Outbreak of lead toxicity during rebar production in a steel mill

İnşaat demiri üreten bir çelik fabrikasında görülen kurşun zehirlenmesi salgını

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ABSTRACT

Objective: Largely due to the widespread use of unleaded petrol and lead-free dyes, the lead toxicity nowadays is associated with occupational exposure rather than environmental exposure in adults. This study aims to identify the characteristics of lead exposure cases and evaluate working environment based on workers' statement in a sector where lead monitoring is not routinely performed during health surveillances and to examine the poisoning of lead toxicity. Moreover, we aimed to start a caution on management and treatment of these cases in our country.

Methods: This descriptive study conducted in hospital which is authorized to diagnose occupational diseases between April and November 2018. In order to evaluate the sociodemographic characteristics, working life characteristics, workplace environment and risk factors and lead toxicity complaints of 34 cases with the elevated blood lead level (BLL), a 38 item questionnaire form was applied. Physical examination findings, laboratory findings, comorbidities and treatment protocols were obtained from the medical records.

Results: 8.3% (n = 34) of the workers applied with a preliminary diagnosis of lead toxicity. Median duration of work was 26 months, average working time was 53.3±7.2

ÖZET

Amaç: Erişkinlerde kurşun zehirlenmesi, günümüzde kurşunsuz benzin ve kurşun içermeyen boya kullanımının yaygınlaşması nedeniyle artık çevresel etkilenimden çok mesleki etkilenime bağlı olarak görülmektedir. Bu araştırma, sağlık gözetimi sırasında rutin olarak kurşun izleminin yapılmadığı bir sektörde tespit edilen kurşun etkilenimli olguların ve çalışma ortamının özelliklerini tanımlaması ve bu işyerindeki kurşun zehirlenmesinin irdelenmesi amacıyla yapılmıştır. Ayrıca, ülkemizde bu vakaların yönetimine ve tedavisine dikkat çekilmesi hedeflenmiştir.

Yöntem: Bu tanımlayıcı araştırma, meslek hastalıkları tanısı koymaya yetkili bir hastanede Nisan-Kasım 2018 tarihleri arasında yürütülmüştür. Kan kurşun düzeyi (KKD) yüksekliği saptanan 34 olguya sosyodemografik özelliklerini, çalışma yaşamına ilişkin özelliklerini, çalışma ortamını ve risk faktörlerini ve kurşun etkilenimine bağlı şikayetlerini değerlendirmek amacıyla oluşturulan 38 maddelik bir soru formu uygulanmıştır. Fiziksel muayene bulguları, laboratuvar bulguları, komorbiditeler ve tedavi protokolleri tıbbi kayıtlardan elde edilmiştir.

Bulgular: Çalışanların %8,3'ü (n=34) kurşun toksisitesi ön tanısı ile başvurmuştur. Ortalama çalışma süresinin 26 ay, ortalama haftalık çalışma süresinin ise 53,3±7.2 saat olduğu

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Geliş Tarihi / Received : 30.07.2019
Kabul Tarihi / Accepted : 23.12.2020

DOI ID : 10.5505/TurkHijyen.2020.62347

Altundaş Hatman E, Torun SD. Outbreak of lead toxicity during rebar production in a steel mill.
Turk Hij Den Biyol Derg, 2021; 78(1): 69 - 78

hours/week. The mean BLL was 44.0 ±5.1 µg/dl at the workplace surveillance, 38.4±11.1 µg/dl determined in the hospital and 36.1±8.9 µg/dl during hospital check. The Blood antimony (Sb) level was 5.5±1.4 µg/dl and mean blood manganese (Mn) level were 17.8±5.9 µg/L and 1.5±0.8 µg/L after the 15-day hospitalization.

Conclusion: The iron and steel processing sector is among the sectors that should be carefully monitored in terms of lead, Mn, and Sb exposure. The legislations and the exposure limits of toxic metals and the biological limit values should be updated in accordance with scientific data. Chelation treatment of patients with clinical findings should be planned by confirming the accumulation of lead in bone tissue.

Key Words: Lead, toxicity, occupational exposure, management of intoxication, outbreak

belirlenmiştir. Ortalama KKD, iş yerinde aralıklı kontrol muayenesi sırasında 44,0±5,1 µg/dl, hastanede alınan ilk örnekte 38,4±11,1 µg/dl ve hastanede kontrol örneğinde 36,1±8,9 µg/dl bulunmuştur. Kan antimon seviyesi 5,5±1,4 µg/dl, ortalama kan mangan seviyesi 17,8±5,9 µg/L ve 15 günlük yatış sonrasında 1,5±0,8 µg/L olarak tespit edilmiştir.

Sonuç: Demir çelik sektörü kurşun, mangan ve antimon maruziyeti açısından dikkatle izlenmesi gereken sektörler arasında yer almaktadır. Toksik metallerin mevzuatı ve maruz kalma sınırları ile biyolojik limit değerleri bilimsel verilere uygun olarak güncellenmelidir. Klinik bulguları olan hastaların şelasyon tedavisi, kemik dokusunda kurşun birikimi değerlendirilerek planlanmalıdır.

Anahtar Kelimeler: Kurşun, toksisite, mesleki maruziyet, intoksikasyon yönetimi, salgın

INTRODUCTION

Largely due to the widespread use of unleaded petrol and lead-free dyes, the lead toxicity nowadays is associated with occupational exposure rather than environmental exposure in adults (1). The workers employed in the workplaces operating in the lead processing and melting, in the production and recycling of batteries, in the processing of scrap metal along with the inadequate level of work hygiene and ventilation conditions are exposed to toxic effects of lead and its compounds (2).

Although lead toxicity is often attributed to the underdeveloped or developing countries, it remains as an important problem for industrialized countries as well. According to the results of the Adult Blood Lead Epidemiology and Surveillance Program (ABLES) conducted by the National Institute of Occupational Health and Safety (NIOSH) in the USA, the ratio of blood lead level (BLL) ≥ 25 µg/dl was 14/100000 in 1994 and decreased to 6.4/100000 in 2011. Despite this decrease, the number of adults with BLL ≥ 25 µg/dl in 2010 was 8793 and ≥ 40 µg/dl was reported to be 1388 (3). NIOSH states that there is no safe limit value for lead and describes highest BLL was ≥5 µg/dl for adults (4).

Occupational lead toxicity can be prevented by measures taken in the work environment. However, in circumstances where it cannot be prevented, determining and eliminating the cause of the exposure are the first steps to be taken. While trying to eliminate the cause of the exposure, the worker(s) at the same time should be dismissed from work for the periods determined by BLL. Chelators used in medical therapy reduce lead concentration in blood and some tissues and increase urinary excretion of lead. Chelators may be recommended for the treatment of acute intoxications, but should be used with caution because of serious side effects. In case of chronic toxicity, chelation therapy is not recommended because of the risk of redistribution of lead as well as hepatotoxicity and nephrotoxicity (5-6). Diagnosis in chronic lead toxicity can be made by measuring lead accumulation in bone tissue with K-shell x-ray fluorescence (K-XRF) (7).

Chelation therapy can be applied in adults with BLLs of 80-100 µg/dL or with symptoms of lead toxicity in adults with BLL over 50 µg/dL. However, due to the rebound effect of chelation, blood lead levels should be followed before and after treatment (6).

The occupational exposure limit values (TWA) for inorganic lead and its compounds was determined to be 0.15 mg/m^3 in the "Implementing Regulation on Health and Safety Measures for Working with Chemical Substances" in Turkey, but 0.05 mg/m^3 by the NIOHS and European Agency for Safety and Health at Work (EU OSHA) (8-10). For the lead and ionic lead compounds, the regulation defines the biological limit value as 70 µg/dl. The conditions for health surveillance are also defines as the TWA of lead in the air (40 hours) ≥ 0.075 mg/m^3, or any one of the employees has BLL ≥ 40 µg/dl (8).

Researchs conducted on occupational influences of lead in Turkey, are concentrated mostly in the battery manufacturing sector and the effect of BLL on immune system, chromosomes, markers of renal damage etc. were investigated (11-18). In recent years, a significant part of the research is conducted on the biochemical parameters, impaired aortic elasticity, cardiac autonomic functions, and inflammation parameters of the patients reported to the hospital with the increase in the rate of BLL (19-21). None of the aforementioned studies have addressed the approaching, management and treatment algorithms of lead exposure cases in Turkey.

This study aims to identify the characteristics of lead exposure cases and evaluate working environment based on workers' statement in a sector where lead monitoring is not routinely performed during health surveillances and to examine the outbreak of lead toxicity. Moreover, we aimed to start a caution on management and treatment of these cases in our country.

MATERIAL and METHOD

This descriptive study conducted in hospital which is authorized to diagnose occupational diseases between April and November 2018. A worker, who was working in a factory producing rebar from melting scrap steel where 410 workers are employed, has applied to a health center and his BLL was determined as ≥ 40 µg/dl. Subsequently the workplace health surveillance for all 410 workers was performed by the occupational health physician, 32 workers with BLL ≥ 40 µg/dl and/or manganese (Mn) level ≥ 20 µg/L were referred to the hospital and hospitalized. Other two workers from the company who have BLL between 35-40 µg/dl were applied to the hospital and hospitalized too. In order to evaluate the sociodemographic characteristics of 34 cases with elevated BLL, job characteristics, workplace environment and risk factors and lead toxicity complaints, a 38 item questionnaire form was prepared by researchers. After the improvement in the acute lead toxicity complaints, patients were discharged from the hospital and they were recommended to re-apply to the hospital within one to three months according to the latest BLL values.

The written informed consent of the subjects was obtained and questionnaire was applied by one of the researchers. Physical examination findings, laboratory findings (CBC, BLL and blood levels of other toxic metals, serum iron, iron binding capacity, ferritin, vitamin B_{12} levels, etc), comorbidities and treatment protocols were obtained from the medical records. Ethics committee approval was obtained from the Ethics Committee of the Hospital (28.10.2018) and research permission from the hospital.

In this study, current guidelines of NIOSH and Center for Disease Control and Prevention (CDC) have been used as the source of biologic limit values and lead-affected cases, management and treatment algorithms.

In data analysis, descriptive statistics, measures of central distribution and tendency, frequencies, and percentages were used and the data were analyzed in SPSS 21.0 program.

RESULTS

In a factory where 410 workers are employed, 8.3% (n = 34) of the workers applied with a preliminary diagnosis of lead toxicity. The mean age of the patients was 33.0±8.2 years. The median duration of work at this workplace were 26 months (min: 6 max: 110) and the average weekly working time was 53.3±7.2 hours. All of the cases stated that they were working overtime and the weekly overtime period was 8.2±3.4 hours. In their work history, all workers declared that production speed and quantity increased in the last few months by a questionnaire form. Table 1 demonstrates the sociodemographic and work life characteristics of the cases.

Table 1. Sociodemographic and working life characteristics of patients who applied to the hospital with lead toxicity

		Number (N)	Percentage (%)
Education status			
	Primary school graduate	8	23.5
	Secondary school graduate	10	29.4
	High school graduate	14	41.1
	Graduated from a University	2	5.8
Department of worker			
	Scrap melting	13	38.2
	Transport of liquid steel	4	11.8
	Mechanical maintenance-repair-welding	7	20.5
	Other	10	29.4
Smoking status			
	Never smoker	3	8.8
	Current smoker	31	91.2
	Mean±sd		**Min-Max values**
Age	33.0 ± 8.2		20 -49
Duration of the employment at current job	26 months*		6 -110
Weekly working hours	53.3±7.2 hours		48- 84
Weekly overtime work	8.2±3.4 hours		3 -25

* Since the data does not conform to the normal distribution, the median value is given.

The workers who attended study listed the workplace characteristics as being in the high temperature (94.1%), dusts, full of toxic metals and noise (91.1%), full of the various gases and requires heavy lifts (82.3%) and includes the vibration (76.4%). Moreover, about 91.1% described the central air ventilation system being inadequate and 76.4% of the interviewees described local ventilation system as inadequate. All of the interviewees stated that they regularly use of helmets and gloves as personal protective equipment,73.5% indicated the simple dust masks.

All workers stated that there was a separate environment where they could eat, relax, wash their hands, take a shower at work and 61.8% of them indicated that they take a shower in the workplace. Only one worker said that his clothes were washed in the workplace, others stated that the work clothes were washed in their homes, separate from regular clothes. All the workers who were smoking reported that they smoked in the work area, did not wash their hands before smoking and 91.1% of the workers stated that they had been eating and drinking in the working environment. Table 2 shows the working environment and risk factors for the employees.

Table 2. Stated work environment risk factors of the patients who applied to the hospital with lead toxicity

		Yes	No
Occupational risks		**N (%)**	**N (%)**
	High temperature	32 (94.1)	2 (5.9)
	Dusts	28 (82.3)	6 (17.7)
	Exposure to toxic metals	28 (82.3)	6 (17.7)
	Noise	28 (82.3)	6 (17.7)
	Lifting heavy things	28 (82.3)	6 (17.7)
	Vibration	26 (76.4)	8 (23.6)
Ventilation systems			
	General ventilation	31 (91.1)	3 (8.9)
	Local exhaust ventilation	26 (76.4)	8 (23.6)
Personal protective equipment			
	Barret	34 (100.0)	0 (0.0)
	Gloves	34 (100.0)	0 (0.0)
	Dust mask	25 (73.0)	9 (27.0)
	Ear plug	1 (2.9)	33 (97.1)

The toxic metal levels, complaints reported by the patients and findings of the workers are shown in Table 3. The BLL of the workers was determined to be 44.0±5.1 μg/dl during a health screening at work. These patients were hospitalized on the basis of health surveillance values. In the hospital they were admitted the mean BLL was determined to be 38.4±11.1 μg/dl 15 days after the first measurement. In the hospital chelation therapy was recommended for six patients whose BLL was above 50 μg/dl. Two patients accepted chelation therapy, however four patients preferred the dismissal from their job. The mean control BLL was found to be 36.1±8.9 μg/dl among 32 hospitalized but not treated cases. On the other hand, the patients who were treated with chelation therapy had pretreatment BLL value of 52.2 μg/dl and 65.3 μg/dl and after four doses of calcium disodium edetate chelation therapy BLL were reduced to 29.1 μg/dl and 28.0 μg/dl, respectively.

Table 3. Serum toxic metal levels, complaints and clinical findings distribution of patients who were admitted to the hospital with lead toxicity

Toxic metal levels	Mean±sd	Min-Max values
Pb-Health surveillance (n=34)	44.0±5.1 μg/dl	26.7-52.8
Pb-Hospital ** (n=34)	38.4±11.1 μg/dl	18.0-65.3
Pb-Hospital check *** (n=32)	36.1±8.9 μg/dl	11.5-53.0
Mn-Health surveillance (n=15)	17.8±5.9 μg/L	3.7-26.2
Mn-Hospital ** (n=15)	1.5±0.8 μg/L	0.3-2.8
Sb-Hospital** (n=34)	5.5±1.4 μg/dl	3.0-8.7
Complaints	**Number (N)**	**Percentage (%)***
Fatigue	24	70.6
Headache	21	61.8
Muscle and joint pain	21	61.8
Numbness and tingling in hands and in feet	8	47.1
Loss of appetite	8	47.1
Metallic taste in the mouth	8	47.1
Findings	**Number (N)**	**Percentage (%)***
Findings related to anemia [a]	6	17.6
Vitamin B_{12} deficiency	4	11.4
Peripheral neuropathy	3	8.8
Hearing loss	5	14.7
Depression	2	5.9

[a] low serum iron, low ferritin, high iron binding capacity and/or CBC showing low MCH and MCV.
* Since the patients had more than one complaints and findings, no column percentage was given.
** The measurements in the hospital were made 15 days after the health surveillance.
*** Control measurement was made 25 days after the first measurement.

While the mean blood Mn level of the 15 patients with high blood Mn levels was 17.8±5.9 µg/L, the value decreased to 1.5±0.8 µg/L after the 15-day hospitalization. Blood antimony (Sb) levels were found to be 5.5±1.4 µg/dl in the initial blood level measurements in hospital.

After the improvement in the acute lead toxicity complaints, patients were discharged from the hospital. Nevertheless, according to the latest BLL values upon discharge, those with BLL of 10-19 µg/dl were given 10 days leave, those with BLL of 20-29 µg/dl were given 20 days, and those with BLL of 30 µg/dl and more were removed from work for one month.

A worker with BLL of 35 µg/dl was admitted to the hospital five months later for a control period and the BLL value of that case was found to be 48.8 µg/dl. However, the other workers did not apply to the hospital.

DISCUSSION

Although lead toxicity is expected in the scrap metal processing sector, data reported in the sector is limited and the research is confined in the battery production, recycling, and the business lines in which the lead is processed. In a study investigating the relationship between chronic lead exposure and kidney damage in workers in Poland, the average BLL of workers was 14.5 µg/dl. In Pakistan, the study compared the level of toxic metals in the biological samples of the steel production workers and the control groups and concluded that the mean BLL was 26.3 ±1.6 µg/dl and the mean Mn level was 7.4±0.6 µg/L (22-23). The difference between the aforementioned studies and our study could be attributed to the fact that they were conducted at workplace whereas the present study reports BLL (44.0±5.1 µg/dl) and blood Mn level (17.8±5.9 µg/L) of workers who reported to the hospital.

In this study, the workers who were referred to hospital (n = 34) corresponded to only about 8.3% of the total number of workers. As the statement of health surveillance in the regulation perceives a BLL>40 µg/dl criterion for referral to hospital, BLL of all the workers could not be evaluated. While this situation is a limitation of the research, it could be assumed that the number of workers who are actually affected are far more, and the cases encountered are only the tip of the iceberg.

Iron and steel industry is a risky sector not only in terms of lead exposure but also in terms of other toxic metals. The metal vapor resulting from the melting process at high temperatures could penetrate to body through the respiratory system and skin and may be accumulated in high concentrations in the body, and thus results in toxicity (24). In this study, the workers who were hospitalized were also exposed to other metals known to be included in the scrap composition, and their exposure was not limited to lead and Mn, e.g. Sb levels were also high. The quick normalization of the blood Mn levels in the hospital despite very high levels in initial health screening could be ascribed to the fact that the half-life of Mn is short (25).

The workers who included in the present study indicated that they work for an average of 53.3±7.2 hours per week. Nevertheless, they are employed in the iron and steel industry, in which the workers ought to adhere the “Implementing Regulation on Maximum Seven and A Half Hours or Lesser Work for Health” in Turkey (26). The increased level of toxic metals in workers may also be result of increased accumulation from the increased exposure to toxic metals due to excess working time (more than 45 hours per week) and not being able to stay away from work during the time required for the excretion of toxic metals in their bodies. The disappearance of the the most common complaints, exhaustion and fatigue, 25 days after being dismissed from the work without a significant decrease in the BLL might imply the long working hours for these complaints. Workers employed in this sector should be prevented from operating for more than 7.5 hours per day and obey the legal limits.

More than 90% of the workers identified high temperature, dust, heavy metals, and noise in the workplace, and also stated that the central and local systems had insufficient ventilation. It was also declared that despite the presence of a separate unit in the workplace in which workers could eat, wash their hands, and take shower, the workers do eat, drink or smoke in the workplace and smoke without washing hands. According to these findings, it can be said that the work hygiene rules are not observed in the workplace, especially the risky behaviors were performed for gastrointestinal intake of lead. In addition to providing appropriate ventilation conditions at the workplace, it is necessary to plan and implement trainings that will alter workers' behavior covering a wide range of subjects such as the intake of the toxic metals, the rules of hygiene, and the individual measures that can be taken.

While the company was informed regarding the precautions to be taken at the workplace and the management of the occupational lead exposure, also the workers were trained to minimize the exposure by researchers.

Despite the dismissal from their jobs and chelation treatment according to the recommendations of NIOSH, no significant decrease was observed in the BLL of the of the hospitalized patients. The initial mean BLL of 44.0±5.1 µg/dl was only decreased to 38.4±11.1 µg/dl in the hospital after 15 days of health surveillance, and to 36.1±8.9 µg/dl in 40 days after the the hospitalized health surveillance. Studies evaluating the half-life of lead in blood revealed that this period is 28-36 days and the Toxic Substances and Disease Records Agency (ATSDR) considered the half-life of the lead to be 28 days (27). CDC states that this period may be 1-2 months (28). The lack of expected decline in BLLs of these cases can be explained by the fact that the lead's half-life in the blood is longer than 28-36 days. When the BLL of the patients receiving chelation therapy is not significantly reduced, it may be an indicator of the chronic lead exposure in the cases. Should the relationship between the duration of work and BLL was present, data would provide a stronger framework to formulate the chronic lead exposure. However, this relationship cannot be discussed because of inability to evaluate the all workers in the workplace and this is another limitation of the present study.

In order to make a correct decision in the clinical management of patients and to evaluate the suitability of chelation therapy, the risk of chronic exposure should be evaluated using K-shell x-ray fluorescent (K-XRF) especially for the cases whose BLLs are estimated for the first time. In Turkey, K-XRF method should be accessible and usable at hospitals which are authorized to diagnose occupational diseases which take the most burden in clinical management of cases with occupational lead exposure.

The occupational exposure limit values and biological limit values for the lead specified by the legislation in Turkey are higher than the values determined by NIOSH and OSHA (8-10). The biological limit value determined for lead exposure is 70 µg/dl in the Turkish regulation while the proposal of the Science Commission for the Occupational Exposure Limit of the European Commission is 30 µg/dl (29). One of the two conditions required for health surveillance in the Turkish Regulation is that "any one of the employees has a BLL of ≥ 40 µg/dl" which implies that BLL<40 µg/dl is not perceived as a criterion for referral to health institutions and can be ignored as also shown in this study.

The regulation also sets the occupational exposure limit value (TWA) for inorganic lead and compounds to 0.15 mg/m^3. This value is three times higher than the exposure limit value set by NIOHS and OSHA. It should be kept in mind that the exposure limit value is the set value for the eight-hour working time per day and that overtime periods may also result in increased levels, as in this study provides a solid example. In a study targeting the lead levels in metal casting workplace environments in Turkey, of all the 41 measurements were taken from work place indicated a lead level above 0.05 mg/m^3, while in four point the measurements even exceeded of 0.15 mg/m^3 (30).

The higher levels of biological and exposure limit values in Turkey and the conditions required for health surveillance compared to the developed countries prevents the recognition of the occupational lead exposure. The corresponding legislation in Turkey needs to be updated in line with scientific data and the recommendations of international organizations.

On the other hand, routine health surveillance is not performed in terms of lead exposure in Turkey, but a medical intervention is foreseen if two conditions in “Implementing Regulation on Health and Safety Measures for Working with Chemical Substances” emerge. As emphasized above, the exposure limit value is determined for a daily working time of eight hours and excess working times will cause an increase in exposure. In the event that the specified limit value is not exceeded in the workplace for health surveillance, exposures to the lower dose for an extended time period may lead to chronic lead toxicity in the long run. For this reason, routine occupational health and safety monitors and workplace measurements should be taken and the biological monitoring should be part of the routine health surveillance for all the businesses operating the risk areas.

In conclusion, the iron and steel processing sector is among the sectors that should be carefully monitored in terms of lead, manganese, and antimony exposure. The legislations and the exposure limits of toxic metals and the biological limit values should be updated in accordance with scientific data. In addition to occupational health and safety practice the biological monitoring of toxic metals should be part of the routine health surveillance, especially taking into account overworking hours. Treatment of patients with clinical findings should be planned by confirming the accumulation of lead in bone tissue.

ETHICS COMITTEE APPROVAL

* The study was approved by the Kanuni Sultan Süleyman Training and Research Hospital Clinic Research Ethics Committee (Date: 28.10.2018 and Number: 2018/10).

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