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Research Article

Effects of ambient air pollution on respiratory health of adults: findings from a cross-sectional study in Chandrapur, Maharashtra, India

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ABSTRACT

Background: Outdoor air pollution and continuous exposure to ambient air pollutants like particulate matter are among the leading contributors to adverse respiratory health outcomes all over the world. This association between air pollution and the impairment of respiratory functions is evident from number of epidemiological studies specific study has been conducted with an objective to evaluate the effects of ambient air pollution on respiratory symptoms and diseases of adults, in Chandrapur district of Maharashtra state in India.
Methods: Comparative cross-sectional quantitative study was undertaken in the Chandrapur district with two geographical locations – study and control between August-November 2013. The data included primary data collection from adults to assess the lung function among adults, spirometry test was used to assess lung function. 2400 adults were selected in this study. Epidemiological information was collected from them by administering structured tool (2400) and Lung function test through spirometry (1200). Data was analysed using frequency tables, crosstab analysis and chi-square test to show significance.
Results: Higher % of adults in study area (84.1%) had illness episodes (2-4 times or more than 4 times) compared to control area (78.3%). Statistically significant difference is observed in prevalence symptoms such as Dry Cough, Sneezing, Sore throat, Breathlessness and Asthma by Chi Square test between study and control groups. Statistically significant difference is observed in prevalence symptoms in Sore Throat, Sneezing, Wheeze and Breathlessness by Chi Square test between ≤ 5 km and >5km distance from the industry.
Conclusion: There is a significant effect of ambient air pollution on respiratory symptoms of adults with high prevalence of the symptoms in the study area which is the industrial area than the control area. Presence of multiple industries in or near the village is more harmful than the single industry. Additionally, it also shows that the presence of steel, cement and paper industry in or near a village has caused more ill-effects as compared to coal and thermal industry.

Keywords: Air pollution, Respiratory health, Disease, Adults, Chandrapur, Maharashtra, India

INTRODUCTION

The high levels of air pollution bring many challenges to public health. To further ameliorate adverse health effects attributable to air pollution, many more toxic pollutants may require regulation and control of industrial emission sources may need to be strengthened. Individual interventions based on personal susceptibility may be needed to protect health of the population while control measures are being implemented.[1]

The study area, Chandrapur is a district in the north-eastern part of Maharashtra has large natural deposits of coal, limestone, high grade iron-ore, bauxite and chromite which have triggered the growth of industries in the district by the Maharashtra industrial developmental corporation (MIDC). There has been a tremendous growth in the number of coal, cement and steel industries in Chandrapur over the years which have contributed to the growing economy of the district and the state.[2,3] there are a total of 6000 small and big scale industries in Chandrapur. Chandrapur city is also called as city of black gold because of the large number of coal industries in and around the city. There are a total of 35 coal mines (out of which 7 are in the city), mostly open cast in the city and surrounding areas, over half a dozen coal washeries, one large paper mill, sponge iron units and several cement industries. The Chandrapur Super Thermal Power Station (CSTPS) is one of the biggest thermal power stations in Asia, which is currently generating 2340 MW of electricity.[4]

Industrialization of such a scale has been responsible for very high levels of ambient air pollution in Chandrapur District. According to the Ministry of Environment and Forests (MoEF), Chandrapur is the most polluted city in Maharashtra and the 4th most polluted industrial cluster in India among the 88 key industrial clusters.[5] In terms of Respirable Suspended Particulate Matter (RSPM) pollution, Chandrapur is the most polluted city in India. The ambient levels of SO2 in Chandrapur are the third highest in India, and the National Aeronautics and Space Administration (NASA) has already warned of acid rains in Chandrapur in the future.[6] Apart from its harmful effects on vegetation and water quality, high levels of air pollutants emitted from the industries have a significant effect on human health, not only among people working in these industries but also among people living in the vicinity of these industries.[7] High levels of PM10, SO2 and NOx have been associated with adverse respiratory health particularly those associated with airways diseases such as COPD and asthma, and cardiovascular health such as ischemic heart disease, hypertension, systemic inflammation and diabetes mellitus (DM).[8]

According to the Ministry of Environment and Forests (MoEF), Chandrapur is the most polluted city in Maharashtra and the 4th most polluted industrial cluster in India among the 88 key industrial clusters. In terms of respirable suspended particulate matter (RSPM) pollution, Chandrapur is the most polluted city in India. The comprehensive environmental pollution index (CEPI) score for Chandrapur air quality was reported to be 70.75 by the MoEF, which represents critical levels of air pollution (score above 60 represents critical levels). Main industries include coal, thermal power stations, steel, paper and cement. Following Table 1 gives location and pollutants emitted from these industries. Five types of industries viz; coal, steel, thermal, cement and paper are present in various blocks in Chandrapur district. During different processes such as drilling, crushing, coke making, many gases, chemicals and dust particles are emitted causing air pollution.

According to the central pollution control board (CPCB), levels of air pollution in Chandrapur district are in the critical zone raising serious concerns of adverse effects on human health. Several questions raised by honourable members of the Maharashtra legislative assembly during the legislative assembly meetings regarding concerns of worsening health of people living in Chandrapur due to industrial air pollution need to be addressed so that appropriate intervention strategies can be adopted and implemented in the future. Therefore, government decided to do a cross-sectional study to assess the health effects of ambient air pollution on the local residents of Chandrapur. This study was commissioned by State health systems resource centre (SHSRC), Pune jointly with prognosis management and research consultants, Pune, Maharastra, India.

The main objective of the study was to determine prevalence of respiratory symptoms and diseases among adults living in Chandrapur District.

METHODS

It was an comparative cross-sectional quantitative study, was undertaken in the district with two geographical locations; study and control between August-November 2013. The study is jointly done by state health systems resource centre, (SHSRC) Pune and Prognosis Management and Research Consultants, Pune in the select blocks of the Chandrapur District (Ballarpur, Chandrapur, Korapana and Rajura). Study location was in the vicinity of industry and control location was more than 25 km from any of the industries. Quantitative data included primary data collection from adults. As this was the study of assessing health effects of ambient air pollutions, adults working in the specified industry were excluded.

Primary data used in study was among adults, to assess lung function, spirometry was done and readings were recorded. The laboratory of the district hospital was used for testing. The informed consent was obtained from the participants.

Sampling was done by Industrial (study) and non-industrial (control) areas which were: One Factory each from power plant, coal mines, cement, paper and steel industry was first identified on the basis of maximal population density within radius of 40 km from the factory in Chandrapur district. The selected regions were then subdivided into radius of 1-5 km, 5-10 km, 10-20 km, 20-30 km, 30-40 km and >40 km = was included in non-industrial area. Based on this criterion, the sample was divided in eleven villages in study area and three villages in control area. Also, these locations were confirmed on consultation with local health functionaries during meeting held before commencement of field work in Chandrapur.

Table 1: A glance of industrial blocks (areas) and village wise distribution of industries.

Name of block	Name of village/city	Type of industry in the village/vicinity
Ballarpur	Visapur	Coal
Ballarpur	Kothari	Coal
Ballarpur	Ballarpur	Coal, Paper
Ballarpur	Bamani	Coal, Paper
Chandrapur	Chandrapur	Coal, Steel, Thermal
Chandrapur	Durgapur	Coal, Steel, Thermal
Chandrapur	Tadali	Coal, Thermal
Chandrapur	Sakharwahi	Coal, Cement
Chandrapur	Pandharkawda	Coal
Chandrapur	Usegaon	Coal
Korapana	Gadchandur	Cement
Rajura	Rajura	Cement, Coal

Table 2: Types of industries present in Chandrapur district and the pollutants emitted by these industries.[9,10]

Type of industry	Location/block	Function /processes and type of air pollutant emitted
Coal	Chandrapur, Ballarpur, Rajura	drilling, crushing, screening, blasting, coal washing- dust, NOx, SO_2, CO, SPM
Steel	Chandrapur	Coke making-coke oven gas, naphthalene, ammonium compounds, NOx, sulfur and coke dust Iron making- Sulfur dioxide and hydrogen sulfide
Cement	Chandrapur, Korapana, Rajura	Pet coke or coal- PM2.5, PM10, SO_2, NO_x, Calcinations- CO2 and CO
Paper	Ballarpur	SPM, H2S, SO_2, CO, Chloroform
Thermal	Chandrapur	SO_2, NO_x, CO_2

Huge amount of dust or particulate matter is generated in cleaning and milling sections in a rice mill.[11] However there is no mechanism to measure the amount of emitted particulate matter. Additionally the MPCB pollution monitoring site is not established at Mul block. Therefore effect of the air pollution caused due to rice mills on the health of people in this block cannot be measured.

The sample size was determined for adults upon considering lowest prevalence of respiratory disease. Asthma being the lowest prevalent respiratory disease its respective prevalence value for adults was taken as ‘P’ in sample size calculation. This also meant coverage of larger population and other diseases. Thus, prevalence of asthma for adult population is considered for respective sample size calculation.

Table 3: Control site: areas free of industry (control), Mul Block (3 villages of this block).

Name of village	Type of industry			
	Rice mill	Oil mill	Poha mill	Power company
Rajoli	6	-	-	-
Chikhali	1	-	-	-
Dongargaon	-	-	-	-

Prevalence of this age group is 2.4% as per the ICMR study. For this group L is taken as 40% of p to allow more variation.

Formula for sample size calculation is:

$$\text{Sample size n} = \frac{4 * p * q}{L * L}$$

Where, p = prevalence of disease

q = 1 – p

L = allowable error in p = taken as 30% of p

Using the above formula, we get the sample size = n = 1017.

This group had to undergo the blood investigations, the drop-out rate of 10% was considered and sample size was 1118 by adding 10%. This was being rounded to 1200. So, this sample was covered from study and equal number was covered from control area as well. Total adult sample was 2400.

Adult sample distribution for epidemiological information and diagnostics:

- Epidemiological information= 2400
- Lung Function Test through Spirometry=1200

Sampling strategy: From every alternate house-hold one female within reproductive age and one elderly not working male was selected for the study.

Sample for patients from practitioners: Total sixteen of twenty identified practitioners participated in this study and recorded information of patients based on the tool provided. Progressive patient data from practitioners (16 practitioners) recorded patient data over 45 days (4800)

Interviews and diagnostics of target population: We have selected 2400 adults. Epidemiological information was collected from them by administering structured tool (2400) and Lung Function Test was done through Spirometry (1200).

Human Resources: Appropriate human resources were deployed for implementing the study. These included public health specialists, clinical specialists, air pollution specialist, social scientists, and auxiliary nurse midwives.

Ethics: Purpose and importance of the study was explained to the individuals. Informed consent was obtained. Signed consent forms are collected back. Individuals were assured that participation in the study was complete voluntarily and participant can withdraw from study at any stage of study. The confidentiality about the identification details of the individuals was maintained.

Data collection of data for the study is done in various steps which includes Training of all the data collectors was conducted prior to commencement of data collection. Data was collected in the following manner:

Adult epidemiological data and blood: auxiliary nursing midwives (ANMs) or lady health visitors (LHVs) of the primary health centre/sub-centre present in the village collected the epidemiological data using a structured tool. Questions related to demographic profile, clinical manifestations including number of illness episodes in last one year, type of illness, system wise presence of symptoms at the time of study were asked. Height and weight of each participant was measured.

Adult spirometry data Fifty per cent of the sample was taken for lung function assessment. Spirometry was conducted by social scientists with prior training. RMS Helios 3.1.85 spirometers were used, which were calibrated every day before use. The respondent was explained the procedure and then asked to perform the spirometry test five times. Best of these five readings was recorded.

Progressive data of clinics: Data from patients attending private clinics was recorded with the help of sixteen practitioners from the study as well as control area. Following table 4 shows the overall sample distribution of primary data and patients' progressive data from private clinics.

Data Entry and analysis includes: collected data which was entered using epi-info software. Exported data from epi-info, imported to SPSS and statistical analysis of collected quantitative primary and secondary data was done using statistical software SPSS Statistics 17.0. Appropriate statistical tools and tests were used to compare the results. The analysis included:

- Descriptive statistics
- Inferential statistics
- Application of Test of Significance

Table 4: overall sample distribution of primary data and patients' progressive data from private clinics.

Name of village	Adult epidemiological	Spirometry	Patients' data at Private clinics
Study			
Durgapur (200)	225	113	300
Tadali (133)	150	78	690
Sakharwahi (133)	150	75	
Urjagram (135)			
Usegaon (100)	113	57	
Pandharkawada (100)	113	57	170
Visapur (36)	80	40	150
Kothari (36)	80	40	300
Bamni (40)	100	50	220
Ballarpur (40)	100	51	
Rajura (25)	150	75	300
Gadchandur (25)	120	61	120
Control			
Rajoli (333)	340	170	3330
Dongargaon (333)	340	172	
Chikhali (335)	341	171	530
Total	2402	1210	6110

RESULTS

To observe the effects of air pollution in different age groups, adults (more than 18 years) were included in the study. As the study focused on effects of ambient air pollution on health, those working in any of the industries were not included in the study.

Clinical manifestations of the study

Following tables present clinical manifestations amongst adults from study and control areas.

Table 5: Mean BMI with respect to study and control area.

Area	Study(n=1271)	Control(n=984)
Mean	21.52	20.38
Std. Deviation	3.91	3.78

The table 5 above shows that the mean BMI of the populations in study and control area are almost similar.

Hence the clinical parameters of these two groups can be compared.

Higher % of adults in study area (84.1%) had illness episodes (2-4 times or more than 4 times) compared to control area (78.3%).

Higher % of adults in study area (19.4%) reported dry cough compared to control area (10.3%). Higher % of adults in study area (6.1%) reported productive cough compared to control area (3.0%). Higher % of adults in study area (8.3%) reported night cough compared to control area (6.1%).

Higher % of adults in study area (14.6%) reported sneezing compared to control area (6.8%). Higher % of adults in study area (14.1%) reported sore throat compared to control area (5.4%).

Higher % of adults in study area (8.0%) reported wheeze compared to control area (1.5%). Higher % of adults in study area (16.0%) reported chest pain/ tightness compared to control area (13.2%).

Table 6: Number of illness episodes with respect to area.

Category	Area		Total
	Study	Control	
Never	213 (15.9%)	218 (21.7%)	431 (18.4%)
2-4 times	891 (66.7%)	574 (57.2%)	1465 (62.6%)
More than 4 times	232 (17.4%)	212 (21.1%)	444 (19.0%)
	1336 (100.0%)	1004 (100.0%)	2340 (100.0%)

Table 7: Respiratory symptoms found in the study and control area in the sample.

Symptom/ disease	Area			Distance between home and industry within Study Group		
	Study n=1335 Number (Percentage)	Control n=1004 Number (Percentage)	P-value	<5km n=1070 Number (Percentage)	>5km n=265 Number (Percentage)	P-value
Dry Cough	259 (19.4)	103 (10.3)	0.000*	208 (19.4)	51 (19.2)	0.943
Productive Cough	81 (6.1)	30 (3)	0.001*	68 (6.4)	13 (4.9)	0.376
Night Cough	111 (8.3)	61 (6.1)	0.041*	87 (8.1)	24 (9.1)	0.622
Continuous Sneezing	195 (14.6)	68 (6.8)	0.000*	185 (17.3)	10 (3.8)	0.000*
Sore Throat	188 (14.1)	54 (5.4)	0.000*	178 (16.6)	10 (3.8)	0.000*
Wheeze	107 (8)	15 (1.5)	0.000*	104 (9.7)	3 (1.1)	0.000*
Chest Pain	214 (16)	133 (13.3)	0.060	173 (16.2)	41 (15.5)	0.777
Breathlessness	185 (13.9)	47 (4.7)	0.000*	171 (16)	14 (5.3)	0.000*
COPD	13 (1)	9 (0.9)	0.811	12 (1.1)	1 (0.4)	0.264
Asthma	105 (7.9)	42 (4.2)	0.000*	95 (8.9)	10 (3.8)	0.006*
Tuberculosis	6 (0.5)	1 (0.1)	0.126	5 (0.5)	1 (0.4)	0.842
LRTI - Pneumonia	7 (0.5)	0 (0)	-	7 (0.7)	0 (0)	

Both sites had stray cases of tuberculosis. Higher % of adults in study area (12.1%) reported breathlessness compared to control area (3.3%). Study area reported 7 cases of LRTI. Control area reported none. Higher % of adults in study area (7.9%) reported asthma compared to control area (4.2%). Small % of respondents both, in study and control areas reported COPD. Higher % of adults in study area (2.6%) reported IHD compared to control area (0.3%). Higher % of adults in study area (10.9%) reported hypertension compared to control area (6.0%). Higher % of adults in study area (12.9%) had skin problems compared to control area (8.3%). Higher % of adults in study area (14.1%) reported ocular infections compared to control area (8.1%). Similar % of respondents who stayed less than 5 km or more than 5 km from industry reported presence of dry cough.

Higher % (6.4%) of adults in study area who stayed less than 5 kms from industry reported productive cough as compared to adults (4.9%) who stayed at a distance of more than 5 km from industry. Almost similar % of respondents who stayed less than 5 km or more than 5 km from industry reported presence of night cough. Higher % (17.3%) of adults in study area who stayed less than 5 kms from industry reported continuous sneezing as compared to adults (3.8%) who stayed at a distance of more than 5 km from industry. Higher % (16.6%) of adults in study area who stayed less than 5 kms from industry reported sore throat as compared to adults (3.8%) who stayed at a distance of more than 5 km from industry. Higher % (9.7%) of adults in study area who stayed less than 5 kms from industry reported productive cough as compared to adults (1.1%) who stayed at a distance of more than 5 km from industry. Almost similar % of respondents who stayed less than 5 km or more than 5 km from industry reported presence of night cough. Higher % (16.0%) of adults in study area who stayed less than 5 kms from industry reported breathlessness as compared to adults (5.3%) who stayed at a distance of more than 5 km from industry. Higher % (8.4%) of adults in study area who stayed less than 5 kms from industry reported asthma as compared to adults (2.7%) who stayed at a distance of more than 5 km from industry. COPD was negligible in both areas.

Statistically significant difference is observed in prevalence of following symptoms between study and control groups:

- Dry Cough: 19.4% in Study and 10.3% in Control, p=0.000 Significant by Chi Square test
- Sneezing: 14.6% in Study and 6.8% in Control, p=0.000 Significant by Chi Square test

- Sore throat: 14.1 in Study and 5.4% in Control, p=0.000 Significant by Chi Square test
- Breathlessness: 13.9 in Study and 4.7% in Control, p=0.000 Significant by Chi Square test
- Asthma: 7.9 in Study and 4.2% in Control, p=0.000 Significant by Chi Square test

Statistically significant difference is observed in prevalence of following symptoms between ≤5 km and > 5km distance

- Sore Throat: 16.6% in ≤5 km and 3.8% in >5 km, p=0.000 Significant by Chi Square test.
- Sneezing: 17.3% in ≤5 km and 3.8% in >5 km, p=0.000 Significant by Chi Square test.
- Wheeze: 9.7% in ≤5 km and 1.1% in >5 km, p=0.000 Significant by Chi Square test.
- Breathlessness: 16.0% in ≤5 km and 5.3% in >5 km, p=0.000 Significant by Chi Square test.

Above table 8 shows that the presence of respiratory symptoms is higher in the villages with multiple industries as compared to villages with single industry.

Also the presence of cement and thermal industry showed higher percentage than other industries.

- The association of respiratory symptoms was assessed with respect to six MPCB monitoring sites. As the levels of pollutants were lower at Chandrapur SRO and Chandrapur MIDC sites, the villages under these two sites were grouped together in one group and the remaining villages into other group.

Table 8: Village wise prevalence of respiratory symptoms in study area.

Name of the Town	Symptoms							
	Dry Cough	Productive Cough	Night Cough	Sneezing/ nasal irritation	Sore Throat	Wheeze	Breathlessness	Asthma
Ballarpur	10 (16.9)	4 (6.8)	7 (11.9)	20 (33.9)	25(42.4)	8 (13.6)	28 (47.5)	2 (3.4)
Bamani	3 (3.0)	4(4.0)	0(0)	1(1.0)	0 (0)	0 (0)	1 (1.0)	4(4.0)
Durgapur	53 (24.2)	21 (9.6)	22 (10.0)	89 (40.6)	70 (31.8)	51(23.2)	59 (26.9)	31(14.2)
Gadchandur	27 (22.5)	9 (7.5)	21 (17.5)	21 (17.5)	19 (15.8)	10 (8.3)	22 (18.5)	16 (13.6)
Kothari	12 (15.0)	8 (10.0)	10 (12.5)	1 (1.3)	2 (2.5)	1 (1.3)	1 (1.3)	2 (2.5)
Pandharkawda	6 (5.5)	2 (1.8)	0 (0.0)	2 (1.8)	1 (0.9)	3 (2.7)	3 (2.7)	4 (3.6)
Rajura	25 (16.3)	1 (0.7)	14 (9.2)	6 (3.9)	8 (5.2)	0 (0.0)	5 (3.3)	7 (4.6)
Sakharwahi	46 (30.5)	13 (8.6)	16 (10.6)	29 (19.3)	34 (22.5)	28 (18.5)	32 (21.2)	14 (9.3)
Tadali	56 (36.1)	10 (6.5)	10 (6.5)	14 (9.0)	15 (9.7)	3 (1.9)	19 (12.3)	14 (9.0)
Usegaon	10 (9.3)	4 (3.7)	2 (1.9)	4 (3.8)	5 (4.7)	0 (0.0)	0 (0.0)	3 (2.8)
Visapur	11 (13.8)	5 (6.3)	9 (11.3)	8 (10.0)	9 (11.3)	3 (3.8)	15 (18.8)	8 (10.0)

Percentages are given in brackets.

Following table 9 shows the association of respiratory symptoms at these six sites.

Table 9: Site wise distribution of respiratory symptoms.

Symptom	MPCB monitoring site	
	Chandrapur SRO+ Chandrapur MIDC	other MPCB sites
Dry Cough	65 (21.7%)	194 (18.7%)
Productive Cough	29 (9.7%)	52 (5.0%)
Night Cough	32 (10.7%)	79 (7.6%)
Continuous Sneezing / nasal irritation	90 (30.1%)	105 (10.2%)
Sore Throat	72 (24.0%)	116 (11.2%)
Wheeze	52 (17.3%)	55 (5.3%)
Breathlessness	60 (20.1%)	125 (12.1%)
Asthma	33 (11.0%)	72 (7.0%)
COPD	4 (1.3%)	9 (0.9%)

Prevalence of respiratory symptoms as reported is seen higher at Chandrapur SRO and MIDC monitoring sites as compared to other MPCB monitoring sites. The reason for this can be given as presence of three industries in or near a village

Diagnostic findings in adults includes

Spirometry: Pulmonary function test (PFT) is an important means for the estimation of pulmonary function, which can be comparable to the ECG for heart. Pulmonary function test is also used to monitor the status of patients with chronic obstructive lung diseases. In clinical practice, spirometry is helpful for the overall assessment of pulmonary function and is associated with the PFT. , Spirometry is a physiological test that measures how an individual inhales or exhales volumes of air as a function of time. The basic measure in spirometry may be volume or flow.

Forced Vital Capacity (FVC) is the maximum volume of air exhaled with utmost forced effort from a highest inspiration, i.e. vital capacity performed with a maximally forced expiratory effort, expressed in litres at body temperature and ambient pressure saturated with water vapour.

Forced Expiratory Volume in 1 second (FEV1) is the maximum volume of air exhaled in the first second of a forced expiration from a position of full inspiration, expressed in litres at body temperature and ambient pressure saturated with water vapour.

The FEV1 is reduced in both obstructive and restrictive lung disease. The FEV1 is reduced in obstructive lung disease because of increased airway resistance. It is reduced in restrictive lung disease because of the low vital capacity.

FEV1/FVC is the percentage of the vital capacity which is expired in the first second of maximal expiration. In patients with obstructive lung disease FEV1/FVC decreases. Restrictive disorders have a near normal FEV1/FVC.

In obstructive lung disorders the forced expiratory volume in 1 second (FEV1) is usually decreased, the forced vital capacity (FVC) is usually normal and the ratio FEV1/FVC is decreased.[12]

Following formulae were used for predicted values of FEV1 and FVC.

Table 10: Formulae for predicted values of pulmonary function tests.[13]

Parameter	Sex	Formula	Standard error of estimate
FVC	Male	-3.44 - 0.013A - 0.00005A2 + 0.048H	0.497
	Female	-2.05 - 0.014A - 0.00004A2 + 0.035H	0.447
FEV1	Male	-1.90 - 0.025A + 0.00006A2 + 0.036H	0.417
	Female	-1.07 - 0.030A + 0.00013A2 + 0.027H	0.323

A= age in years, H= height in cm.

Following values were taken for categorization of FEV1.[14]

FEV1/FVC% deviation- Normal ≥80%, Abnormal <80%.

Following tables present diagnostic findings amongst adults from study and control areas as well as with respect to distance of home from industry within study area.

Significant difference is seen between abnormal FEV1/FVC % in study and control area.

Findings of data from private practitioners: Progressive data of patients attending private clinics was recorded with the help of practitioners from the study as well as control area.

Out of twenty practitioners opted for the study, four practitioners did not participate, out of which two were from study area and two from control area.

Number of patients coming to private practitioners is comparatively less than in the control area. This could be because of the fact that, in study area, majority of them could be accessing the industry run health facilities.

Table 11: Pulmonary function tests with respect to area and distance.

Area				Distance between home and industry within Study Group		
Symptom/ disease	Study n=720 Number Percentage	Control n=490 Number Percentage	Statistical Test result (p-value)	<5 km n=583 Number Percentage	> 5km n=136 Number Percentage	Statistical Test result (p-value)
Abnormal FEV1/FVC % deviation	49 (6.8)	19 (3.9)	0.030 Significant	32 (5.5)	17 (12.5)	-

Table 12: FEV1/FVC % deviation with respect to respiratory symptoms.

Symptom/disease	FEV1/FVC % deviation		p-value
	Abnormal	Normal	
Dry cough	11 (5.70%)	182 (94.30%)	0.892
Productive cough	5 (9.09%)	50 (90.91%)	0.231
night cough	8 (8.70%)	84 (91.30%)	0.160
Continuous sneezing	6 (4.51%)	127 (95.49%)	0.625
sore throat	10 (7.81%)	118 (92.19%)	0.205
wheeze	4 (5.97%)	63 (94.03%)	0.862
Chest pain	19 (11.11%)	152 (88.89%)	0.001
Breathlessness	14 (12.39%)	99 (87.61%)	0.001
Asthma	9 (10.84%)	74 (89.16%)	0.027
COPD	1 (7.69%)	12 (92.31%)	0.716

Following table 13 present findings of progressive data from practitioners.

Table 13: Respiratory symptoms found in the data from practitioners.

Symptom	Area			Distance between home and industry within Study Group		
	study	control	Statistical Test result (p-value)	<5km	>5km	Statistical Test result (p-value)
Dry cough	165 (25.90%)	417 (23.30%)	0.19	226 (25.7%)	17 (25.4%)	.951
Productive cough	76 (11.90%)	138 (7.70%)	0.001*	166 (18.9%)	9 (13.4%)	0.266
Night cough	18 (2.80%)	73 (4.10%)	0.152*	68 (7.7%)	5 (7.5%)	.934
Rhinitis	194 (30.50%)	255 (14.30%)	0.000*	265 (30.2%)	9 (13.4%)	.004
Sore throat	90 (14.10%)	96 (5.40%)	0.000*	98 (11.2%)	3 (4.5%)	.222
Wheeze	7 (1.10%)	57 (3.20%)	0.005*	30 (3.4%)	0(.0%)	.124
Chest pain	8 (1.30%)	55 (3.10%)	-	27 (3.1%)	0 (.0%)	.145
Breathlessness	12 (1.90%)	47 (2.60%)	0.295	19 (2.2%)	0 (.0%)	.224
Asthma	9 (1.40%)	30 (1.70%)	0.648	22 (2.5%)	1 (1.5%)	.604
COPD	5 (0.80%)	25 (1.40%)	0.229	8 (.9%)	0 (.0%)	.433

(* denotes significant p value)

This statement is supported by the number of cases coming in a period of 1 month to practitioners in these areas.

Statistically significant difference is observed in prevalence of following respiratory symptoms between study and control groups:

- Productive Cough: 11.9% in Study and 7.7% in Control, p=0.001 Significant by Chi Square test.
- Rhinitis: 30.5% in Study and 14.3% in Control, p=0.000 Significant by Chi Square test.
- Sore throat: 14.1% in Study and 5.3% in Control, p=0.000 Significant by Chi Square test.
- Breathlessness: 15.5% in Study and 2.1% in Control, p=0.000 Significant by Chi Square test.
- Eye irritation: 3.8% in study and 1.4% in control, p=0.000 Significant by Chi Square test.

Within study group, following symptoms showed statistically significant difference for distance less than 5Km and more than 5Km between home and industry.

- Rhinitis: 30.2% in less than 5Km and 13.4% in more than 5Km, p=0.004 Significant by Chi Square test.

DISCUSSION

Among all the various population groups studied type II Prevalence of respiratory symptoms of this study was compared with the prevalence of study sponsored by ICMR - Jindal SK. Indian study on epidemiology of Asthma, Respiratory symptoms and chronic bronchitis (INSEARCH), September 2010. The INSEARCH study also recorded the prevalence of symptoms, as reported by the respondents, as was done for the current study.[15] The prevalence of respiratory symptoms is significantly higher in Chandrapur compared to the Nagpur district and national figure. This definitely shows that, the health effects of ambient air pollution are visible at symptomatic level and for Asthma. If necessary steps are not taken at right time, the conditions may worsen.

Various studies have shown association between high levels of both gaseous and particulate air pollutants and increased morbidity and mortality due to respiratory and cardiovascular diseases. The exact mechanism though unknown, probable reasons for this can be consistent inflammation and haemostasis caused by these pollutants. Continued exposure to these pollutants may lead to synthesis of inflammatory biomarkers such as C-reactive protein and also can have impact on normal liver and kidney physiology.[17] Also studies have confirmed that chronic exposure to SO2 may lead to chromosome aberrations (CA), sister chromatid exchanges (SCE) and micronuclei (MN) in peripheral blood lymphocytes and bone marrow depression.[18-20]

There are 2 reported studies that have examined the health status of people living in the industrial areas of Chandrapur district, one by the MoEF and one by the MPCB. The pilot study reported by MoEF was conducted by GMC Nagpur and compared the health status of people living in 2 urban areas (Babupeth and Tikum) with relatively higher levels of ambient air pollution, and one control area (Brahmapuri). They reported no differences in health outcomes between the two study sites. The other study reported by the MPCB was conducted by the District Health Officer, who concluded that the diseases noted by them could not be attributed to pollution alone and that the effects of air pollution on health needed to be ascertained further. In July 2001, the Bharatiya Adimjati Sevak Sangh along with the Collectors office in Chandrapur conducted a health survey of 3000 people from 5 study villages (villages in the vicinity of industries) and 2 control villages in Chandrapur(villages away from the industries). This study which was funded by the coal mine company (Western Coal Fields Limited) and executed by GMC Chandrapur and GMC Nagpur reported no significant variation between control and target population.[21]

Table 14: The hazards of these air pollutants on health and suggested strategies to reduce the emission of these air pollutants are given below.[16]

Pollutant	Effect on health	Reduction strategies
SO2	Reduced respiratory capacity, inflammation of respiratory tract, aggravation of asthma, eye irritation	Reduction of source emission
NOx	Airway inflammation, reduced lung function, bronchitis in asthmatics	Reduction of source emission
RSPM	Cardiovascular and respiratory diseases including lung cancer,	Reduction of source emission, utilization of fly ash for construction etc., water treatment for settlement of particulate matter on ground

CONCLUSION

Exposure to a mixture of air pollutants associated with adverse respiratory health of the adults living in the industrial areas of the district.

Clinical manifestations of the study includes: Presence of multiple industries in or near the village is more harmful than the single industry. Additionally, it also shows that the presence of steel, cement and paper industry in or near a village has caused more ill-effects as compared to coal and thermal industry.

This definitely shows that, the health effects of ambient air pollution are visible at symptomatic level and for Asthma. If necessary steps are not taken at right time, the conditions may worsen.

The presence of five types of industries and the transport of products from these industries have made the district vulnerable for exposure to air pollution for many years. The data from six pollution control board monitoring sites shows that population in the district is exposed to high levels of air pollutants, both gaseous as well as particulate matter. Since the monitoring site measures the air pollutants at the level of their source of emission (chimneys of factories), actual levels of these pollutants at ground level are not available. Though the levels of gaseous air pollutants SO2 and NOx are seen to be within standard limits set by national air quality guidelines, the effect of these pollutants can be observed because of chronic exposure. Concentration of particulate matter is much higher than the standard values, almost two to three times at most of the monitoring sites. Presence of cement, paper, steel industry or multiple industries in a village has shown higher levels of RSPM and SPM. There is no mechanism established at these monitoring sites to record levels of carbon monoxide (CO) or PM2.5 in the ambient air.

High prevalence of allergic dermatological and ophthalmic symptoms is observed, which can be associated with chronic exposure to air pollutants. Low prevalence of lung cancer or skin cancer is found, however according to district health authorities, number of reported cases has been increased than earlier years. Though the diseases of respiratory system such as asthma or COPD show low prevalence, the symptoms which can be primitive to these diseases are far above the ground.

The progressive data at private clinics also supports the findings of adult data collected with the help of questionnaires. Higher prevalence of respiratory and cardiovascular symptoms is seen in study area than that in control area. However, since the workers in these factories are more likely to avail treatment from the industry-run hospitals, there is possibility that the actual extent of these problems can be more than is reported at these clinics.

The prevalence of respiratory symptoms as reported by the participants is much higher as compared to prevalence at national level or in the neighbouring district. The relative risk of getting these symptoms is also higher by manifolds. Hence there is an immense need of preventive action to be taken against the causes of air pollution along with regular monitoring of air pollution.

Various Recommendations of the study were:

- Strengthening of source emission monitoring is necessary.
- Strengthening of air quality monitoring network- Levels of PM2.5, CO and CO2 gases should also be recorded along with the presently monitored SO2, NOx and RSPM as these gases are also equally harmful to health.
- Proper mechanism for enforcement and compliance of regulations related to pollution should be built.
- Bypass road should be built for truck transport, and also the transport of industrial products should be done in closed trucks.
- Sentinel Surveillance Centres should be established by Public Health Department wherein, the equipment's like Spirometer and Flow-meter used for the current study should be part of these Sentinel Centres. The Centres will act as Centres of Excellence. The role of these Sentinel Centres is proposed below.

Sentinel Surveillance Centres:

The foremost need of the hour is to establish Sentinel Surveillance Centres at the public health facilities where the MPCB monitoring sites are located i.e. Chandrapur SRO, Chandrapur MIDC, Tadali MIDC, Ghuggus, Ballarshah and Rajura.

Thus, Centres should be established at following facilities- 1.General Hospital, Chandrapur, 2.Primary Health Centre, Durgapur, 3. Primary Health Centre, Tadali, 4. Primary Health Centre, Ghuggus, 5. Rural Hospital, Ballarshah and 6. Rural Hospital, Rajura..

These Centres shall work as “Centre of Excellence” in the district. These Centres should impart promotive, preventive and curative services.

- Target population: Population in the catchment area of 6 health facilities should be the target population. Cases identified in the study for respiratory symptom & diseases and cardio-vascular symptoms & diseases should be treated and followed up in these centres.
- Local NGOs: Local NGOs should be involved in the activity and their help/ support should be taken for following up the cases.
- Awareness creation and prevention measures: This centre should bring all 5 stakeholders together; namely: Public Health Department, MPCB, NGOs, Industries and Community. Every stakeholder will be enrolled in awareness activities. Community will be made aware about early signs of these symptoms and will be encouraged to take treatment on time.
- Clinical Role: These Centres should provide treatment to all the cases that come with respiratory symptoms & diseases. I.e. dry cough, night cough, productive cough, sore throat, wheeze, sneezing like

symptoms should be treated and monitored as they are precursors to the respiratory diseases Asthma and COPD. Similar, Cardiovascular symptoms & diseases will be treated and monitored here. I.e. hypertension, chest pain will be treated and monitored as they are precursors to the cardiovascular diseases. Other diseases or symptoms which should be monitored are ophthalmic problems (redness of eyes, eye infections) and skin problems (itching, eczema).
- Regular supply of medicines for all these symptoms and diseases should be ensured. These centres should also maintain case-wise record of all these diseases and should make its use for planning and further improving health status.

Moreover, these Centres should function as observation and monitoring mechanism for the health outcome of the people residing in the vicinity of industries with respect to changes in air pollution levels.

Although the association with known air pollutants is suggestive, a cross-sectional study cannot confirm a causal relationship and further studies are needed to determine the exposure- effect relationship between individualized air pollution exposure and various adverse respiratory effects. The sample from the current study should be taken as cohort for continued observation and monitoring; along with the cases of possible ill-effects of air pollution detected in all health facilities, including government hospitals and industry-run hospitals in the vicinity of industrial areas. Regular health check-up of these cases should be done in conjunction with pulmonary function tests, ECGs and blood tests if required.

Specific functions should include:

1. Capacity building of Doctors and paramedics
- For detection of illnesses/diseases due to air pollution.
- For monitoring and reporting certain parameters and illnesses related to air pollution,
- For preventive measures to be taken by the people for these effects
- Process of reporting cases showing effects of air pollution
2. Follow up of participants in the study, showing unfavourable health effects of air pollution as well as cases reported by the health facilities in the nearby areas
3. Periodic check-up and investigations of this cohort for the effects of air pollution
4. Advice promotive and preventive measures through awareness such as use of cloth around mouth and nose, nutrition and hygiene, conversion of coal-chulhas to non-coal chulhas to patients showing pre-disease condition or minimal effects.

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