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**A Comparison of Lead Exposures in
Industrial “Hot Spots” in Jordan and Israel**

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Abstract

The aim of this research was to compare between two hot spots of lead exposure in Israeli and Jordanian occupational settings. The study also sought to assess whether any differences in regulations and legislation regarding occupational health could be identified as a source of exposure disparities. Blood and hair specimens were collected from workers in a battery factory in Jordan and a secondary lead smelter in Israel and compared. About 33% of the currently exposed group showed blood lead levels above the internationally recommended concentration of 40 µg/dl. Although the differences of blood lead levels between Israel and Jordan were not statistically significant, average levels were lower in Jordan. Beyond the difference in the factory types, disparity in exposure levels can be explained due to a combination of proclivities of factory management, public policies, existing medical surveillance and insurance, as well as cultural differences. Results reveal that despite existing regulations and the growing attention that is dedicated to lead and lead occupational exposures, there are still hot spots for lead exposure in Israel and Jordan. The contrasting experience found in the current study raise the possibility that information and technology exchange between the two countries: Israel and Jordan, could be beneficial for improving occupational health policy in these two neighboring countries.

(key words: occupational lead exposures, Israel, Jordan, lead smelters, battery factories)

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Introduction

Numerous areas have been identified as potential areas of cooperation in the environmental and health fields as “confidence building mechanisms” for improving relations between Israel and its neighbors. After the peace treaty between Jordan and Israel was signed in 1994, considerable cooperation between the two countries took place on different levels and in different fields. (FOEME, 1997). Coordinating river restoration efforts, groundwater management or air pollution control has been the subject of research and discussion in the search for a regional environmental agenda. (Tal, 2004) Occupational health, however, was never a focus of attention for cooperative efforts in the Middle East, largely because of the presumed gap in exposures and regulatory infrastructure between Israel and its neighbors. In the light of its economic indicators, it would seem predictable that public health as well as occupational health would be relatively more advanced in Israel.

Lead poisoning and lead exposure have been extensively studied by physicians and scientist throughout the years and there are a plethora of studies investigating lead exposure in the field. (Aguilar-Garduño, 2003, Beilligner, 1994, Canfield, 2003, Tong, 2000) Yet, there are still hot spots of lead exposure, where elevated levels of lead exposure occur, such as industrial zones and highly trafficked and crowded areas. (Chuang, 1999, Dykeman, 2002, Ehrlich, 1998)

Israel and Jordan are neighboring countries, sharing the same topography, climate, water sources, and environmental challenges and concerns. Yet, Israel is classified as a

developed country with GDP per capita (PPP)¹ of \$ 24,509 for 2004 (CBS 2006) while Jordan is a developing country of with a per capita GDP of \$4,688 for the same year (UNDP 2006). The life expectancy at birth for total population in Israel is slightly higher than in Jordan: 79.46 versus 78.4 years, respectively (CIA 2006). Jordan has a lower standard of living as well as lower degrees of industrialization and economic growth. This study focuses on the occupational health status of workers in Israel and Jordan who are working in lead industries and assesses the overexposure of those engaged in such occupations.

The aim of this study was to compare between two hot spots of lead exposure in Israeli and Jordanian occupational settings. Beyond the importance of

¹ Purchasing Power Parity (PPP) per capita is often differentiated from Gross domestic product (GDP).

uncovering high worker exposures, it was important to assess whether any differences in regulations and legislation regarding occupational health could be identified as a source of exposure disparities.

The present study explores opportunities for cooperation and information exchange in the occupational health field in the Middle East. The notion that Israel might learn from factory policies that are designed to minimize exposure in Jordan, while Jordan can take advantage of the Israeli experience with regulations and legislated environmental controls has never been contemplated in the public policy realm.

¹ Gross domestic product (GDP) at purchasing power parity (PPP) per capita.

Setting

Two types of industries were selected as potential “hot spots” for lead exposures. A battery processing plant in Jordan and a secondary lead smelter in Israel were considered to be the likely sites of high concentrations of lead during smelting and the handling of lead or as a result of inhalation of lead dust and fumes. The following offers a cursory description of plant specifications.

Case 1: A Jordanian Battery Factory

Sahab is primarily an industrial city located south-east of the capital Amman. Considerable industrial activity takes place in this area. A battery factory was selected for the present research study. The factory processes a wide range of automotive batteries including a lead recycling facility that is to be integrated in the future plans of the factory. This factory currently employs 64-70 workers of which, roughly fifteen work in the management/administration offices.

In terms of occupational health, the factory's policy is to minimize lead exposure to the extent possible. Certain strategies were developed to reduce the exposure levels through requiring the use of Personal Protective Equipments (PPE): cap, disposable respirator that must be changed every eight hours, gloves, safety shoes and protective clothing. Hygienic facilities are also available (showers and changing room) as well as a dining. All workers are obliged to take shower and change before leaving the factory. Moreover, work clothes must be washed at the factory and not taken home.

The laboratory supervisor in the factory is responsible for overseeing the safety measurements in the facility. There are daily inspections for using the personal protective equipments. Furthermore, workers are required to attend safety or training courses relating to industrial hygiene, lead and the risk of exposure, as well as additional lectures by professionals. This takes place every six months or/and whenever a new expert is available, with objective of increasing workers' awareness of lead and health related issues.

The factory also has adopted an innovative incentives system. Whenever the lab supervisor goes down to the production facilities, each worker who is applying the factory policies in term of PPE and practices receives one point. At the end of the month, the points are translated into Jordanian Dinars (JDs) and added to the salary (each point equals one JD or 1.5 U.S. dollars). Smoking, eating and drinking are not allowed inside the factory.

A ventilation system is also available in the factory. Air lead is measured every 3 months, 6 months or year depending on the area, while blood lead level is measured every 6 months by a physician who follows up on the workers health status. The factory applies international standers for occupational exposure for air lead concentrations: 10 ppm for air inside the factory and 20 ppm for outdoor ambient air. Workers are limited to concentrations of 40-50 µg/dl for Blood Lead Levels (BLL). In the event that a worker is found to have blood lead higher than the acceptable level, he/she is given a two week break along with vitamin supplements and diuretic drugs. The Jordan Ministry of Labor, Health and Environment enforces the regulations regarding working conditions through

unexpected inspection visits to the factory, although specific information about inspection frequency was unavailable

Case 2: An Israeli Lead Smelter

A secondary lead smelter located in Ashdod/Israel offered an Israeli case-study for this research. Ashdod is a city of the southern district of Israel and an important industrial center with the largest port in the country. This company recycles imported and local lead scrap metal of different types, including batteries to produce lead alloys according to client specifications. The smelter is divided into two parts: one that receives the lead scrap and raw material and the other, where the smelting processes take place. There are 31 workers in the smelter of which 5 handle the raw materials.

The smelter at present has small hygiene facilities that are to be improved in the near future with the anticipated expansion of the factory. This will include a new administration building, worker facilities, showers and a dining room. The new company policy is to separate the clean areas from lead-contaminated ones. Air lead level is measured and there is also a ventilation system in the factory that sucks the air out as well as water sprayers designed to keep the lead particles from being suspended in the air. Eating smoking and drinking are prohibited in working areas.

Workers' BLL is measured every six months and all workers are checked by an occupational physician including the management. Every three months the workers receive a training course that includes information about industrial hygiene. Workers are

also obliged to use the PPE: respiratory, goggles, gloves, helmet, safety shoes and protecting clothing. Moreover, it is mandatory to change cloth before leaving the factory.

Study Methodology

Population: The study was conducted between April and December, 2006. Two cohorts of workers were studied. The research protocol was evaluated and approved by the "Research Ethics Committee" at Ben-Gurion University of the Negev/Israel. All workers in the Israeli lead smelter who worked during the study dates were invited to participate, while in the Jordanian battery plant, two workers were randomly selected from each section. The subjects tested were from distinct operational sections of production, and the sample included a few office/administration workers as well. Twenty workers were ultimately tested from the lead smelter in Israel (2 females, 18 males). Likewise, 22 workers (3 females and 19 males) from different operational areas of the battery manufacturing facility (grid, lead oxide and plate processing, battery assembly, maintenance, warehouse, and painting) in Jordan were included.

Subject Categories: Workers in both factories were divided into two groups according to occupation and level of exposure: directly and indirectly exposed. Directly exposed workers were defined as those who work in lead-contaminated environment during the entire work day, while the indirectly exposed are those who only spend part of the work day in contaminated environment or work in areas adjacent to contaminated zones. The directly exposed group in the Israeli lead smelter included workers from furnace/smelting, refining and casting sections. The indirectly exposed group included maintenance, forklift operator, workers' supervisor, cleaning, laboratory technician and the security guard. In the Jordanian battery manufacturing plant, directly exposed workers were defined as those who work in lead oxide, plate processing, grid and battery assembly sections, and the indirectly exposed group included maintenance, warehouse, painting and the acid-mixing sections as well as factory supervisors, and administrative staff

Questionnaire: A questionnaire was designed for the purpose of this study, covering demographic information. Independent variables including: age, sex, residential address, educational level, health status, smoking, alcohol consumption and hygienic and working practices as well as awareness and knowledge of the workers about the health effects of lead exposure. All subjects were interviewed and the questionnaire was completed while the blood and hair samples were taken. To ensure comparability, the questionnaire was originally written in English and later translated into Hebrew and Arabic.

Blood and Hair Lead Sampling: Blood and hair specimens were collected from all the participants in both factories. After the skin was cleaned off with alcohol, venous blood samples of 5 ml were obtained from the antecubital vein using disposable plastic syringes and collected in heparin tubes that were sent to be analyzed in a laboratory. In Israel, the samples were sent directly to a central hospital laboratory in Tel Aviv. In Jordan, samples were kept refrigerated and analyzed afterward in the analytical laboratories in the University of Jordan. Hair samples of about 1 to 2 cm were taken as close as possible to the scalp where recent hair growth is located. The hair was cut by a clean stainless steel scissors to avoid contamination. Each hair sample was preserved in separate piece of aluminum paper in a plastic bag and stored at room temperature, in a dry cool environment until they were analyzed in the laboratory.

Blood and Hair Lead Analysis: After collecting the workers' blood samples for the lead smelter in Israel, samples were sent and analyzed at the toxicology laboratory Sheba Medical Center, Tel HaShomer. There BLL was measured using Graphite furnace Atomic Absorption Spectrometry (GFAA) according to standard methods (Karita et al. 1997).

The blood samples from workers in the battery factory were analyzed in Jordan with lead concentrations determined by Anodic Stripping Voltammetry (ASV) method on mercury electrode as described earlier (Searle et al. 1973) using 746 VA Trace Analyzer[®]. In this analysis a whole blood sample of 1 ml was mixed with 10 ml of distilled water, after that 1 ml of 70% perchloric acid (HClO₄) was added to the blood and set on shaker for 10 minutes. The mixture was then centrifuged at 3500 rpm for 10 min. The sample was then

filtrated to obtain the suspended aqueous part used to determine the lead concentration using the anodic stripping voltammeter while adding standard lead solution of 0.1 or 0.3 ppm concentration. Depending on the initial reading, each sample was run in three duplicates and the average value taken. The instrument was calibrated by analyzing four aqueous samples while adding different standard lead solutions (0.1, 0.3, 0.5, and 10 ppm). All glassware were cleaned carefully to avoid interfere with the analysis. A blank sample of distilled water was prepared and treated similarly. BLLs were then calculated and the blank lead concentration was subtracted from each sample.

As for the hair samples, both the Israeli and the Jordanian samples were sent to an Israeli laboratory (AminoLab, Israel) registered and supervised by the Ministry of Health. There, samples were analyzed using the inductively coupled plasma (ICP) scan method (standard SOP# CW-041) as described elsewhere (Sanna et al. 2003). Due to financial constraints only 20 samples from Israel and 11 from Jordan were randomly selected to be sent to the laboratory.

Data Analysis: Descriptive statistics were applied to characterize the study population. Groups were compared using the student *t* test or the Mann-Whitney Rank Sum Test as appropriate for continuous variables. The Chi square or Fisher Exact test was employed for categorical variables. Correlation between various variables was tested by the Pearson or Spearman Rank Order Correlation test as appropriate. A multivariate regression model was used to study the effect of various variables on lead levels in blood and hair.

Results

Characterization of Subjects: Table 1 summarizes the main characteristics of the study population in Israel and Jordan. Forty two workers from Israel and Jordan were included of which 5 were females. Only about 20% of the workers did not have knowledge about the adverse health effect of lead exposure, all of whom worked at the Israeli lead smelter.

Table 1 Workers' main characteristics in a battery manufacturing plant in Jordan and lead smelter in Israel

	Jordan	Israel	Total	P values
Directly exposed n (%)	8 (36.4%)	9 (52.9%)	17 (43.5%)	0.478
Indirectly exposed	14	8	22	
Mean Age (years)	33.3	44.9	38.4	0.002
Range	21 – 47	28 – 68	21 – 68	
Mean Occupancy Period (years)	7.6	8.8	7.1	0.742
Range	0.6 – 17	0.02 – 37	0.02 – 37	
Educational Level				0.014
Primary/secondary	12 (54.5%)	14 (93.3%)	26 (70.3%)	
High	10	1	11	
Marital Status				1
Single/divorced	5 (22.7%)	3 (17.6)	8 (20.5%)	
Married	17	14	31	
Smoking				0.823
Yes	11 (50%)	10 (58.8%)	21 (53.8%)	
No	11	7	18	
Alcohol consumption				<0.001
Yes/ occasionally	4 (18.2%)	14 (82.4%)	18 (46.2%)	
No	18	3	21	
Use of working clothes				1
Yes	14 (63.6%)	15 (88.2%)	29 (74.4%)	
No	8	2	10	
Use of gloves				0.656
Yes	13 (59.1%)	15 (88.2%)	28 (71.8%)	
No/sometimes	9	2	11	

Use of mask				0.118
Yes	10 (45.5%)	14 (87.5%)	24 (63.2%)	
No/sometimes	12	2	14	
Mean hand wash times/day	11.5	7.4	9.9	0.104
Range	3.5 – 27.5	3 – 20	3 – 27.5	
Take shower before leave				1
Yes	14 (63.6%)	14 (87.5%)	28 (73.7%)	
No	8	2	10	
Change clothes before leave				1
Yes	15 (68.2%)	15 (93.8%)	30 (78.9%)	
No	7	1	8	
Know about adverse health effects of lead				0.001
Yes/little	22 (100%)	8 (53.3%)	30 (81.1%)	
No	0	7	7	

No statistically significant difference in blood lead levels between the workers in Israel ($35.9 \pm 13.4 \mu\text{g/dl}$) and Jordan ($27.5 + 13.8 \mu\text{g/dl}$) was observed [$P= 0.065$, 95 percent confidence interval for difference of means: -17.294 to $0.5 \mu\text{g/dl}$ 46] ,(Figure 1).

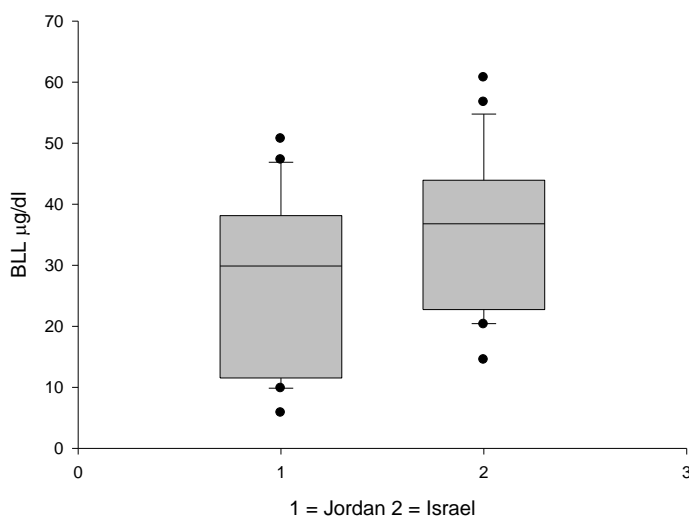


Figure 1 Mean blood lead level (BLL) in Jordan and Israel

An assessment of exposure levels was conducted after classifying the workers in both facilities according to directly versus indirectly exposed. Workers who were directly exposed showed statistically significant higher mean BLLs, 40.0 µg/dl, when compared to the indirectly exposed cohort (24.3 µg/dl, (P <0.001), figure (2)).

Thirteen lead workers from both facilities had blood lead concentrations exceeding the OSHA recommended level of 40 µg/dl with an average of 46.6 µg/dl. These workers were almost exclusively engaged in jobs which brought them directly in contact with lead emissions, with the exception of one worker from maintenance and a warehouse who faced intermittent exposures.

No statistically significant relationship was found between workers' BLLs and a variety of independent variables including: duration of employment (P= 0.58), age (P= 0.874), hand washing (P= 0.266), using mask (P= 0.115), changing clothes at the end of work day (P= 0.196) taking shower before leaving the factory (P= 0.208), smoking (P= 0.602), alcohol consumption (P= 0.327), and knowledge of lead health effects (P= 0.642).

In a multivariate analysis the only variable effecting BLLs was job type (P< 0.05).

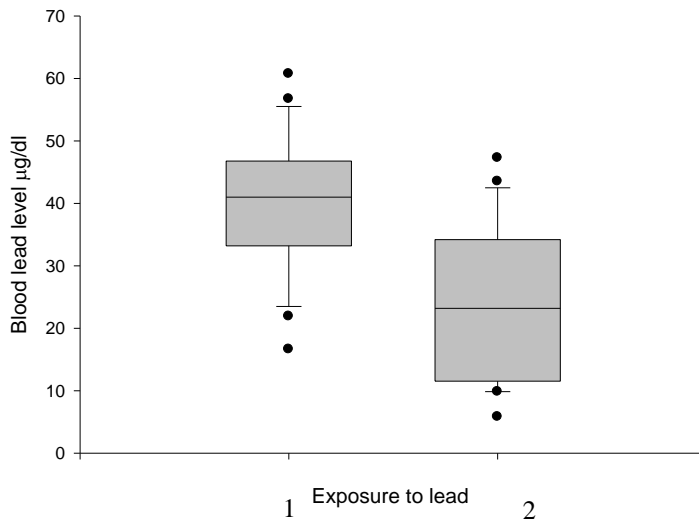


Figure 2 Compression of blood lead levels according to type of occupancy. (1= directly exposed, 2= indirectly exposed).

Twenty hair samples were analyzed from both the smelter and the battery manufacturing plant. The mean hair lead level was 331.5µg/dl and three hair samples were below the limit of detection. A significant correlation was founded between lead concentrations in blood and hair ($P < 0.0001$).

Lead Exposures in Jordan: Three females and nineteen males participated in the study at the battery manufacturing plant in Jordan. Table 2 divides the eight workers who were classified as “directly exposed” with the fourteen in the indirectly exposed group. The mean age was 33.3 years (ranging from 21-47) and the mean duration of employment for workers in the factory was 7.6 years (ranging from 8 months to 17 years). Half of the Jordanian participants (50%) were smokers and only four reported consumption of alcoholic drinks. All participants reported being in good health conditions, except for two

who cited rheumatism and high cholesterol. Industrial and hygienic practices of workers, as well as knowledge about the adverse health effects of lead are also shown in table 2. It is worth noting that all workers claimed to have knowledge about the adverse health effects of being exposed to lead.

Table 3 shows workers' mean blood lead levels ($\mu\text{g}/\text{dl}$) and lead concentrations in hair samples (mg/kg) in the battery manufacturing plant in Jordan. The directly exposed workers had higher average blood lead level $36.2 \pm 10.5\mu\text{g}/\text{dl}$ than the indirectly exposed group $22.5 \pm 13.3\mu\text{g}/\text{dl}$ ($P= 0.02$, 95 percent confidence interval for difference of means: -25.171 to -2.279). The highest level was founded for a lead milling worker, while the lowest was for an accountant, 50.7 and 5.8 $\mu\text{g}/\text{dl}$ respectively. Eleven hair samples were randomly chosen from the two groups to be analyzed. The Mann-Whitney Rank Sum Test was applied to the hair lead levels results, showing a median for the directly exposed group of 151 mg/kg and 43 mg/kg for the indirectly exposed group with a high P value (0.23) indicating that these differences are not statistically significant.

Table 2: Blood and hair lead levels of workers in the battery factory in Jordan

	Directly Exposed				Indirectly exposed			
	Mean	SD	Range		Mean	SD	Range	
	No.				No.			
Blood Lead Level ($\mu\text{g}/\text{dl}$)	8	36.2	10.5	16.6 – 50.7	14	22.5	13.3	5.8 – 47.3
Hair Lead Level (mg/kg)	4	254	249.1	89 - 625	7	382	873.2	≤ 3 – 2358

Lead Exposures in Israel: Of the twenty workers from the Israeli lead smelter who participated in the study, only seventeen underwent blood lead analysis and completed the attendant questionnaire. The average age of the workers was 44.9 years, ranging from 28 to 68 years. The average period of employment for workers in the factory was 8.8 years, ranging from two weeks among the most recent employees to 37 years of employment among the most senior. Only 2 females were among the participants. Out of the 17 participating workers, 10 called themselves smokers and 14 reporting drinking alcohol occasionally. They all reported good health conditions except for one diabetic worker.

In Israel (table 3), the mean BLL (SD) of directly exposed workers was 43.4 µg/dl (11.6) significantly higher than mean BLL (SD) of the indirectly exposed group (27.4 µg/dl (9.9 µg/dl), (P = 0.008) 95 percent confidence interval for difference of means: 27.236 to - 4.739.) From the workers' hair samples, nine were selected to be sent to the laboratory for analysis. Although the mean hair-lead level (SD) of the directly exposed group, (n= 5) was 332.6 mg/kg was clearly higher than the mean hair lead level (SD) of the indirectly exposed group, 74.75 mg/kg (40.4), (n=4) due to the small sample size, no statistically significant differences were founded (P= 0.213).

Table 3 Blood and hair lead levels of workers in the lead smelter in Israel

	Directly Exposed				Indirectly exposed			
	Mean		SD		Mean		SD	
	Range		No.		Range		No.	
Blood Lead Level (µg/dl)	9	43.4	11.6	21.9 – 60.7	8	27.4	9.9	14.5 – 43.5

Hair Lead Level (mg/kg)	5 332.6 369.5 89 - 988	4 74.8 40.3 46 - 134

Discussion

In the present study, blood lead and hair lead levels of workers in an Israeli lead smelter, and battery manufacturing plant in Jordan were investigated. Our study revealed high blood and hair lead levels in the exposed population. About 33% of the currently exposed group showed blood lead levels above the internationally recommended concentration of 40 µg/dl (OSHA 1996). According to American regulations, at this level a written notification is addressed to the worker as well as provided a medical examination. If levels reach 50 µg/dl it triggers removal from exposure on medical grounds. The percentage of workers with BLLs above international standards was high, with several individuals facing significant health risks. The results of the research were forwarded to the managers of the facilities who were advised to take action.

While the small sample size limited the statistical power of the study and the ability to identify statistically significant disparities, the current study offers a basis for arguing that workers in the Israeli lead smelter are exposed to higher levels of lead dust and fumes than those in battery manufacturing plant in Jordan. These findings are consistent with the literature in occupational health. Lead smelting and battery manufacturing workers are considered to be at particularly high risk of high exposures since they constantly work in a lead-loaded environment. Lead smelting in particular is considered a source of

occupational health risks for any of the lead-related industries (INCHEM, 1977). Occupational agencies typically characterize smelting/furnace and refining and casting as the operations with the highest exposure levels (INCHEM, 1977 and OSHA, 2006)

Plate pasting, forming and battery assembling are generally identified as the processes where the highest exposure levels occur during battery manufacturing (Lormphongs et al. 2003 and Ravichandran et al. 2005). These findings correspond with our results. The BLLs of workers who exceeded the standard level were engaged in the furnace/smelting as well as casting and refining in the smelter, while the highest exposures were found among workers whose jobs involved lead oxide/pasting and work in battery assembly sections of the battery manufacturing plant. An additional worker from maintenance and one from warehouse sections in the plant, the forklift operator in the smelter also showed high BLLs. It is likely that such high levels occurred because the workers had not been applying proper hygienic practices and protective measures.

An unambiguous difference in blood lead concentrations was found after dividing the total population study into directly and indirectly exposed group, where the latter showed statistically significantly higher BLLs. Similar findings were reported by Chuang et al. (1999) and Ravichandran et al. (2005) who demonstrated variable exposure levels in different factory and operational sections.

As mentioned previously in the introduction section, in Israel there are specific regulations concerning occupational lead exposure while Jordanian labor law does not include special provisions regarding lead workers. Yet, BLL among workers in Israel

was certainly *not* lower than that among Jordanian workers, not withstanding the presence of specific lead-driven regulations. Even without specific standards for controlling lead exposure in the work place, Jordanian exposures may in fact be lower. Although the differences of BLLs between Israel and Jordan were not statistically significant, this can largely be attributed to the study's relatively small sample size. Beyond the difference in the factory types, disparity in exposure levels can be explained due to a combination of proclivities of factory management, policies, existing medical surveillance and insurance, as well as cultural differences

The first interesting explanation involves the regulatory system itself. Despite formal regulations in Israel, workers are still exposed to high lead concentrations and show high blood lead levels. This indicates that law enforcement is not effective or and that there is probably insufficient compliance with existing regulations. In any event, the Israeli case clearly confirms the notion that occupational health laws alone are not enough to guarantee improved conditions in the work place.

In China, for example, a new Occupational Diseases Prevention and Control Act was passed in 2002, and Ye & Wong (2006) investigated the effectiveness of the new regulations through reviewing the available literature on lead exposure and poisoning in China. Under the Chinese law, in theory, violators are subjected to fines, revocation of business licenses, closing down of operations, and criminal prosecution. The study found that without the necessary enforcement, the 2002 Act appears to have had only a minor impact on the reduction of occupational exposure levels, concluding that more effective enforcement was a prerequisite for progress.

Contrasting Occupational Health Contexts in Israel and Jordan

This study marks the first transboundary research in occupational health between Israel and Jordan, countries that are now moving beyond the historical enmity between them. As mentioned, there are considerable cultural, political and socio-economic differences between the two nations which might serve as barriers to cooperation. To consider the potential for collaboration and mutual assistance, it is important to consider the regulatory context in which each operates.

Israel has laws regarding occupational lead exposure, which mainly appear in the Safety at Work Regulations (Occupational Health and Hygiene for those Working with Lead), 1983 (IIOSH 2006). These regulations cover numerous issues involving occupational exposure to lead, such as: exposure limits, occupational and biological monitoring, engineering controls, personal protective equipment, training, personal hygiene, storage, placarding, and so on. The regulations are promulgated by the Minister of Labor and enforcement is carried out by the Ministry of Industry, Trade and Labor Inspectorate division with the involvement of the Ministry of Health. Moreover, under a government sponsored Israel Institute for Occupational Safety and Hygiene (IIOSH) aims to promote safety and hygiene at work place. IIOSH promotes safety training, assists the labor inspectorate in its activity and advises the Minister of Labor on issues regarding occupational safety and hygiene.

While there is no law directly regulating industrial hygiene in Jordan, the Ministry of Health is the responsible official office (MOH). In this office sits a directorate of occupational health that is responsible for overseeing different factories and production

institutions within Jordan, conducting various environmental measurements with the work environment, and carrying out initial medical examinations, periodic and specialist for workers. The general Labor Law contains a few regulations regarding lead exposure, requiring periodic medical examinations (every 6 months) and provision of appropriate respirators to protect workers from lead fumes. The Ministry of Labor and Health along with the Ministry of Environment is responsible for factories unexpected inspection visits to ensure the regulations regarding working and environmental conditions.

One explanation for the superior performance in Jordan involves the dynamics associated with specific factory management policies and interests in the present case. The battery manufacturing plant adopted and implemented an innovative incentives system. The incentive system appears to have contributed to the successful adoption of better and more appropriate industrial hygiene practices.

Both in Israel and Jordan the facilities apply very similar protective methods. In both factories, eating and smoking is not allowed in working areas. Moreover, workers are obliged to use masks and respirators, as well as take showers before leaving the facility and wear working clothes that are to be changed at the end of the working day. In the Israeli lead smelter, new hygienic facilities are now under construction as well as a dining room for the workers as part of a current plan to completely separate clean and lead contaminated areas. This may contribute to reductions in future exposure levels.

Another important factor worthy of mention is finance. The medical insurance systems in both countries are different. Israel has a national health insurance system. In cases of lead

poisoning, the factory bears no special economic burden and workers are taken care of by the Israeli health system. In contrast, in case of lead poisoning in Jordan, in the event of illness, the factory loses working capacity since skilled workers with elevated blood lead levels have to go home for several days. In Jordan, the factory has to pay for medical treatment if its workers become sick. Accordingly, the factory has an interest in sustaining workers' well-being in order to minimize the associated expenses with treatments as well as the loss of worker production capacity.

It is worth mentioning additional cultural difference between the two groups. The fact that 92% of the Jordanian population is Muslims is significant. Muslim prayer requires high levels of cleanliness. Assuming that they do pray, these workers may have to wash more often -- at least five times daily -- which may contribute to additional hygienic practices.

Ultimately, the best explanation for the results is linked to the production process itself. Applying the multivariate regression analysis regarding lead in blood, only one significant factor was associated with high exposure levels: the job in the factory ($P < 0.05$). The clear association, notwithstanding the relatively small sample size suggests how important rotating workers might be in a high occupational-risk-associated factory's strategy and the need to provide additional monitoring for workers in high exposure jobs.

The high hair lead content observed in the lead smelter and battery manufacturing plant was also clearly related to occupational exposure. This confirms previous researchers' work: Williams et al. (1998) reported elevated mean hair lead levels of 589.41 $\mu\text{g/g}$ in

battery workers as well as high hair lead levels in occupationally exposed subjects (Strumylaite et al. 2004). The differences in median values of lead content in hair for directly and indirectly groups were not statistically significant. This also might be due to the relatively few samples analyzed from each group.

A significant correlation between workers' blood lead levels and hair lead levels ($P < 0.0001$) was founded in the current study. This correlation was also reported by Strumylaitė et al (2000), Štupar et al. (in press) and Sanna et al. (2003), while a small minority of studies reported only a weak relation between hair and blood lead levels (Wilhelm et al. 2002).

In the present study, 75% of the workers were cognizant about the adverse health effects of lead. The knowledge was largely attained through training and awareness sessions. Therefore, workers' awareness and knowledge about lead overexposure as well as proper hygienic practices are essential for future minimization of exposure levels. Chuang et al. (1999) illustrated that health promotion programs along with supervised occupational physicians can reduce workers' average blood lead concentrations. Likewise, Lormphongs et al. (2004) demonstrated the importance of occupational health education and cooperation between workers and management in reducing the risk of lead poisoning.

The study has several limitations. The study sample size was small, including only 42 workers from both factories in the study. Ideally, an occupational health case-study should incorporate all the workers in a plant, but this proved impossible due to the different working shifts in the lead smelter and the unwillingness of the battery

manufacturing plant to include all of their workers in the study group. Another limitation was the need to analyze blood samples in different laboratories, that applied two different analytical methods. This opened a possibility of associated inconsistencies and technical errors. However, a study by Bannon and Chisolm (2001) illustrated that the new anodic stripping voltammetry (ASV) is comparable to the graphite furnace atomic absorption Spectrophotometry (GFAA) for blood analysis.

Conclusions

Our results reveal that despite existing regulations and the growing attention that is dedicated to lead and lead occupational exposures, there are still hot spots for lead exposure in Israel and Jordan. Therefore, extra attention and more restrictive regulations should be considered to insure higher protection and reduction of lead over exposure in such high-risk industries. Despite the ongoing debate regarding the reliability of hair measurements in occupational settings, the current study confirmed a significant correlation between blood and hair lead levels in highly exposed populations, suggesting that hair should be used as a bio-indicator to monitor the levels of lead exposure in lead industries, since hair analysis is less invasive and easier to handle.

Finally, the contrasting experience found in the current study raise the possibility that information and technology exchange between the two countries: Israel and Jordan could be beneficial for these two neighboring countries. The two nations have different approaches to occupational health which should be shared as they both seek to improve workers' health. As a very fragile peace accord between Israel and Jordan continues to

hold, finding common areas of concern and cooperation offers these countries' advantages beyond the important benefits associated with reduction of occupational health risk. .

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