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Occupational Exposure to Mercury among Workers in a Fluorescent Lamp Factory, Quisna Industrial Zone, Egypt

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Abstract

Background: With the fast growth in the market of fluorescent lamps, particularly compact fluorescent light, the associated risk of mercury exposure, which is an essential component in all types of fluorescent lamps, has received increasing public attention worldwide. Even low doses of mercury are toxic.

Objective: To study the health consequences of occupational exposure to mercury in workers of a fluorescent lamp factory.

Methods: In a cross-sectional study 138 workers of a florescent lamp factory and 151 people who had no occupational exposure to mercury (the comparison group) were studied. Environmental study of mercury and noise levels was done. For all participants a neurobehavioral test battery was administered, spirometry was performed and air conduction audiometry was done. Urinary mercury level was also measured for all participants.

Results: Prominent symptoms among workers exposed to mercury included tremors, emotional lability, memory changes, neuromuscular changes, and performance deficits in tests of cognitive function. Among the exposed group, the mean urinary mercury level was significantly higher in those who had personality changes or had manifestations of mercury toxicity. With increasing duration of employment and urinary mercury level, the performance of participants in neurobehavioral test battery and spirometric parameters deteriorated.

Conclusion: Neurobehavioral test battery must be used for studying subclinical central nervous system dysfunction in those with chronic exposure to mercury. The test is especially useful for evaluating the severity of mercury effects in epidemiological studies. This study also reinforces the need for effective preventive programs for florescent lamp industry workplaces especially in developing countries with the lowest unhygienic work conditions.

Keywords: Mercury poisoning; Occupational exposure; Neurobehavioral manifestations; Environmental pollutants; Spirometry; Audiometry

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Introduction

Mercury and its compounds are recognized as potentially hazardous materials and are rated as top category of environmental pollutants.[1]

With the fast growth in the market of fluorescent lamps, particularly compact fluorescent light, the associated risk of emission of and exposure to mercury, which is an essential component in all types of fluorescent lamps, has received increasing public attention worldwide.[2,3] Mercury is introduced into the lamp in a variety of ways, although in some areas mercury is added manually, the predominant way is automatic method, so mercury remains the material of greatest concern during fluorescent lamp making while the exposure is relatively low except to mechanics working during cleanup operations near the exhaust machines.[4]

Elemental mercury may cause a variety of adverse effects on almost all organs and body systems.[5-8] Nevertheless, there is no clear knowledge of the level of exposure at which mercury vapor causes adverse effects.[9] Few Egyptian studies were studied this issue.[10-12] We therefore conducted this study to assess health disorders resulting from occupational exposure to mercury among workers in a fluorescent lamp factory. We also did biological monitoring for workers and environmental monitoring of the factory workplace.

For more information on concentration of mercury in Irrigation water wells used for agriculture in north-eastern Iran see www.theijoem.com/ijoem/index.php/ijoem/article/view/200

Materials and Methods

This study took place in a fluorescent lamp factory in the industrial zone, Quisna city, Menoufiya governorate, between February and July 2012. The Menoufia Faculty of Medicine Committee for Medical Research Ethics reviewed and formally approved the study before it began. Approval from the factory was obtained; all participants gave written informed consent before inclusion.

In this cross-sectional study, we studied 138 occupationally exposed male workers selected from different departments of the aforementioned factory after exclusion of non-responders and application of exclusion criteria which included chronic liver or kidney diseases, chronic alcohol abuse or chronic chest diseases. A comparison group of 151 men selected from the exposed group relatives, who had never been exposed to mercury at work, were matched with the exposed group for age, residence, level of education and income.

Participants were interviewed by trained investigators at the factory clinic during the day shift (between 7:00 and 15:00). At each workplace visit, demographic data, smoking status, medical history of chest, nervous system and auditory diseases, employment history (including years of working in the industry and wearing of protective clothes), and past history of diseases (*eg*, mental, nervous system diseases, hypertension, diabetes, liver and kidney diseases or use of antipsychotic drugs) were gathered.

Neurobehavioral parameters were assessed using neurobehavioral test battery (NBTB) which consisted of subtests from the Wechsler Adult Intelligence Scale (WAIS) revised for adults to cover domain cognitive functions of attention and short-term recall (Paired Auditory Serial Addition Test [PASAT] and Digit Span test, forward and backward), visuospatial (Benton Visual Retention test), psychomotor (Symbol Digit and Trail making part A and B tests) and general intelligence (Vocabulary and Similarities tests).[13] "Better performance" was evaluated by higher scores obtained on all tests but "Trail making" part A and B where lower latencies or time to complete indicated better performance.

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Spirometry was done by a Spirolab (MIR 010) to determine the forced vital capacity (FVC%), forced expiratory volume at the first second (FEV1%), forced expiratory ratio (FEV1/FVC%), forced expiratory flow during 25-75% of FVC ($FEF_{25-75\%}$) and peak expiratory flow (PEF%). The best value of three technically acceptable maneuvers was recorded and expressed as percentages of predicted value. Air conduction audiometry was done by a diagnostic audiometer AS 67 (Danplex). The mean of intensities of three measurements made at 1000 Hz was taken.

A 25-mL morning urine sample was also collected from each participant before the work shift and was kept at (0–4 °C) in a sterile container until analysis. The samples were then analyzed for the presence of inorganic mercury using a cold vapor-atomic absorption spectrophotometer at the institute of measurements and calibration, Cairo, Egypt. Results of the analysis were expressed as µg mercury/g of urinary creatinine to minimize problems due to variations in the urine osmolality and specific gravity.

Environmental mercury levels were also measured in the factory using a mercury vapor analyzer ELTWI-"MS" (survey mode) in places where high mercury levels were expected (*eg*, exhaust machine, mounting machine, sealing machine and automatic basing machine). Three readings were made at each site and the mean values were calculated. Noise level was also measured by a sound level meter (ANSI type 2 Model 452), at the levels of workers' ears, in places where they usually stand during ordinary work. Multiple readings were taken from various places of the factory and the mean reading was recorded.

Statistical analysis

Student's t test was used for comparing means of two normally distributed continuous variables. *Mann-Whitney U test* was used for non-parametric variables. χ^2 test was used for comparison of categorical variables. Partial correlation coefficient was used to test association between continuous variables. All statistical tests were two-tailed. A p value <0.05 was considered statistically significant. Analyses were performed by SPSS® ver 13 for Windows® (SPSS Inc, Chicago, Il, USA) and Epi Info ver 3.3, released by Centers for Disease Control and Prevention (CDC), Atlanta, Georgia, in October 2004.

Results

The highest mean±SD environmental mercury levels were recorded in exhaust machine (53±0.9 µg/m³) followed by basing machine (33±0.2 µg/m³) and sealing machine (29±0.6 µg/m³).

The highest mean±SD sound levels were recorded near the mount machine (82±0.9 dB) followed by sealing machine (81±1.0 dB) and both the exhaust and washing machines (80±1.2 dB).

The exposed group had a significantly higher mean±SD urine mercury level than the comparison group (44.1±17.5 *vs.* 6.1±4.9 µg/g creatinine). Among the exposed group, the mean urinary mercury level was significantly higher in those who had manifestations of mercury toxicity or personality changes (Table 1). Furthermore, pulmonary function and performance of exposed workers deteriorated as their urinary mercury level and duration of employment increased (Table 2). Pulmonary manifestations (*eg*, cough, expectoration, wheeze, dyspnea, rhinitis and asthma) and auditory manifestations (moderate to severe hearing impairment), personality changes, and deteriorated performance of neurobehavioral tests were significantly more prevalent in the exposed than the unexposed group.

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Table 1: Mean±SD urine mercury level among exposed workers (n=138) with or without manifestations of mercury toxicity

Manifestations	Number (%) (n=138)	Mean±SD urine mercury level (μg/g creatinine)	p value*
Tremors			
Present	13 (9.4)	54.0±19.1	0.03
Absent	125 (90.6)	43.1±17.1	
Teeth loss			
Present	21 (15.2)	52.5±16.1	0.01
Absent	117 (84.8)	42.6±17.4	
Gum inflammation			
Present	22 (15.9)	53.3±17.8	0.01
Absent	116 (84.1)	42.4±17.0	
Bleeding gums			
Present	26 (18.8)	51.2±17.5	0.04
Absent	112 (81.2)	42.5±17.2	
Diarrhea			
Present	9 (6.5)	58.7±17.3	0.01
Absent	128 (93.5)	43.1±17.1	
Musculoskeletal disorders			
Present	11 (8.0)	59.4±15.0	0.004
Absent	127 (92.0)	42.8±17.1	
Hearing impairment			
Present	27 (19.6)	51.4±19.5	0.03
Absent	111 (80.4)	42.3±16.6	
Nervousness			
Present	13 (9.4)	54.2±18.6	0.04
Absent	125 (90.6)	43.1±17.1	
Irritability			
Present	9 (6.5)	58.7±17.3	0.01
Absent	128 (93.5)	43.1±17.1	
Sleeplessness			
Present	13 (9.4)	54.0±19.1	0.03
Absent	125 (90.6)	43.1±17.1	
Loss of concentration			
Present	21 (15.2)	52.5±16.1	0.01
Absent	117 (84.8)	42.6±17.4	
Shyness			
Present	17 (12.3)	53.2±19.7	0.03
Absent	121 (87.7)	42.7±16.9	

*Mann-Whitney U test

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Table 2: Pearson's correlation coefficient (r) between pulmonary function and performance parameters with urinary mercury level and duration of employment among the exposed group

Parameter	Urinary mercury level (µg/g creatinine)	Duration of employment (yrs)
Similarity test	-0.55‡	-0.02
Digit span test:		
Forward	-0.47‡	-0.21†
Backward	-0.73‡	-0.20*
Total	-0.68‡	-0.21†
Vocabulary test	-0.57‡	-0.16
PASAT	-0.15†	-0.29‡
Trail making test		
A (time/sec)	0.42‡	0.18*
B (time/sec)	0.43‡	0.19*
BVRT	-0.29‡	-0.10
Digit symbol test	-0.652‡	-0.26‡
FEV1%	-0.16	-0.31‡
FEV1/FVC%	-0.06	-0.04
$FEF_{25-75\%}$	-0.02	-0.04
PEF%	-0.18*	-0.19*
Urine mercury level (µg/g creatinine)	—	0.16*

*p<0.05, †p<0.01, ‡p<0.001

Discussion

In our study, the highest environmental mercury concentrations were 53±0.9 µg/m³ at the exhaust machine and 33±0.2 µg/m³ at basing machine; both values exceeded the Occupational Safety and Health Administration (OSHA) limit[14] of 10 µg/m³ and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit[15] of 25 µg/m³. The measured noise levels inside all sectors of the factory were below the maximal permissible limit[16] of the sound intensity inside closed working areas, according to the Egyptian law of 90 dB. Therefore , any changes observed in the audiometry could be attributed to ototoxic effects of mercury.

Urinary mercury level was significantly higher in mercury-exposed workers than in unexposed group. This is in agreement with the results reported from Egypt,[11] Italy,[17] the USA,[18] and China[19].

Pulmonary manifestations and impaired pulmonary function tests were significantly more prevalent among exposed group than the comparison group. This may be due to ventilation errors in the working environment of the factory or additional effects of mercury vapors present in the factory. This result agrees with oth-

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er reports revealing that cough, dyspnea and chest tightness, appeared as a result of exposure to mercury vapor.[20-22] Another study on workers exposed to mercury vapor reported impaired pulmonary functions, airway obstruction, restrictive lung disease, hyperinflation and decreased vital capacity.[23]

The prevalence of hearing loss was significantly higher in the exposed than the comparison group. This finding is in concordance with another study that found a higher prevalence of hearing loss among dentists chronically exposed to mercury vapors.[24]

In this study, workers exposed to mercury vapor had significantly lower performance in all neurobehavioral tests compared to the comparison group. This agrees with a meta-analysis performed by Meyer, *et al*,[25] on 12 studies of occupational mercury exposure. Zachi, *et al*, also showed lower neuropsychological test performance among former workers of a fluorescent lamp factory compared to a matched unexposed control group in Digit Span subsets and Vocabulary test.[26] Other researchers found evidence for neuropsychological decrements and psychosomatic disorders associated with low-level exposure to mercury; they found that the exposure would negatively affect attention, visual perception, memory, and psychomotor speed.[27,28] On the other hand, Foda found no significant difference between workers exposed and unexposed to mercury in digit span forward and backward test.[11] This difference may be explained by the lower urinary mercury concentration observed among mercury-exposed workers in this study (44.1±17.5 µg/g creatinine) than Foda's study workers (32±4.1 µg/g creatinine).

In this study, a significant adverse association was observed between urinary mercury level and performance in neurobehavioral tests. This was also reported earlier, particularly in Digit Span Forward and Digit symbol test.[29]

In the current study, tremors were significantly prevalent in mercury-exposed group compared to the comparison group. This finding coincides with other studies.[30-33] Moreover, teeth loss, gum inflammation and bleeding gums were significantly more frequent among mercury exposed workers than in the comparison group. These results are also in keeping with another study that reported frequent teeth loss and gum inflammation among mercury-exposed workers.[34]

We found that with increasing duration of employment, urinary mercury level increased. This was also reported by other researchers.[10,12]

In conclusion, this study offers additional evidence that the central nervous system is the most sensitive target for elemental mercury vapor; the sign and symptoms present in the form of performance deficits in tests of cognitive function. This raises concerns about the ability for earlier detection of respiratory and auditory manifestations in mercury-exposed workers. This study also reinforces the need for effective preventive programs at florescent lamp industry workplaces, especially in the developing countries with the lowest unhygienic measures.

TAKE-HOME MESSAGE

- Mercury is a potentially hazardous element, which is an essential component in all types of fluorescent lamps. It is one of the important environmental pollutants.
- Elemental mercury may cause a variety of adverse effects on almost all organs and body systems.
- Long-term exposure to mercury, as evaluated by increased urinary mercury level, deteriorates pulmonary function and performance of workers of fluorescent lamp factory.

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Conflicts of Interest: None declared.

References

1. Agency for Toxic Substances and Disease Registry (ATSDR) (2009): Evaluating Mercury Exposure Information for Health Care Provider. Available from www.atsdr.cdc.gov/mmg/mmg (Accessed April 22, 2013).
2. Cheng H, Hu Y. Mercury in municipal solid waste in China and its control: a review. *Environ Sci Technol* 2012;**46**:593-605.
3. United States Environmental Protection Agency (USEPA)(2007). Mercury-containing Products. Available from www.epa.gov/epaoswer/nonhw/reduce/epr/products/mercury.htm (Accessed April 27, 2013).
4. Wu F. Production of low mercury fluorescent lamps. *Zhejiang ZhaomingDianqiXinxi* 2010;**11**:5-7.
5. Zahir F, Rizwi SJ, Haq SK, Khan RH. Low dose mercury toxicity and human health. *Environ Toxicol Pharmacol* 2005;**20**:351-60.
6. United States Environmental Protection Agency (USEPA). Mercury Study Report to the Congress. EPA 452/R-97-0003, Washington, **1997**.
7. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for Mercury. U. S. Department of Health and Human Services, Centers for Disease Control and Prevention, **1999**.
8. United Nations Environment Programme (UNEP). Global Mercury Assessment. Geneva, **2002**.
9. Costa MF, Tomaz S, de Souza JM, *et al.* Electrophysiological evidence for impairment of contrast sensitivity in mercury vapor occupational intoxication. *Environ Res* 2008;**107**:132-8.
10. El-Safty IA, Shouman AE, Amin NE. Nephrotoxic effects of mercury exposure and smoking among Egyptian workers in a fluorescent lamp factory. *Arch Med Res* 2003;**34**:50-5.
11. Foda N. Assessment of Memory Status among Workers Exposed to Mercury. *Bulletin of Alexandria Faculty of Medicine* 2008;**44**:3.
12. Farahat SA, Zawilla NH, Farouk SM. Impact of occupational exposure to metallic mercury on thymus gland functions among dental staff. *Egyptian J Occup Med* 2008;**32**:191-211.
13. Wechsler D. *Wechsler Memory Scale-Revised Manual.* SanAntonio, TX: The Psychological Corporation **1981**.
14. Pohanish RP. Mercury. In: *Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens.* 4th ed. Vol2, Norwich, New York, Noyes Publications, William Andrew Publishing, **2002:**1479-82.
15. American Conference of Governmental and Industrial Hygienists (ACGIH). TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, OH, **2008**.
16. Law 4. Egypt environmental law. Appendix 1994;**7**:47.
17. Soleo L, Urbano ML, Petrera V, Ambrosi L. Effects of low exposure to inorganic mercury on psychological performance. *Br J Ind Med* 1990;**47**:105-9.
18. Tsuji JS, Williams PR, Edwardes MR, *et al*. Evaluation of mercury in urine as an indicator of exposure to low levels of mercury vapor. *Environ Health Perspect* 2003;**111**:623-8.
19. Ping L, Xinbin F, Guangle Q, *et al.* Mercury exposures and symptoms in smelting workers of artisanal mercury mines in Wuchuan, Guizhou, China. *Environmental Research* 2008;**107**:108-14.
20. Bluhm RE, Bobbitt RG, Welch LW, *et al.* Elemental mercury vapour toxicity, treatment, and prognosis after acute, intensive exposure in chloralkali plant workers: Part I. History, neuropsychological findings and chelator effects. *Human and Experimental Toxicology* 1992;**11**:201-10.
21. Schwartz JG, Snider TE, Montiel MM. Toxicity of a family from vacuumed mercury. *Am J Emerg Med* 1992;**10**:258-61.
22. Decharat S. Mercury Exposure among Garbage Workers in Southern Thailand. *Safety and Health at Work* 2012;**3**:268-77.
23. Snodgrass W, Sullivan JB, Rumack BH. Mercury poisoning from home gold ore processing: Use of penicillamine and dimercaprol. *JAMA* 1981;**246**:1929-31.

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24. Cesarani A, Minoia C, Pigatto PD, Guzzi G. Mercury, dental amalgam, and hearing loss. *Int J Audiol* 2010;**49**:69-70.

25. Meyer-Baron M, Schaeper M, Seeber A. A meta-analysis for neurobehavioural results due to occupational mercury exposure. *Arch Toxicol* 2002;**76**:127-36.

26. Zachi EC, Ventura DF, Faria MA, Taub A. Neuropsychological dysfunction related to earlier occupational exposure to mercury vapor. *Braz J Med Biol Res* 2007;**40**:425-33.

27. Moen BD, Hollund EB, Riise T. Neurological symptoms among dental assistants: a cross sectional study. *J Occup Med Toxicol* 2008;**3**:10.

28. Liang Y, Sun R, Sun Y, *et al.* Psychological effects of low exposure to mercury vapor: application of a computer administered neurobehavioral evaluation system. *Environ Res* 1993;**60**:320-7.

29. Echeverria D, Woods JS, Heyer NJ, *et al.* Chronic low-level mercury exposure, BDNF polymorphism, and associations with memory, attention and motor function. *Neurotoxicol Teratol* 2005;**27**:781-96.

30. Fawer RF, de Ribaupierre Y, Guillemin MP, *et al.* Measurement of hand tremor induced by industrial exposure to metallic mercury. *Br J Ind Med* 1983;**40**:204-8.

31. Piikivi L, Hanninen H. Subjective symptoms and psychological performance of chlorine-alkali workers. *Scand J Work Environ Health* 1989;**15**:69-74.

32. Maarten MV, Herman JA, Cornelia HK. Tremor in workers with low exposure to metallic mercury. *Am Ind Hyg Associ* 1986;**47**:559-62.

33. Mc Cullough JE, Dick R, Rutchik J. Chronic Mercury Exposure Examined With a Computer-Based Tremor System. *J Occup Environ Med* 2001;**43**:295-300.

34. Holland RI, Ellingsen DG, Olstad ML. Dental health in workers previously exposed to mercury vapour at a chloralkali plant. *Occup Environ Med* 1994;**51**:656-9.

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