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Pollutants and climatic conditions related to the formation of photochemical oxidants

Shigeru Suna *

Private Health Research Laboratory, 14-22 Shinkita-machi, Takamatsu-shi, Kagawa 760-0001, Japan.

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Abstract

Solar radiation produces harmful compounds such as atmospheric oxidants and pharmaceutical intermediates through photochemical reactions. To clarify the variables related to the formation of photochemical oxidants, hourly data of air pollutants and climatic conditions in the Tokyo region of Japan from late May to early June 2020 were analyzed. Air pollutants, NO, NO_2, CO, SO_2, NMHCs and CH_4, were significantly lower in 2020 than those in 2019. It seems to indicate that Japan's economic activity was suppressed by the COVID-19 emergency. Photochemical oxidants and NO were significantly higher during the day than at night. It shows the photochemical reaction is progressing during the day. Stepwise linear regression analysis revealed that relative humidity, ambient temperature, NO, CO, wind speed and NMHCs (non-methane hydrocarbons) were significant independent variables for photochemical oxidants formation.

Keywords: Photochemical oxidants; NO; CO; NMHCs; Relative humidity; Ambient temperature; Wind speed.

1. Introduction

Sunlight have positive and negative effects on the community environmental health. Solar radiation produces harmful compounds such as atmospheric oxidants [1] and pharmaceutical intermediates [2] through photochemical reactions [3], increasing environmental health burden. Since atmospheric oxidants are formed under the influence of sunlight by a complex photochemical reaction in the air containing nitrogen oxides and reactive hydrocarbons as precursors, climatic conditions play an important role in oxidants formation [4, 5, 6, 7].

This study reports the relationship between photochemical oxidants formation and air pollutants and climatic conditions in the Tokyo region of Japan, from late May to early June 2020.

2. Methods

2.1. Air pollutants levels

Hourly levels of air pollutants of the Tokyo National Environmental Observatory were obtained from the Japan Atmospheric Environmental Regional Observation System (soramame.taiki.go.jp). Air pollutants were as follows; photochemical oxidants, nitrogen monoxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), non-methane hydrocarbons (NMHCs) and methane (CH_4).

* Corresponding author: Shigeru Suna
Affiliations: Private Health Research Laboratory, 14-22 Shinkita-machi, Takamatsu-shi, Kagawa 760-0001, Japan.

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2.2. Climatic conditions

The climatic conditions were from the values of the Tokyo Meteorological Observatory. The climatic value such as hourly ambient temperature, relative humidity, wind speed and global solar radiation was downloaded from the Japan Meteorological Agency.

(www.data.jma.go.jp/obd/stats/etrn/index.php?sess=6ef525a9cdef28cea634ce58ca736e68)

2.3. Statistical analysis

Results were expressed as means ± standard deviations (SD). Multiple linear regression analysis was performed to determine the relationship between photochemical oxidants formation and air pollutants and climatic conditions. $p < 0.05$ was considered as statistically significant.

3. Results and discussion

3.1. Air pollutant levels and climatic conditions

Table 1 shows air pollutant levels and climatic conditions from May 26 to June 8, 2020 compared to the same period previous year. NO, NO_2, CO, SO_2, NMHCs and CH_4 were significantly lower in 2020 than those in 2019. Table 2 compares air pollutant levels and climatic conditions during the day with those at night. Photochemical oxidants and NO were significantly higher during the day than at night.

Table 1 Air pollutant levels and climatic conditions from May 26 to June 8, 2020 compared to the same period previous year.

	Year	n	Mean	SD	*P*-value#
Photochemical Oxidants (ppm)	2020	330	0.0392	0.0170	0.901
	2019	329	0.0394	0.0190	
NO (ppm)	2020	323	0.0007	0.0005	0.000
	2019	328	0.0016	0.0009	
NO_2 (ppm)	2020	323	0.0119	0.0067	0.000
	2019	328	0.0155	0.0079	
CO (ppm)	2020	331	0.2514	0.0810	0.048
	2019	329	0.2657	0.1027	
SO_2 (ppm)	2020	327	0.0006	0.0007	0.000
	2019	329	0.0016	0.0014	
NMHCs (ppmC)	2020	329	0.1440	0.0383	0.001
	2019	328	0.1548	0.0481	
CH_4 (ppmC)	2020	329	2.0009	0.0413	0.000
	2019	328	1.9624	0.0548	
Ambient Temperature (°C)	2020	336	22.4	3.1	0.547
	2019	336	22.5	3.2	
Relative Humidity (%)	2020	336	76.5	15.7	0.007
	2019	336	73.1	17.1	
Wind Speed (m/s)	2020	336	0.58	0.42	0.011
	2019	336	0.67	0.49	
Global Solar Radiation (MJ/m^2)	2020	238	1.0580	1.0597	0.678
	2019	238	1.0183	1.0239	

#Statistical analysis of mean values between "2020" and "2019"

Table 2 Air pollutant levels and climatic conditions during the day (4: 00 AM- 8:00 PM) and at night (8: 00 PM-4:00 AM)

	Section	n	Mean	SD	*P*-value#
Photochemical Oxidants (ppm)	Day	206	0.0427	0.0180	0.000
	Night	124	0.0335	0.0135	
NO (ppm)	Day	199	0.0010	0.0006	0.000
	Night	124	0.0003	0.0010	
NO_2 (ppm)	Day	199	0.0121	0.0058	0.517
	Night	124	0.0116	0.0079	
CO (ppm)	Day	207	0.2546	0.0798	0.350
	Night	124	0.2480	0.0830	
SO_2 (ppm)	Day	203	0.0006	0.0007	0.170
	Night	124	0.0005	0.0007	
NMHCs (ppmC)	Day	205	0.1467	0.0399	0.096
	Night	124	0.1394	0.0352	
CH_4 (ppmC)	Day	205	2.0020	0.0394	0.569
	Night	124	1.9993	0.0443	
Ambient Temperature (°C)	Day	209	23.4	3.0	0.000
	Night	127	20.8	2.3	
Relative Humidity (%)	Day	209	71.4	16.4	0.000
	Night	127	85.0	9.8	
Wind Speed (m/s)	Day	209	0.65	0.42	0.000
	Night	127	0.46	0.38	
Global Solar Radiation (MJ/m²)	Day	209	1.2048	1.0497	0.000
	Night	127	0.0000	0.0000	

#Statistical analysis of mean values between "Day" and "Night"

3.2. Multiple linear regression analysis

Air pollutants and climatic conditions, which are potential variables for the formation of photochemical oxidants, were entered as independent variables for multiple regression analysis. The analysis results are shown in Table 3. Stepwise linear regression analysis revealed that relative humidity, ambient temperature, NO, CO, wind speed, and NMHCs are significant independent variables. The Durbin–Watson statistic of 0.732 from the residual analysis was out of the preferred range of 1.5–2.5, suggesting presence of autocorrelation [8].

Table 3 Stepwise multiple linear regression analysis of variables related to the formation of photochemical oxidants.

	Estimated regression coefficient B	95% confidence interval		Partial regression coefficient β	Cumulative R_2	*P*-value
		Lower bound	Upper bound			
Intercept	0.034	0.013	0.054	-	-	0.001
Relative Humidity	-0.001	-0.001	0.000	-0.524	0.560	0.000
Ambient Temperature	0.001	0.001	0.002	0.266	0.630	0.000
NO	-5.439	-6.769	-4.108	-0.309	0.690	0.000
CO	0.032	0.013	0.051	0.146	0.711	0.001
Wind Speed	0.005	0.001	0.009	0.127	0.718	0.010
NMHCs	0.048	0.009	0.087	0.106	0.725	0.015

4. Discussion

Photochemical oxidant, 98% of which is ozone [9]. Ozone and other photochemical oxidants (such as peroxyacyl nitrates and aldehydes) can form as a result of solar oxidation of precursor pollutants (nitrogen oxides and reactive hydrocarbons, etc.) released into the atmosphere and have adverse effects on health and environmental quality [10], [11, 12]. The quantities of the several formed photochemical oxidants are mainly dependent on intensity and duration of daily sunshine, temperature, oxidant concentrations at the beginning of a build-up period, and on emission rates and concentrations of primary pollutants [13]. Therefore, climatic conditions play an important role in the formation of oxidants. Present study investigated the relationship between photochemical oxidants formation and air pollutants and climatic conditions in Tokyo, Japan, from late May to early June 2020. The levels of air pollutants such as NO, NO_2, CO, SO_2, NMHC and CH_4 in 2020 were significantly lower than those in 2019. It seems to indicate that Japan's economic activity was suppressed by the COVID-19 emergency. Quarterly estimates of GDP from April to June 2020, Japan, was declining significantly [14]. Photochemical oxidants and NO were significantly higher during the day than at night. It shows the photochemical reaction is progressing during the day. Stepwise linear regression analysis revealed that relative humidity, ambient temperature, NO, CO, wind speed, and NMHCs are significant independent variables. Partial regression coefficients that allow comparison of effect sizes between independent variables indicate that relative humidity has a strong inhibitory effect on photochemical oxidants formation. High humidity causes ozone decomposition [15, 16, 17]. Other independent variables have been shown in previous studies [4, 5, 6, 7]. However the Durbin–Watson statistic of 0.732 from the residual analysis is outside the preferred range of 1.5–2.5 [8], suggesting presence of autocorrelation that causes an overestimation of the likelihood of a change.

5. Conclusion

Hourly data of air pollutants and climatic conditions in the Tokyo region of Japan from late May to early June 2020 were analyzed to clarify the variables related to the formation of photochemical oxidants. Stepwise linear regression analysis revealed that relative humidity, ambient temperature, NO, CO, wind speed, and NMHCs are significant independent variables.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this work.

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