Respiratory toxicity in bone-based industrial workers in India

Iqbal Ahmad*[1], Huma Siddiqui[1], S.K. Rastogi[1], M.I. Khan[1,2], Govil Patil[1], Jamal M. Arif[3], and Rajendra Prasad[4]
[1]*Fibre Toxicology Division, CSIR-Indian Institute of Toxicology Research, Lucknow 226 001, India*
[2]*Department of Dermatology, University of Wisconsin, Medical Sciences Centre, 1300 University Avenue, Madison, WI 53706, USA*
[3]*Department of Biochemistry, College of Medicine, University of Hail, P.O. Box 2440,Hail, KSA*
[4]*Uttar Pradesh Rural Institute of Medical Sciences and Research, Saifai, Etawa, India*
**To whom correspondences should be addressed*
E-mail: ahmadi@sify.com

Received January 30, 2012, Revised manuscript received April 24, 2012, Accepted 27 April, 2012

Abstract

In this investigation, we report respiratory toxicity in bone-based industrial workers in India. Industrial workers significantly showed higher prevalence of respiratory symptoms as compared with reference group (47.4% vs. 9.9%). The primary respiratory impairment was found to be bronchial obstruction (18.64%) in the exposed workers in comparison to 2.70% in the controls, thereby reflecting obstructive changes in lung airways of exposed workers primarily due to exposure of occupational dust. The overall pulmonary impairment was noted to the tune of 22% compared with 8% observed in the controls, indicating predominantly obstructive ventilatory defects. These positive spirometric functions indicating deterioration in fundamental respiratory tests as well as the significant respiratory symptoms among the workers suggest for the safety standard and regulations. Currently, there is no standard permissible exposure limit for the safety of workers in bone based industrial units.

Keywords: Bone Based Industries, Pulmonary Function Test, VC, FVC, FEV1.0, FEF

1. Introduction

There is no study on the evaluation of health status of the workers employed in the manufacture of bone items particularly in Indian sub-continent. We recently reported the prevalence of occupational dust (total, PM_{10} and $PM_{2.5}$) in such industries and their toxicological profiles [1-2]. But exposure effects on respiratory health of workers were absolutely not known. Generally, exposure to occupational dust is primarily responsible for the respiratory health hazards in dusty industries [3-5]. The relationship between particle size and health effects is due to the efficiency of particle deposition in different regions of respiratory tract [6-14]. The occupational dust in bone-based industries presumably contain calcium, phosphorus, magnesium, potassium, sodium, sulfur and trace elements such as zinc, copper, manganese, copper, lead, fluoride and silica which are the known constituents of bone [15-18]. For the first time, the current respiratory health study was conducted to assess the prevalence of upper and lower respiratory symptoms, associated pulmonary function changes and type of ventilatory impairment suffered by the workers on chronic exposure to occupational dust.

2. Materials and Methods

2.1. Selection of Bone-Based Industrial Units

Bone-based industrial units, manufacturing a variety of decorative and ornamental items were randomly selected (1, for pictures of industrial unit and bone-based items). These unorganized micro scale industrial units were located in Lucknow, U.P., India. There were mostly two to three workers per industrial unit. Industrial workers were seen working without face masks in small rooms lacking air exhaust facility.

2.2. Study Groups

A total of 59 male workers were drawn from twenty one bone – based industries. The recruitment of big sample size had been critical due to their microscale nature and difficulty in tracing them who operate without any registration. A reference group of 111 subjects belonging to similar sex, age and socio – economic status was taken. A complete history of the workers was recorded with respect to duration and nature of occupation, respiratory symptoms, smoking habit etc. The details of respiratory symptoms were obtained through a structured respiratory questionnaire based on British Medical Research Council (19). The study was performed after approval by the Ethical Committee, C.S.M. Medical University, Lucknow, India.

2.3. Lung Function Testing

The spirometric lung functions were recorded in the standing position using an electronic computerized portable spirometer according to the guidelines recommended by American Thoracic Society [20,21]. Each individual performed spirometry thrice to produce the best results. Following the lung function testing, the standing height and weight of subjects were noted to predict the normal values of pulmonary function tests using Rastogi's prediction equations [22]. The spirometer used was recalibrated each day prior to use. The room temperature was recorded every day during the period of study. The following respiratory parameters were studied:

- Forced vital capacity (FVC)
- Forced expiratory volume in 1 sec. (FEV 1.0)
- FEV1/FEV%
- Peak expiratory flow rate at various levels of VC/FVC
  - FEF 25 – 75%
  - FEF 25%
  - FEF 50 – 75%

FEV1/FVC percent values between 70-80% were considered normal and values less than 70% indicated bronchial obstruction. Standard reference values for spirometry were taken from our previous report [22]. The ventilatory disturbances were classified as per Millers Prediction Quadrant [23].

2.4. Statistical Analysis

The data were expressed as the mean ± SE. and the significance of differences among the groups was determined by one-way analysis of variance (ANOVA) and Dunnett's Multiple Comparison Test using Graph Pad prism (Version 5.0) software. P values < 0.05 were considered statistically significant.

Table 1. Demographic and occupational histories of workers in different bone-based industrial units

Sub- groups (N)	Age (years)#	Height (cms)	Smoking prevalence		Exposure (years)		
			n	%	< 5	5-10	> 10
Workers (59)	31.2 ± 8.4	163.6 ± 3.2	31	52.54	23	19	17
Controls (111)	32.6 ± 9.2	162.5 ± 2.6	53	47.74	-	-	-

3. Results

Demographic data of exposed population and reference subjects are given in Table 1. The mean ages of workers and control groups were 31.2 years and 32.6 years, respectively. Likewise, smoking prevalence in both the groups was quite matching. The prevalence of respiratory symptoms in these groups is shown in Table 2. The overall prevalence of respiratory symptoms was 47.45% ($p < 0.05$) in industrial workers in comparison to 9.90% in control population. The pulmonary flow rates in both exposed and control groups in relation to smoking habit are shown in Table 3. The airway flow rates like MMEF (Maximum mid expiratory flow), Forced Expiratory Flow Rate at 25%, 50%, and 75% (FEF 25%, FEF 50%, and FEF 75%) show a reduction in mean values among smokers compared to non smokers. Although the difference between the mean values of lung function was not significant, the trends of the result denote obstructive type of lung function abnormalities especially in smaller airways among smokers. The small sample size was a limitation for the statistical significance between the mean values of airway flow rate parameters.

Table 2. Prevalence of respiratory symptoms in workers of bone-based unorganized units

Groups	N	Respiratory symptoms	
		N	%
Workers	59	28	47.45*
Controls	111	11	9.90

N: total number of subjects; n: number of subjects with respiratory symptoms;%: percent of subjects with respiratory symptoms; *: $p < 0.05$

Lung function data of industrial workers and controls are shown in Table 4. There is no statistically significant difference among various groups with respect to their VC and FVC. However when the mean values of VC and FVC observed in each group were compared with their respective predicted values they showed significant reduction thereby indicating occupational effects. In case of FEV 1.0, which is indicative of obstructive type of ventilatory abnormalities, the mean observed values were significantly reduced in industrial workers as compared to that recorded in the unexposed controls. These findings are further supported by the reduction in observed FEV1/FVC% ratio in case of exposed workers compared to the unexposed controls. The values of various flow rates in the industrial workers and the controls are also shown in Table 4. The different flow rates defining early, mid and late air flow obstruction in the exposed workers were significantly impaired compared to the corresponding values obtained in the unexposed controls. The results indicate a synergistic action (occupational dust exposed and cigarette smoking) caused impaired flow rates among the exposed workers. The prevalence and type of pulmonary abnormalities observed in this study are listed in Table 4. The overall prevalence of pulmonary impairment was found to be significantly higher in the exposed group than that observed in the control group (22.03% vs. 8.10%). The primary respiratory impairment was found to be bronchial obstruction (18.64%) in the exposed workers in comparison to 2.70% seen in the controls thereby reflecting obstructive changes in lung airways primarily due to exposure of occupational dust in the exposed workers.

Table 3. Mean values of various lung function and flow rates in relation to smoking in study subjects

Variables	Non-smokers	Smokers
	(n = 86)	(n = 84)
MMEF (L/S)	3.10 ± 0.65	2.80 ± 0.66
FEF 25% (L/S)	3.52 ± 1.20	2.74 ± 0.91
FEF 50% (L/S)	2.75 ± 0.75	2.27 ± 0.73
FEF 75% (L/S)	2.12 ± 0.59	1.84 ± 0.61

n: total number of subjects

4. Discussion

The present study reports for the first time, the prevalence of upper and lower respiratory symptoms. This was accompanied by pulmonary function impairment primarily of obstructive type (18.64%) in unorganized microscale industrial units engaged in the manufacture of ornamental and decorative items from bone. These respiratory health effects resulted from chronic exposure to occupational dust emitting due to manufacturing processes. Prevalence of total, PM_{10} and $PM_{2.5}$ occupational dust was recently recorded in these industrial units [1]. Moreover, this occupational dust produced cytotoxicity and oxidative stress in different test models [1,2]. There are no parallel studies in the available literature for comparative purposes. Generally, there is a close association between airborne occupational dust and pulmonary health of exposed population [24]. Chronic exposure of air particulates is known to impair clearance mechanism leading to inflammatory reactions in lungs [11,25-28]. Very recently we have shown the prevalence of respirable mass as PM_{10} and $PM_{2.5}$ in these industries [1] which have potential of reaching terminal airways thereby causing peripheral airway obstruction. Our findings therefore corroborate many previous epidemiological studies reporting association between pulmonary disease and dust concentration in occupational environment [3,7,29]. Mean values of lung functions, FVC, VC, FEV1 and pulmonary flow rates FEF 25-75%, MEF 75% showed significant reduction in exposed subjects compared to controls. Lung function abnormalities viz., low FVC, FEV1, PEFR observed among bone workers may be due to work-related exposure to bone dust. The workers in these unorganized industrial units are not permanent employees; thereby frequently shift themselves from unit to unit. Under this scenario, it was difficult to correlate their respiratory morbidity with severity of exposure in terms of total SPM, PM_{10}, and $PM_{2.5}$ which was previously monitored in these microscale industries [1]. These industrial units generally employee 2-3 workers so the recruitment of workers in sizeable number had been also critical. Due to this problem, workers could not be sub-grouped as smokers and nonsmokers in order to statistically distinguish the role of smoking on overall respiratory health. Non use of personal protective equipments by the workers, poor and prolonged work practices may add to respiratory health hazards. The findings of the study do warrant further detailed investigation. The reduction in different flow rates viz., MMEF, FEF 25%, FEF 50%, and FEF 70%, among the exposed workers indicated peripheral airway effects resulting from exposure to occupational dust. Similar findings we have earlier reported in the carpet workers exposed to cotton and wool dust [3]. Pulmonary function data also suggest that peripheral airway obstruction (PAO) is just the beginning of the early effects of bone dust on the lung airway preceding central airway obstruction (CAO). It has been further observed that the organic dust exposure is primarily the etiological factor in the causation of respiratory morbidity and functional disorders [30-32]. Direct correlation between the period of exposure and the pulmonary abnormalities suggests that ventilatory impairments are related to the length of exposure to occupational dust in the bone - based unorganized industries.

5. Conclusion

These positive spirometric functions indicating deterioration in fundamental respiratory tests as well as the significant respiratory symptoms among the workers in the bone based industry suggest for the safety standard and regulations. Currently, there is no prescribed permissible exposure limit for the safety of workers in bone based industrial units.

Acknowledgments

The authors are thankful to Dr. K.C. Gupta, Director, CSIR-Indian Institute of Toxicology Research, Lucknow, India for his interest in the study. Financial grants from Council of Science and Technology, Uttar Pradesh and Senior Research Fellowship from Council of Scientific and Industrial Research, New Delhi to Miss Huma Siddiqui, are gratefully acknowledged. The CSIR-IITR communication number is 2855.

References

[1] Siddiqui H, Ashquin M, Prasad R, Arif JM, Patil TN, Ahmad I (2011). Industrial Hygiene and Toxicity Studies in Unorganized Bone – Based Industrial Units. Environ Monit Assess 176 (1-4): 213-223.

[2] Ahmad I, Siddiqui H, Akhtar MJ, Khan MI, Patil G, Ashquin M, Patel DK, Arif JM, (2011). Toxic responses in primary rat hepatocytes exposed with occupational dust collected from work of bone-based industrial unit. Chemosphere 83 (4): 455-460.

[3] Rastogi SK, Ahmad I, Pangtey BS, Mathur N (2003). Effects of occupational exposure on respiratory system in carpet workers. Indian J Occup Environ Med 7(1): 19-26.

[4] ALA (American Lung Association) (2012). State of The Air. Health Risks. Particle Pollution. Accessed 26 April 2012 at http://www.stateoftheair.org/2011/health-risks/health-risks-particle.html.

[5] Valberg PA (2004). Is PM more toxic than the sum of its parts? Risk assessment toxicity factors vs. PM mortality “Effect Functions”. Inhal Toxicol 16 (s1): 19-29.

[6] Kittelson DB, Watts WF, Johnson JP, Remerowki ML, Ische EE, Oberdorster G et al. (2004). On-road exposure to highway aerosols. 1. Aerosol and gas measurements. Inhal Toxicol 16 (1): 31-39.

[7] Wichmann HE, Spix C, Tuch T, Wolke G, Peters A, Heinrich J, et al. (2000). Daily mortality and fine and ultra-fine particle in Erfurt, Germany, Part I: Role of particle number and particle mass, Res Rep Health Eff Inst 98, 5-86.

[8] Chen L, Yang W, Jennison BL, Omaye ST (2000). Air particulate pollution and hospital admissions for chronic obstructive pulmonary disease in Reno, Nevada. Inhal Toxicol 12 (4): 281-298.

[9] Sunyer J, Basagana X (2001). Particle and not gas, are associated with the risk of deathin patients with chronic obstructive pulmonary disease. Int J Epidemiol 30 (5): 1138-1140.

[10] Atkinson RW, Anderson HR, Sunyer J, Ayres J, Baccini M, Vonk JM, et al. (2001). Acute effect of particulate air pollution on respiratory admissions: Results from APHEA 2 Project. Air pollution and health: A European Approach. Am J Respir Crit Care Med 164 (10 pt 1): 1860-1866.

[11] Robert A, Freitas Jr (2003). Nanomedicine, VolumeII A: Biocompatibility Landes

Bioscience, Georgetown, TX. S. Karger Publishers, Inc.
[12] Hoek G, Kos G, Harrison R, Hartog J de, Meliefste K, Brink H ten et al. (2008). Indoor-outdoor relationships of particle number and mass in four European cities. Atmos Environ 42 (1): 156-169.
[13] Wu Z, Hu M, Lin P, Liu S, Wehner B, Wiedensohler A (2008). Particle number size distribution in the urban atmosphere. Atmos Environ 42: 7967-7980.
[14] Chen Y, Yang Q, Krewski D, Shi Y, Burnett RT, McGrail K (2004). Influence of relatively low level of particulate air pollution on hospitalization for COPD in elderly people. Inhal Toxicol 16 (1): 21-25.
[15] Morris HP, Nelson JW, Palmer LS (1931). Quantitative determination of calcium, magnesium and phosphorus in feedstuffs and cattle excreta (improved technique). Ind and Eng Chem Anal Ed, 3: 164.
[16] Marken PA, Weart CW, Carson DS, Gums JG, LopesVirella MF (1989). Effects of magnesium oxide on the lipid profile of health volunteers. Atherosclerosis 77 (1): 37-42.
[17] Vincent JH, Donaldson K (1990). A dosimetric approach for relating the biological response of the lung to the accumulation of inhaled mineral dust. Br J Ind Med 47 (5): 302-307.
[18] Altura BT, Wilimzig C, Trnovec T, Nyulassy S, Altura BM (1994). Comparative effects of magnesium enriched diet and different orally administered magnesium oxide preparations on ionized Mg, Mg metabolism and electrolytes in serum of human volunteers. J Am Coll Nutr 13 (5): 447-454.
[19] Cotes JE (1987). Medical Research Council questionnaire on respiratory symptoms (1986). Correspondence. Lancet 2: 1028.
[20] (1995). Standardization of spirometry, 1994 Update. American Thoracic Society. Am J Resp Crit Care Med 152 (3): 1107-1136.
[21] Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. (2005). Standardisation of spirometry. Eur Respir J 26 (2): 319-338.
[22] Rastogi SK, Mathur N, Clark SH (1983). Ventilatory norms in health industrial male workers. Indian J Chest Dis Allied Sci 25 (3): 186-195.
[23] Miller WF, Wu N, Johnson RL Jr (1956). Convenient method of evaluating pulmonary ventilatory function with a single breath test. Anest 17 (3):480-493.
[24] World Health Organization (1999). Hazard prevention and control in the work environment: Airborn dust. Occupational and Environmental Health, Department of Proetection of the Human Environment, WHO, Geneva.
[25] Borish LC, Steinke JW (2003). Cytokines and chemokines. J Allergy Clin Immunol 111 (2): S460-S475.
[26] Dosman JA, Fukushima Y, Senthilselvan A, Kirychuk, SP, Lawson JA, Pahwa P et al. (2006). Respiratory response to endotoxin and dust predicts evidence of inflammatory response in volunteers in a swine barn. Am J Ind Med 49 (9): 761-766.
[27] Poole JA, Wyatt TA, Von Essen SG, Hervert J, Parks C, Mathisen T, et al. (2007). Repeat organic dust exposure–induced monocyte inflammation is associated with protein kinase C activity. J Allerg Clin Immunol 120 (2): 366-373.
[28] Sehlstedt M, Dove R, Boman C, Pagels J, Swietlicki E, Londahl J et al. (2010). Antioxidant airway responses following experimental exposure to wood smoke in man. Part Fibre Toxicol 7: 21.
[29] Dockery DW, Pope CA 3rd, Xu X, Spengler JD, Ware JH, Fay ME, et al. (1993). An association between air pollution and mortality in six U.S. cities. N Engl J Med 329 (24): 1753-1759.
[30] Bonner JC (2007). Lung Fibrotic Responses to Particle Exposure. Toxicol Pathol 35 (1): 148-153.
[31] Kleinman MT, Sioutas C, Froines JR, Fanning E, Hamade A, Mendez L et al. (2007). Inhalation of concentrated ambient particulate matter near a heavily trafficked road stimulates antigen-induced airway responses in mice. Inhal Toxicol 19 (1): 117-126.
[32] Valavanidis A, Fiotakis K, Vlachogianni T (2008). Airborne particulate matter and human health: toxicological assessment and importance of size and composition of particles for oxidative damage and

carcinogenic mechanisms. J Environ Sci Health C Environ Carcinog Ecotoxicol Rev 26 (4): 339-362.

Table 4. Pulmonary impairment, mean values of lung function and pulmonary flow rates of workers in bone-based industrial units

Groups	N	VC (ml)	FVC (ml)	FEV1 (ml)	FEV1/FVC%	MMEF (L/S)	FEF 25% (L/S)	FEF 50% (L/S)	FEF 75% (L/S)	Restrictive		Obstructive		Mixed		Total	
										n	%	n	%	n	%	n	%
Workers	59	3319 ± 393	3159 ± 339	2561 ± 433	77.8 ± 8.6	2.95 ± 0.41	3.21 ± 1.28	2.31 ± 0.85	1.75 ± 0.60	2	3.38	11	18.64*	-	-	13	22.03*
Controls	111	3566 ± 366	3686 ± 367	2964 ± 329	83.4 ± 11.7	3.09 ± 0.78	3.57 ± 0.98	2.98 ± 0.67	2.39 ± 0.63	4	3.6	3	2.70	2	1.80	9	8.10

Values are means ± S.E.; N: total number of subjects; L/S: liter per second; n: number of subjects with respiratory impairment; *: $p < 0.05$