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Original Research Article

A cross-sectional study of health profile of tuberculosis patients with special reference to air pollution exposure in central India

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ABSTRACT

Background: Exposure to air pollution worsens the health outcomes of tuberculosis (TB) patients, leading to severe symptoms, more comorbidities and poor treatment response. This study examines the health profile of TB patients concerning their residential air quality. To assess the health profile of TB patients with special reference to air pollution exposure.
Methods: A cross-sectional study was conducted among 205 registered TB patients from four TB units under NTEP, residing in regions with moderate and poor Air Quality Index (AQI), between October 2023 and October 2024. Patients were randomly selected using the lottery method. Data were collected through household surveys, health records and anthropometric measurements. Statistical analysis was performed using EPI Info 7.2.6.0.
Results: Of 205 patients, 55.1% were from moderate AQI and 44.8% from poor AQI regions. Males formed 66.3% and the most affected age group was 36–55 years. Over half (56.4%) belonged to the lower socioeconomic class. Previously treated cases and family history of TB were more frequent in poor AQI areas. Pulmonary TB was higher in poor AQI regions (78.2%) compared to moderate AQI areas (65.4%). Respiratory symptoms such as cough, sputum production, haemoptysis, chest pain, dyspnoea and allergy were significantly more common among patients from poor AQI regions.
Conclusions: Poor air quality is strongly associated with severe respiratory symptoms and TB recurrence. The findings underscore the need for better air pollution control and targeted measures to reduce environmental risk among TB patients.

Keywords: Air pollution, Central India, Exposure, Health profile, Tuberculosis

INTRODUCTION

TB is a preventable and usually curable disease. However, in 2023, TB likely returned as the world's leading cause of death from a single infectious agent. Each year, more than 10 million people fall ill with TB and this number has been increasing since 2021. TB is caused by Mycobacterium tuberculosis, which spreads when infected individuals expel bacteria into the air, such as through coughing. The disease most commonly affects the lungs but can also involve other organs. According to the Global TB Report 2024, the majority of TB cases are concentrated in 30 high TB burden countries, contributing to 87% of the global total in 2023. Five countries accounted for 56% of cases globally: India (26%), Indonesia (10%), China (6.8%), the Philippines (6.8%) and Pakistan (6.3%).[1]

India is the highest TB burden country in the world 27% of global incidence, out of estimated global annual incidence 10.6 million, 2.8 million were from India.[2] Air pollution, especially fine particulate matter, is a leading environmental risk factor for multiple noncommunicable diseases including ischaemic heart disease, stroke, chronic respiratory disease and lung cancer. It remains the most significant avoidable environmental cause of disease and premature mortality worldwide. Every year, household air pollution is responsible for 4 million deaths and ambient air pollution for another 3.7 million. Approximately 40% of indoor air pollution-related deaths and 25% of outdoor air pollution-related deaths occur in the eleven countries of the WHO South-East Asia Region.[3]

There is mounting evidence linking ambient air pollution to increased TB risk. Exposure to particulate matter less than 10 µm (PM_{10}) and 2.5 µm ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_x) and nitrogen dioxide (NO_2) is strongly associated with elevated TB incidence.[4] PM exposure weakens respiratory immunity through oxidative stress, making individuals more susceptible to TB found positive correlations between PM, SO_2, NO_2 levels and TB occurrence.[5,6] Other studies also show significant associations between TB and exposure to $PM_{2.5}$ or PM_{10}.[7-9] Although the precise mechanisms remain unclear, it is suggested that air pollution triggers chronic oxidative stress, inflammation and macrophage inactivation, thereby facilitating TB development.[10]

Despite growing global evidence, there is limited region-specific data from Central India on the health profile of TB patients in relation to air pollution. Previous studies have not adequately addressed local environmental conditions or demographic variations. Socioeconomic aspects such as access to care, treatment compliance and disease outcomes are also insufficiently explored. This study seeks to address these gaps by evaluating the health profile of TB patients in Central India with specific reference to air pollution exposure, as well as their demographic and clinical characteristics.

METHODS

This descriptive, cross-sectional study was conducted among 205 tuberculosis patients registered under the National Tuberculosis Elimination Program (NTEP). The study included all patients receiving treatment in four selected TB units out of sixteen TB units in the district. Two of these units were in areas identified as having poor air quality index (AQI), while the other two were in regions with moderate AQI based on the previous year's air quality data from the Central and state pollution control boards. Registered TB patients under the National Tuberculosis Elimination Program (NTEP) from these selected units were randomly chosen using the lottery method.

The sample size for this study was determined using Cochran's formula to estimate a representative proportion with a 95% confidence level and a 5% margin of error. Since the expected proportion of the outcome was unknown, the value of p=0.5 was used to maximize the sample size. The initial calculation yielded a sample size of 384. Because the total population of registered TB patients in the selected TB units was 420, the finite population correction was applied to adjust for the limited sampling frame. This adjustment reduced the required sample size to 201. To ensure adequate representation and account for any potential non-response, a final sample of 205 patients was selected. The sampling frame included all TB patients registered under the National Tuberculosis Elimination Program (NTEP) during 2023-2024 in four TB units chosen randomly from areas with moderate and poor air quality index within the study district.

Inclusion criteria

All the registered TB patients under NTEP from the selected Region during the specified period (October 2023 to October 2024) were included in the study.

Exclusion criteria

TB Patients with Chronic Diseases like CKD, CLD, Malignancies, chronic Lung problems and participants who are not willing to participate in the study were excluded from the study.

Data collection

A total of 205 TB patients participated in the study: Unit A-52, Unit B-61, Unit C-40 and Unit D-52. This included 113 participants from moderate AQI areas and 92 participants from poor AQI areas. Data collection was carried out through household surveys using a self-administered questionnaire, review of health records and anthropometric measurements. Data analysis was performed using Epi Info version 7.2.6.0.

RESULTS

The most affected age group was 36–55 years (42.8%), predominantly male (66.3%), Hindu (62.4%), married (70.7%) and from nuclear families (53.1%). A majority lived in urban areas (70.7%) and belonged to the lower socio-economic class (56.4%) (Table 1). Most participants lived in pucca houses (58.5%), with 79.0% having a separate kitchen. However, 14.1% lacked kitchen ventilation. Clean fuel (LPG/electricity) was used by 52.1% of households. Overcrowding was reported in 31.8% of moderate AQI and 39.1% of poor AQI households (Table 2). New TB cases were more common in patients under 40 years from poor AQI regions, whereas in moderate AQI areas, they were more frequent in those over 40 years (Table 3). Tobacco use (52.2% in moderate, 63.0% in poor), alcohol use (35.4% in moderate, 51.0% in poor), family history of TB (33.7%), past TB infection (35.9%) and retreatment cases (26.1%) were more prevalent in poor AQI areas. Pulmonary TB was seen in 71.2% (65.4% in moderate, 78.2% in poor), while 28.7% had extrapulmonary TB (34.5% in moderate, 21.7% in poor). Pulmonary TB was more common in males (72%) than in females (28%). Extrapulmonary TB was more common in females (55%) than males (45%) (Table 3).

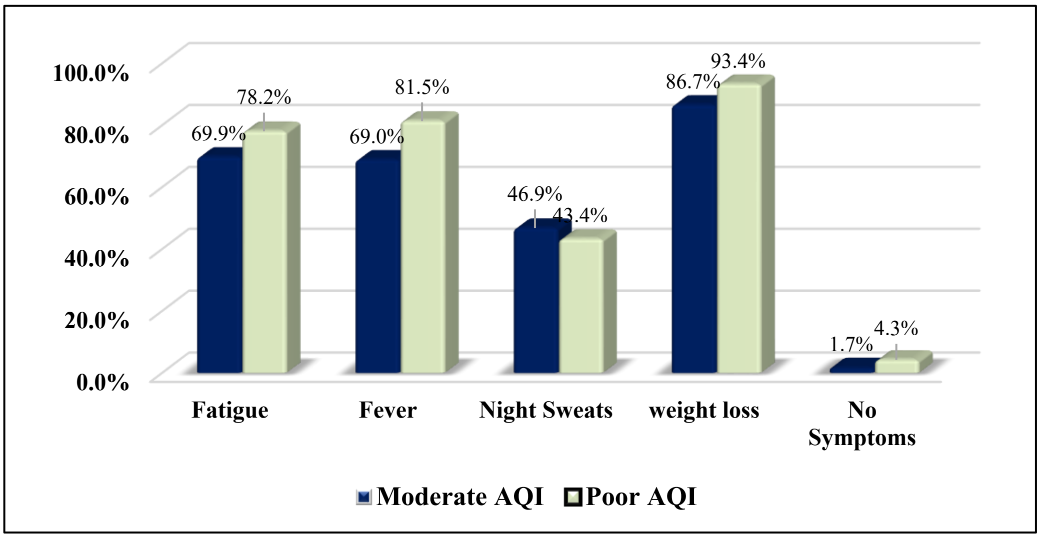

Figure 1: General symptoms in the study subjects from both moderate and poor AQI areas.

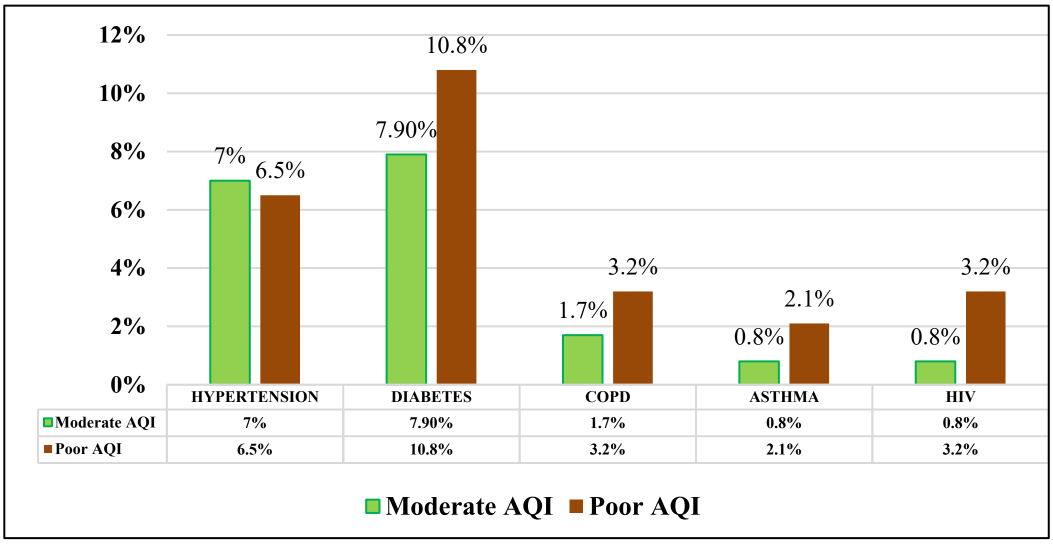

Figure 2: Pre-existing health problems in the study subjects from both Moderate and poor AQI areas.

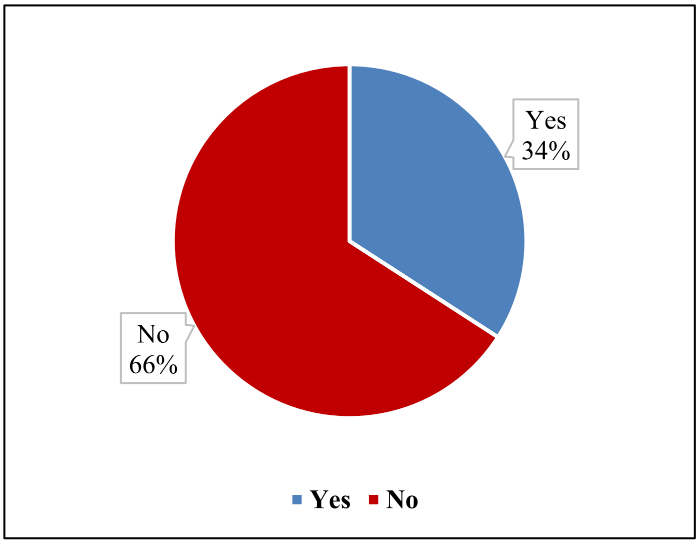

Figure 3: Missed the TB medication during treatment in participants from both moderate and poor AQI areas.

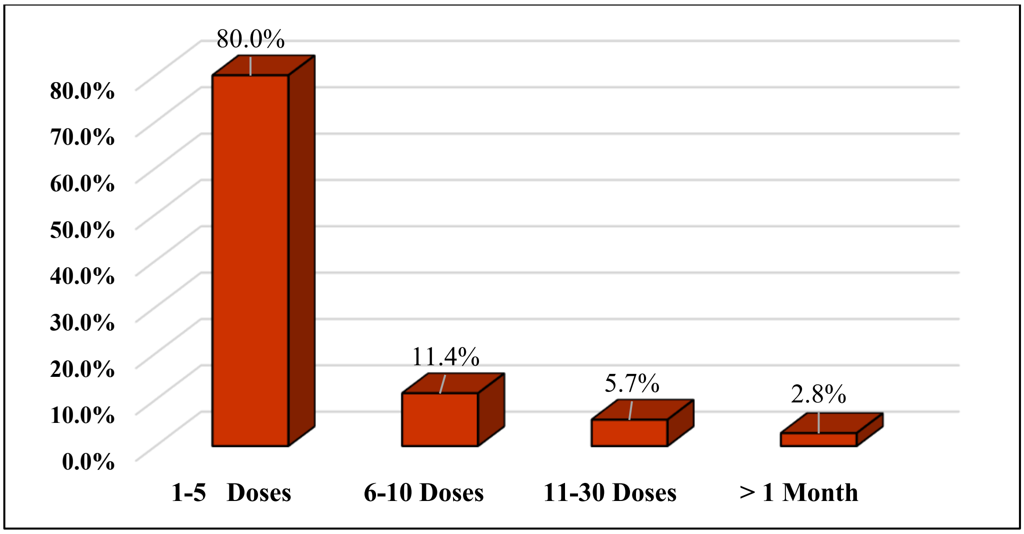

Figure 4: Number of doses missed during TB treatment by the participants from both moderate and poor AQI areas.

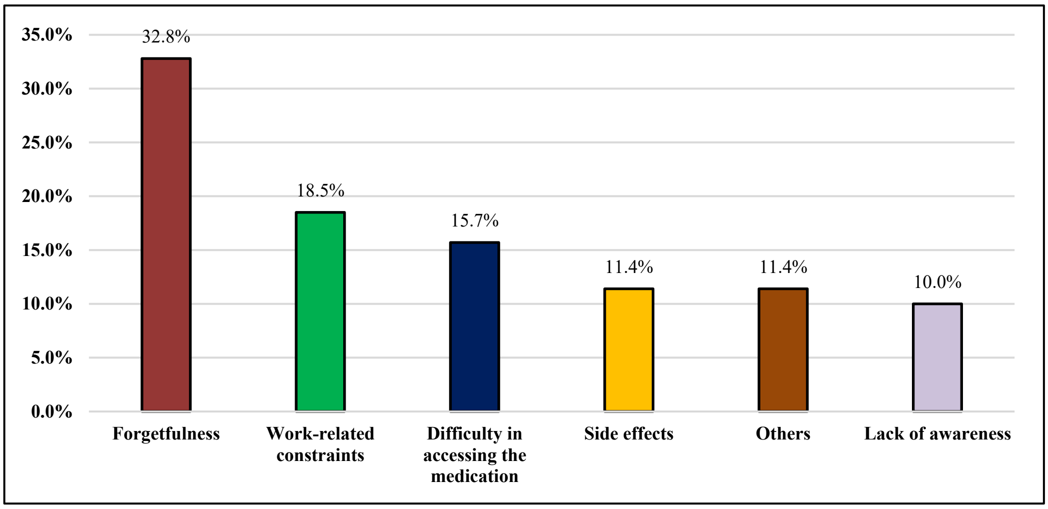

Figure 5: Reason for missing doses during TB treatment by the participants from both moderate and poor AQI areas.

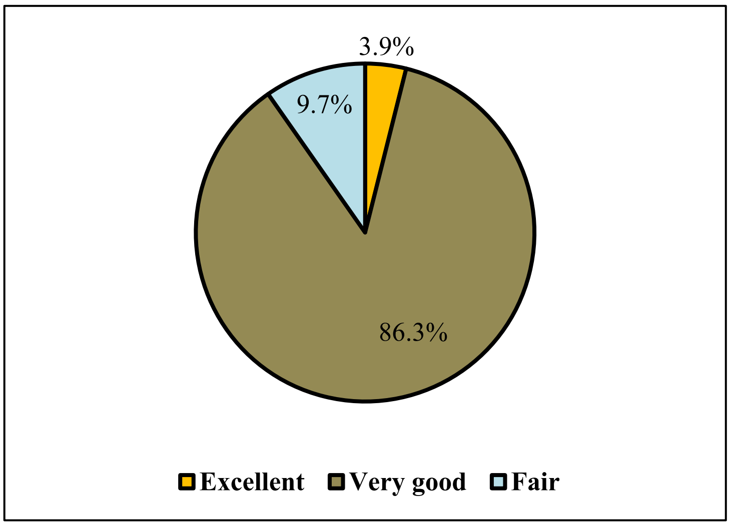

Figure 6: Overall Quality of TB treatment according to the study participants.

Exposure to air pollution (Outdoor and Indoor) was reported by 86.7% in moderate and 100% in poor AQI areas. On perceived impact on air pollution exposure and TB development, 70.2% responded as harmful and 31.2% said it is not harmful (Table 3). History of recurrent respiratory infections (12.0%) and pollution-related allergies (16.3%) were also more frequent in poor AQI regions (Table 3).

Respiratory symptoms were more severe in poor AQI regions: cough (79.4%), prolonged cough (46.0%), cough with expectoration (77.2%), increased sputum (83.1%), thick coloured sputum (73.2%), dyspnoea (51.1%), chest pain (56.5%) and haemoptysis (19.6%) were all higher compared to moderate AQI areas and statistically significant (Table 4). General symptoms such as fever (81.5%), fatigue (78.2%) and weight loss (93.4%) were higher among patients from poor AQI areas (Figure 1). Of the total, 56% were undergoing treatment, 43.4% had completed treatment and 1.0% had discontinued (Figure 2). Pre-existing conditions such as diabetes (10.8%), asthma (2.1%), COPD (3.2%) and HIV (3.2%) were slightly more common in poor AQI areas (Figure 3).

Treatment adherence issues were noted, with an overall 34% missing doses, 80.0% (mostly 1–5), primarily due to forgetfulness (32.8%) or personal reasons (Figure 4 and Figure 5). The Healthcare service quality was rated as very good by 86.3%, excellent by 3.9% and fair by 9.7% (Figure 6). Most of the patients used to visit the health care facility on as an as-and-when required 74.1%. 90.2% participants are satisfied with the treatment they received.

Table 1: Sociodemographic distribution of study participants from areas with moderate and poor AQI.

Variable	Group	Moderate AQI (n=113) N (%)	Poor AQI (n=92) N (%)	Total (n=205) N (%)
Age groups (in years)	Up to 15	1 (0.9)	3 (3.2)	4 (1.9)
	15-25	14 (12.4)	11 (11.9)	25 (12.1)
	26-35	22 (19.5)	16 (17.4)	38 (18.5)
	36-45	22 (19.5)	22 (23.9)	44 (21.4)
	46 to 55	22 (19.4)	22 (23.9)	44 (21.4)
	56 to 65	13 (11.5)	9 (9.7)	22 (10.7)
	Above 65	19 (16.8)	9 (9.7)	28 (13.6)
Gender	Male	70 (61.9)	66 (71.7)	136 (66.3)
	Female	43 (38.0)	26 (28.3)	69 (33.6)
Religion	Hindu	66 (58.4)	62 (67.4)	128 (62.4)
	Buddhist	32 (28.3)	25 (27.2)	57 (27.8)
	Muslim	14 (12.3)	3 (3.3)	17 (8.2)
	Others	1 (0.9)	2 (2.2)	3 (1.4)
Marital status	Single	26 (23.0)	19 (20.7)	45 (21.9)
	Married	75 (66.3)	70 (76.1)	145 (70.7)
	Divorce/separated	4 (3.5)	2 (2.2)	6 (2.9)
	Widowed	8 (7.0)	1 (1.1)	9 (4.3)
Type of family	Nuclear	61 (53.9)	48 (52.2)	109 (53.1)
	Joint	50 (44.2)	41 (44.6)	91 (44.3)
	Three generation	2 (1.7)	3 (3.3)	5 (2.4)

Table 2: Socioeconomic factors of study participants from areas with moderate and poor AQI.

Variable	Age group	Moderate AQI (n=113) N (%)	Poor AQI (n=92) N (%)	Total (n=205) N (%)
Location of residence	Rural	2 (1.8)	58 (63.0)	60 (29.2)
	Urban	111 (98.2)	34 (37.0)	145 (70.7)
Education	Professional degree	1 (0.9)	0 (0.0)	1 (0.4)
	Intermediate/diploma	25 (22.1)	16 (17.4)	41 (20.0)
	Graduate	13 (11.5)	13 (14.3)	26 (12.6)
	High school	26 (23.0)	14 (15.2)	40 (19.5)
	Middle school	19 (16.8)	19 (20.7)	38 (18.5)
	Primary school	14 (12.4)	18 (19.6)	32 (15.6)
	Illiterate	15 (13.3)	12 (13.0)	27 (13.1)
Occupation	Professionals	5 (4.4)	0 (0.0)	5 (2.4)
	Skilled workers	9 (2.7)	5 (3.3)	14 (6.8)
	Semi-skilled workers	35 (31.0)	29 (31.5)	64 (31.2)

Continued.

Variable	Age group	Moderate AQI (n=113) N (%)	Poor AQI (n=92) N (%)	Total (n=205) N (%)
	Elementary occupation	34 (30.1)	40 (43.5)	74 (36.0)
	Unemployed	30 (26.6)	18 (19.6)	48 (23.4)
S/E status	Upper class	5 (4.4)	1 (1.1)	6 (2.9)
	Middle class	35 (31.0)	48 (52.2)	83 (40.4)
	Lower class	73 (64.6)	43 (46.7)	116 (56.4)
Type of house	Own house	104 (92.0)	81 (88.0)	185 (90.2)
	Rented house	3 (2.7)	6 (6.5)	9 (4.3)
	Government-provided housing	4 (3.5)	4 (4.4)	8 (3.9)
	Others	2 (1.8)	1 (1.1)	3 (1.4)
Type of housing	Pucca house	65 (57.5)	55 (59.8)	120 (58.5)
	Kacha house	48 (42.5)	37 (40.2)	85 (41.4)
Overcrowding	Yes	36 (31.8)	36 (39.1)	72 (35.1)
	No	77 (68.1)	56 (60.8)	133 (64.8)

Table 3: Positive association of air pollution with in TB patients from areas with moderate and poor AQI.

Variable	Age group	Moderate AQI (n=113) N (%)	Poor AQI (n=92) N (%)	Total (n=205) N (%)	P (χ2, df)
S/E status	Upper class	5 (4.4)	1 (1.1)	6 (2.9)	0.005 (10.41, 2)
	Middle class	35 (31.0)	48 (52.2)	83 (40.4)	
	Lower class	73 (64.6)	43 (46.7)	116 (56.4)	
Exposure to air pollution (indoor and outdoor)	Yes	98 (86.7)	92 (100)	190 (92.6)	0.0002 (13.176, 1)
	No	15 (13.3)	0 (0.0)	15 (7.3)	
Family history of TB	Yes	18 (15.9)	31 (33.7)	49 (23.9)	0.003 (8.800,1)
	No	95 (84.1)	61 (66.3)	156 (76.0)	
Treatment category	Previously treated	11 (9.7)	24 (26.1)	35 (17.0)	0.00196 (9.577,1)
	New	102 (90.3)	68 (73.9)	170 (82.9)	
History of TB infection	Yes	16 (14.2)	33 (35.9)	49 (23.9)	0.0002 (13.141,1)
	No	97 (85.8)	59 (64.1)	156 (76.0)	
Type of TB	Pulmonary TB	74 (65.4)	72 (78.2)	146 (71.2)	0.0445 (4.0372, 1)
	Extra pulmonary tuberculosis	39 (34.5)	20 (21.7)	59 (28.7)	
Alcohol consumption	Yes	40 (35.4)	47 (51.0)	87 (42.4)	0.0237 (5.109, 1)
	No	73 (64.6)	45 (48.9)	118 (57.5)	
Any allergies due to air pollution exposure	Yes	6 (5.31)	15 (16.3)	21 (10.2)	0.0237 (5.109, 1)
	No	107 (94.7)	77 (83.7)	184 (89.7)	
H/O Medical treatment for respiratory illness in last 6 months	Yes	5 (4.4)	11 (12.0)	16 (7.8)	0.0455 (3.997, 1)
	No	108 (95.6)	81 (88.0)	189 (92.1)	
Weight loss	Yes	98 (86.7)	88 (95.6)	186 (90.2)	0.0283 (4.805, 1)
	No	15 (13.2)	4 (4.3)	19 (9.7)	
Age group of New TB Cases	< 40 years	45 (44.1)	41 (60.3)	86 (51.0)	0.0387 (4.271, 1)
	> 40 Years	57 (63.7)	27 (39.7)	84 (49.0)	
Effect of Air pollution in causing TB	Harmful	53 (46.9)	88 (95.6)	141 (70.2)	0.0387 (4.271, 1)
	Not harmful	60 (53.1)	4 (4.3)	64 (31.2)	
Use of tobacco products	Yes	59 (52.2)	58 (63.0)	117 (57.0)	0.1191 (2.4283, 1)
	No	54 (47.7)	34 (36.9)	88 (42.9)	

Table 4: Respiratory symptoms in TB patients from moderate and poor AQI Areas.

Variable	Age group	Moderate AQI (n=113) N (%)	Poor AQI (n=92) N (%)	Total (n=205) N (%)	P (χ2, df)
Cough	Yes	80 (70.0)	77 (79.4)	157 (74.1)	0.0300 (4.705, 1)
	No	33 (30.1)	15 (20.7)	48 (25.8)	
Duration of cough	<4 weeks	73 (91.1)	42 (53.9)	115 (72.8)	<0.00001 (26.975, 1)
	>4 weeks	7 (8.9)	35 (46.0)	42 (27.0)	
Cough with expectoration	Yes	75 (66.4)	74 (77.2)	149 (71.2)	0.0246 (5.051, 1)
	No	38 (33.6)	18 (22.8)	56 (28.7)	
Amount of sputum expectoration per day	<1 Teaspoon	34 (45.3)	8 (8.5)	42 (27.2)	0.000002 (21.930, 1)
	>1 Teaspoon	41 (54.7)	66 (83.1)	107 (72.7)	
Colour of sputum	Clear/ mucoid sputum	60 (80.0)	21 (26.8)	81 (54.1)	<0.00001 (40.008, 1)
	Coloured/blood-tinged sputum	15 (20.0)	53 (73.2)	68 (42.4)	
Haemoptysis	Yes	10 (8.9)	18 (19.6)	28 (13.6)	0.026 (4.937, 1)
	No	103 (91.2)	74 (80.4)	177 (86.3)	
Frequency of haemoptysis	Rarely (once a month or less)	9 (8.5)	13 (14.1)	22 (10.7)	0.2719 (1.2067,1)
	Multiple times a month	1 (0.9)	5 (5.4)	6 (2.9)	
Chest pain while coughing	Yes	26 (23.0)	52 (56.5)	78 (38.0)	<0.00001 (24.162, 1)
	No	87 (77.0)	40 (43.5)	127 (61.9)	
Dyspnoea	Yes	33 (29.2)	47 (51.1)	80 (39.0)	0.00139 (10.205,1)
	No	80 (70.8)	45 (48.9)	125 (60.9)	
Severity of dyspnea (mMRC Dyspnea scale)	Grade 0	21 (63.6)	6 (12.8)	27 (33.7)	0.000022 (24.294,3)
	Grade 1	6 (18.2)	30 (63.8)	36 (45.0)	
	Grade 2	5 (15.2)	10 (21.3)	15 (18.7)	
	Grade 3	1 (3.0)	1 (2.1)	2 (2.5)	

DISCUSSION

This study offers a comprehensive overview of the socio-demographic and environmental profile of TB patients in a heavily polluted district in Central India. It confirms that air pollution, both ambient and indoor, remains a significant contributor to TB burden. Similar to the findings of Yi-Jun et al, Esmaeil et al and Firdian et al, the data show that prolonged exposure to PM2.5, CO and other pollutants increases the risk of TB and its recurrence.[4,11,12] The higher number of pulmonary TB cases and retreatment cases in poor AQI areas further supports the role of pollution in exacerbating disease severity.

Demographically, our participants were predominantly male and middle-aged, aligning with trends reported by Saleem et al, Arup et al and Jitendra et al.[13-15] Most were from urban nuclear families and belonged to lower socioeconomic classes, consistent with studies by Khan et al, Tudu et al and Seong et al.[16-18] Occupationally, the majority were involved in manual or elementary work, placing them at greater risk due to increased exposure to dust and pollutants, as also shown by Zhongqi et al.[19] Housing and living conditions further highlighted vulnerability. A significant proportion lived in kacha houses, with overcrowding and limited ventilation known contributors to airborne TB transmission. These findings parallel those of Mishra et al, Bhat et al.[20-22] Notably, exposure to indoor air pollution was higher in homes using mixed fuels or lacking separate kitchens, echoing results from Colin et al and Patel et al.[10,23] While most participants were on treatment, a notable portion missed doses due to forgetfulness, side effects or access issues. Although direct links between air pollution and non-adherence are limited, factors like chronic illness and socioeconomic strain intensified by polluted environments may indirectly contribute, as discussed by Munro et al and Suparna et al.[24,25]

General and respiratory symptoms, such as persistent cough, sputum production, chest pain and dyspnoea, were more common in poor AQI areas. These findings are supported by Evangelopoulos et al and Olive et al, who reported similar symptom exacerbation in polluted settings.[26,27] Additionally, a greater proportion of participants in poor AQI areas reported past TB, family history of TB and co-existing conditions like diabetes and COPD all of which further elevate risk, as noted by Gupta et al, Prabhakaran et al and Amy et al.[28-30] Awareness about air pollution as a TB risk factor was low, with only 19.5% acknowledging a link. This calls for targeted health education, as emphasized by Nilesh S et al and Peggy A O et al.[31,32] Despite this, most patients expressed satisfaction with treatment, with responses comparable to findings by Ali et al and Periyasamy et al.[33,34]

In conclusion, this study reinforces the association between air pollution and TB, both in terms of incidence and treatment outcomes. Targeted interventions addressing environmental exposure and patient education may play a critical role in TB control efforts in high-pollution settings.

As a cross-sectional study, causal links between air pollution and TB outcomes cannot be established. Reliance on self-reported exposure and behaviour introduces potential recall bias and pollution assessment was based on regional AQI and housing conditions rather than individual monitoring. Comparisons were limited as no areas with 'Good' air quality were available and seasonal variations were not considered. The study was restricted to a single district, limiting generalizability, while nutritional assessment was confined to BMI and reported weight loss. Psychosocial aspects such as stigma and mental health were also not assessed. Despite these limitations, the findings emphasize the role of environmental factors in TB and support the need for longitudinal studies with more precise exposure assessment.

CONCLUSION

The present study demonstrates that air pollution is an important factor influencing the epidemiological and clinical profile of TB patients in Central India. Poor air quality, overcrowding, biomass fuel use and unhealthy lifestyle practices were found to aggravate disease severity and contribute to higher rates of comorbidities and recurrence. These observations emphasize that TB control efforts need to extend beyond medical management and address underlying environmental and social determinants.

Improving awareness about the role of air pollution, promoting the use of cleaner fuels, ensuring better housing and ventilation and reducing tobacco and alcohol use are essential steps. Targeted screening of high-risk groups in areas with poor air quality, along with strengthening adherence to treatment, can help reduce the burden of TB. Integrating environmental interventions with routine TB control strategies will be important for improving outcomes and achieving national and global TB elimination goals.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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