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ORIGINAL ARTICLE

Health Risk Assessment of Petrol Filling Workers of West Bengal, India

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ABSTRACT

Introduction: In recent decades, rapid urbanization has led to a surge in the number of automobiles on the roads, and consequently, an increase in petrol filling stations. In India, petrol stations are manually operated, and during fuel dispensing workers are routinely exposed to volatile organic compounds (VOCs) and vehicular exhaust. As a result, petrol filling workers face substantial health risks, though their well-being often receives minimal attention. This study aims to assess the adverse effects of VOC exposure on pulmonary function and evaluate associated health risks. **Method:** A cross-sectional study was conducted among 152 petrol filling workers and 100 control individuals. Spirometry and Peak Expiratory Flow rate tests were performed on both groups along with physical parameters. Respiratory symptoms were recorded via questionnaires. In addition, environmental analysis has been made for total VOCs, benzene, PM2.5 and PM10 and from this analysis carcinogenic and non-carcinogenic risk has been assessed. **Results:** Pulmonary function parameters were significantly lower in petrol filling workers than in controls. Odds ratios indicate increased risks of respiratory symptoms, including cough, phlegm, and chest tightness, correlated with years of exposure. Workers with over 20 years of exposure reported higher incidences of chronic cough (85%), chronic bronchitis (50%), and chest tightness (35%) compared to those with fewer years of exposure. Carcinogenic and non-carcinogenic risk assessments revealed elevated Lifetime Cancer Risk and Hazard Quotient values. **Conclusion:** Exposure to benzene, toluene, ethylbenzene, and xylene (BTEX) in petrol and diesel may reduce lung function and elevate the risk of respiratory impairment, alongside heightened carcinogenic and non-carcinogenic health risks.

Keywords: BTEX, cancer risk, hazard quotient, petrol filling workers, pulmonary function

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INTRODUCTION

Petrol and diesel are globally used hydrocarbon-based fuels derived from fractional distillation of crude oil. Benzene is one of the most active compounds of petrol and diesel which can cause different physiological dysfunctions in humans. In rapidly developing countries like India, the number of automobiles on roads is increasing day by day. As a result, the number of fuel stations are also increasing. In India, petrol stations are manually operated where petrol fillers are exposed to the VOCs like benzene, toluene, ethylbenzene and Xylene (BTEX), vehicular exhaust along with environmental pollutants. The toxicity, stability and cumulative properties of BTEX compounds can have severe effects on the environment and human health. Since inhalation exposure is the most important route of entry of VOCs in the air into human body, determining the concentration of pollutants in the air and checking the amount of exposure through breathing air is a suitable tool for assessing health risk(carcinogenic and non-carcinogenic) (Kamani *et al.*, 2023) Research underscores that exposure to BTEX with other exhaust and dust particles can increase airway resistance and inflammatory changes in lungs which causes lung dysfunction (Rahhal, 2022). Exposure to air pollutants and VOCs for prolonged period also leads to broncho-constriction. Studies have shown that prolonged exposure to petroleum products can affect the respiratory system which leads to breathlessness, chronic cough and wheezing among the petrol filling workers (Ameen and Abdulla, 2023).

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In West Bengal, India, there is little research on this major health issue, which examines the altered pulmonary function of petrol station workers. The study aims to assess the pulmonary function of petrol filling workers. Furthermore, this research will also provide possible recommendations to prevent occupational lung disorders. The objective of the present study is to: Assess the respiratory health status of petrol filling workers and its association with respiratory symptoms; Evaluate the carcinogenic and non-carcinogenic risk assessment of BTEX exposed petrol filling workers.

METHODS

This cross-sectional study was conducted across petrol filling stations located in various regions of the Howrah and Hooghly districts in West Bengal. The study population comprised 152 male petrol filling workers and a control group of 100 individuals, matched for age and socioeconomic background. Participants were selected through a simple random sampling method, ensuring a representative and unbiased sample.

Sample Size

This research was carried out at 14 petrol stations within Howrah, Hooghly, and nearby Dankuni in West Bengal, India. The designated area was chosen because it has a high density of petrol filling stations. This concentration arises from an intricate road network of interstate highways and feeder channels linking the districts of Howrah and Hooghly to major cities across West Bengal. The representative sample size was calculated using the PS Power and Sample Size Calculator Software (Version 3.1.6), ensuring statistical rigor and adequate power for comparative analysis.

Ethical Consideration

Approval for this study was granted by the Institutional Ethical Committee of Raja Peary Mohan College [Ref No. 2/2022]. Written consent was obtained from both the petrol station owners and the workers before study commencement, emphasizing the ethical commitment to informed and voluntary participation.

Inclusion Criteria

Participants were required to be male.

Age range: 20-60 years.

Participants must have worked as petrol pump fillers for over one year, with a minimum of 8 hours per day.

Exclusion Criteria

Individuals with any pre-existing lung disease were excluded to prevent confounding results; Unwilling and uncooperative workers were not included in the study; Individuals with vertebral column or thoracic abnormalities, impacting standing posture, were also excluded to maintain consistency in data collection methods.

This methodology aimed to ensure a robust, ethically sound, and representative analysis of the potential health risks associated with VOC exposure among petrol filling workers.

Physical Parameters Studied

Physical parameters like age, body height, body weight and body mass index (BMI) were analyzed. Age was recorded from the Aadhar card. Body height was measured by the anthropometric rod. Body weight was taken by using a weighing machine with light clothing and without shoes. BMI was calculated using formula body weight in Kg / (body height in meters)^2.

Respiratory Health Questionnaire

To evaluate individual characteristics such as age, years of work experience, smoking habits, and respiratory health, a questionnaire was administered (Occupational Safety and Health Administration. OSHA respirator Medical Evaluation Questionnaire, 2012) and a Standard Questionnaire (Nicholson *et al.*, 2004). The data enabled a stratified analysis of participants based on age group, years of exposure, and smoking habits.

Pulmonary Function Parameters Studied

Lung function among participants was assessed with the Digital Spirometer (Spirovit – SP1), following the American Thoracic Society's standardized protocol. The procedure is simple, non-invasive, and user-friendly. The spirometer was calibrated before each session. Participants were familiarized with the equipment and procedure, and tests were conducted in a standing position. Participant information, including name, age, sex, height, and weight, was recorded before testing. Each participant was instructed to take a full breath and exhale forcefully through a mouthpiece attached to the Spirovit sensor, while a nose clip was used to prevent nasal airflow. Key lung function parameters recorded included Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), FEV_1/FVC ratio, $FEF_{0.2-1.2}$, $FEF_{25-75\%}$, and FEF

$_{75\text{-}85\%}$. Two to three trials were conducted, with the best result selected for analysis. Spirometric analysis provided insights into each individual's respiratory status.

Peak Expiratory Flow Rate (PEFR) was measured using Wright's Peak Flow Meter, with the best reading recorded after three successive trials. This comprehensive data collection facilitated an accurate assessment of respiratory function.

Environmental parameters like $PM_{2.5}$ and PM_{10} ($\mu g/m^3$), SO_2, NO_2, TVOC and benzene were analyzed in three petrol stations of the study area by the instruments Envirotech APM-550for fine Particulate Sampler, Ecotech AAS 217 NL for Respirable Dust Sampler, Digital VOC Analyzer and the instrument Envirotech APM 850 for Organic Vapor Sampler. The air analysis was made for at least 4 hours between 11am to 5pm within a 2 meter radius of fuel dispensers. These results were compared with national (National Ambient Air Quality Status., 2009) and international standards (USEPA). and REL (Recommended Exposure Limit) of NIOSH as well as the maximum allowable air concentration Standard (<0.2 mg/m^3) of TVOC (Edokpolo, Yu and Connell, 2014) and national standard value for benzene (5$\mu g/m^3$) (Kesavachandran *et al.*, 2006).

Data Analysis

Statistical analysis was made using the SPSS 25.0 version. The results obtained from the analysis were presented in tabular form. Descriptive statistics, correlation, ANOVA, multiple logistic regression and odds ratio were performed.

RESULTS

Table 2 represents the socio-demographic status of study participants. It was found that 37.5% petrol filling workers (PFW) were from a lower age group (20-35 years) and 62.5% were from a higher age group (36-60 years). Similarly, 43% control group workers were from a lower age group and 57% were from a higher age group. Furthermore, 5.9% petrol filling workers and 8% of the control group were under weight and 55% of petrol filling workers and 21% of control group workers were overweight. Moreover, 59.2% PFW and 53% control group workers were smokers, 56.6% petrol filling workers had 1- 10 years of exposure and 26.3% had more than 20 years of exposure.

Table 3 presents the Mean ± SD values for physical and pulmonary function parameters of PFW and controls. Both groups were stratified by age (younger and older) and smoking status. Significant reductions ($p<0.02$ - 0.001) were observed across all pulmonary function parameters in older PFW smokers and non-smokers when compared to controls. Pulmonary functions were lower in younger PFW than controls, with significant differences ($p < 0.05 - 0.01$) specifically in $FEF_{0.2\text{-}1.2}$, $FEF_{25\text{-}75\%}$, and PEFR for both smokers and non-smokers.

Table 1. Environmental Analysis

Air Components	National Standard	International Standard	WHO Standard (AQG)	Present study
$PM_{2.5}$ ($\mu g/m^3$) *	60	25	15	36.5
PM_{10} ($\mu g/m^3$) **	100	50	45	97.2
SO_2 ($\mu g/m^3$) **	80	41.66	40	7.3
NO_2 ($\mu g/m^3$) **	80	40	25	36.4
O_3 ($\mu g/m^3$) **	180	120	60	21.6
NH3 ($\mu g/m^3$) **	400	-	-	26.4
TVOC (mg/m^3) ***	0.3-0.5 mg/m^3	0.2mg/m^3		
(USEPA)	-	1.3 mg/m^3		
Benzene ($\mu g/m^3$) ****	5 $\mu g/m^3$	1ppm (OSHA PEL)	-	0.145 mg/m^3
Temperature (^{0}C)	-	-	-	350C
Relative Humidity (%)	-	-	-	73%

*By the instrument Envirotech APM-550, Fine Particulate Sampler.
**By the instrument Ecotech AAS 217 NL, Respirable Dust Sampler.
*** By the instrument Digital VOC Analyzer.
**** By the instrument Envirotech APM 850, Organic Vapor Sampler

Additionally, the mean age, body weight, and BMI values of the older PFW were significantly higher ($p < 0.02$-0.001) than those of the control group.

Table 4 shows the Mean ± SD values for physical and pulmonary function parameters based on years of exposure. An ANOVA comparison revealed a significant decline in pulmonary function parameters ($p < 0.05$-0.01) with increasing years of exposure, except for FVC and $FEF_{0.2\text{-}1.2}$.

Table 5 details the correlation coefficients between physical parameters and years of exposure with pulmonary function measures. Significant correlations ($p < 0.05$-0.001) were observed between age, height, years of exposure, and pulmonary function parameters among PFW.

Table 6 highlights that PFW with over 20 years of exposure experienced higher incidences of chronic cough (85%), chronic bronchitis (50%), and chest tightness (35%) compared to workers with less than 10 years or 11-20 years of exposure. The odds ratios (OR) for these respiratory conditions among workers with 10-20 years of exposure were 12.59, 6.51, and 8.30 respectively. For those with over 20 years, ORs rose to 21.40 for chronic cough, 7.6 for chronic bronchitis, and 14.89 for chest tightness indicating a 21.4-fold increased risk of chronic cough, a 7.6-fold increased risk of chronic bronchitis, and a 14.89-fold increased risk of chest tightness compared to those with less than 10 years of exposure. Respiratory diseases were notably higher in smoking PFW, with prevalence rates of 56.7% for chronic cough, 37.8% for chronic bronchitis and 20% for chest tightness—higher than non-smokers by 33.8%, 11.3%, and 6.4% respectively. An analysis of smoking's impact indicated significant associations between smoking and respiratory disease prevalence among PFW (OR = 2.55, 4.09, and 7.15 respectively). For older PFW, the prevalence of these diseases was 52.6%, 25.3%, and 15.8% respectively—significantly higher than in younger workers by 38.6%, 29.8%, and 12.3%. OR values suggest older PFW had a 1.36-fold greater risk for chronic bronchitis than younger workers.

Table 7 provides a logistic regression analysis of the prevalence of respiratory symptoms. Multivariate analysis indicated that years of exposure significantly correlated with chronic cough, chronic bronchitis, and chest tightness ($p = 0.0001$), adjusting for age, BMI, smoking, and exposure duration.

Table 8 highlights respiratory abnormalities among PFW, showing that 43.4% of PFW exhibited restrictive lung disease compared to 6% in the control group. Obstructive and combined respiratory abnormalities were found in 5.9% and 5.3% of PFW, respectively.

Ambient air analysis confirmed that the concentration of BTEX compounds in petrol stations exceeded permissible thresholds, with benzene—a known carcinogen—identified as a significant risk factor. Other BTEX compounds, such as xylene, toluene, and ethylbenzene, were associated with

Table 2. Socio-demographic Status of Study Participants

Socio-demographic Characteristics		Petrol Filling Workers(n=152)		Control(n=100)	
		No. of participants	Percentage	No. of participants	Percentage
Age inYears	20- 35Years	57	37.5%	43	43%
	36- 60Years	95	62.5%	57	57%
BMI (kg/m2)	Underweight	9	5.9%	8	8%
	Normal	59	38.8%	71	71%
	Overweight	84	55.3%	21	21%
Type of Work	Petrol fillers	152	100%	-	-
	Student	-	-	20	20%
	Driver	-	-	5	5%
	Lab Technician	-	-	15	15%
	Office workers	-	-	40	40%
	Shop keepers	-	-	20	20%
Year of Exposure	1-10 Years	86	56.6%	-	-
	11-20 Years	26	17.1%	-	-
	>20 Years	40	26.3%	-	-
Smoking Habit	Smokers	90	59.2%	53	53%
	Nonsmokers	62	40.8%	47	47%

non-carcinogenic effects, including skin and eye irritation, headaches, nausea, and hypertension. Notably, there is a lack of published data quantifying Lifetime Cancer Risk (LCR) and Hazard Quotient (HQ) for PFW. Consequently, this study assessed LCR and HQ based on air quality data.

Analysis Of Carcinogenic Risk And Non-Carcinogenic Health Risk

Carcinogenic risk and non-carcinogenic risk were calculated using the method provided by the Lifetime Cancer Risk (LCR) and Hazard Quotient

Table 3. Mean ±SD values of Physical and Pulmonary Function Parameters of Higher and Lower Age Group of PFWs and Control Group

Parameter	All(152)	Petrol Filling Workers				All (100)	Control			
		Higher age (95)		Lower age(57)			Higher age(57)		Lower age(43)	
		Smoker (52)	Nonsmoker (43)	Smoker (38)	Nonsmoker (19)		Smoker (37)	Nonsmoker (20)	Smoker (16)	Nonsmoker (27)
Age	38.45 ± 10.61	47.61 ± 7.18 **	48.64 ± 7.42 **	28.13 ± 4.55 *	26.89 ± 4.22	36.93 ± 9.02	42.91 ± 6.78	43.55 ± 6.14	30.56 ± 2.30	27.59 ± 3.91
Height(cm)	162.78 ± 7.27	161.6 ± 5.98	162.4 ± 7.51	164.4 ± 8.52	163.44 + 7.10	162.51 ± 6.76	164.02 + 7.44	160.65 + 5.88	163.06 + 8.41	161.41 + 4.93
Weight (kg)	66.96 ± 13.47 ****	66.64± 13.34 **	71.44 ± 13.04 ****	64.73 ± 12.26	62.15 ± 15.15	59.57 ± 8.30	59.35 ± 9.63	58.30 ± 7.10	59.81 ± 10.28	60.6 ± 5.77
BMI (kg/m^2)	25.21 ± 4.28 ****	25.55± 4.67 ***	26.85 ± 3.56 ****	23.86 ± 3.55	22.85 ± 2.82	22.85 ± 2.82	22.32 ± 2.99	22.96 ± 2.68	22.78 ± 3.97	23.54 ± 1.64
FVC(L)	2.65 ± 0.79 ****	2.52± 0.58 ****	2.54 ± 0.68 ***	2.86 ± 1.06	3.15 ± 0.32	3.15 ± 0.32	3.18 ± 0.48	3.10 ± 0.22	3.17 ± 0.17	3.12 ± 0.17
FEV_1(L)	2.27 ± 0.57 ****	2.11± 0.50 ****	2.14 ± 0.54 ***	2.52 ± 0.57	2.68 ± 0.37	2.68 ± 0.37	2.72 ± 0.39	2.62 ± 0.30	2.56 ± 0.46	2.75 ± 0.35
FEV_1/FVC	87.08 ± 12.43 ****	84.4± 12.34 ****	85.38 ± 12.55 **	90.56 ± 12.30	95.40 ± 4.75	95.40 ± 4.75	95.74 ± 4.91	94.76 ± 5.05	94.75 ± 6.34	95.77 ± 3.32
$FEF_{0.2-1.2}$(L/min)	4.37 ± 1.82 ****	4.18± 1.89 ****	4.05 ± 1.69 ****	4.64 ± 1.84 **	5.84 ± 1.22	5.84 ± 1.22	5.71 ± 0.99	5.90 ± 1.19	6.22 ± 1.10	6.46 ± 1.23
$FEF_{25-75\%}$(L/min)	2.94 ± 1.26 ****	2.57± 1.29 ****	2.73 ± 1.07 ****	3.42 + 1.19 *	4.08 ± 0.92	4.08 ± 0.92	3.98 ± 0.88	4.24 ± 1.11	4.17 ± 1.11	4.02 ± 0.75
$FEF_{75-85\%}$(L/min)	1.43 ± 0.78 ****	1.25 ± 0.74 ****	1.10 ± 0.55 ****	1.88 + 0.84	2.11 ± 0.53	2.11 ± 0.53	2.06 ± 0.49	2.21 ± 0.69	2.05 ± 0.50	2.16 ± 0.49
PEFR(L/min)	453.09 ± 77.87 ****	435.19± 76.70	441.39 ± 85.42 *	477.89 + 72.52	493.60 ± 76.28	493.60 ± 76.28	463.5 ± 76.51	491.5 ± 68.46	500.6 ± 63.40	532.2 ± 74.02

$p<0.05$-*, $p<0.01$-**, $p<0.001$-***, $p <0.0001$-****

(HQ) are analyzed using the formula of Ricci (2005).

LCR can be calculated by multiplication of the chronic daily intake (CDI) by the slope factor for benzene.

$$LCR = CDI \times SF \tag{1}$$

The slope factor is an upper level, with 95% confidence interval, on the increased cancer risk from a lifetime exposure to a chemical through ingestion or inhalation (mg/kg-day). The slope factor of benzene through inhalation was obtained from the California Environmental Protection Agency (0.1mg/kg-day), 2017.

CDI is the amount of absorbed chemical through the human body for the duration of working life.

$$CDI = \frac{C_{adj-24h} \times IR \times ED \times EF}{BW \times AT \times NY} \tag{2}$$

$$C_{adj-24h}(mg/m^3) = \frac{C_{air} \times ET \times EF \times ED}{AT \times (AF \times PPF)} \tag{3}$$

$C_{adj-24h}$ - Pollutant concentration in inhalation for 24 hours in a day (mg/m^3)

IR - Rate of inhalation (m3/ day) [20m3/day]

ED -Exposure duration (years) [20 years, assumed]

EF - Exposure frequency (days / year) [300days/ year, assumed]

AT - Average time [70 years for carcinogenic effects, 30 years for non-carcinogenic]

BW - Body weight [67kg, average bodyweight]

ET- Exposure time (8hrs/day)

AF - Average frequency [90%]

PPF - Particle penetration frequency [0.082]

NY - Number of days per year (365 days)

$C_{adj-24hr}$ (mg/m^3) for carcinogenic compound = [(1.3 x 8 x 300 x 20) / (70 x 365)] x (90 x 0.082) = 2680.54 mg/m^3

We measured benzene concentration in ambient air from four petrol pumps for at least 4 hours in each and average value was taken.

Value for C_{air} of benzene = 0.145 mg/m^3

$C_{adj-24hr}$ (mg/m^3) for benzene = [(0.145 x 8 x 300 x 20)/ (70 x 365)] x (90 / 0.082) =296.34 mg/m^3 (As per Equation 3)

CDI for benzene = (296.34 x 20 x 20 x 300)/ (67 x 70 x 365).(As per Equation 2) = 20.77 mg/ kg-day

Table 4. Comparison between Mean+ SD values of different Pulmonary Function Parameters of PFWs based on Year of Exposure

Parameters	1-10 Years	11-20 Years	>20 Years	F	p value
FVC(L)	2.76±0.69	2.74±1.24	2.49±0.67	1.952	0.146
FEV1(L)	2.40±0.56	2.25±0.49	1.99±0.56	10.432	0.000***
FEV1/FVC	89.45±10.31	86.31±13.73	81.13±15.46	5.322	0.006**
$FEF_{0.21.2}$ (L/min)	4.51±1.76	4.40±1.55	3.96±2.02	2.674	0.072
$FEF_{25-75\%}$ (L/min)	3.18±1.14	2.84±1.11	2.35±1.41	6.391	0.002**
$FEF_{75-85\%}$ (L/min)	1.59±0.77	1.22±0.63	3.75±15.79	5.224	0.006**
PEFR(L/min)	463.02±72.87	452.3±71.45	428±87.06	3.375	0.037*

$p<0.05$-*, $p<0.01$-**, $p<0.001$-***, $p<0.0001$-****

Table 5. Correlation between Pulmonary Function Parameters with Age, Height, Weight, BMI and Year of Exposure of PFWs

Parameters	Age	Height	Weight	BMI	Year of Exposure
FVC(L)	-0.215**	0.210**	0.074	-0.019	-0.123
FEV1(L)	-0.432****	0.306****	0.082	-0.056	-0.346****
FEV1/FVC	-0.342****	0.020	-0.067	-0.083	-0.286****
$FEF_{0.2-1.2}$(L/min)	-0.256***	0.303****	0.182*	0.070	-0.159
$FEF_{25-75\%}$(L/min)	-0.372****	0.173*	0.060	-0.007	-0.316****
$FEF_{75-85\%}$(L/min)	-0.425****	0.064	-0.039	-0.059	-0.271***
PEFR(L/min)	-0.343****	0.302****	0.160*	0.025	-0.232**

$p<0.05$-*, $p<0.01$-**, $p<0.001$-***, $p<0.0001$-****

LCR for benzene = 20.77 x 0.1= 2.077 (As per Equation 1)

Standard value for LCR (for benzene) = 1.681E-3

For Calculating Non-carcinogenic Risk, Hazard Quotient (HQ) Can be Calculated using the Following Equation-

$$HQ = {}^{CDI}/_{RFD} \tag{4}$$

RFD = Reference dose factor (mg/kg-day)

RFD = (RFC x IR) / BW

RFC = Reference concentration factor (100ppm=433.54mg/m^3)

HQ for TVOC

Cadj-24hr(mg/m3) for non-carcinogen = [(1.3 x 8 x 300 x 20) / (30 x 365)] x (90/0.082) mg/m3= 6254.59 mg/m3 (As per Equation 3)

CDI for non-carcinogen= (6254.59 x 20 x 20 x 300)/ (67 x 30 x 365) mg/m3= 1023.03 mg/kg-day (As per Equation 2)

RFC = 433.54 mg/m^3

RFD = (433.54 x 20)/67 = 129.41 mg/kg-day (As per Equation 5)

HQ=1023.03/129.41= 7.90 (As per Equation 4)

HQ for Xylene

Ca$_{dj\text{-}24hr}$ (mg/m^3) for xylene = [(0.195 x 8 x 300 x 20)/ (30 x 365)] x (90 / 0.082) mg/m3 = 938.18 mg/m3 (As per Equation 3)

CDI = (938.18 x 20 x 20 x300) / (67 x 30 x365) mg/m^3. = 153.45 mg/kg-day (As per Equation 2)

RFD = (433.54 x 20) / 67 mg/kg-day = 129.41mg/m3 (As per Equation 5)

HQ = 153.45/129.41 = 1.185 (As per Equation 4)

HQ for Toluene

C$_{adj\text{-}24hr}$ (mg/m^3) for toluene = [(0.26 x 8 x 300 x 20) / (30 x 365)] x (90/ 0.082) = 1250.88 mg/m^3 (As per Equation 3)

CDI = (1250.88 x 20 x 20 x 300) / (67x 30 x365) mg/m^3 = 204.601 mg/kg-day (As per Equation 3)

RFD = (433.54 x 20) / 67 mg/kg-day = 129.41 mg/kg-day (As per Equation 5)

Table 6. Effects of Smoking Habit, Age & Year of Exposure on the Prevalence of Chronic Cough, Chronic Bronchitis and Chest Tightness with ODDs Ratio and 95% CI among PFWs

Group	No. examined	Chronic Cough				Chronic Bronchitis				Chest Tightness			
		No.	%	OR	95%CI	No.	%	OR	95%CI	No.	%	OR	95%CI
Smoking Habit													
Smokers	90	51	56.7	2.55**	1.30 - 4.99	34	37.8	4.09 ***	1.74 - 9.64	18	20	7.15**	2.04 - 24.97
Non-smokers	62	21	33.8	1		7	11.3	1		4	6.4	1	
Age Group													
HA	95	50	52.6	0.63	0.32 - 1.23	24	25.3	1.36	0.66 - 2.82	15	15.8	0.87	0.34 - 2.20
LA	57	22	38.6	1		17	29.8	1		7	12.3	1	
Year of Exposure													
11-20 Years	26	20	76.9	12.59 ****	4.40 - 35.98	12	46.1	6.51 ****	2.68 - 20.27	5	19.2	8.30 **	1.90 - 36.07
>20 Years	40	34	85	21.40 ****	7.78 - 58.86	20	50	7.60 ****	3.07 - 18.78	14	35	14.89 ****	3.96 - 55.90
10 Years	86	18	20.9	1		9	10.4	1		3	3.5	1	
Total	152												

p<0.05-*, p<0.01-**, p<0.001-***, p <0.0001-****

HQ = 204.601 / 129.41= 1.581 (As per Equation 4))

Table 9 details the Lifetime Cancer Risk (LCR) and Hazard Quotient (HQ) for BTEX compounds. The LCR for benzene was calculated at 2.077 mg/kg-day, exceeding the reference threshold (1 x 10^{-6} mg/m^3). Non-carcinogenic risk assessment showed HQ values for xylene and toluene at 1.1857 mg/m^3 and 1.1581 mg/m^3, respectively, surpassing the acceptable HQ reference level (<1) (Rahimpour, Farhadi and Jalali, 2017). Figure 1 illustrates the prevalence of chronic respiratory conditions among PFW. Of the 152 PFW, chronic cough, chronic bronchitis, and chest tightness were reported in 46.5%, 26.45%, and 12.90% of individuals, respectively.

These comprehensive data underscore the heightened respiratory and cancer risk among petrol filling workers due to prolonged exposure to BTEX compounds and highlights the need for stringent workplace safety measures and health monitoring in this occupational sector.

Table 7. Multiple Logistic Regression Equation of Respiratory Symptoms among PFWs

Parameters	Coefficient	SE	p value	Adjusted OR	95%Confidence Interval	
					Lower	Upper
Chronic Cough						
Age	-0.12	0.03	0.001***	0.88	0.82	0.94
BMI	-0.22	0.35	0.52	0.79	0.39	1.59
Smoking Habit	-0.75	0.51	0.13	0.46	0.17	1.27
Years of Exposure	0.34	0.05	0.0001****	1.41	1.26	1.58
Chronic Bronchitis						
Age	-0.09	0.03	0.01**	0.91	0.84	0.97
BMI	0.05	0.29	0.8	1.05	0.59	1.87
Smoking Habit	-0.26	0.46	0.56	0.76	0.31	1.90
Year of Exposure	0.19	0.04	0.0001****	1.21	1.12	1.31
Chest Tightness						
Age	-0.06	0.045	0.13	0.93	0.85	1.02
BMI	-0.13	0.35	0.70	0.87	0.44	1.74
Smoking Habit	0.35	0.56	0.52	1.42	0.47	4.30
Years of Exposure	0.18	0.04	0.0001****	1.20	1.09	1.31

p<0.05-*, p<0.01-**, p<0.001-***, p <0.0001-****

Table 8. Percentage Prevalence of Respiratory Impairment Among PFWs and Control group

Respiratory Abnormalities	Petrol Filling Workers(n=152)									
	No. (All=152)	(%)	Smokers(n=90)				Nonsmokers(n=62)			
			LA (n=38)	%	HA (n=52)	%	LA (n=19)	%	HA (n=43)	%
Normal	69	45.4	17	44.7	26	50	12	63.1	14	32.5
Restrictive	66	43.4	20	52.6	19	36.53	04	21	23	53.5
Obstructive	9	5.9	01	2.7	04	7.69	01	5.3	03	6.9
Combined	8	5.3	-	-	04	7.69	02	10.5	02	4.6
	Control Group (n=100)									
Respiratory Abnormalities	No. (All=100)	%	Smokers(n=53)				Nonsmokers(n=47)			
			LA (n=16)	%	HA (n=37)	%	LA (n=27)	%	HA (n=20)	%
Normal	94	94	16	100	32	86.5	26	96.3	20	100
Restrictive	06	6	-	-	05	13.5	01	3.7	-	-
Obstructive	-	-	-	-	-	-	-	-	-	-
Combined	-	-	-	-	-	-	-	-	-	-

DISCUSSION

The results show a significant reduction ($p < 0.02-0.001$) in all dynamic pulmonary function parameters among older petrol filling workers (PFW), both smokers and non-smokers, compared to the control group. Younger PFW, regardless of smoking status, also demonstrated significantly lower respiratory flow rates, likely due to chronic exposure to VOCs and particulate matter, which may cause restrictive lung diseases. This decline is attributed to the accumulation of particulates in peribronchial lymphoid and connective tissues, leading to wall thickening and structural changes in the tracheo-bronchial tree and respiratory bronchioles (Rahhal, 2022). Similar restrictive patterns in pulmonary function have been reported in studies by Mandal and Mukherjee (2020); Dhamecha (2021); Obazee *et al.* (2023). Dhamecha (2021), found that accumulation of particulate matters occurs in terminal bronchioles and surrounding lung tissues causing structural changes leading to a restrictive type of breathing pattern. Exposure to VOCs and air pollutants causes irritation in bronchial epithelium including cilia and clara cells which stimulates the macrophages to release proteolytic enzymes. These changes reduce the expansion capacity of lungs leading to the declination of pulmonary function parameters (Ameen and Abdulla, 2023). Furthermore,SO_2 can produce multiple adverse effects on the respiratory system like tissue hypoxia, constriction of the bronchioles, severe airway obstruction and pulmonary edema, while NO2 impairs the immune defense mechanism of lungs and local production of reactive oxygen and nitrogen species (Indumathy, Gandhimathi and Kishore, 2022; Karak and Maiti, 2022).

The questionnaire data further revealed that respiratory symptoms such as chronic cough, bronchitis, and chest tightness are prevalent among PFW and are significantly associated with reduced lung function, suggesting these symptoms as predictors of impaired lung function in this population. PFW with over 20 years of exposure showed a notably high incidence of chronic cough (85%), chronic bronchitis (50%), and chest tightness (35%) compared to those with <10 years (OR=7.6) or 11-20 years (OR=14.9) of exposure, highlighting the deleterious impact of prolonged VOC exposure on pulmonary health.

Similarly, Thomas *et al.* (2020) reported that >10 years of exposure to harmful fumes and vapor

Table 9. Lifetime Cancer Risk (LCR) and Hazard Quotient related to BTXs Compounds in PFWs

Parameters	Air TVOC	Benzene	Toluene	Xylene
Air Concentration (mg/m3)	1.3 mg/m3	0.145 mg/m3	5- 20% = 0.26 mg/m3	2 – 15% = 0.195 mg/m3
Cancer Risk LCR		2.077	-	-
Non-cancer Risk (HQ) for Xylene		-	-	1.1857
Non-cancer Risk (HQ) for Toluene		-	1.581	-

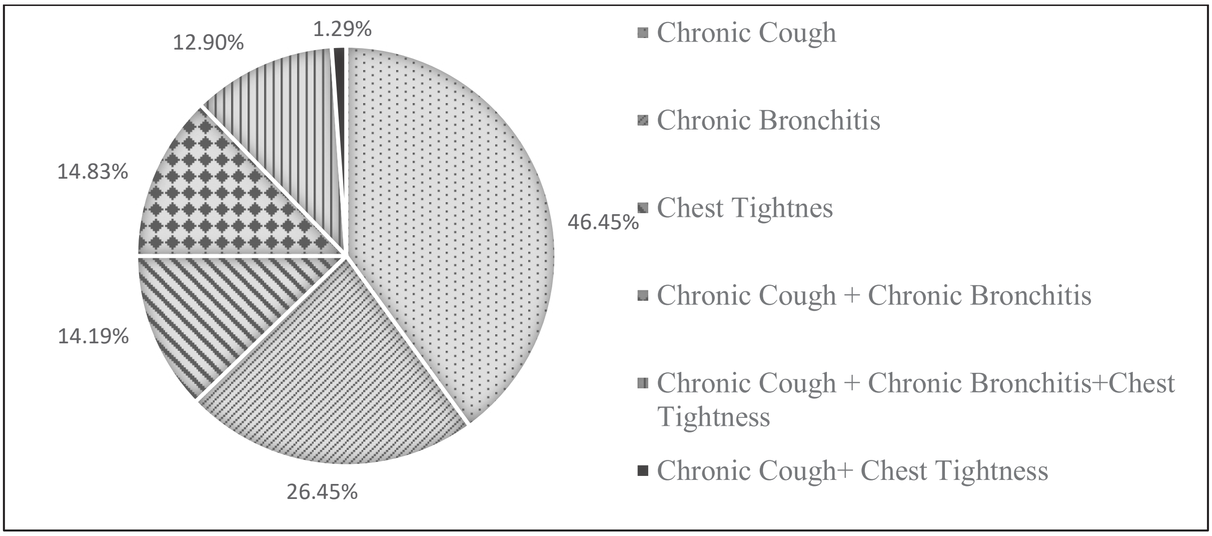

Figure 1. Percentage Prevalence of Respiratory Symptoms among PFWs

produce respiratory illness which corroborates our findings. Deora, Hulke and Bhargava (2019) found no significant respiratory impairment despite >9 years of exposure, possibly due to differences in environmental conditions or control measures. Continuous exposure to petrol vapors, benzene, and vehicular exhaust for more than 8 hours daily may contribute to chronic respiratory tract inflammation and structural changes in the lung parenchyma, as well as increased genotoxicity (Shaikh, Barot and Chandel, 2018). In India, the limited implementation of vapor recovery systems may further contribute to these respiratory impairments (Dhamecha, 2021).

Adjusted odds ratio (AOR) values indicate that both age and years of exposure are significantly correlated with all respiratory symptoms. The effect of smoking is particularly pronounced, as seen in the lower pulmonary function values among older smoker PFW compared to both older and younger non-smokers in the control group. Smoking may exacerbate VOC exposure effects by increasing oxidant stress and reducing ciliary activity, leading to mucus hypertrophy. Environmental dust, along with smoking, can cause lung function reduction. In this study, OR values for chronic cough, chronic bronchitis, and chest tightness were 2.55, 4.09, and 7.15, respectively, among smokers. Aging also contributes to restrictive pulmonary changes, with studies indicating an FEV1 decline rate of 25-30 ml/year from age 35-40, which can double post-70 (Dhamecha, 2021).

BMI values for PFW (25.2-26.8 kg/m²) were higher than those in the control group, making them more susceptible to lipophilic VOC absorption, which correlates with adipose mass and BMI (Moghadam *et al.*, 2019). Excessive fat under the diaphragm and chest wall may exacerbate respiratory restrictions, and a negative correlation with BMI. Razak, Hamzah and Ismail (2021) observed reduced FVC value in obese individual compared to non-obese. Excessive fat accumulation in the abdominal and thoracic region creates mechanical restrictions on the chest wall and diaphragm results in reduced lung compliance. This results in decreased FVC values due to diminished lung expansion during inhalation (Silva-Reis *et al.*, 2024). Furthermore, the long and irregular shifts work by PFW likely increase stress, leading to poor sleep, anxiety, and oxidative damage (Benson *et al.*, 2021) .This results may lead to increased heart rate and blood pressure among petrol filling workers (Karak and Maiti, 2022).

Comparison between PFW and office staff at petrol stations revealed lower pulmonary function values among Petrol fillers, though the difference was only statistically significant for $FEF_{0.2\text{-}1.2}$, likely due to the smaller office staff sample (n=12) versus PFW (n=152). A higher incidence of chronic respiratory issues was found among PFW like 46.45% chronic cough, 26.45% chronic bronchitis, and 12.9% chest tightness. It was suggested that $PM_{2.5}$ is the predictor of respiratory illness and each 0.002 mg/m3 rise in $PM_{2.5}$ was linked to a 13.5ml lower FEV_1 and 2.1ml/year faster reduction in FEV1 (Razak, Hamzah and Ismail, 2021). The high concentration of dust and volatile organic compounds (VOC), including $PM_{2.5}$, PM10, SO_2, and NO_2, was found to exceed international and WHO standards, with total VOC (TVOC) levels reaching 1.3 mg/m³, far above the accepted range of 0.3-0.5 mg/m³. This exacerbates respiratory impairment among PFW, particularly in combination with smoking, age, and extended exposure. Our study is the first to examine the carcinogenic and non-carcinogenic risk of BTEX exposure among PFW, finding benzene levels at 0.145 mg/m³, xylene at 0.195 mg/m³, and toluene at 0.26 mg/m³, each exceeding the California EPA threshold (California Environmental Protection Agency [CalEPA]. Toxicity Criteria Database, 2017).

Our findings on carcinogenic and non-carcinogenic assessment is supported by Chaiklieng, Suggaravetsiri and Autrup (2019). Again, Chaiklieng *et al.* (2021) in Thailand reported that BTEX levels in the working air at 0.1-136.9 ppb for benzene and up to 105.5 ppb for xylene, exceeds the safe threshold limits. A comparative analysis by Jayaraj and Nagendra (2023) found HQ values under 1 for one-year exposure but rising significantly over extended exposure periods, aligning with our study's finding of HQ values >1 for xylene and toluene, indicating substantial non-carcinogenic risks.

The study has some limitations – The major limitation of the study is lack of measurement of personal VOC exposure and short duration sampling of workplace environment which overlooks the long-term exposure risk assessment. Only male workers are taken for this study so that it cannot reflect the gender variability.

CONCLUSION

Our study demonstrates significant respiratory impairment and risk of respiratory disorders among

PFW exposed to VOCs and particulate matter, emphasizing the need for occupational health risk assessments for VOC and PM exposure on a larger scale. These assessments will facilitate better risk management and inform public health policies. Further investigations into VOC emissions from fuel stations can contribute to revised VOC threshold values to improve air quality standards in India. Mitigating health risks among PFW may require pre-employment and periodic health check-up for respiratory parameters, proper use of personal protective equipment, employee training for health awareness, self-service pump implementation to reduce exposure, change in work type or work schedule and introduction of control technologies like phytoremediation, vapor recovery systems, and photocatalytic materials for reduction of VOC emission. Such measures are crucial to protect workers' health by prompt and proper medical attention and reduce morbidity and mortality in this occupational group.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS' CONTRIBUTION

SB: Collection of data, statistics and manuscript writing

AMM: Planning and implementation of work, Data Collection and manuscript writing.

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