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SPATIOTEMPORAL VARIATIONS IN PHOTOCHEMICAL SMOG CONCENTRATIONS IN LOS ANGELES COUNTY

*Gong-Yuh Lin and Warren R. Bland**

Los Angeles County has waged a relentless three decade battle against photochemical smog (oxidant air pollution). For much of this period, but especially in the 1970's when motor vehicle exhaust controls began to impact positively on total emissions and on air quality, air management officials and politicians in the County were generally optomistic that within a decade or so Los Angeles would attain the national air quality standard for oxidant. Unfortunately, the increasing frequency of oxidant episodes in 1978 and 1979 casts doubt on such a positive scenario. Consequently, the South Coast Air Quality Management District was forced to obtain a postponement of the deadline for attainment of the oxidant standard from 1982 to 1987.

Whereas 1978's worsened air quality went relatively unnoticed, 1979's did not. Because 1979's worst oxidant episodes were clustered in early September and were unusually severe, Los Angeles' smog situation attracted nationwide attention. Newsweek[1], under the headline A Smog Attack in Los Angeles, wrote that "the worst smog in 24 years shrouded the Los Angeles area last week - dozens of emphysema

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*Drs. Lin and Bland are, respectively, Associate Professor and Professor in the Department of Geography, California State University, Northridge.

and asthma sufferers were hospitalized, and unhealthy people complained of burning eyes, running noses, headaches and shortness of breath." Newsweek explained that "what made the smog so bad was a freak high-pressure system that trapped pollution over the Los Angeles Basin," but repeated a warning from "experts", that Los Angeles would remain prone to dangerous pollution levels until it curbs its emissions from cars. (Fig. 1) Los Angeles County Supervisor Kenneth Hahn put the matter more dramatically, if not more accurately, when he was quoted that "we have lost the battle on smog."[2]

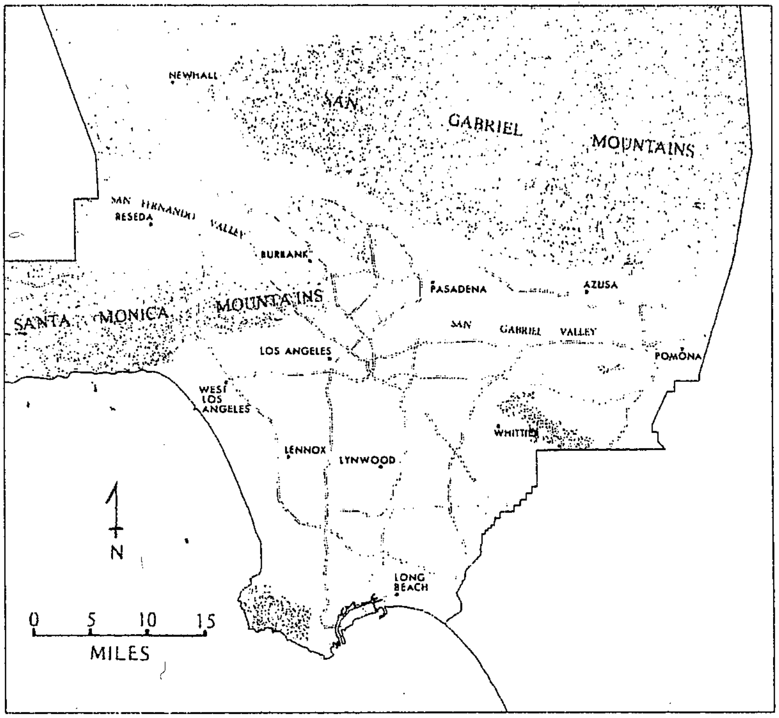


Figure 1

This paper steps back a little from the current furor in order to assess scientifically several aspects of the smog situation in Los Angeles. It asks three basic questions:

1) What pollution factors are responsible for Los Angeles' unusually severe oxidant problem?
2) How severe is the oxidant problem in general, and what is its spatial variation: a) diurnally; b) from weekday to week end; c) seasonally; and d) secularly, i.e., over the long term.
3) What practical measures can be taken to ameliorate the oxidant problem over the next decade?

Answers are sought primarily from a meteorological perspective. Although a number of studies have investigated various aspects of oxidant concentration in Los Angeles,[3] a sophisticated meteorologically-based interpretation is lacking. This paper attempts to fill that lacuna.

Pollution Factors

Air pollution concentrates are functions of contiminant emission rates and the capacity of the atmosphere to disperse pollutants vertically and horizontally. Los Angeles' oxidant problem is particularly severe because emissions of oxides of nitrogen and hydrocarbons, the principal precursors of oxidant, are frequently greater than the atmosphere's capacity to dilute them to concentrations low enough to impede generation of oxidant via photochemical processes. Thousands of tons of oxides of nitrogen and hydrocarbons are injected into Los Angeles' air daily by transportation and industry. The lion's share of both (71 percent of the oxides of nitrogen and 83 percent of the reactive hydrocarbons in 1975, Fig. 2) was contributed by transportation, especially the private automobile.

Figure 2. Daily Average Air Contaminant Emissions in Los Angeles County (Tons/Day)

Sources	Year	THC	RHC	NOx	CO	SO2
Stationary	1973	570	75	280	10	320
	1975	555	75	260	15	250
Transportation	1973	980	695	835	7290	45
	1975	460	355	640	4205	40
Total	1973	1550	770	1115	7300	365
	1975	1015	430	900	4220	290

Source: South Coast Air Quality Management District (SCAQMD).
THC: Total Hydrocarbons.
RHC: Reactive Hydrocarbons.

Although substantial reductions in emissions by stationary and mobile sources occured in the 1950's and 1960's, and although these decreases have been projected into the future (Fig. 3) [4] there is little evidence that control measures sufficiently strong to bring about the desired reductions will be adopted.[5]

Vertical dispersion of contaminants is hampered in Los Angeles by the persistence of a low inversion caused by compressional heating of

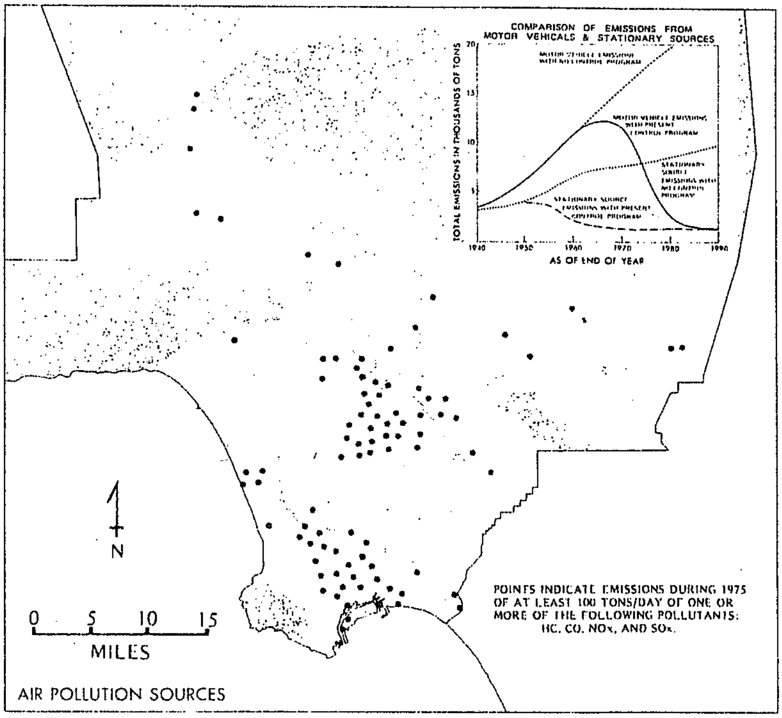


Figure 3.

subsiding air associated with the North Pacific subtropical anticyclone. Below the inversion is a marine layer, a shallow layer of cool moist air which does not heat compressionally but does move horizontally.[6]

Although inversions occur on a majority of days in all seasons, their height and persistence vary greatly. Most winter inversions are of the surface type. At Los Angeles International

Airport (LAX), for instance, the mean height of the inversion base for the December-January period in the mid-1970's was only 200-300 feet. Such shallow inversions tend to break relatively early in the day, thereby permitting upward dispersion of contaminants. In contrast, in summer the mean height of the inversion base at LAX is 1500-2000 feet (Fig. 4). These data, plus values for height of inversion top, inversion magnitude, inversion breaking temperature, and maximum mixing height, suggest that summer inversions are far stronger and more persistent and thus more favorable for oxidant formation than those of winter.

Horizontal dispersion of pollution is controlled by light winds in all seasons. The daily pattern of surface winds is dominated by weak night-time land breezes and stronger day-time sea breezes. Early morning, when land and sea breezes are at a standoff, is especially stagnant. Mean morning wind speeds vary little seasonally, and tend to to be a little stronger at the coast than inland.[7] The principal seasonal variation is the contrast between the light and directionally variable breezes of winter, and the stronger and more persistent sea breezes of summer. The greater strength and persistence of summer's sea breezes is explained by their being in harmony with the onshore flow associated with the synoptic pressure gradient.[8] Occasionally, the relatively stagnant regieme described above is broken by winter storms and Santa Ana (Foehn type) winds which disperse the pollutants more completely.

Figure 4. Mean Monthly Variations of Weather Variables, 1974-1976.

Variables	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Surface Temperature (°C)	10	11	11	12	14	17	19	18	18	16	14	10
950 mb Temperature (°C)	13	11	10	9	12	15	17	18	19	16	15	13
850 mb Temperature (°C)	5	7	2	7	13	19	21	20	19	14	9	6
Inversion Base (feet)	284	421	1041	1199	2287	1719	1680	1628	1464	1296	452	248
Inversion Top (feet)	1477	1350	1491	1526	3571	3229	3339	3218	2898	2181	2550	1248
Inversion Magnitude (°C)	5	3	3	2	7	8	8	8	7	5	5	5
Inversion Breaking Temp (°C)	15	11	8	6	25	30	33	30	28	21	19	16
Max. Mixing Height (feet)	2050	1714	1565	1659	2865	2937	2799	2733	2584	2301	1907	2363
Morning Wind Speed (mph)	4	5	5	5	5	4	4	4	4	4	4	4
Inversion Day	27	22	21	19	28	29	31	30	28	28	27	28
Surface Inversion Day	21	12	6	4	1	2	0	2	4	6	17	22
Rule 444 Day	9	6	2	3	5	7	9	11	12	6	9	11

Figure 5 Correlation Coefficients Between Oxidant Concentrations And Weather Variables In Winter (Upper Values) And Summer (Lower Values).

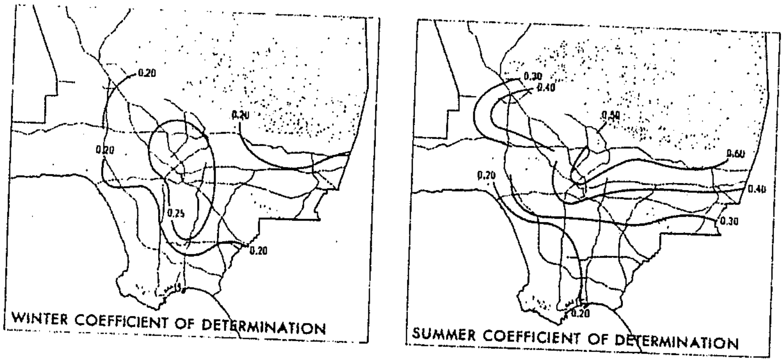
Stations	SFC T	950 T	850 T	Inv Base	Inv Top	Inv Mag	Inv Break	Max Mix Ht	Wind Speed
Azusa	0.24	0.26	0.26	-0.04	0.07	0.22	0.35	-0.15	-0.20
	0.19	0.55	0.45	-0.53	-0.25	0.47	0.43	-0.51	-0.19
Burbank	0.28	0.33	0.28	-0.05	0.07	0.22	0.41	-0.11	-0.27
	0.23	0.49	0.41	-0.46	-0.22	0.43	0.42	-0.41	-0.25
Lennox	0.20	0.21	0.13	-0.04	0.06	0.18	0.31	-0.03	-0.08
	0.02	0.16	0.12	-0.17	-0.09	0.19	0.09	-0.12	-0.27
Los Angeles	0.27	0.37	0.25	-0.11	0.00	0.32	0.42	-0.13	-0.27
	0.16	0.56	0.38	-0.52	-0.27	0.39	0.35	-0.34	-0.31
Long Beach	0.31	0.28	0.21	-0.04	0.03	0.16	0.36	-0.01	-0.15
	0.03	0.25	0.34	-0.26	-0.05	0.28	0.24	-0.13	-0.12
Lynwood	0.28	0.31	0.24	-0.09	0.03	0.20	0.40	-0.02	-0.23
	0.03	0.43	0.11	-0.39	0.23	0.09	0.07	-0.13	-0.31
Newhall	0.32	0.12	0.19	-0.12	0.11	0.16	0.30	-0.11	-0.13
	0.17	0.12	0.35	-0.12	0.00	0.39	0.44	-0.34	-0.10
Pasadena	0.29	0.31	0.28	-0.04	0.09	0.21	0.42	-0.11	-0.20
	0.23	0.59	0.47	-0.55	-0.29	0.46	0.43	-0.50	-0.28
Pomona	0.26	0.27	0.24	-0.04	0.08	0.23	0.41	-0.17	-0.23
	0.19	0.50	0.43	-0.48	-0.21	0.46	0.43	-0.52	-0.13
Reseda	0.25	0.21	0.23	-0.01	0.11	0.22	0.36	-0.13	-0.25
	0.20	0.36	0.43	-0.34	-0.11	0.48	0.47	-0.44	-0.25
West Los Angeles	0.28	0.34	0.21	-0.12	0.02	0.20	0.35	-0.00	-0.14
	0.09	0.39	0.26	-0.41	-0.24	0.26	0.20	-0.20	-0.34
Whittier	0.22	0.29	0.20	-0.08	0.03	0.17	0.36	-0.02	-0.22
	0.08	0.45	0.28	-0.39	-0.21	0.27	0.23	-0.23	-0.26

The Los Angeles atmosphere appears to have its greatest dispersive capacity in spring (March and April). Then the inversion is relatively weak and non persistent, while average winds are relatively strong. Furthermore, the mean inversion magnitude is only about 2° to 3°C in spring, compared to 5°C in winter and 8°C in summer, while spring temperatures at the 950 and 850 mb levels are at their annual low.

To test the hypothesized association between atmospheric conditions and oxidant concentrations,[9] average daily one hour oxidant maxima at 12 Los Angeles air monitoring stations (Fig. 1) were correlated with nine weather variables, i.e., temperatures at surface, and at 950 and 850 mb levels, heights of inversion base and top, maximum mixing height, inversion magnitude, inversion breaking temperature, and mean morning wind speed. Daily records of all variables except the last were obtained for 0600 PST for the 1974-1976 period from LAX. Data for mean morning wind speed were obtained for downtown Los Angeles. The correlation coefficients obtained are higher for summer than for winter and higher for inland valley than coastal areas (Fig. 5). The coefficient of determination shows that more than 50 percent of total summertime variation in oxidant concentration at Azusa, Pasadena, and downtown Los Angeles (all inland stations) can be explained by the nine weather variables (Fig. 6). In contrast, they had little predictive value for coastal stations in summer, or for any of the 12 in winter.

Variations in Pollution Concentrations

Previous meso-scale studies have demonstrated clearly that oxidant air pollution in Los Angeles is severe, with most monitoring stations recording daily maximum hourly averages for oxidant well in excess of the federal air quality standard on the average summer day.[10] This paper examines in greater detail diurnal, day-to-day, seasonal, and secular variations in oxidant concentrations.


WINTER COEFFICIENT OF DETERMINATION

SUMMER COEFFICIENT OF DETERMINATION

Figure 6

Marked diurnal variations in oxidant levels are characteristic because formation of oxidant requires the presence of ultraviolet sunlight. Very low oxidant levels, typically 0.01 to0.02 ppm, occur during night hours (Fig. 7). In summer, the oxidant level begins to rise immeadiately after sunrise, reaching a peak concentration on average at noon over the entire Los Angeles area. Levels then decline gradually toward evening.

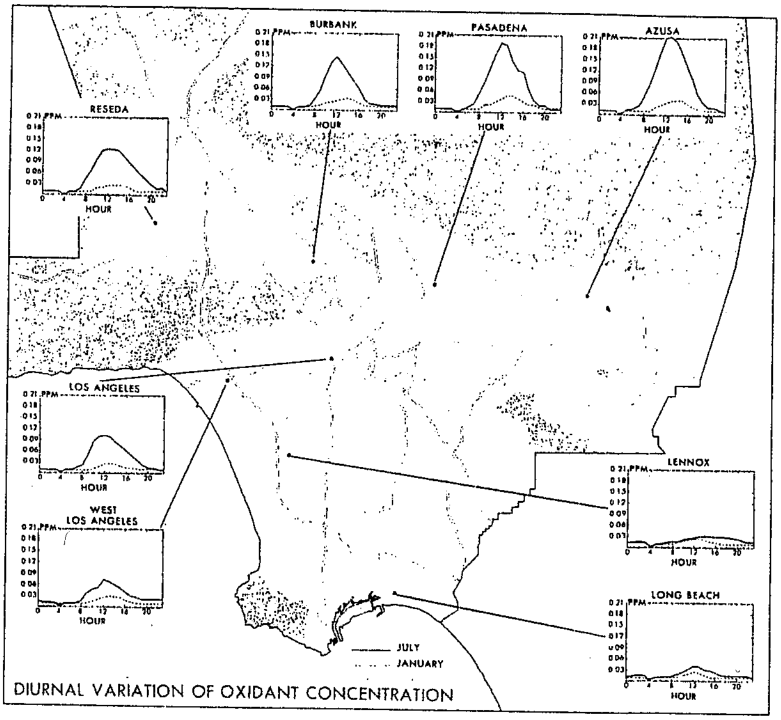


Figure 7

Magnitude, timing, and diurnal amplitude of oxidant peaks are influenced strongly by the strength of solar heating and the sea breeze. In summer, strong daytime solar heating in the inland valleys and along the south-facing slopes of the San Gabriel mountains, results in development of convective cells. These cells will strengthen the sea breeze and often carry oxidant through the inversion base aloft. This "chimney effect,"[11] can prevent ground-level oxidant concentrations from rising further and may explain the clustering of oxidant peaks around noon over much of the Los Angeles basin. In the absence of chimney effect, peak oxidant concentrations would occur later in the day and would be higher, especially in the inland valleys. Unfortunately for residents there, amelioration of smog levels by convection currents is impeded by strengthening of the sea breeze. Both the San Fernando and the San Gabriel valleys are located downwind of dense concentrations of industry and motor vehicle traffic which generate the precursors of oxidant. Because several hours of photochemical reactions are required for oxidant to accumulate in the marine layer, it is the receptor areas, i.e., the inland valleys, which suffer the worst smog effects. Since night-time oxidant minima vary little spatially, the diurnal amplitude of oxidant concentration is lowest near the coast and increases gradually inland. This pattern is especially conspicuous in summer.

In winter, oxidant peaks are of lesser magnitude and tend to occur later in the day than in summer. Lower winter temperatures and radiation intensity weaken photochemical reactions and delay their onset for an hour or two after sunrise. However, the general absence of chimney effect in winter allows oxidant to accumulate well into the afternoon, so peak concentrations occur later and are higher than might otherwise be expected.

Considerable controversy exists as to whether oxidant concentrations vary significantly from weekdays to weekend. Studies in

New York, New Jersey, Washington, D.C., Baltimore, and St. Louis found markedly higher weekend readings.[12] Findings for Los Angeles have been mixed,[13] perhaps because samples were taken at different locations and in different seasons.

The hypothesized difference between weekday and weekend oxidant concentrations was evaluated using 1974-1976 daily maximum one-hour averages at 12 air monitoring stations (Fig. 8). Oxidant concentrations showed very little variation from Monday through Friday, but all stations had a marked weekend increase. These varied from a low of 1 percent at Newhall to a high of 21 percent at Lennox. Student's t-values indicated weekday to weekend differences at the one percent level for Lennox, Long Beach, Los Angeles, and Whittier; and a significant difference at the ten percent level for West Los Angeles. T-values too small to indicate significant differences were found for the San Fernando Valley stations of Burbank and Reseda, and for Newhall. When data were segregated into summer (May-October) and winter (November-April) periods, a generally similar weekday to weekend dichotomy was formed.

Variations in weather are not likely responsible for the weekend increase. Temperatures at the 950 and 850 mb levels, which correlate positively with oxidant concentrations, show a slight decline on weekends (Fig. 9). Furthermore, the slight decreases in inversion base height, maximum mixing height, and wind speed on the weekend cannot explain remarkable increases in oxidant concentrations such as the

Figure 8. Day Of The Week Variations In Mean Oxidant Concentrations (ppm).

Stations	M	T	W	Th	F	S	S	Weekday	Weekend	%Increase	t-values
Azusa	0.111	0.104	0.108	0.103	0.110	0.122	0.117	0.107	0.120	12.15	2.33
Burbank	0.096	0.095	0.098	0.094	0.098	0.101	0.098	0.096	0.099	3.13	0.66
Lennox	0.039	0.037	0.038	0.038	0.037	0.044	0.047	0.038	0.046	21.05	4.37
Los Angeles	0.079	0.077	0.079	0.077	0.077	0.086	0.089	0.078	0.088	12.82	2.72
Long Beach	0.033	0.033	0.033	0.032	0.031	0.037	0.038	0.033	0.038	15.15	3.07
Lynwood	0.043	0.043	0.044	0.043	0.045	0.049	0.047	0.044	0.048	9.08	1.96
Newhall	0.090	0.089	0.092	0.089	0.096	0.095	0.089	0.091	0.092	1.10	0.37
Pasadena	0.109	0.103	0.108	0.103	0.110	0.114	0.115	0.107	0.115	7.48	1.67
Pomona	0.092	0.093	0.096	0.090	0.099	0.107	0.102	0.094	0.105	11.70	2.12
Reseda	0.098	0.094	0.097	0.095	0.099	0.100	0.097	0.097	0.099	2.01	0.50
West Los Angeles	0.061	0.062	0.064	0.060	0.060	0.063	0.067	0.061	0.065	6.56	1.51
Whittier	0.069	0.068	0.067	0.061	0.068	0.077	0.079	0.067	0.078	16.41	2.97

Figure 9. Mean Weather Conditions On Weekday And Weekend.

Weather Variables	Weekday	Weekend
Surface Temperature (°C)	14.1	13.8
950 mb Temperature (°C)	14.1	13.7
850 mb Temperature (°C)	12.0	11.0
Inversion Base (feet)	1183.1	1059.3
Inversion Top (feet)	2270.6	2242.8
Inversion Magnitude (°C)	5.3	5.4
Inversion Breaking Temp. (°c)	20.4	19.9
Maximum Mixing Height (feet)	2358.9	2131.1
Morning Wind Speed (mph)	4.4	4.0

Ironically, the most plausible explanation of higher oxidant readings on weekends is the weekend decrease in primary pollutant emissions, especially nitric oxide, from industrial sources. Since nitric oxide scavanges oxidant,[14] the lower nitric oxide emissions on the weekend favor increased accumulation of oxidant. Not surprisingly, the industrial areas experience the greatest decreases in nitric oxide emissions on weekends and the greatest weekend increases in oxidant.

Dramatic seasonal differences in oxidant concentrations occur in inland areas of Los Angeles. In contrast, little seasonal variation in oxidant exists at coastal stations (Fig. 10). Oxidant concentrations, whether indexed by mean monthly concentration or by mean monthly concentration for Rule 444 days, increase inland from the coast in winter and summer,

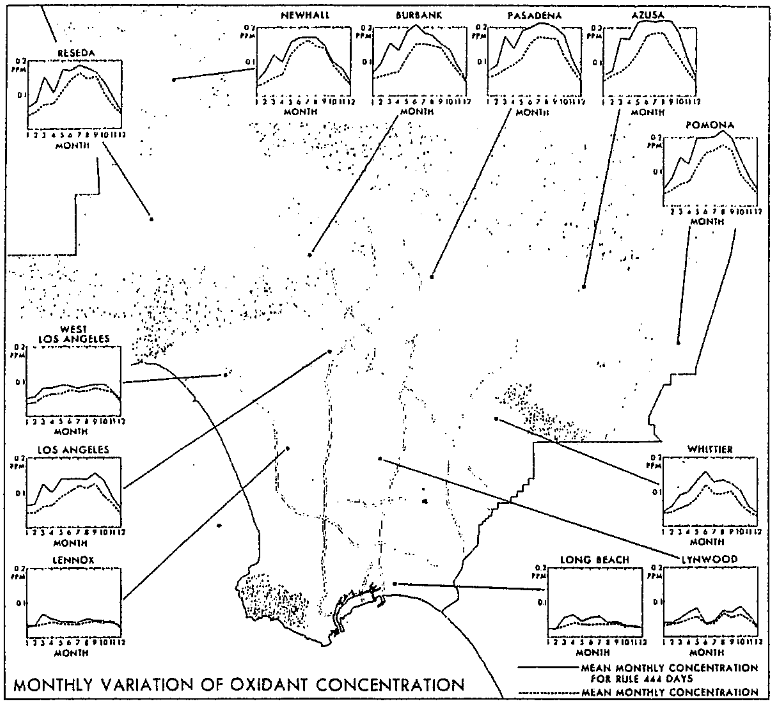


Figure 10

but the spatial gradient is much greater in summer.[15]

The generally low oxidant levels of winter throughout Los Angeles, and the generally higher readings of summer, especially in the inland valleys, are explained by seasonal contrasts in weather. Weather conditions in Los Angeles on the average winter day are not favorable for strong photochemical activity. Winter's low and shallow inversions tend to be destroyed by surface heating early in the day, thereby permitting upward dispersal of primary contaminants before photochemical reactions produce heavy accumulations of oxidant. Strong photochemical activity is inhibited also by the lesser intensity and duration of winter sunlight. In contrast, average day-time weather in summer favors smog formation. During summer, the temperature inversion is low and persistent,[16] enabling oxidant precursors to concentrate in the shallow marine layer.[17] Intense irradiation of this polluted air mass induces strong photochemical reactions which generate large amounts of oxidant which accumulate under the persistent inversion.

Oxidant concentrations increase inland markedly in summer for several reasons. Probably most important is the fact that a time lag of several hours occurs between maximum emissions of hydrocarbons and oxides of nitrogen, and maximum accumulation of oxidant. During this time span, the sea breeze ventilates coastal areas with comparatively clean air, and carries the heavily polluted air into inland valleys.[18] Oxidant concentrations in the inland valleys would, however, be higher than in coastal areas even in the absence of oxidant transport, because climatic conditions are typically sunnier and warmer inland. As noted above, temperatures at the 950 and 850 mb levels have high positive correlation coefficients with oxidant concentrations. Significantly, temperatures at these levels increase generally from coastal areas toward inland valleys.[19]

Careful analysis of secular (long term) oxidant trends is crucial in evaluating the sucess of pollution control strategies, and via feedback analysis, in estimating emission standards needed to achieve federal air quality standards.[20] Simple graphing of mean annual oxidant concentrations is of limited use because year-to-year variations in weather cause parallel variations in oxidant concentrations which obscure long term oxidant trends. Therefore curves of cumulative percentage deviation from the mean oxidant concentrations were compiled (Fig. 11). An upward sloping curve indicates that the oxidant concentration is higher than the mean of the period analyzed, whereas a downward sloping curve shows the reverse.

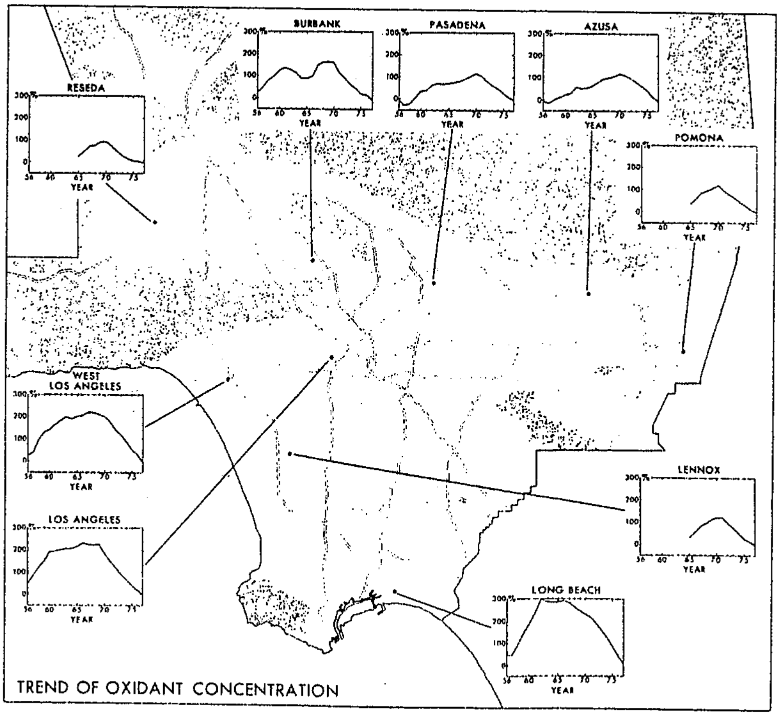


Figure 11

The trend analysis shows a general steady increase in oxidant contentrations from the beginning of the data record to around 1970, and a sharp decline thereafter, for all monitoring stations.[21] Even so, reductions in oxidant concentrations have been spatially uneven. Coastal areas enjoyed approximately 40 percent reductions in the 1970's, compared to only a 15-20 percent reduction in the San Gabriel valley (Fig. 12).

Figure 12. Mean Oxidant Concentrations (ppm) For Different Periods.

Stations	Pre-1970	1970-1977	Differences (%)
Azusa	0.143	0.121	-15.4
Burbank	0.123	0.092	-25.2
Lennox	0.061	0.043	-36.1
Los Angeles	0.120	0.077	-35.4
Long Beach	0.065	0.039	-40.0
Reseda	0.124	0.095	-23.4
Pasadena	0.143	0.115	-19.6
Pomona	0.141	0.101	-28.3
West Los Angeles	0.099	0.062	-37.0

Recent improvements notwithstanding, air quality in Los Angeles County is still far from satisfactory. In 1978, oxidant concentrations exceeded the state standard of 0.10 ppm were reached on nearly 200 days in the San Gabriel and San Fernando valleys.[22] Worse still, projections indicate that the federal oxidant standard will not be attained in inland areas of Los Angeles County by the 1982 deadline mandated by amendments to the Clean Air Act in 1977.[23]

Conclusion

This paper has described the pollution factors responsible for for photchemical (oxidant) air pollution in Los Angeles, established that the oxidant problem is severe, and shown how smog varies diurnally, from weekday to weekend, seasonally, and secularly. There remains the task of recommending practical measures to ameliorate the problem in the 1980's.

The writers forsee no quick or easy solution to the oxidant problem. We are not sanguine that weather modification or tinkering with the nitric oxide/hydrocarbon balance will reduce the smog problem. Since oxides of nitrogen are themselves toxic pollutants, we regard any attempt to reduce oxidant concentrations by increasing oxides of nitrogen emissions as extremely dangerous. Therefore, we recommend measures to curb emissions of both precursors of oxidant, i.e., hydrocarbons and nitric oxide.

Moblie sources, especially the private automobile, remain the principal contributors of hydrocarbon and nitric oxide emissions in Los Angeles. For this reason, and because there is considerable potential for further reductions in automotive emissions, our emphasis is on reducing emissions from transportation. We recognize, however, that stricter enforcement of existing anti-pollution ordinances could also impact favorably on air quality.

The keys to reducing total automotive emissions are reduced auto use per capita, and lower emissions per vehicle-mile. Reduced auto use per capita is a realistic goal in Los Angeles because auto use is currently inordinately high, even by U. S. standards. Discretionary driving could be reduced without great sacrifice, and some auto travel could be directed to other modes. Some progress toward lower per capita use of autos will occur in response to free market mechanisms such as increased costs of car ownership and operation, and/or as a result of fuel shortages. But changes in travel behavior sufficient to significantly reduce emissions will require additional measures. These include:

1) massive expansion of the regional bus system;
2) vigorous provision of priority treatment for buses and carpools to give them an advantage over single occupant cars; and
3) development of a light rail rapid transit system oriented to the major arterial routes of the more densely populated parts of the region.

Expansion of the bus system and provision of priority treatment (such as exclusive use of bus/carpool lanes on arterials and freeways) for high occupancy vehicles, are relatively inexpensive short term palliatives. Construction of a light rail system would in contrast, cost billions of dollars and extend to the 1990's.

Lower average emissions per vehicle mile are attainable at relatively low cost by requiring that all cars, not just new models, meet the stiff emission standards of the late 1970's. The requirement is vital, because although new cars run very cleanly, older models emit, on the average, much larger quantities of hydrocarbons and oxides of nitrogen. This occurs because their pollution control systems were ineffective at time of manufacture, deteriorated in use, or are now "out of tune". Legislation requiring compulsory annual inspection of automobile pollution control systems, repair of same, and/or retrofitting of catalytic converters or other abatement devices is clearly needed.

The writers believe that these abatement measures are realistic responses to the pollution crisis, and not expensive compared to the costs of continuing current wasteful and polluting ways. The measures are vital to the future environmental health of the region, and with oil and gas supplies increasingly uncertain and costly they may prove essential to the future economic health of the region as well.

NOTES

[1] *Newsweek*, September 21, 1979, p. 42.

[2] *Los Angeles Times*, September 22, 1979, Part I, p. 1.

[3] See, for example Warren R. Bland, "Seasonal Variations in Air Pollution in Los Angeles County," *The Professional Geographer*, Vol. 26 (August, 1974), pp. 277-282; Warren R. Bland, "Smog Monitoring and Control in Los Angeles Area," *The California Geographer*, Vol. 15, 1975, pp. 60-65; Warren R. Bland, "Smog Control in Los Angeles County: A Critical Analysis, 1976, pp. 283-289.

[4] Los Angeles County Air Pollution Control District, *Profile of Air Pollution Control*, 1974, pp. 9-10.

[5] Bland, 1976, pp. 287-288.

[6] Edinger, J. G., *Watching for the Wind*, (New York: Anchor, 1967), pp. 83-114.

[7] South Coast Air Quality Management District, *Air Quality and Meteorology, Annual Report*, 1976, p. 9.

[8] Neilburger, M. and J.G. Edinger, *Summary Report on Meteorology of the Los Angeles Basin with Particular Respect to the Smog Problem*, Los Angeles, Southern California Air Pollution Foundation, 1954, p. 25.

[9] Myrabo, L. N., et. al., "Survey of Statistical Models for Oxidant Air Quality Prediction," *Advances in Environmental Science and Technology*, Vol. 7. (1977), pp. 391-422.

[10] Bland, 1976, p. 2.

[11] Edinger, J. G. "Modification of the Marine Layer over Coastal Southern California," *Journal of Applied Meteorology*, Vol. 2. (1963), pp. 706-712; South Coast Air Quality Management District, Op. cit, p. 9.

[12] Clevand, W. S. et. al., "Sunday and Workday Variations in Photochemical Air Pollutants in New Jersey and New York," *Science*, Vol. 186, 1974, pp. 1037-1038; Lebron, F., "A Comparison of Weekend-Weekday Ozone and Hydrocarbon Concentrations in the Baltimore-Washington Metropolitan Area," *Atmospheric Environment*, Vol. 9, 1975, pp. 861-863; Karl, T. R. "Day of the Week Variations of Photochemical Pollutants in the St. Louis Area," *Atmospheric Environment*, Vol. 12, 1978, p. 1657-1667.

[13] Elkus, B. and K. R. Wilson, "Photochemical Air Pollution: Weekend-Weekday Difference," *Atmospheric Environment*, Vol. 11, 1977, pp. 509-515.

[14] Jeffries, H. E. et. al., "Photochemical Conversion of NO to NO_2 by Hydrocarbons in Outdoor Chamber," *Journal of the Air Pollution Control Association*, Vol. 26, 1976, pp. 480-484.

[15] The Rule 444 day, formerly termed Rule 57 day, is defined by three parameters: (1) a morning inversion height of less than 1500 feet, (2) a maximum mixing height of 3500 feet or lower, and (3) an average morning (0600-1200 PST) wind speed of five miles per hour or less. Disposal of agricultural wastes in open fires is not permitted on Rule 444 days.

[16] Los Angeles County Air Pollution Control District, *Profile of Air Pollution Control*, 1971, p. 61.

[17] Edinger, J. G. *The Meterology of Los Angeles' Polluted Layer*, U. C. L. A. Department of Meteorology, 1958, p. 2.

[18] Neilburger, M. "The Role of Meteorology in the Study and Control of Air Pollution," *Bulletin of the American Meteorological Society*, Vol. 50, 1969, pp. 957-965; Stephens, E. R. "Chemistry and Meteorology in An Air Pollution Episode," *Journal of the Air Pollution Control Association*, Vol. 25, 1975, pp. 521-524.

[19] Edinger, J. G. "Vertical Distribution of Photochemical Smog in Los Angeles Basin," *Environmental Science and Technology*, Vol. 7, 1973, pp. 247-252.

[20] Pierrard, J. M. et. al., "A New Approach to Setting Vehicle Emission Standards," *Journal of the Air Pollution Control Association*, Vol. 24, 1974, pp. 841-848; Trijonis, et. al., "Oxidant and Precursor Trends in the Metropolitan Los Angeles," *Atmospheric Environment*, Vol. 12, 1978, pp. 1413-1420.

[21] The slight decreases at Burbank and Long Beach in the mid 1960's reflect the changed locations of the air monitoring stations.

[22] South Coast Air Quality Management District, *Air Quality and Meterology*, December 1978, p. 24.

[23] Southern California Association of Government, *Summary Draft Air Quality Management Plan*, 1978, 91 pp.