Pulmonary function of Paint Industry workers from West Bengal, India

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ABSTRACT

Objectives: Paint industry workers are usually exposed to many solvents (toluene, acetone, butanol, xylene, benzene, trichloro ethylene). We investigated whether chronic exposure to solvents had any adverse effect on respiratory system.

Materials and Methods: This cross-sectional study involving 149 paint industry workers selected from paint industries of West Bengal, India and 141 control group individuals was undertaken. The study parameters include FVC, FEV_1 ,$FEV_{1\%}$ FEF200-1200, $FEF_{25-75\%}$, $FEF_{75-85\%}$ and PEFR. Besides the same, the individuals' age, smoking habit, duration of smoking, type of work, duration of work and other respiratory illness symptoms were recorded.

Results: 77.68% higher age group workers and 83.78% in lower age group workers of paint industry have restrictive ventilatory impairment. Again, prevalence of restrictive ventilatory impairment is recorded as 76.9% in smoker and 78.4% in nonsmoker workers, but 94% restrictive impairments are observed in workers of the hazardous zone of high volatile organic compounds (VOC) concentration and 69.75% in workers of the non hazardous zone of low VOC concentration indicating the effects of dust and VOC in respiratory impairment than smoking. Significant correlation has been found between Pulmonary functions and duration of exposure to solvents and dust in older workers. Prevalence of respiratory symptoms was low but significantly associated with VOC concentration (OR=1.15-1.43) and duration of VOC exposure (OR=1.15-1.71) Thus restrictive lung impairment mainly depends on high VOC concentration as well as duration of exposure. In addition50% of high VOC exposed, and 47.6% of low VOC exposed paint workers suffered from liver dysfunction.

Conclusion: This study helped in achieving baseline information regarding respiratory status of Paint workers of West Bengal. Most paint workers have restrictive pulmonary function impairment, which can be checked by using high-quality protective equipments as also by reduction of VOC concentration in work environment and workers' health education.

Key words: Pulmonary function, paint workers, India, restrictive lung function impairment, odds ratio

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INTRODUCTION

Solvents are the most important components of paints. The major purpose of their application is to dilute paints to a suitable handling consistency or viscosity for easier manufacturing and application. After the application of paint, the solvents evaporate leaving the dry paint on the painted surface [1].

In paint solvent vapours are produced throughout the manufacturing process. If the process is not controlled, high concentration of organic solvents can be accumulated within the working environment threatening workers' health and safety.

At low or moderate concentration, organic solvents may cause transient symptoms in central nervous system such as euphoria, headache, dizziness, etc. At high concentration failure of respiratory and circulatory control centres and disturbances in consciousness may result [2].

Organic solvents are used in manufacturing a wide range of products like paints, plastics, adhesive, textiles, electronics, etc. Among solvents xylene is used extensively in the industries as a safe replacement of benzene [3]. Xylene is used as thinner for paints and varnishes. Xylene and other volatile organic components produced or used in paint industries have been associated with effects in a number of organs like lungs, skin, eyes, neurological system, heart, gastro-intestinal system, kidney and reproductive system. High level of xylene exposure for short periods is associated with irritation of the skin, eyes, nose and throat [4].

The exposure levels of solvents in industrialized countries have been declining since 1970s due to increasing use of water base products and improved work process. But even now several hundred million tonnes of solvents are used annually throughout the world. In India Paint manufacturing, factories mainly use xylene as solvent. Besides, thousands of chemical compounds are used in Paint products as pigments, extenders, binders, solvents and additives. Paint industry workers are exposed to inhalation of solvents and other volatile paint components, which can cause respiratory illness and chronic obstructive pulmonary disease. Very few studies have been conducted on pulmonary function of Paint industry workers [3,5] and others, reported mostly on pulmonary function of car painting and automobile painting workers [6-8]. In India, particularly in West Bengal study on pulmonary function of Paint industry workers is still to be conducted. Therefore we prompted and planned to study pulmonary function of Paint industry workers. The purpose of the present study is

a) To evaluate the respiratory health status of paint industry workers of West Bengal
b) To determine the relationship between volatile organic compound and xylene exposure with the respiratory problems among paint industry workers.

METHODS AND MATERIALS

This cross-sectional study was carried out in a paint industry in Howrah district of West Bengal during the period of June 2009 - March 2010.

The study population consists of 149 male workers of paint industry from a total 600 workers exposed to xylene and other volatile organic compounds. The workers (n=149) have been selected from different departments- Bead mill, Ball mill, Mixing shop, filling, protecton, Resin plant and also from Quality control, Powder coating, Research and development, Main gate, Despatch, etc. by simple random sampling method.

The control group of unexposed subjects outside the industry has been taken mainly from school, college employees, shopkeepers, having same socio-economic and demographic criteria, by simple random sampling method.

Exclusion Criteria:

1. Unwilling workers.
2. Temporary and contractual workers.
3. Workers with previous exposure to any occupational agents other than paint.
4. Any diagnosed case of asthma or family history of any respiratory diseases or other diseases like diabetes mellitus, pulmonary tuberculosis, having history of acute or chronic infection or recent case of hospitalization.

All the subjects completed a questionnaire in order to collect demographic, socio-economic, work history, smoking habit, current work activities, use of personal protective equipments. Besides, prevalence of chest pain, wheezing, cough, chest tightness, headache, liver/digestive problem, skin irritation, eye problem, if any, was recorded by the questionnaire [9]. All the subjects taken for study were working in Paint industry for 8 hrs with a shifting pattern and 6 days in a week. But we conducted our work between 8 AM to 5 PM (including cardiovascular and anthropometric parameters) in working days but pulmonary function was taken between 12 noon to 3 PM. Before starting our survey work a written consent was taken from the concerned authority as also from the individual worker. Besides, this study protocol was approved by Human Ethical Committee of our institution.

Age was recorded from the factory record book

and physical parameters like body height, body weight were measured by standard procedure without shoes to nearest 0.5 cm and BMI was calculated from body weight/ (body height in meter)^2.

Restrictive impairment was diagnosed if {FVC (VC)/Predicted FVC) X 100% was smaller than 80%. WhereasFEV_1/FVC (FEV_1%) X 100 ratio < 70% was indicated as obstructive impairment. If both the above mentioned conditions are satisfied, combined ventilator defect is indicated [8].

Pulmonary function test

Pulmonary function test (PFT) was made by automatic Spirometer (Spirovit SP1 model). Before starting the survey in each day the instrument was calibrated and new filter was taken. Besides the test, each worker was instructed on how the tests would be carried out. Measurements were made by recording the volume of air that a worker can forcibly blow out at a time from the lungs after a full inspiration. A flow-volume curve generated and thus all the measured values were derived from this maneuver, where the best value would be taken after three trials. The Spirometer used was according to the recommended method by American Thoracic Society [10]. The calibrations and measurements were carried out by using NIOSH Analytical Method 1501 [11].

Peak Expiratory Flow Rate (PEFR) was measured by Wright's Peak Flow Meter. All the measurements were taken on the subject in standing upright position with the nose clip [12]. All the volumes were adjusted to body temperature, and pressure saturated with water vapor.

Environmental Study

Thousands of chemical compounds are used in paint products as pigments, extenders, binders, solvents and additives. Paint workers are commonly exposed by inhalation to solvents and other volatile paint components. Besides inhalation of non-volatile components, such as dust is common among paint workers.

The concentration of volatile organic compounds (VOC) mainly aliphatic hydrocarbons, ethyl acetate, glycolic ethers and acetone, concentration of xylene (solvent), suspended particulate matter and respirable particulate matter in different departments of Paint industry has been taken from their recent pollution report (Table 1). In this factory, the paint is made up of mixtures with thinner containing up to 30-40% xylene. All the tests have been performed within the medical room of the Paint industry and room temperature has been recorded. It is found that Central pollution-control board (CPCB) recommendation for VOC and xylene exposure are 50 ppm [13].

Statistical analysis

Mean, Standard deviation and correlation between parameters were analyzed. One-way ANOVA and Student *t*-test were performed to compare the mean between groups after performing the normality test by histogram, b1, b2 method and Q-Q Plot method. Multiple regression equations were constructed to predict pulmonary function parameters based on age, body height and year of exposure. Odds ratio and 95% Confidence Interval (CI) were calculated to study the prevalence of respiratory distress (dependant variable), using SPSS Package (16.0 version) among smoker/non-smoker, high and low VOC and compared the Odds of exposure to VOC of different levels of years of exposure.

RESULTS

Total and respirable particulate matter concentration, concentration of volatile organic compound and xylene in different sections of paint industry have been shown in Table 1.

Table 1. Concentration of solvents,VOC, and dust in different Sections of a Paint Industry.

Sections	Suspended Particulate matters (SPM) µg/m3	Respirable Particulate matters (RPM) µg/m3	VOC ppm	Xylene µg/m3
Zone with High VOC level				
Bead Mill	296	123	95	0.037
Mixing Shop	280	112	95	0.029
Ball Mill	341	176	120	0.017
Filling	306	138	52	
Protecton	301	131	97	0.01
Resin Plant	210	78	43	0.01
Zone with Low VOC level				
Powder Coating	324	166		
Quality Control				0.01
Main gate	286	116		
Despatch			21	
Research and Development			65	

The mean dust concentration of Bead Mill, Industrial platform, Mixing shop, Ball Mill, Filling, Protecton, Resin plant, Powder coating and Boiler room and surrounding area near Main gate is 284.6µg/m^3 and respirable dust concentration is 124.9µg/m^3 which has been found lower than emission limit as per CPCB notification, New Delhi, India [13]. But according to VOC concentration, except powder coating main gate and research anddevelopment 1st floor (VOC concentration 43 ppm), all the above mentioned sections were within 'hazardous zone' (mean VOC concentration was 95.28 ppm). Other sections having low VOC

concentration (43 ppm) were classified as 'non-hazardous zone'. From pollution report it was found that Bead mill, Mixing shop, Ball mill, Protecton, Research and Development (2nd Floor) had high VOC concentration but dust concentration remained within the permissible limit. The recommended permissible limit of CPCB [13] for VOC is 50 ppm, for total dust is 10mg/m^3 and respirable dust is 5mg/m^3. Out of 149 paint workers 50 workers (lower age group n=12 and higher age group n=38) were in 'hazardous zone' (33.55%) and 99 workers (lower age group, n=25 , higher age group, n=74) belonged to 'non-hazardous zone' (66.44%) according to VOC concentration of different departments.

Table 2 shows the mean± SD values of physical characteristics and pulmonary functions of paint industry workers as well as of the control group. It was found that FVC, FEV_1, $FEF_{25-75\%}$ were significantly ($p<0.05$-0.001) higher in control group in comparison to lower age group smoker workers. whereas in case of non-smoker workers of lower age group, all the pulmonary function parameters except FEV_1% were significantly higher ($p<0.05$-0.001) in the control group in comparison to Paint workers. But in case of higher age group workers of both smoker and non-smoker except FEV_1% all the pulmonary function values were significantly ($p<0.05$-0.001) higher in the control group in comparison to the paint workers. Significant ($p<0.01$-0.001) difference in pulmonary function parameters was found between smokers and non-smokers of higher and lower age group paint workers except FEV_1% and $FEF_{200-1200}$ of higher age group smoker and non-smoker workers. It was found that workers mostly did not use protective guards and was exposed to high and low VOC concentration during their work period.

Table 2. Mean ± SD values of different physical parameters and pulmonary functions of paint workers and control group.

PARAMETERS	PAINT WORKERS						CONTROL GROUP					
	Lower Age Group			Higher Age Group			Lower Age Group			Higher Age Group		
	All (n=37)	S (n=11)	NS (n=26)	All (n=112)	S (n=41)	NS (n=71)	All (n=60)	S (n=21)	NS (n=39)	All (n=81)	S (n=26)	NS (n=55)
Age (yr.)	29.38 ±3.97 ****	30.18 ±2.93 *	29.04 ±4.35 ****	46.46 ±7.00	46.93 ±7.37	46.18 ±6.8	24.9 ±6.06	26.76 ±6.36	23.90 ±5.72	47.83 ±7.30	47.73 ±7.76	47.87 ±7.14
Height (cm)	168.81 ±6.52	170.89 ±5.56	167.93 ±6.79	166.45 ±7.61	164.70 ±7.62	167.46 ±7.47	168.43 ±5.95	168.4 ±5.97	168.46 ±6.02	166.40 ±7.35	166.5 ±6.89	166.33 ±7.62
Weight (kg)	64.81 ±10.05	68.45 ±8.33	63.27 ±10.46	67.20 ±11.41	65.87 ±11.74	67.96 ±11.22	62.7 ±10.76	63.8 ±12.17	62.13 ±10.03	67.1 ±10.58	67.6 ±11.23	66.9 ±10.35
BMI (kg/m^2)	22.67 ±2.77	23.39 ±2.28	22.36 ±2.94	24.22 ±3.55	24.23 ±3.66	24.22 ±3.52	22.10 ±3.65	22.48 ±4.06	21.89 ±3.44	24.21 ±3.18	24.29 ±2.9	24.17 ±3.33
FVC (L)	3.29 ±0.65 ****	3.40 ±0.66 ***	3.25 ±0.65 ****	2.88 ±0.54 ****	2.8 ±0.55 ****	2.92 ±0.53 ****	4.30 ±0.61	4.19 ±0.45	4.35 ±0.67	3.69 ±0.61	3.7 ±0.61	3.68 ±0.62
FEV_1 (L)	3.03 ±0.57 ****	3.10 ±0.62 ***	3.0 ±0.55 ****	2.52 ±0.50 ****	2.45 ±0.53 ****	2.56 ±0.48 ****	3.91 ±0.64	3.82 ±0.53	3.96 ±0.70	3.17 ±0.56	3.12 ±0.58	3.2± 0.56
FEV_1%	92.18 ±5.63	91.11 ±7.32	92.64 ±4.85	87.70 ±6.92	87.4 ±7.19	87.88 ±6.81	90.98 ±6.31	90.96 ±5.45	90.99 ±6.8	86.09 ±6.93	84.33 ±7.8	86.92 ±6.39
$FEF_{200-1200}$ (L/min)	6.40 ±1.55 ***	6.54 ±1.66	6.35 ±1.53 **	5.52 ±1.64 ****	5.09 ±1.81 ***	5.77 ±1.50 ****	7.44 ±1.98	7.44 ±1.84	7.45 ±2.08	6.94 ±1.89	6.65 ±1.94	7.09 ±1.87
$FEF_{25-75\%}$ (L/min)	3.99 ±0.92 ****	4.01 ±1.16 *	3.98 ±0.83 ****	3.13 ±0.98 ****	2.95 ±1.03 *	3.23 ±0.94 ***	5.04 ±1.34	4.92 ±1.2	5.11 ±1.42	3.80 ±1.27	3.54 ±1.16	3.93 ±1.31
$FEF_{75-85\%}$ (L/min)	1.63 ±0.48 ****	1.64 ±0.58	1.62 ±0.44 ****	1.09 ±0.50 ***	1.09 ±0.39	1.08 ±0.55 ***	2.34 ±0.98	2.16 ±1.04	2.43 ±0.95	1.33 ±0.62	1.2 ±0.48	1.39 ±0.67
PEFR (L/min)	504.59 ±78.27	526.36 ±92.23	495.38 ±71.57	480.09 ±81.82 ****	468.05 ±91.19 **	487.04 ±75.69 ***	530.5 ±59.96	533.33 ±57.13	528.97 ±62.10	517.04 ±59.13	511.15 ±54.14	519.82 ± 61.63
Exposure (yr)	6.28 ±4.57	5.82 ±2.71	6.48 ±5.20	17.51 ±7.58	16.59 ±8.40	18.04 ±7.08	-	-	-	-	-	-
C/Day	-	4.36 ±2.80	-	-	5.49 ±3.65	-	-	4.50 ±3.15	-	-	10.87 ±7.95	-
Pack-yr	-	159.27 ±102.29	-	-	200.30 ±133.39	-	-	164.25 ±114.84	-	-	396.79 ±290.13	-
Duration of smoking(yr)	-	8.01 ±4.51	-	-	16.22 ±9.22	-	-	7.72 ±5.87	-	-	22.78 ±9.75	-

*=p<0.05, **=p<0.02, ***= p< 0.01, ****=p<0.001
ALL== All the workers of lower / higher age group. S== Smoker workers. NS== Non-smoker workers.

Table 3 represents the comparison between physical and pulmonary function parameters of Paint industry workers of high and low VOC exposed as well as an unexposed group. It showed that all the Pulmonary function parameters except $FEV_{1\%}$ were significantly (P<0.05-0.001) lower than unexposed group and significantly (P<0.05-0.001) lower values of the above mentioned parameters had been found in high VOC exposed paint workers than low VOC exposed workers.

Pulmonary function parameters at the different level of duration of VOC exposure (<10yrs,10-20yrs and >20 yrs) among paint industry workers has been presented and compared in Table 4. Significantly lower (P<0.02-0.001) pulmonary function parameters had been found in workers exposed to >20 years of VOC in paint industry than <10 yrs. and 10-19 years of exposure.

Comparison between smoking habit and pulmonary function parameters, it was observed that both smoker and non-smoker paint industry workers had significantly (P<0.05-0.001) lower pulmonary function parameters in comparison to smoker and nonsmoker unexposed group (Table 5). No significant difference had been found between smoker and non-smoker group of paint industry workers, indicating there in the role of VOC exposure which was much more prominent than smoking habit.

Table 3. Comparison between pulmonary functions of workers exposed to high and low VOC in Paint Industry and unexposed group.

PARAMETERS	High VOC	Low VOC	Unexposed
Age (yr.)	43.68±10.63 ***	41.48±9.25 **	38.07±13.24
Weight (kg)	64.95±12.70	67.49±10.19	65.26±10.84
Height (cm)	164.53±7.79 $$$ *	168.27±6.88	167.25±6.84
BMI (kg/m^2)	23.91±3.88	23.82±3.21	23.31±3.53
FVC (L)	2.56±0.53 $$$$ ****	3.18±0.51 ****	3.95±0.68
FEV_1 (L)	2.30±0.56 $$$$ ****	2.81±0.47 ****	3.49±0.70
FEV_1 %	89.51±7.47	88.48±6.60	88.17±7.08
$FEF_{200-1200}$ (L/min)	4.66±1.64 $$$$ ****	6.26±1.36 ****	7.16±1.94
$FEF_{25-75\%}$ (L/min)	2.96±1.11 $$$ ****	3.52±0.93 ****	4.33±1.43
$FEF_{75-85\%}$ (L/min)	1.16±0.54 ****	1.25±0.55 ****	1.76±0.93
PEFR (L/min)	464.80±90.29 $ ****	495.96±73.66 ***	522.77±59.64
$ → Comparison between the parameters of high and low VOC zone * → Comparison between the parameters of worker and control groups *,$p<0.05 **,$$ p<0.02 ***,$$$ p<0.01 ****,$$$$ p<0.001			

Table 4. Mean ± SD values of different physical parameters and pulmonary functions of paint workers of different duration of exposure.

PARAMETERS	Duration of Exposure		
	<10 yrs. (n=40)	**10-20 yrs. (n=60)**	**>20 yrs. (n=49)**
Age (Yr.)	34.23±11.41	41.47±6.23 ****	49.65±5.48 ****
Body Weight (Kg)	64.16±9.56	66.83±11.40	68.32±11.74
Height (cm)	167.78±6.95	168.28±7.86	164.91±6.85
BMI (Kg/m^2)	22.78±3.03	23.48±3.28	25.05±3.61 ***
FVC (L)	3.20±0.66	3.01±0.52	2.76±0.56 ****
FEV_1 (L)	2.90±0.59	2.71±0.50	2.36±0.48****
FEV_1%	90.74±6.59	89.84±5.96	85.98±7.39 ***
$FEF_{200-1200}$ (L/min)	6.14±1.75	5.91±1.54	5.21±1.62 **
$FEF_{25-75\%}$ (L/min)	3.68±1.05	3.53±0.96	2.83±0.92 ****
$FEF_{75-85\%}$ (L/min)	1.49±0.53	1.30±0.57	0.90±0.35 ****
PEFR (L/min)	495.75±73.27	497.17±80.68	464.90±85.86
Exposure (Yr.)	4.24±2.37	13.63±2.77 ****	24.61±3.85 ****
**p<0.02, ***p<0.01, ****p<0.001			

Table 5. Comparison between Pulmonary functions of smoker and non smoker Paint Industry workers with control group.

PARAMETERS	PAINT WORKER		CONTROL	
	S	NS	S	NS
Age (yr.)	43.38±9.59 *	41.59±9.85 *	38.36±12.70	37.93±13.56
Weight (kg)	66.41±11.08	66.71±11.17	65.93±11.69	64.93±10.44
Height (cm)	166.01±7.62	167.59±7.26	167.33±6.50	167.21±7.04
BMI (kg/m^2)	24.05±3.41	23.72±3.46	23.48±3.55	23.23±3.54
FVC (L)	2.93±0.62 ****	3.01±0.58 ****	2.92±0.59	3.96±0.72
FEV_1 (L)	2.59±0.61 ****	2.68±0.53 ****	3.43±0.65	3.51±0.72
FEV_1%	88.18±7.31	89.15±6.66	87.29±7.56	88.61±6.83
$FEF_{200-1200}$ (L/min)	5.40±1.86 ****	5.93±1.52 ****	7.0±1.91	7.24±1.95
$FEF_{25-75\%}$ (L/min)	3.17±1.13 ****	3.43±0.97 ****	4.16±1.35	4.42±1.47
$FEF_{75-85\%}$ (L/min)	1.21±0.48 ***	1.23±0.58 ****	1.63±0.91	1.82±0.94
PEFR (L/min)	480.38±93.64 ***	489.28±74.33 ****	521.06±56.0	523.62±61.66
*p<0.05, ***p<0.01, ****p<0.001				

Table 6 shows correlation between pulmonary function parameters with duration of exposure and duration of smoking. Significant negative correlation had been found between duration of exposure and different lung function parameters in higher age group and all age group combined paint industry workers. But significant negative correlation had been found between duration of smoking and pulmonary function parameters only in higher age group paint workers.

Table 6. Correlation between different Pulmonary Function Parameters with year of exposure to high and low concentration of Volatile Organic Compound (VOC) and Duration of Smoking of Paint Industry workers.

Parameters	Duration of Exposure			Duration of Smoking		
	All	Lower Age Group	Higher Age Group	All	Lower Age Group	Higher Age Group
	(n=149)	(n=37)	(n=112)	(n=52	(n=11)	(n=41)
FVC	-0.31 ****	-0.09	-0.56 ****	-0.25	-0.27	-0.52 ****
FEV_1	-0.39 ****	-0.07	-0.61 ****	-0.27	-0.27	-0.53 ****
$FEV_{1\%}$	-0.26 ***	0.03	-0.52 ****	-0.19	-0.36	-0.50 ****
$FEF_{2-1.lit}$	-0.21 ***	0.03	-0.49 ****	-0.17	-0.05	-0.47 ***
$FEF_{25-75\%}$	-0.33 ****	0.06	-0.56 ****	-0.17	-0.34	-0.43 ***
$FEF_{75-85\%}$	-0.42 ****	-0.11	-0.63 ****	-0.30 *	-0.49	-0.54 ****
PEFR	-0.17 *	0.20	-0.49 ****	-0.27	0.06	-0.65 ****

From the percentage of prevalence of respiratory abnormalities among paint workers and control group, it was found that 83.78% lower age group paint workers and 77.68% higher age group paint workers had restrictive pulmonary abnormalities in comparison to control group (18% restrictive) (Table 7).

Table 7. Prevalence of different Respiratory diseases in Paint Industry worker from West Bengal.

	PAINT WORKERS														CONTROL (n=141)	
	Lower Age Group						Higher Age Group						ALL (n=149)			
	All (n=37)		Smoker (n=11)		Non-Smoker (n=26)		All (n=112)		Smoker (n=41)		Non-Smoker (n=71)					
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Normal	6	16.22	2	18.18	4	15.38	25	22.32	9	21.95	16	22.54	31	20.81	112	79.43
Restrictive	31	83.78	9	81.82	22	84.62	87	77.68	31	75.61	54	76.06	118	79.19	26	18.44
Obstructive	-	-	-	-	-	-	-	-	-	-	1	1.41	1	0.07	3	2.13
Combined	-	-	-	-	-	-	-	-	1	2.44	-	-	1	0.07	-	-

ALL== All the workers of lower / higher age group.
LA==Workers of lower age group,
HA=Workers of higher age group

Besides, paint workers as a whole had 79% restrictive pulmonary function in comparison to control group (20.81%). Again, 81.82% smoker lower age group paint workers and 75.61% higher age group paint workers showed restrictive impairment.

But effect of smoking on prevalence of respiratory abnormalities indicated no significant association between smoking habit and prevalence of respiratory diseases in paint workers (OR=0.64 and 0.68) (Table 8).

Table 8. Effect of smoking on the prevalence of chest tightness, chronic bronchitis, and bronchial asthma with ODDS Ratio and 95% CI among Paint Industry workers.

Group	No. Examined	Chest Tightness				Chronic Bronchitis				Bronchial Asthma			
		No	(%)	OR	95% CI	No	(%)	OR	95% CI	No	(%)	OR	95% CI
Smokers	**66**	20	30.3	1.57	0.81-3.07	19	28.79	1.46	0.75-2.87	0	-	-	-
Non-Smokers	**134**	29	21.64	1	-	29	21.64	1	-	2	1.49	1	-
Total	**200**	49	24.50	-	-	48	24		-	2	1	-	-

The prevalence of chest tightness and chronic bronchitis with Odds ratio and 95% confidence interval based on duration of exposure to VOC and Xylene and suspended particulate matter (SPM) was shown in Table 9.

It was established that percentage of prevalence of Chest tightness and chronic bronchitis increased with an increase in duration of exposure and OR of the above mentioned diseases of 10-19 years of exposure was 1.15 and that for >20 years of exposure was 1.55 and 1.43 respectively indicating workers engaged in 10-19 years of exposure in paint industry had 1.15 times more risk in developing chest tightness and chronic bronchitis and 1.43 times more risk in developing chronic bronchitis with >20 years of service.

The effect of VOC and xylene concentration on prevalence of respiratory diseases is given in Table 10. It revealed that percentage of prevalence of respiratory diseases increases without an increase in VOC concentration and OR of prevalence of chest tightness, chronic bronchitis and bronchial asthma were 1.55,1.03 and 1.71 respectively, although OR values were not so high, but it indicated that paint workers working in high VOC had more risk in developing the above respiratory diseases than workers with low VOC exposure. Multiple regression equations of Pulmonary function parameters on the basis of age, body height and year of exposure to VOC has been presented in Table 11. All the coefficients of regression (R) were significant ($P<0.001$). In case of age and duration of exposure the coefficients were negative thereby indicating that if the above-mentioned parameters increased, the pulmonary function parameters would consequently, decrease.

Comparative analysis of different physiological disorders like chest compression, liver dysfunction, skin irritation and pain in different parts of the body in high and low VOC exposed paint

workers is represented in Figure 1. It was observed that percentage prevalence of liver dysfunction and pain in different parts of the body, mainly pelvic and knee pains were high in high VOC exposed paint workers like that of chest compression.

Table 9. Effect of duration of exposure on prevalence of chest compression, chronic bronchitis, and bronchial asthma with ODDS Ratio and 95% CI among paint Industry workers.

Group	No. Examined	Chest Tightness				Chronic Bronchitis				Bronchial Asthma			
		No	(%)	OR	95% CI	No	(%)	OR	95% CI	No	(%)	OR	95% CI
>20 yr	58	17	29.31	1.55	0.66-3.64	16	27.59	1.43	0.61-3.37	-	-	-	-
10-19 yrs	85	20	23.53	1.15	0.51-2.59	20	23.53	1.15	0.51-2.59	1	1.18	0.67	0.04-10.88
<10 yrs	57	12	21.05	-	-	12	21.05	-	-	1	1.75	-	-
Total	200	49	24.50	-	-	48	24		-	2	1	-	-

Table 10. Effect of dust on the prevalence of chest tightness like symptoms, chronic bronchitis and bronchial asthma along with Odds Ratio among workers exposed to paint dust.

Group	No. Examined	Chest Tightness				Chronic Bronchitis				Bronchial Asthma			
		No	(%)	OR	95% CI	No	(%)	OR	95% CI	No	(%)	OR	95% CI
Zone with High VOC level	**74**	22	29.73	1.55	0.81-2.99	18	24.32	1.03	0.53-2.01	1	1.35	1.71	0.11-27.79
Zone with Low VOC level	**126**	27	21.43	-	-	30	23.81	-	-	1	0.79	-	-
Total	**200**	49	24.50	-	-	48	24	-	-	2	1	-	-

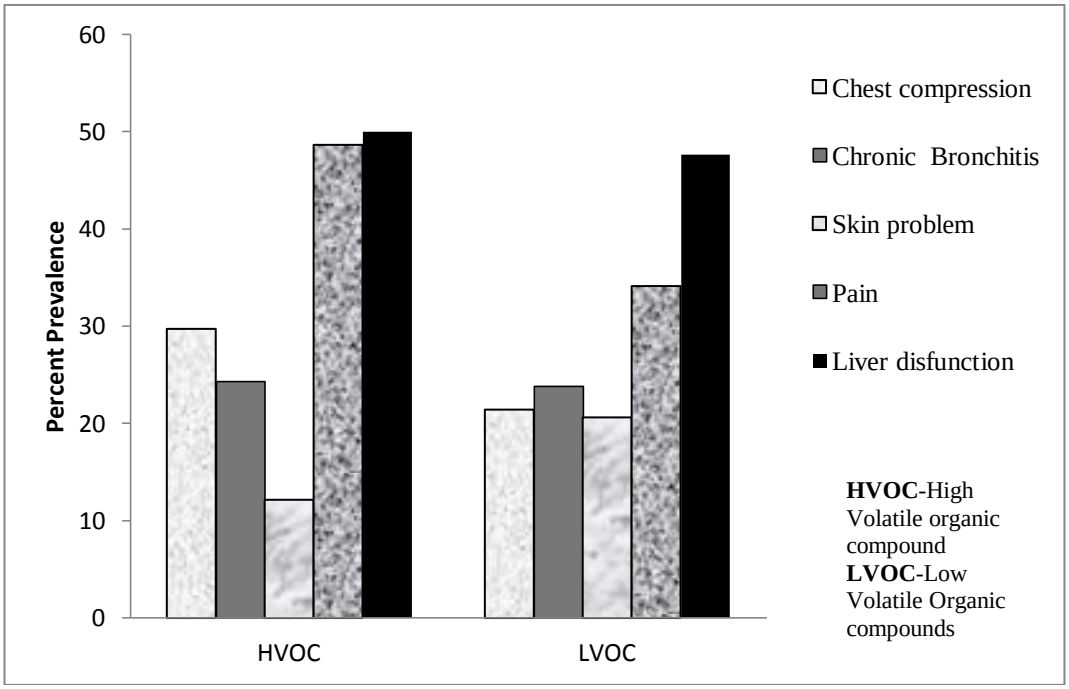

Figure 1. Comparison of prevalence of chest compression, chronic bronchitis, skin problem, pain and liver dysfunction among high and low VOC exposed Paint workers.

Table 11. Multiple regression equations of pulmonary function parameters of Paint Industry Workers.

Parameters	Constant	Age (yrs.)	Height (cm)	Exposure (yrs.)	R	R^2
FVC	-1.47	-0.02	0.03	-0.005	0.57****	0.31
FEV1	-0.48	-0.02	0.02	-0.006	0.61****	0.38
FEV_1%	114.27	-0.24	-0.09	-0.05	0.37****	0.14
$FEF_{200-1200}$	-3.11	-0.05	0.07	-0.004	0.45****	0.20
$FEF_{25-75\%}$	2.69	-0.04	0.02	-0.006	0.48****	0.23
$FEF_{75-85\%}$	1.55	-0.02	0.005	-0.01	0.54****	0.29
PEFR	185.75	-2.4	2.37	0.45	0.37****	0.14
**** $p<0.001$						

DISCUSSION

Inhalation is the most important route of exposure for most of the solvents. Once solvent vapour enters into the nose, it can irritate the upper respiratory tract and lung. In the present study significantly lower FVC, FEV_1 and $FEF_{25-75\%}$ values were found in both higher and lower age group smoker and non-smoker paint workers in comparison to control group except $FEV_{1\%.}$ and PEFR values of higher age group paint workers, where it showed significantly lower values than control group workers. No significant difference had been found among all studied groups in respect of age, body height, body weight except lower age group paint workers. The similar findings were revealed by Ould-Kadi et al. [14] who found lowered FEV_1 in solvent exposed group of workers than the control group. Yoon et al. [15] concluded that exposure to toluene and xylene exert a harmful effect on pulmonary functions in the form of reduction of FVC, FEV_1 and $FEF_{25-75\%}$ .Again ,Saad et al. [16] studied on tannery workers exposed to benzene and formaldehyde and found that the values of pulmonary function parameters (FVC,FEV_1) were significantly reduced in the exposed workers . In contrast, Ernstgard et al. [17] found no effects of solvent exposure on the pulmonary functions. Besides, abstaining the workers from use of personal protective equipments might be the reason for deterioration of lung function.

When paint industry workers were classified into high and low VOC exposed group, significantly lower pulmonary function parameters were found in high VOC exposed group in comparison to low VOC exposed group. Similar observation was reported by Metwally et al. [5] and they explained these findings by longer duration of exposure and older age with high solvent exposed group of workers resulting in further deterioration in lung function parameters. These results corroborated with the study of Schweigert et al. [18] in their study on automobile finishing workers exposed to solvent. They found that there was progressive decline in percentage of predicted FEV_1 with increasing intensity of solvent exposure.

In the present study, pulmonary function parameters declined with increase in duration of exposure but the decrease in mean values was significant in >20 years of exposure in comparison to<10 years of exposure. Metwelly et al. [5] found a progressive decrease in mean values of Pulmonary functions throughout the three groups of exposure (<10 years,10-20 years,>20 years). Uzma et al. [19] studied the pulmonary function parameters of Petrol filling workers exposed to organic solvent and observed a significant deterioration in lung volume and capacities in workers exposed for more than 10 years. Similar result had been obtained by Ott [20] among workers exposed to toluene diisothyanate in case of FEV_1 .On the contrary, Gupta et al. [21] did not show any significant difference in respiratory impairment between solderers in electronics industry exposed either less or more than 10 years. Winck et al. [22] showed that mean peak flow in workers decreased on the day of exposure to solvents and increased on days when the workers were away from the work. Again Chattopadhyay [7] in a 2.5 years follow-up study observed that pulmonary function parameters of isocyanate exposed workers for long duration were reduced even in very low concentration.

In our study, a significant negative correlation had been found between pulmonary function parameters and year of exposure indicating gradual deterioration of lung function parameters with an increase in year of exposure. Similarly Kogevinas et al. [23] showed a negative correlation between FEV_1 and years of solvent exposure. The correlation values for higher age group workers were significant probably due to a small number of workers in a lower age group in comparison to higher age group.

No significant difference was found between smoker and non smoker paint workers in

prevalence of respiratory symptoms probably due to differences in number of smoker and non-smoker(67% and 33%) [24]. But Rom [25] stated that smokers had an increased frequency of cough and sputum production. Siddanagoudra et al [8] and Khanzadeh and Rivas [26] and Schwarz and Baker [27] concluded that increased risk of air flow obstruction in painters was related to duration of exposure to isocyanate (>5 yrs.) and was independent of the effects of cigarette smoking.

In this study, the percentage of prevalence of chest tightness and chronic bronchitis increased with an increase in the year of exposure indicating occupational risk of developing the above respiratory symptoms. On the contrary, no difference had been found with an increase in duration of exposure to feed dust by Baser et al. [28].

The paint workers in the present study had restrictive type respiratory abnormalities, which corroborated by the study of Uzma et al. [19]. They found deterioration in lung volumes and capacities and change of restrictive to the combined pattern of respiratory abnormalities in workers exposed to solvent for more than ten years. Chattopadhyay [7] concluded that 25.83% of automobile repair workers had obstructive impairment, and 21.19% had restrictive impairment. In contrast, Gee et al [29] stated that year of working in non-functioning paint booth along with smoking were associated with low FEV_1/FVC indicating obstructive disease of lung. Chattopadhyay [7], Parkar et al. [30] and Cullen et al [31] pointed out that obstructive impairment was more frequent in smoker workers but increased frequency of restrictive impairment was not statistically significant with smoking which corroborated with our findings. Besides, a reduction in vital capacity may as well be related to an obstructive defect and may falsely use to diagnosed restriction [32]. Aggarwal et al. [33] stated that a true restrictive defect could be diagnosed only when there was reduction in total lung capacity (TLC).

Metwally [5] and Dement et al. [34] demonstrated increased risk of COPD among paint workers exposed to solvent, which was in accordance with our findings where prevalence of chest tightness, chronic Bronchitis and Bronchial asthma was high among high VOC exposed paint workers in comparison to low VOC exposed group. Weinmann et al. [35] ensured that COPD incidence was linked to occupational solvent exposure. Metwally [5] again indicated that prevalence of clinical respiratory symptoms was higher in the high exposed group (HEG) than in the low exposed group (LEG). These were statistically significant regarding a symptom of productive cough, chronic bronchitis and dyspnoea. These respiratory effects were probably due to VOC, and Xylene induced oxidative stress [36]

Multiple regression equations of pulmonary function parameters were constructed on the basis of age, body height and year of exposure, which could be used to predict the pulmonary function parameters of paint industry workers and rate of progression of disease could be identified.

Dust concentration in different departments of paint industry was below the permissible limit of Indian standard [13] for total dust ($10mg/m^3$) and respirable dust ($5mg/m^3$). VOC and Xylene concentration of different departments of this industry were also below the permissible limit of International standards (100 ppm for 20 min and 50 ppm for 8 hours) [37-39] but the same in many departments of paint industry exceed the permissible limit of Indian standard(50 ppm) [13]. In our study, the declining trend in pulmonary function of paint industry workers depends mainly on VOC and Xylene concentration in the working environment, thus we recommend VOC and xylene concentration below the national and International permissible limit of standards, i.e, below 10 ppm.

CONCLUSIONS

Our findings suggest that in case of longer exposure to VOC in paint industry workers, it will lower down more of FVC, FEV_1 and flow rates of workers and higher will be the risk of developing bronchial asthma, and chronic bronchitis. In our study from questionnaire, high VOC concentration probably affects the metabolic process of the body and induces oxidative stress, which is reflected on liver disorder. This indicates high occupational health hazards, which indicate an alarming situation if remains unchecked and allowed to continue as such.

This study also reports restrictive pulmonary function in paint industry workers of West Bengal exposed to dust and VOC. This base line information is expected to aid the development of regional occupational health database for use in local regulation, and this can be used to ensure safe and healthy working condition of paint industry workers.

The concentration of xylene and VOC in few departments like Bead mill, Mixing shop, Protecton and Ball mill were above the recommended Indian standard as well as very close and above the International standards. Besides dust, concentration remained far below the recommended National and International standards. Thus, we recommend xylene and VOC concentration below the National standard that is 10 ppm. Again, workers of paint industry are reluctant about the use of protective gadgets, which can protect them from harmful exposure.

Recommendation

The paint workers of West Bengal are exposed to higher than the permissible level of VOC. Thus for safe guarding them, protective gadgets (Respirators, Gloves, Eye protection) must be provided to all workers, and it's wearing must be made compulsory to minimize exposure. The necessity of utilization of better quality safety protection gadgets is considered essential along with periodic medical checkup and rotation of workers from hazardous to non hazardous departments along with overall control of the work environment, including VOC concentration below the permissible limit (e.g.; 10 ppm) and implementation of occupational safety and health regulation. Proper ventilation in the work place, engineering and administrative control, and formal training to improve workers' awareness of health hazards of the chemicals are essential. These practices will, in turn, help increase labour productivity thereby enhancing competitiveness. These measures will further control the deterioration of the health of workers and protect the skilled workers from being degraded; thereby industrial growth of the country will roll on prosperously.

Conflicts of interest

The authors have declared no conflicts of interest.

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