, Mar–Apr(2):31–3.

22. Revich BA. Lead in hair and urine of children and adults from industrialized areas. *Archives of environmental health*, 1994, 49(1):59–62.

23. Esteban E et al. Hair and blood as substrates for screening children for lead poisoning. *Archives of environmental health,* 1999, 54:436–40.

24. Ghorbel H et al. Plomb et cadmium dans le tabac fumé en Tunisie [Lead and cadmium in tobacco smoke in Tunisia]. *Maghreb médical*, 1996, 309:40–2.

25. Grandjean P et al. Impact of maternal seafood diet on fetal exposure to mercury, selenium and lead. *Archives of environmental health*, 1992, 47(3):185–95.