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Relationship between Temperature and Air pollution in Hot Areas: A Comprehensive Review Paper

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Abstract
While temperature has long been referred to as a catalyst for pollutants to be more airborne, it is nclear however a rise in temperature affects pollution throughout heatwaves. Through a regression analysis of the connection between selected air pollutants i.e. Ozone gas (O3), particulate matter (PM10,particles less than 10 µm in diameter), nitrogen dioxide (NO2), and temperatures in urban and rural areas of the state Uttar Pradesh in India, it had been found that in heatwaves, all pollutant levels rose at every inspection site utmost temperature coinciding with the peak levels of O3 and PM10. These findings established that the influence of temperature on air pollution failed to change with rural or urban locations as air pollutants (O3, PM10, and NO2) increases with increasing temperatures, significantly throughout heatwavesirrespective of urban and rural location. Levels of ozone were found to extend by quite 50% with increase in temperature. This supports studies wherever the incidence of high levels of pollutants has once and for all been found to be rather more rife throughout prolonged heatwaves. The implications of these findings are important to the establishment of long-term prevention measures in heatwave plans. When a heatwave is forecast, additional measures to reduce air pollutant concentrations may be appropriate when commencing emergency responses.

1. Introduction

Worsening air quality and extreme weather events, like heatwaves, are progressively affecting individuals worldwide. Heatwaves have long been called a vital driver of air pollutant levels, leading to numerous health, environmental, and economic impacts.Air pollutants whose concentrations and impacts are identified to be affected by heatwaves include Ozone (O_3), Particulate Matter (PM_{10}) and Nitrogen Dioxide (NO_2). These pollutants, once emitted into the atmosphere from a variety of natural and anthropogenic sources, are poses seriousthreat to human health (World Health Organization, 2010). The concentration of these pollutants in ambient air depends on the extent of emission and the ability of the atmosphere to soak up or disperse these pollutants (World Health Organization, 2010). Since meteorological variables like temperature and concentrations of air pollutants vary on a daily basis, it's vital to consider their relationship within the planetary physical phenomenon, since the atmosphere is the medium during which air pollutants are transported away from the source.Lee et al. (2006) indicated that in photochemical pollution episodes, air pollutants (O_3, PM_{10}, and NO_2) are the results of a combination of varied meteorological effects and chemical reactions. These pollutants are of the greatest health concern, as their emissions could also be exacerbated throughout heatwaves (Analitis et al., 2014; Fouillet et al., 2006; Johnson et al., 2004). As a result, sensitive people might not only be stressed by high temperatures, however could also be additional subject to mortality because of pollution throughout heatwaves (Analitis et al., 2014). Unusually hot weather throughout summer led to elevated levels of air pollutants throughout the heatwaves. The mix of elevated air pollution levels and high temperatures was involved in the increase in urban heat islands (UHIs) and pollution in Uttar Pradesh, India. Heatwaves are significantly intense in urban areas, wherever surface characteristics alter the temperature variations between urban and rural areas. The variations are generated by low levels of vegetation in cities, and therefore the production of anthropogenic heat and air flow caused by urban infrastructure like buildings and asphalt streets (Bibri and Krogstie, 2017). Mirzaei (2015) indicated that extreme air temperatures in cities (UHIs) increase heat- and air pollution-related mortality and raise the energy demands for cooling buildings that successively ends up in an additional increase in air pollutants and greenhouse emissions. Despite this, many studies have shown that sustainable urban planning, and smart city design including green roofs and cool pavements might considerably scale back both UHIs and air pollution; particularly O_3, NO_2, and PM_{10} (Bibri and Krogstie, 2017; McDonald et al., 2007; silva et al., 2018; yang et al., 2008). Previous studies investigating temperature and air pollution throughout heatwaves (Fouillet et al., 2006; Fischer et al., 2004) have only explored the role of air pollution in modifying the effects of heatwaves on mortality. There is scarcity of research studies examining the relationship between temperature and air pollution during heatwaves, while not considering mortality. Additionally, it seems there is no analysis into the spatial relationships of temperature and air quality throughout heatwaves, like between urban and rural areas in Country.Thereforethe objectives of current study are to:

(1) Assess the relationship between Temperature and Air Pollution during heatwaves;

(2) Quantify the impact of Temperature on Air Pollutants specifically Ozone (O3), Particulate Matter (PM10) and Nitrogen dioxide (NO2)); and

(3) Differentiate impact of heatwaves on air quality between urban and rural areas of Uttar Pradesh, India caused due to heatwave events identified duringthe year 2005 to 2017.

2. **Materials and Methods**

2.1. Study location

Data used in this study is beingcollected inLucknow, a metro city in the north region of the India. Lucknow is selected as a study location because it is representative of typical population exposure as the largest and most populouscity. This study used a 12-year data series (2005-2017) of O_3, PM_{10}, and NO2 and meteorological data (temperature) provided by LucknowAir Quality Monitoring Stations of urban and rural locations.

2.2. Air quality data

Historical air quality data (O_3, PM_{10}, and NO_2) from both the urban and rural backgrounds required for this study is being obtained from the National Ambient Air Quality Monitoring in

India started in 1984 and presently ambient air quality is monitored in 13 cities of Uttar Pradesh

(UP) (Refer Table 1). A total of 39 ambient air quality monitoring stations are maintained by UP Pollution Control Board (UPPCB) and Central Pollution Control Board (CPCB) in these 13 districts covering various land use patterns. The station will be chosen because a comprehensive range of measurements had been reliably collected over time. The first assessment will be of the availability of daily concentrations of O_3 (maximum 8-hour running average), NO_2 (the daily maximum value of the 1-hour mean) and PM_{10} (mean, 24 hours).

S. No.	Districts	Location of Monitoring Station	Land Use Pattern	Monitoring Days	Monitoring Agency
1	Agra	Tajmahal	Sensitive	Sunday, Monday, Tuesday, Wednesday, Thursday, Saturday	CPCB
		Regional Office Bodla	Residential	Monday, Thursday	UPPCB
		Nunhai	Industrial	Tuesday, Friday	UPPCB
		DIC Nunhai	Sensitive	Wednesday, Saturday	CPCB
		Itmad-ud-daulah	Sensitive	Tuesday, Friday	CPCB
		Rambagh	Sensitive	Monday, Thursday	CPCB
2	Allahabad	Square Crossing	Residential	Monday, Thursday	UPPCB
		Bharat Yantra Nigam	Residential	Monday, Thursday	UPPCB
3	Anpara	Anpara Colony	Industrial	Tuesday, Thursday	UPPCB
		Renusagar Colony	Industrial	Monday, Wednesday	UPPCB
4	Firozabad	CDGI	Industrial	Tuesday, Friday	UPPCB
		Tilak Nagar	Residential	Wednesday, Saturday	UPPCB
		Raza ka Tal	Residential	Monday, Thursday	UPPCB
5	Gajraula	Indira Chowk	Residential	Friday, Sunday	UPPCB
		Raunaq Auto Ltd.	Industrial	Tuesday, Friday	UPPCB
6	Ghaziabad	Atlas Cycles Ind. Ltd.	Industrial	Tuesday, Friday	UPPCB
		Bulandshahar Road	Industrial	Monday, Thursday	UPPCB
7	Jhansi	Jail Chauraha	Residential	Tuesday, Thursday	UPPCB
		Veeranga Nagar	Residential	Saturday, Tuesday	UPPCB
8	Kanpur	Fazalganj	Industrial	Wednesday, Saturday	UPPCB
		Jajmau	Industrial	Tuesday, Friday	UPPCB
		Deputy ka Parao	Residential	Tuesday, Friday	UPPCB
		Dabauli	Residential	Monday, Thursday	UPPCB
		Vikas Nagar	Residential	Monday, Tuesday, Thursday, Friday	CPCB
		Kidwai Nagar	Residential	Monday, Thursday	UPPCB
9	Khurja	CGCRI	Industrial	Sunday, Thursday	UPPCB
		Ahirpara	Residential	Tuesday, Saturday	UPPCB
10	Lucknow	Talkatora	Industrial	Monday, Thursday	UPPCB
		Mahanagar	Residential	Tuesday, Thursday	UPPCB
		Kapoor Hotel Hazratganj	Residential& Commercial	Tuesday, Friday	UPPCB
		Chandganj	Residential	Monday, Wednesday	UPPCB
		Aminabad	Residential	Tuesday, Wednesday, Friday	UPPCB
11	Meerut	Begum Bridge	Residential	Tuesday, Friday	UPPCB
		Thana Railway Road	Residential	Wednesday, Friday	UPPCB
12	Noida	R.O. UPPB	Residential	Tuesday, Thursday	UPPCB
		GEE-PEE	Industrial	Monday, Thursday	UPPCB
13	Varanasi	Regional Office	Residential	Monday, Thursday	UPPCB
		Shivpuri	Residential	Tuesday, Friday	
		Sigra	Residential	Tuesday, Friday	UPPCB

Table 1: Details of Air Monitoring Stations in Study area

2.3. Temperature data

The daily maximum temperature data from 1 January 2005 to 31 December 2017 is being obtained from Indian meterological department (IMD) website.

2.4. Heatwave definition

One of the challenges in this study was to define a heatwave day, as the concept of a heatwave has no universal definition (Meehl et al., 2000), being dependent on the average climate for each region in question. In this study, the definition of a heatwave was close to the definition provided by the World Meteorological Organization (WMO), with some modification. According to the WMO, a heatwave is a phenomenon, during which the daily maximum temperature for at least five consecutive days exceeds the average daily maximum temperature by 5 °C,

2.5. Data analysis

The relationship between daily mean temperature and air pollution levels during heatwave periodsfor Lucknow city is being determined using a simple linear regression model (linear correlation model)to highlight the possible correlation between temperature and each of the air pollutants. Statisticalanalysis is being performed using Statistical Analysis Software (SAS).IBM SPSS version 22software is used in this data analysis.

3. Results and Discussion

This investigation is only being focused on severe heatwaves where a high intensityand long duration of elevated temperatures are observed.Heatwave duration and intensity can be important factors for a significant increasein the concentration of air pollutants, particularly O_3. Pearce et al. (2011)state that urban areas are warmer than their surrounding areas due to the characteristics of urbansurfaces, radiative trapping effects, significant human activity, heat release, high heat capacity andthe lack of green space (vegetation and moisture). However, the use of the daily maximumtemperature metric may explain the behavior of urban heat islands (UHIs), which is normally most apparentduring the night. In addition, summer temperatures dry the ground in rural areas, which enhancesthe amount of solar radiation reflected back to the atmosphere and increases the daytimetemperature. Research in the UK showed that the UHI effect enhances night-time temperatures,especially during heatwaves (Tomlinson et al., 2012; Oke, 1973). Many cities in Indialike Kanpur, Delhireported night-time air temperatures that were warmer in urban areas than surrounding rural areas. Again, the albedo (the amount of incident radiation orlight that is reflected by a surface) can have a significant effect on air temperature, with hightemperatures associated with dark, low-albedo surfaces such as tarmac. Highalbedosurfaces reflect back much of the incoming light from the sun into the atmosphere whilelow-albedo surfaces absorb more energy from the sun. Rural areas tend to have a high albedobecause the daytime temperature becomes high once incoming radiation is reflected in theatmosphere, while urban areas (urban materials) absorb heat during the day and release it duringthe night. Furthermore, Johnson (1985) indicated that the level of heating and cooling in urban andrural areas could be explained by the sky view factor (SVF), which is the amount of sky visiblefrom the ground. For example, the sky view factor controls the radiation balance in XYZcity centre because of the tall buildings. Cooling rates reduce with a decrease in SVF ($r = -0.xx$).Therefore, XYZ was found to heat up and cool down more than its surrounding rural areas.

3.1. Air pollution and heatwaves

3.1.1. Temperature and air pollution relationship.

Over the 12 years covered by the data in this study, the mean concentration of O_3 andthe peak daytime temperature were significantly higher in rural than urbanareas. However, the mean concentrations ofNO_2 were significantly higher in the urbanenvironment compared to the rural area. Only PM_{10} did not show a statisticallysignificant difference in mean concentration between rural and urban areas. Thecomparisons of mean concentrations of air pollutants (O_3, PM_{10}, and NO_2) (Refer Table 2 for concentration of pollutants in ambient air) and temperaturesbetween urban and rural sites for all 12 years are shown. Details for each year (2005 to2017) for mean concentrations of air pollutants (O_3, PM_{10}, and NO_2) and temperatures in rural andurban areas arepresented. Temperature, O_3, PM_{10}, and NO_2concentrations on days with heatwaves will significantly be higher than those on non-consecutive"hot" days.

S.No.	Pollutants	Time Weighted Average	Concentration in Ambient Air	
			Industrial, Residential, Rural, and others Areas	Ecologically Sensitive Area (Notified by Central Government)
1	Sulphar Dioxide (SO_2),µg/m^3	Annual	50	20
		24 Hour	80	80
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual	40	30
		24 Hour	80	80
3	Particulate Matter (Size<10µm) or PM_{10} , µg/m^3	Annual	60	60
		24 Hour	100	100
4	Particulate Matter (Size<2.5µm) or $PM_{2.5}$, µg/m^3	Annual	40	40
		24 Hour	60	60
5	Ozone (O_3), µg/m^3	8 Hour	100	100
		1 Hour	180	180
6	Lead (Pb), µg/m^3	Annual	0.50	0.50
		24 Hour	1.0	1.0
7	Carbon Monoxide (CO), mg/m^3	8 Hour	02	02
		1 Hour	04	04
8	Ammonia (NH_3), µg/m^3	Annual	100	100
		24 Hour	400	400
9	Benzene (C_6H_6), µg/m^3	Annual	05	05

Table 2: National Ambient Air Quality Standards.

3.2. Correlation analysis of air pollution and all intense heatwaves identified within 2005 to 2017.

Based on simple linear regression analysis, the relationships between air pollutants (O_3, PM_{10}, andNO_2) and temperature during all intense heatwaves in 2005 to 20017 is being presented. Observation-based statistical analysisare being used to calculate temperature effects of all three air pollutants,particularly O_3 and PM_{10}. Strong correlations are expected to be found between these pollutants andtemperatures during heatwaves in both urban and rural areas. Theannual number of exceedances of air quality standards (40 μg/m3 annual mean), is expected to match theannual number of heatwave days. This may be attributable to the atmospheric conditions thatusually prevail during heatwave days. Stagnation of air masses is usually observed duringheatwaves, favouring the accumulation of particles and O_3 precursors (NO_2) (Tressol et al., 2008).A comparison of the influence of temperature on air pollution, between rural and urban areas during all intense heatwaves is being performedfor both rural and urban areas.

3.2.1 Ozone (O3)

The maximum O_3 concentration is being recorded at Lucknow Rural Air quality Station. Theseconcentrations should coincide with the daily maximum temperature in rural (34.1°C) and urban (33.2°C)areas. The concentration of O_3 was significantly lower in the urban than in the rural area. Statistically significant positive correlations are expected to be found between temperature and O_3in all the heatwaves identified in the rural area and urban area. The fact that ozone levels found more commonly higher in rural areasthan in cities can be explained by ozone degradation by its precursors (NO_x) (Simon et al., 2015).Ozone is a secondary pollutant, which means it is not directly emitted by traffic or industryemissions in cities, but is formed on hot days by the influence of solar radiation and becomesairborne. The O_3 concentrations were found to increase withincreasing daily maximum temperature. This phenomenon exists because the elevatedconcentration of nitrogen oxides helps the removal ofOH radicals, through reaction with NO_2(Qian et al., 2012). There are various possibleexplanations for a synergistic association between elevated temperature and air pollutants.Processes in the atmosphere in the presence of sunlight generate ozone and a proportion of particles(secondary particles) and primary emitted pollutants. Since sunlight is associated with hightemperatures, production of secondary pollutantsis likely to be increased during warmseasons (Elminir, 2005; Tressol et al., 2008). During heatwaves, the air becomes stagnant, andtraps emitted pollutants, often resulting in increases in ground-level O_3.

3.2.2 Particulate matter (PM10)

Air pollutants are generally more concentrated in urban areas than in rural areas due to largeemissions caused by human activities. Temperature increases led to increased levelsof PM_{10}. In this study, the mean concentration of PM_{10} increased with rising temperatures duringheatwaves in both urban and rural areas. The higher concentration of PM_{10} in urban areasthan in rural areas is probably due to there being more emission sources in urban areas. This resultsin turbulent flow and elevated PM_{10} levels in congested areas with high-rise buildings, which stop airmovement and trap pollutants. There are number of high-rise buildings in Lucknow city which contribute to increases in ground-level concentrations of PM_{10}. In addition, PM_{10} increases inurban areas because of vehicle emissions and road transport-related emissions (tyre wear and brakewear), (Dore et al., 2003; Barlow et al., 2007). Pollution levels can therefore be further increased during heatwaves because of theatmospheric conditions that prevail, leading to the accumulation of pollutants (Tressol et al., 2008).

3.2.3 Nitrogen dioxide (NO_2)

The mean concentration of $NO_2$was significantly higher in urban (51.7 μg/m3) than in rural areas (18.4 μg/m3). The higherconcentration in urban areas was largely due to emissions from traffic congestion, which is greaterin urban than in rural areas. NO_2 is elevated in most urban areas, particularly atkerbside locations. Local dispersion and temperature play an important role. However, lessresearch has been directed to the meteorological link (temperature) with NO_2 levels duringheatwave events.

5. Conclusion

This study examined the relationship between temperature and air pollution during heatwaveperiods in Lucknow, Uttar Pradesh. A heatwave was defined by taking both intensity and duration intoaccount. The implications of these findings are important for policydevelopment; for example, when there is a heatwave forecast, additional measures to reduce airpollutant concentrations may be appropriate when commencing emergency responses and thesemeasures may be applicable in both urban and rural environments. Air pollution is soclosely related to temperature that removing one variable (either air pollutants or temperature),could reduce the effect of the other variable substantially. Thus, the correlation betweentemperature and air pollution cannot be assessed based on the incidence of health effects.

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World Health Organization, (2010). WHO guidelines for indoor air quality: Selected pollutants.

- Lee, J. D., Lewis, A. C., Monks, P. S., Jacob, M., Hamilton, J. F., Hopkins, J. R., Watson, N. M.,Saxton, J. E., Ennis, C., Carpenter, L. J., Carslaw, N., Fleming, Z., Bandy, B. J., Oram, D. E.,Penkett, S. A., Slemr, J., Norton, E., Rickard, A. R., Whalley, L. K, Heard, D. E., Bloss, W. J.,Gravestock, T., Smith, S. C., Stanton, J., Pilling, M. J., & Jenkin, M. E. (2006). Ozonephotochemistry and elevated isoprene during the UK heatwave of August 2003. AtmosphericEnvironment, 40(39), 7598-7613.

- Analitis, A., Michelozzi, P., D'Ippoliti, D., de'Donato, F., Menne, B., Matthies, F., Atkinson, R.W., Iñiguez, C., Basagaña, X., Schneider, A., Lefranc, A., Paldy, A., Bisanti, L., &Katsouyanni,K. (2014). Effects of heat waves on mortality: Effect modification and confounding by airpollutants. Epidemiology, 25(1), 15-22.

- Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J.,Jougla, E., &Hémon, D. (2006). Excess mortality related to the August 2003 heat wave inFrance. International Archives of Occupational and Environmental Health, 80(1), 16-24.

- Johnson, H., Kovats, S., McGregor, G., Stedman, J., Gibbs, M., Walton, H., & Cook, L. (2004).The impact of the 2003 heat wave on mortality and hospital admissions inEngland. Epidemiology, 15(4), S126.

- Tomlinson, C. J., Chapman, L., Thornes, J. E., & Baker, C. J. (2012). Derivation of Birmingham'ssummer surface urban heat island from MODIS satellite images. International Journal ofClimatology, 32(2), 214-224.

- Meehl, G. A., Karl, T., Easterling, D. R., Changnon, S., Pielke, R., Changnon, D., Evans, J.,Groisman, P. Y., Knutson, T. R., Kunkel, K. E., Mearns, L. O., Parmesan, C., Pulwarty, R., Root,T., Sylves, R. T., Whetton, P., & Zwiers, F. (2000). An introduction to trends in extreme weatherand climate events: Observations, socioeconomic impacts, terrestrial ecological impacts, andmodel projections. Bulletin of the American Meteorological Society, 81(3), 413-416.

- Pearce, J. L., Beringer, J., Nicholls, N., Hyndman, R. J., & Tapper, N. J. (2011). Quantifying theinfluence of local meteorology on air quality using generalized additive models. Atmospheric Environment, 45(6), 1328-1336.

- Qian, J., Hospodsky, D., Yamamoto, N., Nazaroff, W. W., &Peccia, J. (2012). Size-resolvedemission rates of airborne bacteria and fungi in an occupied classroom. Indoor Air, 22(4), 339-351.

- Elminir, H. K. (2005). Dependence of urban air pollutants on meteorology. Science of the TotalEnvironment, 350(1-3), 225-237. Tressol, M., Ordonez, C., Zbinden, R., Brioude, J., Thouret, V., Mari, C., Nedelec, P., Cammas, J. -P., Smit, H., Patz, H.-W., & Volz-Thomas, A. (2008). Air pollution during the 2003 European heat wave as seen by MOZAIC airliners. Atmospheric Chemistry and Physics, 8, 2133-2150.

- Dore, C. J., Goodwin, J. W. L., Watterson, J. D., Murrells, T. P., Passant, N. R., Hobson, M. M.,Haigh, K. E., Baggott, S. L., Pye, S. T., Coleman, P. J., & King, K. R. (2003). UK emissions of air pollutants 1970 to 2001.

- Bibri, S. E., &Krogstie, J. (2017). Smart sustainable cities of the future: An extensiveinterdisciplinary literature review. Sustainable Cities and Society, 31, 183-212.

- Silva, B. N., Khan, M., & Han, K. (2018). Towards sustainable smart cities: A review of trends,architectures, components, and open challenges in smart cities. Sustainable Cities and Society, 38, 697-713.