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ANALYSIS OF SEASONAL VARIATION IN PARTICULATE MATTER AND RELEVANT POLLUTANTS FOR THREE STATIONS OF ANDHRA PRADESH (INDIA) DURING THE PERIOD (2018-2020) USING MULTIVARIATE REGRESSION ANALYSIS

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ABSTRACT. Collocated particulate matter concentration data of three stations Visakhapatnam, Amaravathi and Tirupathi belonging to state of Andhra Pradesh in India was analysed for the period $2018-2020$. These stations were selected based on their geographical, demographical and industrial conditions. Regression analysis was done by taking PM2.5 and PM10 as dependent and $\mathcal{NO}, CO, SO2, O3, T$ (Temperature) and RH(Relative Humidity) as independent variables for all three stations along with analysis of seasonal variation. The observed average values of PM2.5 and PM10 concentrations are 84.84 $\mu g/m^3$ and 106.52 $\mu g/m^3$ for Visakhapatnam followed by 34.99 $\mu g/m^3$ and 71.98 $\mu g/m^3$ for Amaravathi follwed by 24.96 $\mu g/m^3$ and l57.01 $\mu g/m^3$ for Tirupathi between January 2018 to September 2020. The observed mean values of PM2.5 and PM10 concentrations for Visakhapatnam are 73.37 $\mu g/m^3$ and 146.52 $\mu g/m^3$ during winter, 29.7 $\mu g/m^3$ and 90.48 $\mu g/m^3$ during summer and l35.11 \$$\mu g/m^3$ and 93.00 $\mu g/m^3$ during monsoon. Their values for Amaravthi are 61.42 $\mu g/m^3$ and 108.28 $\mu g/m^3$ during winter, 20.07 $\mu g/m^3$ and 63.19 $\mu g/m^3$ during summer and 18.37 $\mu g/m^3$ and 45.55 $\mu g/m^3$ during monsoon. Similarly for Tirupathi these values are 39.65 $\mu g/m^3$ and 73.07 $\mu g/m^3$ during winter, 29.22 $\mu g/m^3$ and 63.08 $\mu g/m^3$ during summer and 15.11 $\mu g/m^3$ and 47.07 $\mu g/m^3$ during monsoon. These observations indicate higher particulate matter concentration during winter season. Summer concentrations should be minimum but slightly more than monsoon which might be due to COVID-19 lock-down during 2020 summer.

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Key words and phrases. Regression Analysis, PM2.5, PM10, NO, NO2, SO2, CO, O3, Temperature, Relative Humidity.

1. Introduction

India being the rapid developing country with big population, urbanization and huge industrialization that led to severe enhancement in traffic pollution as well as industrial pollution in addition to other regular emissions. This impacts local environment affecting human health [1]. Many reports world wide indicated the affect of particulate matter on surrounding environment as well as human health on global scale [2]. Monitoring and analysis of PM concentrations for eight Chinese stations indicated that PM2.5/PM10 ratios decreased from southeast to northwest depending on different industries and other developments in that region. High values were reported during winter season for all the regions of study particularly weekends recorded high values than normal weekdays in majority regions [3]. The concentration of PM2.5 show declining trend in USA since the year 2000 on implementation of several precautionary measures [1]. Padoan E et.al., 2016 reported [4] that PM10 concentration injects harmful chemicals into human respiratory system affecting blood vessels, heart and other immune systems. Reshmi Das et.al., 2015 [5] measured winter concentrations of PM2.5 and PM10 for sixteen locations in Kolkata(India) during 2013 and 2014 and reported huge increase in concentration from $83\mu g/m3 - 783\mu g/m3$ for year 2013 and $167\mu g/m3 - 928\mu g/m3$ for year 2014 through modelling. Since winter season affects more on human respiratory system seasonal analysis of particulate matter concentration may lead to significant output. Millions of people are reported to die due to air pollution [6]. Keeping this in view statutory body of Indian Government, Central Pollution Control Board (CPCB) fixed the values of PM10 as $100\mu g/m3$ (daily limit) and $60\mu g/m3$ (annual limit) through out India [7]. However, continous industrial and vehicular emissions enhance PM10 above CPCB levels in maximum number of cities [8]. New Delhi, the capital of India witnessed heavy air pollution during November 2019. According to Indian Air Quality standards the concentration of RSPM in ambient air on 24 hour basis for rural,residential or other location is $100\mu g/m3$, for sensitive location $75\mu g/m3$ and for industrial location it is 150 μg/m3 [7].Since particulate matter concentration varies according to season and impacts human health especially in winter we attempted to analyse this concentration seasonally at mentioned three locations in the state of Andhra Pradesh in India.

Andhra Pradesh is a newly divided state formed in 2014 with 54 million population and 13 districts in southeastern coastal region of India. It has a big coastline of about 974 km and known as the rice bowl of India for being a major producer of rice. It is the only state in India with three capitals in which Visakhapatnam the biggest city being the executive capital while Amaravati being the legislative capital. Tirupathi is one of the world famous religious city with 18.25 million visitors per year. Visakhapatnam represents coastal, urban and industrial station and is the only rapid growing cities with increase in population and traffic pollution on daily basis. Its population is twenty four lakhs in 2019 (Population Research Centre, Andhra University). As per the data of City Police 7.9 lakh vehicles pass through the city every day with annual increase of twenty thousand new vehicles. Since this city encounters heavy constructions, huge traffic, have many public and private industries air pollution need to be monitored and analyzed. Amaravathi represent plain and green station with less traffic and population of 7.52 lakh while Tirupathi is an urban agglomerated city with hills and huge tourist traffic having 6.79 lakh population. These three locations are different in their geographical and demographical conditions with Visakhapatnam being highly polluted followed by Amaravathi followed by Tirupathi. Hence they are selected to analyse the particulate matter concentration at these locations and arrive at interesting results if any. Regression analysis for all three mentioned locations was done with PM2.5 and PM10 as dependent and NO, NO2, SO2, CO, O3, RH and T variables as independent. The idea is to check the dependence of PM2.5 and PM10 concentrations on other variables on diurnal and seasonal basis for these stations. The impact of RH on PM concentration was reported by [9].

2. Data and Methodology

Hourly values of PM10, PM2.5, SO2, NO2, NO, CO, O3, RH and T during January 2018 - September 2020 were downloaded from the official government web site of CPCB [10] assuming no quality compromise exists. From these values relevant analysis was done to estimate the dependence of PM2.5 & PM10 on other independent variables. This analysis may help in developing a regression model that enabling us to estimate the correlation of PM2.5 & PM10 with other variables. Significant correlation between PM2.5 and other variables for Xian (China) was reported by using multi regression analysis [11]. Relevant feature analysis

TABLE 1. Correlation between between PM2.5 and other variables for three stations

Visakhapatnam(PM2.5)			**Amaravathi(PM2.5)**			**Tirupathi(PM2.5)**		
Multiple R	0.839862823		Multiple R	0.806836152		Multiple R	0.791381175	
R2	0.705369562		R2	0.650984576		R2	0.626284163	
Adjusted R2	0.703122924		Adjusted R2	0.648153628		Adjusted R2	0.623477285	
Std. Error	15.61776693		Std. Error	15.59596207		Std. Error	10.04302086	
Observations	926		Observations	871		Observations	940	
	P-value	**Corr. Coff**		**P-value**	**Corr. Coff**		**P-value**	**Corr. Coff**
Intercept	0.37089721	-9.2242761	Intercept	0.009245141	19.54774	Intercept	7.7815E-10	-59.33336
RH	0.705739758	0.0400548	RH	9.20036E-08	0.407861	RH	1.2309E-23	0.361054
Temp	2.13362E-05	-0.9910962	Temp	0.000322253	0.765708	Temp	0.02111003	0.730251
SO2	0.521438409	0.05464663	SO2	0.000282103	0.323090	SO2	3.7148E-16	1.123330
NO	0.040199406	-0.1324347	NO	0.037841991	0.318325	NO	4.1169E-10	0.295039
NO2	9.10476E-33	0.59032321	NO2	4.3955E-101	0.902959	NO2	4.8794E-35	0.269869
CO	5.23214E-34	26.6579507	CO	0.000113499	7.912222	CO	5.7485E-08	7.198026
O3	3.55222E-97	0.53618131	Ozone	1.50102E-37	0.488051	O3	1.9727E-56	0.414889

TABLE 2. Correlation between PM10 and other variables for three stations

Visakhapatnam(PM10)				**Amaravathi(PM10)**		**Tirupathi(PM10)**		
Multiple R	0.815423109		Multiple R	0.816955492		Multiple R	0.736825	
R2	0.664914847		R2	0.667416276		R2	0.542911	
Adjusted R2	0.662359731		Adjusted R2	0.66471861		Adjusted R2	0.539478	
Std. Error	30.14589415		Std. Error	25.30964535		Std. Error	18.66002	
Observations	926		Observations	871		Observations	940	
	P-value	Corr.Coff		P-value	Corr.Coff		P-value	Corr.Coff
Intercept	5.7274E-18	175.395498	Intercept		80.84029771	Intercept		-50.8675
RH	4.89181E-11	-1.3621031	RH	5.26642E-11	-0.76755449	RH	0.004234441	0.057591
Temp	4.45608E-08	-2.4707561	Temp	6.52253E-10	-0.92618417	Temp	0.376790555	1.815173
SO2	0.919693156	-0.0165854	SO2	0.007246996	0.331086602	SO2	0.002059147	1.727434
NO	0.002136939	0.38311331	NO	0.021549365	0.561469138	NO	1.1961E-11	0.080133
NO2	8.5065E-44	1.34544290	NO2	0.024042145	1.340025468	NO2	0.356008133	0.507512
CO	2.57245E-29	47.2916038	CO	5.01576E-88	13.91101634	CO	8.67358E-36	10.15515
O3	2.71893E-25	0.46784232	Ozone	2.93406E-05	0.712097469	O3	3.56261E-05	0.507131

between PM2.5 and PM10 and other independent variables for Visakhapatnam, Amaravathi and Tirupathi are given below.

3. RESULTS AND DISCUSSION

Tables.1&2 display the obtained significance levels (p-value) for PM2.5 and PM10 with RH, T, SO2, NO, NO2, CO and O3 for the study period. If p-value is below 0.050 it qualifies the significance test and can be used in model building. But many of the variables are found to be not significant. Table.1 indicate +ve correlation between PM2.5 & RH, SO2, NO2, CO, O3 and -ve correlation between PM2.5 and NO,Temperature for Visakhapatnam. This is due to Visakhapatnam being coastal station Relative Humidity is always high. Hence RH exhibit positive correlation indicating that the particle size increases with humidity and probability of converting PM2.5 to PM10 is high. At the same time temperature exhibiting negative correlation indicate less formation of PM2.5 particles which is more relevant during summer season. Since Visakhapatnam is an industrial location emission of SO2 is always intact showing positive correlation. At the same time Amaravathi and Tirupathi stations show positive correlation between PM2.5 and other variables during the same period but with low correlation values. Table. 2 depict +ve correlation between PM10 & NO, NO2, CO, O3 and -ve correlation between PM10 and RH, T,SO2 for Visakhapatnam. Amaravathi show negative correlation between PM10 & RH, T and +ve correlation with remaining variables during the same period. Tirupathi show positive correlation between PM10 and all variables. From the two tables it is observed that Amaravathi and Tirupathi show same behavior in case of PM2.5 concentration while Visakhapatnam and Amaravathi show similar behaviour in case of PM10 concentration. However seasonal analysis of particulate matter concentration is necessary to know the impact of this pollution on human health with more focus on winter season.

4. SEASONAL VARIATION IN PARTICULATE MATTER CONCENTRATION

Particulate matter concentration (PM2.5 or PM10) affects human health. Reports have already indicated its impact on respiratory system. However this concentration need to be analysed seasonally since parameters like temperature and humidity vary depending on particular season. Even though emission of pollutants may depend on many factors seasonal changes impact pm concentration to some extent. Hence the obtained data is aggregated season wise given by Winter(Nov -Feb), Summer(Mar-June) and Monsoon(July to Oct) and regression analysis is done for all the three stations for the study period.

4.1. **Seasonal Trends of PM2.5 and PM10 at Visakhapatnam.** Particulate matter concentration affects human respiratory system. Since diseases related to respiratory system depends on season an attempt was made to analyse PM2.5 and PM10 in terms of three seasons winter , summer and monsoon.

Tables 3 and 4 show the correlation between PM2.5 and PM10 concentrations on Relative Humidity(RH), Temperature(T), SO2, NO, NO2, CO and O3 for winter,

TABLE 3. Seasonal variation of PM2.5 for Visakhpatnam(2018-2020)

Winter		**Summer**		**Monsoon**	
Multiple R	0.830951	Multiple R	0.752464	Multiple R	0.681437
R2	0.69048	R2	0.566202	R2	0.464357
Adjusted R2	0.681983	Adjusted R2	0.557526	Adjusted R2	0.451732
Std. Error	19.0122	Std. Error	9.640032	Std. Error	12.75555
Observations	263	Observations	358	Observations	305
	Corr. Coff		**Corr. Coff**		**Corr. Coff**
Intercept	-12.5389	Intercept	22.78854	Intercept	55.35415
RH	0.734927	RH	-0.00655	RH	-0.55059
Temp	-2.18444	Temp	-0.8883	Temp	-0.50285
SO2	1.693031	SO2	-0.1528	SO2	-0.33209
NO	-0.06339	NO	0.0279	NO	0.072566
NO2	0.378278	NO2	0.449018	NO2	0.554524
CO	39.70086	CO	19.84147	CO	14.11457
O3	0.419132	O3	0.422997	O3	0.383771

TABLE 4. Seasonal variation of PM10 for Visakhpatnam(2018-2020)

Winter		**Summer**		**Monsoon**	
Multiple R	0.876757	Multiple R	0.726865	Multiple R	0.710866
R2	0.768702	R2	0.528332	R2	0.50533
Adjusted R2	0.762353	Adjusted R2	0.518899	Adjusted R2	0.493671
Std. Error	30.45344	Std. Error	24.43042	Std. Error	29.00444
Observations	263	Observations	358	Observations	305
	Corr. Coff		**Corr. Coff**		**Corr. Coff**
Intercept	105.4907	Intercept	160.4952	Intercept	270.7231
RH	0.036262	RH	-0.78612	RH	-3.09441
Temp	-4.24569	Temp	-2.8215	Temp	-0.7485
SO2	2.473484	SO2	-0.17282	SO2	-0.6866
NO	0.537755	NO	-0.03074	NO	0.298818
NO2	0.919919	NO2	0.937703	NO2	1.34382
CO	64.91499	CO	51.0744	CO	32.28153
O3	0.414429	O3	0.616367	O3	0.383299

summer and monsoon seasons during the period 2018-2020 for Visakhapatnam station. From this analysis it is clear that RH and SO2 shows negative correlation during summer and monsoon while Temperature shows negative correlation for all the three seasons with PM2.5. The same trend is exhibited by RH, SO2 and Temperature with PM10 concentration also. This clearly indicates that Temperature exhibits negative correlation with PM2.5 irrespective of season. At the same time RH exhibit positive correlation with PM2.5 for overall data while it show negative correlation during summer and monsoon seasons. The same trend is shown by PM10 concentration with respect to RH. Since Visakhapatnam is a station with year long high humidity which impact PM concentration its dependence on RH should be analysed in more detail which may lead to interesting results. Similarly SO2 which exhibited positive correlation with PM2.5 for overall data show negative correlation during summer and monsoon while PM10 which show negative correlation for overall data as well as during summer and monsoon seasons.

TABLE 5. Seasonal variation of PM2.5 for Amaravathi(2018-2020)

Winter		**Summer**		**Monsoon**	
Multiple R	0.7695601	Multiple R	0.506249	Multiple R	0.849574
R2	0.59222275	R2	0.256288	R2	0.721777
Adjusted R2	0.58237985	Adjusted R2	0.238819	Adjusted R2	0.714257
Std. Error	17.2155427	Std. Error	9.610927	Std. Error	7.112837
Observations	298	Observations	306	Observations	267
	Corr. Coff		**Corr. Coff**		**Corr. Coff**
Intercept	16.6496209	Intercept	1.883892	Intercept	-44.5311
RH	0.78745076	RH	-0.03256	RH	0.198172
Temp	-2.4638798	Temp	-0.02627	Temp	0.445379
SO2	0.21774832	SO2	0.342115	SO2	0.275103
NO	-0.6265041	NO	0.761818	NO	-0.26828
NO2	0.78412576	NO2	0.397629	NO2	1.001184
CO	0.28956581	CO	15.48405	CO	6.848215
O3	0.60177005	O3	0.113657	O3	0.442206

4.2. **Seasonal trends of PM2.5 and PM10 at Amaravathi.** Tables 5 and 6 show the correlation between PM2.5 and PM10 concentrations on Relative Humidity(RH),

TABLE 6. Seasonal variation of PM10 for Amaravathi(2018-2020)

Winter		**Summer**		**Monsoon**	
Multiple R	0.817657	Multiple R	0.621392	Multiple R	0.850521
R2	0.668563	R2	0.386128	R2	0.723386
Adjusted R2	0.660563	Adjusted R2	0.371708	Adjusted R2	0.71591
Std. Error	24.56404	Std. Error	22.14755	Std. Error	17.62713
Observations	298	Observations	306	Observations	267
	Corr. Coff		**Corr. Coff**		**Corr. Coff**
Intercept	213.9539	Intercept	94.69784	Intercept	-53.0152
RH	-0.84583	RH	-1.13742	RH	-0.40661
Temp	-4.12254	Temp	-0.37868	Temp	2.04477
SO2	0.315318	SO2	0.246679	SO2	0.449633
NO	-0.00279	NO	1.612356	NO	-0.21844
NO2	1.18221	NO2	1.221588	NO2	2.138547
CO	-9.89259	CO	33.32454	CO	15.07161
O3	0.635538	O3	0.262209	O3	0.800635

Temperature(T), SO2, NO, NO2, CO and O3 for winter, summer and monsoon seasons during the period 2018-2020 for Amaravathi station. From this analysis it is clear that RH show negative correlation during summer while Temperature shows negative correlation for winter and summer seasons with PM2.5. At the same time RH show negative correlation for all seasons with PM10 concentration while Temperature show negative correlation during winter and summer seasons. Here it should be noted that in case of PM10 overall data show positive correlation with all variables while PM2.5 exhibited negative correlation with temperature in the same case. Hence seasonal impact on RH and Temperature at Amaravathi need to be analysed.

4.3. **Seasonal Trends of PM2.5 and PM10 at Tirupathi.** Tables 7 and 8 show the correlation between PM2.5 and PM10 concentrations on Relative Humidity(RH), Temperature(Temp), SO2, NO, NO2, CO and O3 for winter, summer and monsoon seasons during the period 2018-2020 for Tirupathi station. From this analysis it is clear that all the variables show positive correlation with PM2.5 for all seasons

TABLE 7. Seasonal variation of PM2.5 for Tirupathi(2018-2020)

Winter		**Summer**		**Monsoon**	
Multiple R	0.69575	Multiple R	0.722804	Multiple R	0.741309
R2	0.484068	R2	0.522445	R2	0.549539
Adjusted R2	0.47103	Adjusted R2	0.512376	Adjusted R2	0.539268
Std. Error	13.83234	Std. Error	7.019088	Std. Error	5.893147
Observations	285	Observations	340	Observations	315
	Corr. Coff		**Corr. Coff**		**Corr. Coff**
Intercept	-29.6658	Intercept	-59.4095	Intercept	-44.1554
RH	0.17436	RH	0.26733	RH	0.213306
Temp	0.269276	Temp	1.334027	Temp	0.8327
SO2	0.809634	SO2	1.346483	SO2	0.144516
NO	0.353023	NO	0.076589	NO	-0.11815
NO2	0.203707	NO2	0.220153	NO2	0.40851
CO	8.594673	CO	4.951078	CO	6.385528
O3	0.536445	O3	0.208666	O3	0.324194

as well as overall data. This clearly indictee seasonal impact on PM2.5 concentration for Tirupathi station is negligible. In case of PM10 concentration RH during monsoon and Temperature during winter show slight negative correlation contra to Positive correlation exhibited for overall data which may be analysed. However NO show negative correlation with PM10 during summer and monsoon.

4.4. **Mean concnetration of PM2.5 and PM10 for Visakhapatnam, Amaravathi and Tirupathi.** Table 9. shows the mean concentrations of PM2.5 and PM10 for the overall study period 2018-2020 as well as for Winter , Summer and Monsoon. From the table it is clear that both concentrations are high for Visakhapatnam followed by Amaravathi and Tirupathi for the study period as well as season wise. Since Viskhapatnam is densely populated city with huge traffic and industries it witnesses highest concentrations. As per the previous reports winter will witness high concentrations while summer will encounter low concentrations. However in the above table summer values are slighlty less than monsoon which may be attributed to recent worldwide lockdown effect during summer 2020 (March to June).

TABLE 8. Seasonal variation of PM10 for Tirupathi(2018-2020)

Winter		Summer		Monsoon	
Multiple R	0.712881	Multiple R	0.68167	Multiple R	0.760792
R2	0.5082	R2	0.464674	R2	0.578804
Adjusted R2	0.495772	Adjusted R2	0.453388	Adjusted R2	0.5692
Std. Error	19.49401	Std. Error	17.14458	Std. Error	15.06914
Observations	285	Observations	340	Observations	315
	Corr. Coff		**Corr. Coff**		**Corr. Coff**
Intercept	-2.82297	Intercept	-47.2985	Intercept	-7.34717
RH	0.260395	RH	0.371305	RH	-0.51414
Temp	-0.47839	Temp	1.505875	Temp	1.424874
SO2	1.204536	SO2	1.115463	SO2	1.886859
NO	0.373743	NO	-0.66296	NO	-0.12315
NO2	0.301171	NO2	0.892143	NO2	0.965227
CO	12.93526	CO	9.734559	CO	12.14179
O3	0.833403	O3	0.155192	O3	0.406394

TABLE 9. Mean concentration of PM2.5 and PM10 for three stations(2018-2020)

Station	Overall Period		Winter		Summer		Monsoon	
	PM2.5 ($\mu g/m^3$)	PM10 ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)	PM10 ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)	PM10 ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)	PM10 ($\mu g/m^3$)
Visakhapatnam	84.84	106.52	73.37	146.52	29.7	90.48	35.11	93
Amaravathi	34.99	71.98	61.42	108.28	25.07	63.19	18.37	45.55
Tirupathi	24.96	57.01	39.65	73.07	22.99	61.08	15.11	42.07

5. CONCLUSIONS

PM2.5, PM10 and other pollutant data between 2018-2020 for three stations Visakhapatnam, Amaravathi and Tirupathi of state of Andhra Pradesh(India) was analysed by using multi variant correlation analyses. Correlation between PM2.5 & PM10 concentrations and other pollutants such as SO2, NO, NO2, CO, O3 including parameters like Relative Humidity(RH) and Temperature was done. The results indicated linear relationship between PM2.5&PM10 with SO2, NO, NO2, CO, O3, RH, T during this period with correlation between different pollutants due to various processes involved. Correlation analysis for complete data as well as seasonal data was done.The main observations include

1. No significant relevance between PM2.5 & PM10 with majority of dependent variables. Hence all these variables cannot be used for building regression model.
2. The seasonal concentrations of PM2.5 and PM10 for the three stations are not uniform indication the impact of other local and meteorological factors that influence these concentrations.
3. Both PM2.5 and PM10 concentrations are high for Visakhapatnam followed by Amaravathi and Tirupathi for the study period as well as season wise. Summer concentrations are slighlty less than monsoon which may be attributed to recent worldwide lockdown effect during summer 2020 (March to June).

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REFERENCES

[1] A. W. CORREIA, C. A. POPE, D. W. DOCKERY, Y. WANG, M. EZZATI, D. F. CORREIA: *Effect of air pollution control on life expectancy in the United States an analysis of 545 US counties for the period from 2000 to 2007*, Epidemiology, **24** (2013), 23-31.

[2] P. SINGH, R. SAINI, A. TANEJA: *Physicochemical characteristics of PM2.5: Low, middle, and high–income group homes in Agra, India–a case study*, Atmopsheric Pollution Research., **5**(3) (2014), 352-360.

[3] D. ZHAO, H. CHEN, E. YU, T. LUO: *PM2.5/PM10 Ratios in Eight Economic Regions and their relationship with Meteorology in China*, Advances in Meteorology, 2019, Article ID 5295726, 15 page.

[4] E. PADOAN, M. MALANDRINO, A. GIACOMINO, M. M. GROSA, F. LOLLOBRIGIDA: *Spatial distribution and potential sources of trace elements in PM10 monitored in urban and rural sites of Piedmont Region*, Chemosphere, (2016), 495-507.

[5] R. DAS, B. KHEZRI, B. SRIVASTAVA, S. DATTA, P. K. SIKDAR, R. D. WEBSTER, X. WANG: *K,Trace element composition of PM2.5 and PM10 from Kolkata – a heavily polluted Indian metropolis*, Atmos. Pollut. Res., **6**(5) (2015), 742-750.

[6] S. S. LIM, T. VOS, A. D. FLAXMAN, G. DANAEI, K. SHIBUYA: *A comparative risk assessment of burden of disease and injury attributable to67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study,2010*, Lancet, **380**(9859) (2012), 2224-2260.

[7] D. S. SATISH KUMAR: *Air Pollution in Visakhapatnam – An Overview*, International Journal of Civil Engineering, **2** (2013), 11-14.

[8] *Central Pollution Control Board*, http://cpcb.nic.in/

[9] C. LOU, H. LIU, Y. LI, Y. PENG, J. WANG, L. DAI: *Relatioships of relative humidity with PM2.5 and PM10 in the Yangtze River Delata, China*, Environmental Monitoring and Assessment, **189** (2017), article no.582.

[10] https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/data

[11] J. LI, L. WANG: *The research of PM2.5 concentrations model based on regression calculated model*, AIP conference Proceedings, **1794**(1) (2016), art.no. 030005.

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