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Respiratory Function Tests in Rubber Factory Workers

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Abstract: Respiratory functions of 607 workers from rubber processing unit were studied in relation to occupational exposure to various pollutants viz. suspended particulate matter, polycyclic aromatic hydrocarboin compound (PAH), sulphates and nitrates. The results showed significant decline in lung functions proportionately with the longer working duration and to the increased pollutant concentration of the various sections of the rubber factory. Workers in the compounding (mixing) unit were most affected as pollutant concentration found in this section was maximum; this was supported by the abnormal Xray findings.

Introduction

The presence of suspended particulate matter (SPM), polycyclic aromatic hydrocarbon compounds (PAH) e.g. benzo(a)pyrene, benzo(e)pyrene, benzo(a)anthracene, sulphates and nitrates in the rubber factory has raised concerns about the respiratory health of the workers. Long term exposures of workers to these pollutants in their workplace environment not only derange lung functions, but may produce effects ranging from chronic bronchitis to cancer of lungs[1-3]. Approximately 500 substances are used in the manufacture of rubber[4] and most of these are capable of causing acute and chronic respiratory effects[4-7]. Quite a few studies from abroad do reveal the presence of benzo(a)pyrene in the air as a good indicator of expsoure to PAH compound[8]. Exposure to noxious agents in the rubber factory are associated with the development of acute and chronic respiratory impairment[9]. Some workers[10,11] demonstrated significantly lower ventilator capacity tests and higher prevalence of respiratory symptoms in rubber factory workers as compared to the controls. The present study was carried out in the rubber factory workers to evaluate the effect of particulate matter and PAH various lung functions e.g. forced vital capacity (FVC: the maximum volume air expelled after a maximum voluntary inspiration), the forced expiratory volume in 1 second (FEV_1: that part of the FVC expired in first second of forced expiration), peak expiratory flow rate (PEFR), peak inspiratory flow rate (PIFR) and forced expiratory flow 25-75% (FEF 25-75%). Radiographic examination of their chest was also done.

Methods

Environment Sampling : Air sampling at the factory was carried out with a five-stage Kimoto cascade sampler operating at a flow rate of 1.7 I/M^3/min on glass fibre filter paper (GF/A Whatman) giving fraction sizes of (in µm): >10.4, >5.2, >1.6, >0.6 and <0.5. Six samples (8 hour duration) were collected over a period of 3 months in each of the following three different stages of the rubber manufacturing process: packing and loading, vulcanization and compounding. The particle concentrtion (total suspended particulate matter: TSP) of each sample was estimated gravimetrically, and the benzo(a)pyrene from the five fractions of particles was determined after extraction with benzene in a Soxhlet apparatus for 8-10hr[12-13]. The extracted material was concentrated in a Buchi rotavapour and then deoxygenated by passing nitrogen through it. Finally, the sample was analysed in a Ferrands-3 scanning spectrfluorometer[14]. The qualitative determination was carried out using an excitation-correction module coupled with the instrument.

Lung Function Tests : Information regarding rubber factory workers employed in different sections was collected between October 1989 and March 1990. A questionnaire requesting details on age, duration of employment, smoking habits and full medical history was completed by all 667 workers examined. Their height and weight were measured, as were their FVC, FEV_1, FEF 25-75%, PIFR and FEFR (with an electronic lung function machine: model Elf, P.K. Morgan, UK). A chest X-ray (posterior-anterior view) was taken of each worker studied.

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Data Analysis : To examine the effect of the duration of exposure, three subgroups of workers were formed according to the duration of employment. Statistical analysis was by one-way analysis of variance with Tukey's test technique, using an SPSS package. The relationship between the results of the pulmonary function tests and variables was assessed by multiple linear regression with an examination of residuals. Values are expressed as the mean and standard deviation.

Results

The quantity of suspended particulate matter (SPM) (mean+SD) to which each group of workers was exposed was as follows (in $\mu g/m^3$): packing and loading 77.32+21.86; vulcanization, 147.37+47.87, and compounding, 155.44+12.68 respectively. The highest SPM (66.0µg/m^3) and benzo(a)pyrene (10.94 ng/^{m}) concentrations were observed in he particle fraction size of <0.5µm, of compounding section (Table 1). The SPM concentration of packing and loading workers were exposed was significantly less than that to which the other workers were exposed at the two smallest fraction sizes ($p<0.01$). The concentration of benzo(a)pyrene was seen to decrease with an increase in particle size throughout (Table 1).

Table 1 : Concentrations of SPM and benzo(a)pyrene, according to particulate size in rubber factory.

Particulate size (µm)	Packing + Loading unit		Vulcanization unit		Compounding unit	
	SPM (µ/m^3)	Benzo(a) pyrene	SPM (µ/m^3)	Benzo(a) pyrene	SPM (µ/m^3)	Benzo(a) pyrene
>10.4	5.52+3.63	0.32+0.46	5.46+2.46	0.31+0.11	5.74+0.40	0.1+0.01
>5.2	7.22+4.65	0.72+0.30	11.02+3.83	0.82+0.18	11.77+3.45	0.71+0.12
>1.6	9.62+4.17	1.16+0.57	15.11+3.46	1.16+0.51	16.53+4.59	2.01+0.97
>0.6	10.27+3.67	2.01+0.59	20.90+1.98	1.34+0.34	21.86+4.59	5.94+2.21
<0.5	38.49+12.79	3.65+1.70	65.09+22.67	5.85+1.20	65.99+11.12	10.94+2.10
TSPM	77.32+21.86		147.37+47.87		155.44+12.68	

Values are mean + SD. TSPM = Total SPM

Table 2 : Mean Concentration of rubber factory pollutants in three sections of rubber factory.

Parameter	Section I	Section II	Section III	F value
SPM (µ/m^3)	77.32+21.36	147.37+47.87	155.44+12.68	11.16
Benz(a)pyrene (ng/m^3)	0.90+0.59	0.74+0.49	9.66+1.55	202.31
Benzo(a)pyrene (ng/m^3)	46.76+14.23	128.43+94.93	283.62+104.63	13.75
Benzo(a)anthracene (ng/m^3)	1.15+0.58	1.66+1.56	6.83+3.07	17.94
Sulphates (µ/m^3)	27.96+5.84	23.24+3.77	40.96+12.13	10.44
Nitrate (µ/m^3)	6.41+2.87	5.23+1.65	20.70+7.50	26.46

Table 2 shows the concentration of SPM and PAH compounds, viz. benzo(a)pyrene, benzo(e)pyrene, benzo(a)anthracene, sulfates and nitrates. It is evident that the SPM and other chemicals were in highest concentrations in the compounding (mixing) unit as compared to those in other two units. From the analysis of variance of significant difference ($p<0.001$) could be seen amongst these pollutants from one section to another. (Table 2)

Demography and Symptoms

The monthly income of the workers studied ranged from Rs. 1,469 to 1,639 per month, which reflects their average socio-economic status. Their mean age, height and weight ranges were, 23.8-27.9 years, 161, 1-161.7cm and 50.0-51.6 kg respectively, and there was homogeneity between workers in all groups.

Symptoms indicative of respiratory difficulty (Table 3) were present in factory workers involved in the three different stages of the rubber manufacturing process studied, but were both most prevalent and severest in the workers belonging to compounding section (n=148), followed by those in the vulcanization section (n=441). The subjects from the packing and loading unit (n=78) had FVC and FEV_1 values of 2.79 and 2.60 litres such that the FEV_1/FVC ratio was 93%; whereas the values of these workers from vulcanisation section were 2.51 and 2.31 litres with a ratio of 92% and in the compounding group, 2.35 and 2.12 litres and 90% respectively. (Table 3)

Table 3 : Distribution of respiratory signs and symptoms in the rubber factors workers

Section	Blood	Breathing	Chest	Chest	Throat	Cough	Sputum
Packing and loading	-	+ve	+ve	-	-	-	-
Vulcanization	+ve	+ve	+ve	-	-	+ve	with blood
Compounding	+ve	+ve	+ve	+ve	+ve	+ve	with blood, black colour

Mean values of FEF 25-75%, PEFR and PIFR of different groups of workers are represented in Table 4. As compared to other groups, a significant decrease in FEF 25-75%, PEFR and PIFR values were noted in compounding unit ($p<0.05$). The relationship of the deterioration in lung function with the duration of exposure to pollutants is given in Table 5. As compared to different subgroups of working duration among the three groups of workers, a significant reduction in lung functions in workers having a working duration of 6 years and more was observed. In packing and loading section (group 1), no two subgroups were different from each other in their values of FEF 25-75%, PEFR and PIFR raw ingredients and other chemicals are heated and milled to obtain softened rubber. In all these locations, one would anticipate that there was exposure to particles and benzo(a)pyrene. (Table 4 & 5)

Researchers have correlated Benzo(a)pyrene with the mixture of PAH analysed, confirming the presence in air as a good indicator of exposure to PAH compounds[8].

Table 4 : Mean measured values of lung functions of workers belonging to Section I, II and III

Group No.	Section	Parameters				
		FEF25% (L/Sec)	FEF50% (L/Sec)	FEF75% (L/Sec)	PEFR (L/Sec)	PIFR (L/Sec)
1	I	4.13+0.99	3.63+0.92	2.56+0.55	4.40+1.02	3.95+0.99
2	II	3.97+1.34	3.57+1.12	2.34+0.78	4.13+1.45	3.48+1.15
3	III	3.34+1.13	3.04+0.82	2.20+0.61	3.33+1.21	2.97+0.89
F value		4.636*, 8.045*, 4.199*, 11.00, 16.57*				

*p<0.05 ANOVA)

Discussion

The highest particles and benzo(a)pyrene concentrations were found in the compounding section workers. Such a particle size distribution is consistent with the results from the pulmonary function tests. This study showed that the lowest measures of lung function were found in the workers from the compounding section, which was the most polluted environment. Furthermore, the longer the workers had spent in the factory, the lower was their lung function, regardless of the stage of production process they were involved. This suggests that there may be a causal link between the exposure to particles and benzo(a)pyrene or other chemicals and the depression of lung function. That this depression has clinical implications as revealed by the finding that the severity and frequency of respiratory difficulty was greatest in workers from the compounding section, who were exposed to the highest concentrations of respiratory particles and benzo(a)pyrene. The loss of pulmonary function seen in the present study was supplemented by the X-ray findings, conforming that lung damage was greatest in the workers in the compounding section.

The inverse relationship between lung function and concentration of pollutants that has been found in the present study is consistent with other findings. Such a relationship was demonstrated by Zejde et al[16] in Swine producers. In a study on rubber factory workers by Zuskin et al[10] also showed significantly lower values of FVC, FEV1, FEF 25%, FEF 50% and higher prevalence of acute and chronic respiratory symptoms. A study on Shoe and Cement factory workers has shown fall in various spirometric values (FVC, FEV_1/FVC) indirect proportion to duration of exposure[11]. The high incidence of respiratory symptoms and X-ray findings in workers in the compounding section are similar to those reported by Shah and Co-workers[17] in asbestos workers. These results are also in geneal agreement with those of other workers[18] who have

Table 5 : Multiple regression analysis ofFVC and FEV_1, FEF 25%, FEF 50%, FEF 75%, PEFR and PIFR vis a vis physical parameters and pollutants.

Effects of various	FVC(L)		FEV_1(L)		FEF 25%(L/sec)		FEF 50%(L/sec)		FEF 75%(L/sec)		PEFR(L/sec)		PIFR(L/sec)	
parameters	Coff	t	coff	t	coff	t	Coff	t	Coff	t	Coff	t	Coff	t
Age	-9.18	-1.63	0.011	-1.82	-0.24	-1.59	-.021	-1.90	-6.20	-2.68*	-1.78	-.110	.024	-2.40*
Height	0.021	3089*	0.013	2.40*	-3.15	-.224	9.81	.936	.011	1.64	5.15	.034	.021	1.86
Weight	0.029	5.06*	0.020	3.29*	.035	2.369	.026	2.28*	.014	1.98*	.017	1.04	.011	9.21
Calorie intake	1.22	0.163	7.77	0.960	-1.05	1.01	2.36	1.76	7.98	.822	2.30	1.08	6.67	.421
Smoking duration	-1.59	-0.25	-1.76	-0.255	-1.76	-.895	-2.26	-1.54	-2.74	-2.88*	-3.03	-1.37	4.81	.311
Employment duration	-1.14	-1.50	-1.59	-1.98	-1.76	-.895	-2.26	-1.54	-2.74	-2.88*	-3.03	-1.37	4.81	.311
Working hours/day	4.81	0.272	9.62	0.510	-.024	-.521	.023	.666	8.25	.366	.015	.298	.014	.368
SPM (µg/m^3)	-3.87	-3.41*	-4.18	-3.35*	-1.58	-.443	-3.21	-.116	-3.68	-1.85	-4.96	-1.26	-6.95	-2.04*
Benzo(a)pyrene	-0.014	-1.45	-0.016	-1.55	-0.88	-3.66*	-.046	-2.74*	-3.48	-.335	-.094	-3.73*	-.037	-2.10*
r^2 (%) for all 9 parameters	0.513(51.3%)		0.413(41.3%)		.343(34.3%)		.355(35.5%)		.398(39.8%)		.303(30.3%)		.317(31.7%)	
r^2 value (%)for first 7 parameters additional contribution	0.486(48.6%)		0.383(38.3%)		.222(22.2%)		0.300(30.0%)		0.380(38.0%)		0.157(15.7%)		0.273(27.3%)	
Additional contribution (%) of pollutants	0.029(2.9%)		0.054(5.4%)		12.1%		5.5%		1.8%		14.6%		4.4%	

*p<0.05

Table 6 : Pulmonary lung functions of subgroups (a,b,c and d) durationwise.

Section	Parameter	Group according to work duration			
		a	b	c	d
		6 months	6 months to 3 years	3 years to 6 years	6 year & above
	FEF25% (L/sec)	4.48+1.07	4.21+0.87	3.96+1.00	3.74+0.83
	FEF50% (L/sec)	3.82+0.91	3.64+1.00	3.52+0.84	3.37+1.06
	FEF75% (L/sec)	2.70+0.53	2.68+0.52	2.49+0.58	2.14+0.35
Packing &	PEFR (L/sec)	4.68+1.04	4.44+0.83	4.20+0.91	4.21+1.51
loading	PIFR (L/sec)	4.33+1.17	3.82+0.65	3.81+1.10	3.63+1.03
group (I)	FVC(L)	2.96+0.41	2.90+0.37	2.68+0.36	2.63+1.08
	FEV_1(L)	2.81+0.21	2.68+0.44	2.48+0.38	2.41+0.51
	FEV_1/FVC(%)	94.9+5.7	92.4+6.2	92.5+6.3	91.5+7.5
	FEF25% (L/sec)	4.07+1.28	4.04+1.33	3.85+1.31	3.75+1.53
	FEF50% (L/sec)	3.69+1.07	3.64+1.06	3.39+1.04	3.33+1.35
	FEF75% (L/sec)	2.48+0.76	2.36+0.72	2.30+0.78	2.02+0.81
Vulcanizing	PEFR(L/sec)	4.25+1.41	4.14+1.44	4.02+1.47	3.92+1.54
(group II)	PIFR (L/sec)	3.53+1.12	3.47+1.18	3.47+1.17	3.38+1.18
	FVC(L)	2.59+0.61	2.56+0.61	2.39+0.64	2.38+0.65
	FEV_1(L)	2.39+0.59	2.36+0.59	2.17+0.59	2.14+0.66
	FEV1/FVC(%)	92.3+9.6	92.2+11.7	90.8+10.1	89.9+12.3
	FEF25%(L/sec)	3.46+0.41	3.4+0.47	3.33+1.35	3.24+1.48
	FEF 50%(L/sec)	3.22+0.45	3.16+1.02	3.03+0.93	2.83+0.86
	FEF 75% (L/sec)	2.40+0.48	2.35+0.77	2.22+0.62	1.93+0.54
Compounding	PEFR (L/sec)	4.08+1.00	3.10+1.17	3.09+1.30	2.90+1.10
(group III)	PIFR (L/sec)	3.13+1.02	3.09+0.93	3.01+0.66	2.69+0.78
	FVC(L)	2.40+0.46	2.36+0.51	2.34+0.37	2.30+0.41
	FEV_1(L)	2.21+0.40	2.15+0.65	2.09+0.49	2.05+0.60
	FEV1/FVC(%)	92.1+8.0	91.1+13.8	89.3+19.0	89.1+17.1

Table 7 : Physicial parameters of the subjects studied

Parameter	Packing and loading	Vulcanization	Compounding
Age, years	25.2+7.3	23.8+5.9	27.9+7.4
Height, cm	161.7+6.3	151.1+6.3	161.6+6.2
Weight, kg	50.4+5.63	50.0+5.92	51.6+6.00
Smoking duration, years	7.4+7.7	5.5+4.3	7.7+6.4
Employment duration, months	2.3+1.1	2.1+1.1	2.6+1.2
Beedi/day	12.2+11.7	8.7+5.5	7.3.+6.2
Cigarettes/day	3.7+1.6	3.6+2.6	4.8+4.8
Tobacco, g/day	3.1+2.3	3.1+2.1	3.0+1.7
Work time, h/day	9.5+1.7	9.7+1.6	9.5+1.7
Caloric intake, kcal/day	1747+325	1822+406	1802+372
Major family members	3.4+1.8	4.4+3.2	4.2+2.5
Minor family members	2.6+1.4	2.9+2.0	3.1+2.4
Income, Rs/month	1469+1-21	1639+1284	1585+1187
Subjects	78	441	148

reported significant reductions, in FVC values in samill and ricemill workers after 5 years of exposure and in FEV_1 values within a 1-year exposure time. In anoher study, rubber factory workers with an exposure of 10 yers showed a significant decrease in FEV_1/FVC when compared with controls[19]. A time-related decline in lung function has also been reported in Indian workers who have been exposed to talc dust[20].

In any study such as the present one, it is possible to implicate a pollutant in medical effect erroneously because of conpounding factors. In the present study, the workers in each group were examined with regard socioeconomic status and medical history. No relationship between these factors could be demonstrated, allowing the conclusion to be made that the impairment of lung function was related to the concentrations of particles and chemicals in the respirable fraction of air to which workers in a rubber factor were exposed. Of course, the possibility remains that the benzo(a)pyrene could be a surrogate for some other substance that causes the damage to the lungs. However, as benzo(a)pyrene was employed in the present study as a marker for all polycyclic aromatic hydrocarbons, it seems likely that such a chemical is responsible for the pulmonary damage in the rubber factory workers. Whatever the relationship between polycyclic aromatic hydrocarbons and pulmonary toxicity, it is clear that respirable particles are involved in the observed effects.

References

1. Van Houdt JJ. Mutagenic activity of airborne particulate matter in indoor and outdoor environments. Atmos Environ 1990;243:207-220.
2. Teranishi K, Hamada K, Watanebe H. Quantitative relationship between carcinogenicity and mutagenicity of PAH in ST mutants. Mutat Res 1975;31:97-102.
3. Tokiwa H, Kitamori S, Takhashi K, Ohnishi Y. Mutagenic and chemical assay of extracts of airborne particulates. Mutat Rees 1980;77:99-108.
4. Monrca S, Pasquini R, Sforsolini GS, et al. F. Application of the salmonella mutagenicity assay and determination of PAH in workplace exposed to petroleum pitch and petroleum coke. Int Arch Occup Environ Health 1982;49:223-239.
5. Pani B, Lauremi U, Babydri M, et al. Mutagenicity test of extracts of airborne dust from the muncipal incinerator of Trieste. Environ Mutag 1983;5:23-32.
6. Holmberg B, Syostrom BA. Toxicology survey of chemicals used in the Swedish rubber industry (National Board of Occupational Safety and Health, investigation report No. 19, Stockholm, 1977).
7. Keith WKC, Morgan C. The deposition and clearance of dust from the lungs - Their role in the etiology of occupational lung disease: in Occupational Lung Disease, ed. 2 Philadelphia, Saunders, 1984, pp 77-96.
8. Perico A, Gottardi M, Boddi V, et al. Assessment of exposure to polycyclic aromatic hydrocarbons in police in Florence, Italy, through personal air sampling and biological monitoring of the urinary metabolite 1-hydroxypyrene. Arch Environ Health 2001;56(6):506-12.
9. Zuskin E, Mustajbegovic J, Schachter EN, et al. Longitudinal study of respiratory findings in rubber workers. Am J Ind Med 1996;30(2):171-9.
10. Zuzkin E, Mustajbergovic J, Doko-Jelinic J, et al. Respiratory function in rubber-processing workers. Lijec Vjesn 1994;116(5-6):115-20.
11. Gupta P, Salman KB. Forced expiratory capacity and volumes in factory workers of Iraq. Ind J Med Res 1986;84:310-313.
12. Handa T, Kato Y, Tamamura T, et al. Correlation between concentration of polyaromatic hydrocarbons and those of particulates in an urban atmosphere. Environ Sci Technol 1980;14:416-422.
13. Katz M, Chan C. Comparative distribution of eight polycyclic aromatic hydrocarbons in airborne particulates collected by conventional high volume sampling and by size fractionation. Environ Sci Technol 1980;7:838-843.
14. Chaudet JH, Kaye WJ. Fluorescence analysis for polycystic aromatic hydrocarbons. Ann Chem 1961;33:113-117.
15. Brooks AL, Li AP, Dutcher JS, et al. A comparison for genotoxicity of automotive exhaust particles from laboratory and environmental sources. Environ Mutag 1984;6:651-668.
16. Zejde J, Gomez S, Hurst T. The relevance of appropriate assessment of occupational environment and biological probability of response in demonstrating exposure-related respiratory effect. Am Rev Respir Dis 1991;143:199.
17. Shah SP, Kamat SR, Mahashur AA. Pattern of asbestos workers in Bombay. Ind J Occup Health 1983;26:13-36.
18. Bhat MR, Ramaswamy CA. Comparative study of lung functions in ricemill and sawmill workers. Indian J Physiol Pharmacol 1991;35:27.
19. Governaa M, Comal M, Valentino M, et al. Ventilatory function in rubber processing workers: Acute changes over the workshift. Br J Ind Med 1987;44:83-89.
20. Bachani D. Chronic airflow limitation in talc industry: Role of age, smoking habits and dust exposure. Indian J chest Dis Allied Sci 1984;26:220-224.