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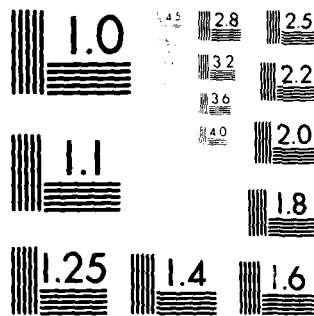UNCLASSIFIED   NRL-MR-4228   SBIE-AD-E000 441   NL

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This report is a summary of the air quality data measured and recorded during the calendar year 1979. This annual summary is part of a continuing series initiated in 1975. The variables summarized include ozone (O_3), sulfur dioxide (SO_2), nitric oxide (NO, nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (RHC), carbon monoxide (CO), air temperature, relative humidity, wind direction, and wind speed. The instruments in use at the NRL air monitoring station are interfaced to a data acquisition system which in turn is

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20. Abstract (Continued)

coupled to a magnetic tape recorder. The data input is for one month on a tape which is subsequently analyzed by the NRL air computer program and results in a monthly computer printout of the essential air quality data. Each of the monthly computer printouts is then analyzed and a digest of the information obtained is reported as the annual summary. Included in the report is some background information thought necessary in understanding the data. Finally, a brief description of the odor nuisance problem at NRL is described.

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CONTENTS

THE 1979 NRL AIR QUALITY DATA

INTRODUCTION

This report is the fifth in a continuing series of yearly summaries of the air quality data measured at NRL (1,2,3,4). The present review includes the air quality data for the calendar year 1979. The variables measured and recorded during this time were ozone (O_3), sulfur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (RHC), carbon monoxide (CO), air temperature, relative humidity, wind direction, and wind speed.

The purpose of the report is to characterize, interpret, and summarize the large amount of the air quality data generated over the one-year period.

BACKGROUND

The NRL air monitoring station is located in Building 207, Room 409. *Details in the housing and instruments in use have been reported in a previous publication (5).* Some new additional instruments in use at the NRL air monitoring station during the calendar year 1979 included a continuous nitrogen oxides (NO_x) analyzer (based on the reaction between nitric oxide (NO) and ozone which produces light energy at a given wavelength). Any nitrogen dioxide (NO_2) in the ambient air is converted to NO, and the total NO, as NO_2 plus NO, is the total oxides of nitrogen, NO_x. Electronic subtraction of NO from NO_x yields NO_2 in ppmv), an air temperature system using a radiation shielded thermocouple, and a continuous relative humidity monitor using the hair hygrometer principle. The instruments in use are interfaced to a data acquisiton system which is, in turn, coupled to a magnetic tape recorder. The input on the magnetic tape is in 5-minute average electrical voltages. A tape is run continuously for one month and the data is retrived, via the air quality computer program with a computer printout of the essential air quality data (6). The air quality data from the monthly computer printouts were used to extract the main body of information contained in this report.

GENERAL INFORMATION

At any given time, there are thousands of substances present in the ambient air. These materials enter the atmosphere from natural

sources (dust storms, forest fires, lightning, sea salt spray,
vegetation, and volcanos), human activity (agricultural practices,
animal husbandry, commercial establishments, highway and roadway con-
struction, industrial and manufacturing operations, institutions,
solid and liquid waste disposal, and transportation systems),
tropospheric-stratospheric exchange, and extra-terrestrial entry of
cosmic debris into the earth's atmosphere. From these sources,
materials injected into the atmosphere include gases, liquids, and
solids. A few of these substances form the natural composition of
the atmosphere as it has evolved up to the present time, some are
inert, others reactive or act as catalysts; while, for a great number,
much remains to be understood. A select few have been recognized as
interfering with human health and welfare, i.e., the air pollutants.
An air pollutant may be defined as a chemical substance, usually a
product of human activity, that has a negative effect on human well-
being, and whose deleterious effects are above a given concentration
(this concentration may be zero, or equal to the background value).

Air pollutants, singly or in combination with other substances,
cause, or accelerate, acid rain (below pH 5.5), building grime,
deteriorating climatic changes, fabric damage, human and animal sick-
ness, metal corrosion, vegetation damage, and visibility degradation.
In addition, the effects of an air pollutant may be immediate (acute)
or long-term (chronic). Acute response may be discerned in minutes,
hours, or days, while chronic symptoms may be revealed in months,
years, or even longer periods of time. For humans, the effects of air
pollutants, directly or indirectly, are associated with asthma, cancer,
cardiovascular problems, chronic bronchitis, eye irritation, odor-
nuisance, and respiratory diseases.

Some of the recognized air pollutants that cause such concern
include asbestos, beryllium, carbon monoxide, lead, mercury, nitrogen
dioxide, ozone, particulate matter, and sulfur dioxide. Other air
pollutants include carbon dioxide, Freons, nitric acid, organic and
inorganic sulfates, polynuclear hydrocarbons, sulfuric acid, as well
as a number of inorganic and organic halogens, nitrogen, oxygen, and
sulfur compounds, which are recognized as air pollutants, or are
precursors or promoters of air pollutants. The influence of these
substances may vary from curbside, fenceline, street, city, metro-
politan area, region, national, international, or global, and, with
respect to human response, may vary from a single individual to the
entire earth's population, or affect areas where one lives, plays, or
works.

In urban communities, like the metropolitan Washington area, the
main sources of air pollutants are the result of human activity
(anthropogenic sources) and include emissions from air traffic, com-
mercial establishments (dry cleaning plants, gasoline stations,

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restaurants, etc.), electric power plants, heating plants, incinerators, institutions, light industry, motor vehicles, residential home heating units, and sewage treatment plants. These emission sources may be further described as: area-line-source, combustion-noncombustion, continuous-intermittent, elevated-ground, gas-liquid-solid, inorganic-organic, and/or urban-suburban-local. In any case, the total quantity of air pollutants combined is significant and may well be several thousand tons per day.

The lifetimes of the air pollutants, or any trace substances present in the atmosphere, depend on the sequence emission-transport-receptor and may last from a few minutes to several years, or longer. Once an air pollutant is emitted into the atmosphere, or is formed there, it is diluted and dispersed by horizontal advection (wind) and/or vertical convection. Their subsequent fate is determined by meterological conditions and reactivity (reaction rate). Scavenging mechanisms such as precipatation, clouds, and dry deposition (impingement on surfaces) remove most of the air pollutants from the atmosphere or transport them to another area. Some air pollutants are slow reacting and reactions may occur far from their source. Other air pollutants are highly reactive and may form other more potent air pollutants. Still other substances are inert, or are ineffectually removed from the atmosphere by scavenging mechanisms, and may persist in the atmosphere for long periods of time. Therefore, non-reactive substances will have time to build up their background concentrations to as yet unforeseen effects.

The sequence, emission-transport-receptor, is also a neverending, overlapping cycle. Superimposed on this sequence are air pollutants from other metropolitan areas. Exchange of air pollutants may occur within Washington, D. C.-Baltimore, Maryland; Washington, D. C.-Richmond, Virginia; and with other areas further away. Consequently, the concentrations measured and recorded at the NRL air monitoring station are from a combination of sources: natural, local human activity (fresh), and from long distance human activity (aged). However, for most practical purposes, the emission sources from local human activities will be considered the most influential in biasing the air quality data.

AIR QUALITY DATA AND RESULTS

Valid Measurements

Table I lists the number and percent of valid hourly measurements of each variable measured and recorded during the calendar year 1979.

Table 1		
Valid Number and Percent of Measured and Recorded Air Quality Data		
Variable	Number of Hours	Percent of Hours*
O_3	7376	84.2
SO_2	7307	83.4
THC	6647	75.9
CH_4	6647	75.9
RHC	5860	66.9
CO	6647	75.9
NO	5972	68.2
NO_2	5972	68.2
wind speed	7521	88.9
wind direction	7521	88.9
air temperature	7541	85.9
relative humidity	7301	83.4
* based on 8760 hours (1 year)		

Instrument downtimes were due to calibration procedures, maintenace and repair work, and electrical glitches. In addition, the number of hourly observations were decreased because the magnetic tape recorder was started on the first working day of the month and turned off on the last working day of the month, or as close as possible to those days. Even so, the percentages listed in the table are high enough to give, for each variable, a reliable estimate of representative values for any time-averaging period of interest.

Percentages less than 49% would be considered a poor representation of the data, 50%-59% would be considered fair, 60%-74% good, and above 75% excellent. Obtaining higher percentages would require backup systems for most of the instruments in use.

Meteorological Data

Table 2 lists the percent occurrence of each of the sixteen wind directions measured and recorded during the calendar year 1979. Also included in the table is the average wind speed for each of the wind directions.

Table 2		
Percent Occurrence of Each Wind Direction and Corresponding Average Wind Speed		
Wind Direction	% Occurrence	Average Wind Speed (mph)
NNW	13.6	11.0
S	12.9	6.7
NNE	9.5	7.9
N	9.1	8.4
SSW	9.1	6.9
SW	9.1	8.1
SSE	8.3	8.2
NW	7.2	10.0
NE	4.9	7.5
WSW	3.6	7.1
SE	2.8	8.3
WNW	2.6	9.1
ENE	2.3	8.8
W	1.7	8.2
E	1.7	8.9
ESE	1.6	9.9

As shown in the table, the prevailing wind direction was NNW. This wind direction lies in the Virginia sector, with respect to the Laboratory, and directly in line with the Washington National Airport (2 miles). The airport accommodates about 1000 operations per day. Other nearby reference points, and possible emission sources, are

the Pentagon (3-1/2 miles), and the approaches, on the Virginia side, to the George Mason Memorial, Center Highway, and Rochambeau Memorial bridges.

The second most prevailing wind direction during 1979 was south. In this direction lie the Blue Plains Sewage Treatment Plant (NRL's neighbor) and the Wilson Bridge (2 miles); the bridge is a part of the Washington Beltway-Route 495 (and 95). The traffic on the bridge is approximately 103,000 motor vehicles per workday. Also, from this wind direction, the air traffic (landings and takeoffs) is about 500 operations per day.

The third most prevailing wind direction during the year was NNE. In this direction, with respect to the Laboratory, lies most of the downtown section of the District of Columbia. Reference points for this wind direction are the Washington Navy Yard (3-1/2 miles) and the U. S. Capitol (4-1/2 miles). A major emission source from this wind direction is the Benning Road electric power plant (5-3/4 miles). Another major emission source, the Buzzard Point electric power plant, lies midway between the N and NNE wind direction.

Fortunately, for the Laboratory, some nearby major emission sources are located in the least prevailing wind directions. For example, to the west, across the Potomac River, on the Virginia side, is located a coal-fired electric power plant (1 mile) which burns about one million tons of coal a year. In the east is the Anacostia Freeway, Route 295, with about 53,000 motor vehicles per workday. Of course, what is favorable for the Laboratory is not so favorable for some other areas.

Within the Laboratory grounds is located the NRL heating plant (SSW of the air monitoring station) which, during 1979, consumed 3,859,275 gallons of fuel oil (mostly #6). The major air pollutants for this type of emission sources are particulate matter, sulfur dioxide, and nitrogen oxides, with lesser amounts of other pollutants being emitted such as hydrocarbons and carbon monoxide. Other emission sources within the Laboratory may be considered insignificant except on a local level. One may, however, consider no source as insignificant since it is the combined output of all emission sources that determines the air quality of a given area.

Another important meteorological condition that influences pollutant concentrations is surface-based temperature inversions; also called nighttime or radiation inversions. This is measured routinely at the NRL air monitoring station and is based on an indirect method developed at the Laboratory (7). This type of inversion is indicated by a temperature increase in altitude from the ground surface up to a given height; depending on the strength of the inversion. With corresponding low wind speeds, a usual condition at night, the pollutants

are trapped within the inversion layer since horizontal and vertical dispersion is limited. Generally, this type of inversion is initiated in the late evening or early morning hours, peaks in the mid-morning hours, and decays in the early afternoon hours. After the surface-based temperature inversion is dissipated, the pollutants are diluted and dispersed with fresh incoming air.

In addition to the daily occurrence of surface-based temperature inversions, there is another type of inversion that results in high pollutant concentrations. This condition is known as the sub-sidence temperature inversion and occurs aloft at a higher layer of the troposphere. The subsidence inversion results from the sinking of air at great altitudes above a high pressure region. As this air descends, it gains heat and forms a deep warm layer that overlies the cooler air beneath it. Consequently, high pressure systems are related to subsidence temperature inversions. When a high pressure system hovers over an area, or moves slowly (stagnating anti-cyclone), vertical motion is diminished and pollutant concentration build-up is enhanced. In fact, these are the conditions when most severe air pollution episodes occur.

Air Quality Data

The actual air pollutants for which air quality standards have been issued by the federal government, and which were measured and recorded at the NRL air monitoring station during the calendar year 1979, included carbon monoxide (CO), nitrogen dioxide (NO_2), non-methane hydrocarbons (RHC), ozone (O_3), and sulfur dioxide (SO_2). In addition, air quality data were also collected for methane (CH_4), nitric oxide (NO), and total hydrocarbons (THC). These gases, although not presently considered as air pollutants, serve to identify emission sources, enter into chemical reactions in the atmosphere, relate con-centration fluctuations to corresponding meteorological conditions, and/or establish concentration profiles typical of gaseous behavior in the atmosphere.

For each gas, a table of air quality data has been constructed listing for each month, in ppmv, the monthly average, the maximum concentrations for the three time-averaging periods of interest, i.e., 5 minutes, 1-hour, and 24-hours. The table for CO includes the 8-hour maximum concentration, and for THC, CH_4, and RHC the 3-hour maximum concentration that occurred in the period corres-ponding to the morning rush hour traffic (6 a.m. - 9 a.m.). At the bottom of each table, the representative yearly average is shown. This information is listed in Tables 3 - 10.

Table 3
Air Quality Data for O_3 in ppmv

Month	Monthly Average	C_{max} 5-min	C_{max} 1-hr	C_{max} 24-hr
January	0.006	0.015	0.013	0.009
February	0.009	0.039	0.037	0.019
March	0.006	0.021	0.021	0.011
April	0.032	0.387	0.355	0.047
May	0.027	0.159	0.075	0.048
June	0.032	0.101	0.096	0.051
July	0.034	0.130	0.121	0.052
August	0.034	0.141	0.132	0.053
September	0.023	0.145	0.134	0.038
October	0.016	0.082	0.075	0.032
November	0.017	0.342	0.085	0.040
December	0.013	0.046	0.044	0.027
representative yearly average = 0.021 ppmv				

Table 4
Air Quality Data for SO_2 in ppmv

Month	Monthly Average	C_{max} 5-min	C_{max} 1-hr	C_{max} 24-hr
January	0.028	0.300	0.206	0.046
February	0.019	0.184	0.074	0.035
March	0.026	0.163	0.089	0.039
April	0.017	0.169	0.089	0.034
May	0.015	0.163	0.072	0.032
June	0.013	0.320	0.139	0.027
July	0.013	0.269	0.107	0.022
August	0.012	0.269	0.093	0.021
September	0.013	0.269	0.084	0.031
October	0.015	0.322	0.097	0.031
November	0.018	0.282	0.077	0.031
December	0.022	0.384	0.173	0.053
representative yearly average = 0.018 ppmv				

		C_{max}		
Table 5				
Air Quality Data for NO in ppmv				
Month	Monthly Average	5-min	1-hr	24-hr
January	0.025	0.435	0.377	0.078
February	0.028	0.425	0.327	0.101
March	0.031	0.485	0.422	0.128
April	0.008	0.181	0.153	0.028
May	0.009	0.424	0.362	0.066
June	--	--	--	--
July	0.008	0.260	0.113	0.029
August	0.013	0.233	0.183	0.042
September	0.024	0.384	0.339	0.104
October	0.034	0.473	0.375	0.122
November	0.054	0.485	0.425	0.221
December	--	--	--	--
representative yearly average = 0.023 ppmv				

		C_{max}		
Table 6				
Air Quality Data for NO_2 in ppmv				
Month	Monthly Average	5-min	1-hr	24-hr
January	0.024	0.050	0.040	0.037
February	0.028	0.155	0.122	0.055
March	0.026	0.101	0.085	0.052
April	0.021	0.140	0.119	0.058
May	0.010	0.070	0.065	0.032
June	--	--	--	--
July	0.035	0.127	0.118	0.063
August	0.019	0.082	0.066	0.030
September	0.022	0.130	0.095	0.047
October	0.023	0.151	0.128	0.070
November	0.033	0.256	0.191	0.101
December	--	--	--	--
representative yearly average = 0.024 ppmv				

Table 7					
Air Quality Data for CO in ppmv					
	Monthly	C_{max}			
Month	Average	5-min	1-hr	8-hr	24-hr
January	1.42	7.53	5.95	3.42	2.09
February	1.67	10.76	7.16	5.49	3.53
March	1.80	29.27	23.31	8.48	3.66
April	1.75	23.27	23.04	12.41	2.15
May	1.08	26.97	6.21	2.79	1.24
June	0.98	2.95	1.91	1.57	1.16
July	1.59	18.09	6.71	6.69	3.99
August	0.96	16.67	2.41	1.24	1.04
September	1.26	9.79	7.20	4.58	2.79
October	1.63	11.39	8.27	5.84	3.33
November	--	--	--	--	--
December	1.99	12.35	6.78	5.35	4.00
representative yearly average = 1.47 ppmv					

Table 8					
Air Quality Data for THC in ppmv					
	Monthly	C_{max}			
Month	Average	5-min	1-hr	3-hr	24-hr
January	2.19	12.32	7.08	3.03	3.27
February	2.25	15.68	5.70	3.48	3.00
March	3.24	14.37	11.56	9.29	8.03
April	2.66	26.97	24.84	5.87	3.80
May	1.99	23.11	6.78	4.23	2.39
June	2.10	16.79	8.91	3.75	3.05
July	5.13	23.68	23.55	20.42	19.64
August	2.02	16.05	3.90	2.98	2.31
September	2.03	9.70	6.72	4.57	2.88
October	2.34	19.79	7.82	6.35	3.82
November	2.47	14.24	8.68	3.56	3.88
December	2.48	13.98	8.34	4.30	3.39
representative yearly average = 2.58 ppmv					

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Table 9					
Air Quality Data for CH_4 in ppmv					
	Monthly	C_{max}			
Month	Average	5-min	1-hr	3-hr	24-hr
January	2.37	10.03	7.49	2.75	2.79
February	2.44	8.87	5.29	3.62	2.82
March	2.28	8.50	5.21	3.85	2.76
April	2.04	25.42	17.68	6.04	2.29
May	1.96	14.03	4.40	3.82	2.41
June	1.93	14.35	7.38	3.62	2.79
July	2.61	7.91	7.58	6.34	6.51
August	1.90	8.39	3.74	2.52	2.26
September	1.84	6.34	4.68	3.24	2.60
October	2.11	13.99	6.63	4.71	3.07
November	2.12	10.52	5.43	3.08	3.08
December	2.36	11.98	7.45	4.08	3.21
representative yearly average ≈ 2.16 ppmv					

Table 10					
Air Quality Data for RHC in ppmv					
		C_{max}			
Month	Average	5-min	1-hr	3-hr	24-hr
January	0.06	4.30	2.62	0.25	0.16
February	0.04	13.45	1.51	0.36	0.27
March	1.02	8.37	6.38	5.82	5.36
April	0.95	24.98	11.29	1.81	1.51
May	0.12	20.93	4.67	1.89	0.40
June	0.28	14.19	3.00	0.72	0.52
July	2.53	16.06	15.97	7.55	--
August	0.32	14.41	2.74	--	--
September	0.26	7.05	2.14	1.69	0.72
October	0.32	15.70	3.42	1.48	0.74
November	0.44	7.93	3.57	0.88	0.88
December	0.23	6.37	1.77	0.87	0.70
representative yearly average ≈ 0.55 ppmv					

A common feature of the data in the tables is that, for any given month, the shortest time averaging period always has the highest concentration value, i.e., the 5-minute maximum concentration is higher in value than the 1-hour maximum concentration, etc. This concentration behavior is typical of all trace substances present in the ambient air. Conversely, the minimum concentration increases with longer time-averaging periods. These results are trivial because it should be expected that in a long sampling time, say, one month, there are more shorter time-averaging periods than longer time-averaging periods, so that the probability is higher for a 5-minute maximum concentration to have a larger value than the 1-hour maximum concentration. In other words, there are more concentration fluctuations with shorter time-averaging periods than longer time-averages. As longer time-averaging periods are used, concentration fluctuations tend to be damped.

Another common feature of the air quality data is that none of the gases have a normal, or Gaussian, concentration distribution in the atmosphere for a given time-averaging period. An analysis of all of the 1-hour data for each gas (see Table 1) has revealed that CO, NO, O_3, RHC, and SO_2 follow a log-normal type distribution, while THC, CH_4, and NO_2 have a more complicated concentration distribution.

For the O_3 air quality data listed in Table 3, the most significant feature is the high concentration values during the warmer months for each of the time-averaging periods of interest. This is no coincidence since a prerequisite for O_3 production is high air temperatures. An anamoly is the November data, but that month had unseasonably high temperatures.

For the SO_2 data listed in Table 4, the most significant feature is the generally higher concentration values during the colder months. This is to be expected since there is a higher demand on fuel and power requirements during the colder months.

For the NO data listed in Table 5, the most significant feature (even though the June and December Data are missing) is the generally higher concentrations during the colder months. Like SO_2, NO is high in the colder months because of higher fuel and power use but, in addition, NO enters into less reactions during this period. In the warmer months, NO enters into the photochemical reaction scheme and, in addition, is an O_3 scavenger, entering into reactions with that pollutant and forming organic nitrogen compounds.

For the NO_2 data listed in Table 6, the most significant feature (even though the June and December data are missing) is that there is no apparent seasonal effect that can be detected with

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certainty. Perhaps this is not too surprising since NO_2 is emitted in small amounts from all combustion sources, is a product of the oxidation of NO, and is formed in the atmosphere; it is the single most important compound in the photochemical reaction scheme (8).

For the CO data listed in Table 7, the most significant feature is the generally higher values in the colder months. Some anomalies exist in the data because of the emission of this pollutant from random operations of nearby sources such as road and roof tarring operations and fire department training exercises (at Washington National Airport and from the District of Columbia Fire Department Training Facility). CO concentrations would also be expected to be lower in the warmer months because of its reactions with the hydroxyl radical (OH) (8,9). This free radical is very important in atmospheric chemistry, and would tend to be present in higher concentrations during the warmer months.

An interesting point about CO is that the quantity emitted, during a year, is equal to, or greater than the combined tonnage of all other air pollutants combined. Only carbon dioxide and water are emitted in greater amounts from combustion processes.

For the THC data listed in Table 8, there is no apparent seasonal effect. Because of the anomalous effect of random emission sources, such as those listed for CO, there were also occasions when solvent release occurred near the air sampling probe (intake). Specifically, painting operations, hood exhaust emissions, and solvent release from a newly constructed, slow-setting concrete facility, resulted in abnormally high THC concentrations.

For the CH_4 data listed in Table 9, the most significant feature is that, for any given time-averaging period, the concentration values do not show much abnormal variations except for a few known types of anomalies. What is significant is that a major CH_4 source exists near the Laboratory, i.e., the Blue Plains Sewage Treatment Plant. Fortunately, CH_4 is not considered an air pollutant and its global background concentration of approximately 1.4 ppmv has not been found to be increasing. In addition, CH_4 is not considered to be involved in any chemical reactions in the atmosphere, typical of paraffinic hydrocarbons, because of its low reaction rate with compounds involved in the photochemical reaction scheme. However, at long enough times, via long distance transport, CH_4 may enter into chemical reactions with free radicals, notably the OH radical.

For the RHC data listed in Table 10, the significant feature is the generally higher concentration values in the warmer months. Generally, a large fraction of the hydrocarbons are emitted from combustion sources, but in a few instances, non-combustion sources, with minimal CH_4 emissions, are present in the NRL air environment so that RHC concentrations would tend to be high. Also, even with

combustion processes, the ratio of total hydrocarbons to methane is, in some cases, high so that, again, RHC concentrations are high. In addition, some organic compounds are formed in the atmosphere via the photochemical sequence of reactions which could also result in high RHC concentration values. However, it should be pointed out that not all RHC compounds are involved in photochemical reactions, i.e., their reaction rates are low. Consequently, they do not readily participate as precursors in oxidant formation.

In another approach to characterizing the air quality data, the 1-hour maximum concentrations that occurred, with the corresponding conditions of interest, are listed in Table 11, for each air pollutant and gas, for each month of the year in which data were available.

Table 11

1-hr Maximum Concentration Values During Each Month of 1979
for Each Pollutant and Trace Gas and Corresponding Conditions

Pollutant	Month	Conc. (ppmv)	Day of Week	Hour of Day (Military Time)	Wind Speed (mph)	Wind Direction	Relative Humidity (%)	Air Temperature (°C)
O_3	Jan	0.013	Wed	1200	15	S	30	-10
	Feb	0.037	Tue	0500	6	S	62	2
	Mar	0.020	Fri	1300	7	SSE	42	12
	Apr	0.355	Sun	1300	4	NNE	25	16
	May	0.075	Wed	1600	7	SW	33	27
	Jun	0.096	Sat	1500	7	SW	--	--
	Jul	0.121	Tue	1400	4	NW	53	28
	Aug	0.132	Fri	1500	6	SW	45	31
	Sep	0.134	Tue	1400	3	NNW	47	28
	Oct	0.077	Thu	1500	4	N	55	24
	Nov	0.085	Thu	1400	5	SW	39	22
	Dec	0.044	Wed	0200	8	SW	74	12
SO_2	Jan	0.206	Sun	1800	7	W	90	5
	Feb	0.074	Sat	0800	4	W	53	-12
	Mar	0.089	Wed	1200	8	WSW	79	15
	Apr	0.089	Mon	1200	8	WNW	69	19
	May	0.072	Sat	1800	9	W	46	16
	Jun	0.139	Wed	1200	9	W	65	27
	Jul	0.107	Tue	1300	6	NW	53	28
	Aug	0.093	Tue	1400	10	SW	45	31
	Sep	0.084	Thu	0900	10	NNW	47	28
	Oct	0.097	Thu	0800	6	N	55	24
	Nov	0.077	Fri	0800	5	SW	39	22
	Dec	0.173	Sat	0000	8	SW	74	12

Table 11

1-hr Maximum Concentration Values During Each Month of 1979
for Each Pollutant and Trace Gas and Corresponding Conditions

Pollutant	Month	Conc. (ppmv)	Day of Week	Hour of Day (Military Time)	Wind Speed (mph)	Wind Direction	Relative Humidity (%)	Air Temperature (°C)
THC	Jan	7.08	Wed	2200	15	S	85	3
	Feb	5.70	Wed	2300	5	S	58	9
	Mar	11.56	Sat	2300	12	SSE	72	8
	Apr	24.84	Sun	1200	5	NNE	26	16
	May	6.78	Wed	0700	4	NNE	59	9
	Jun	8.91	Wed	0400	7	SW	99	20
	Jul	23.55	Tue	1500	12	NNE	58	26
	Aug	3.90	Thu	1800	9	SW	67	29
	Sep	6.72	Wed	2300	20	SSW	100	20
	Oct	7.82	Fri	0700	17	SW	100	16
	Nov	8.68	Sun	1900	12	S	52	17
	Dec	8.34	Sun	2200	3	S	--	14
CH₄	Jan	7.49	Wed	2200	15	S	85	3
	Feb	5.29	Wed	2300	5	S	58	9
	Mar	5.21	Sat	2300	12	SSE	72	8
	Apr							
	May	4.46	Sun	0500	7	SW	100	22
	Jun	7.38	Wed	0400	7	SW	99	20
	Jul	7.58	Tue	1500	12	NNE	58	26
	Aug	3.74	Thu	1800	9	SW	67	29
	Sep	4.68	Fri	2300	4	S	50	22
	Oct	6.63	Mon	0700	6	S	--	11
	Nov	5.44	Mon	1900	9	SSE	60	16
	Dec	7.45	Sun	2200	3	S	--	14

Table 11

1-hr Maximum Concentration Values During Each Month of 1979
for Each Pollutant and Trace Gas and Corresponding Conditions

Pollutant	Month	Conc. (ppmv)	Day of Week	Hour of Day (Military Time)	Wind Speed (mph)	Wind Direction	Relative Humidity (%)	Air Temperature (°C)
RHC	Jan	2.62	Sat	0700	8	NNE	--	0
	Feb	1.51	Wed	1900	6	NNW	74	-3
	Mar	6.38	Sat	0500	16	WNW	88	1
	Apr	11.29	Sun	1100	4	NNE	29	15
	May	4.67	Wed	0700	4	NNE	59	9
	Jun	3.00	Thu	0000	8	S	83	21
	Jul	15.97	Tue	1500	12	NNE	58	26
	Aug	2.74	Sun	1000	9	N	57	19
	Sep	2.14	Wed	2300	20	SSW	100	20
	Oct	3.42	Wed	0600	3	NNE	--	7
	Nov	3.57	Sun	2000	10	S	69	15
	Dec	1.77	Tue	0400	4	SSE	43	0
CO	Jan	5.95	Tue	0700	4	E	61	-2
	Feb	7.16	Fri	0000	10	ENE	88	3
	Mar	23.31	Wed	1400	7	N	36	17
	Apr	23.04	Sun	1200	5	NNE	26	16
	May	6.21	Tue	1100	5	SSW	73	21
	Jun	1.91	Tue	0000	7	SSW	100	18
	Jul	6.71	Tue	0000	7	N	48	17
	Aug	2.41	Wed	0500	7	NNW	75	18
	Sep	7.20	Thu	0800	3	NNE	99	18
	Oct	8.27	Wed	0800	17	NW	42	12
	Nov	20.86	Sun	0700	3	NNE	48	5
	Dec	6.78	Mon	0200	2	NNE	--	17

Table 11

1-hr Maximum Concentration Values During Each Month of 1979
for Each Pollutant and Trace Gas and Corresponding Conditions

Pollutant	Month	Conc. (ppmv)	Day of Week	Hour of Day (Military Time)	Wind Speed (mph)	Wind Direction	Relative Humidity (%)	Air Temperature (°C)
NO	Jan	0.377	Wed	2300	6	S	87	2
	Feb	0.327	Fri	0300	4	NE	97	1
	Mar	0.422	Fri	0800	11	S	91	5
	Apr	0.153	Sat	0700	12	N	67	7
	May	0.362	Fri	0700	7	SSW	100	22
	Jun	--	--	--	--	--	--	--
	Jul	0.113	Sat	0600	5	NE	98	17
	Aug	0.183	Fri	0700	13	NNE	92	15
	Sep	0.339	Thu	0800	3	NNE	99	18
	Oct	0.375	Wed	0900	2	N	100	13
	Nov	0.425	Sun	0400	7	N	94	9
	Dec	--	--	--	--	--	--	--
NO_2	Jan	0.048	Fri	1600	4	SSW	31	-4
	Feb	0.122	Thu	1000	11	NE	88	5
	Mar	0.085	Sat	0800	14	SSW	81	4
	Apr	0.119	Sat	0700	12	N	67	7
	May	0.065	Thu	2200	3	NE	46	18
	Jun	--	--	--	--	--	--	--
	Jul	0.118	Sat	0900	18	NE	98	17
	Aug	0.066	Wed	0900	7	NNE	92	15
	Sep	0.095	Tue	1000	8	NNE	99	18
	Oct	0.128	Thu	1800	3	N	100	13
	Nov	0.191	Mon	1000	4	N	94	9
	Dec	--	--	--	--	--	--	--

For the O_3 data in the table, the main characteristic feature is the occurrence of the maximum 1-hour concentrations in the afternoon hours; the highest values occurring in the warmer months with corresponding higher air temperatures. It is also noteworthy that these high concentrations occur with low wind speeds and relatively low relative humidity.

For the SO_2 data in Table 11, the main characteristic is that maximum 1-hour concentrations occur from the westerly directions.

For the THC 1-hour maximum concentrations, the main characteristic is that the high concentrations occur in the late evening hours. In addition, another feature is that these high concentrations occur with southerly wind directions and from the NNE. Also, a number of the 1-hour maximum THC concentrations occur at high relative humidities. This suggests that a large fraction of the THC components might be water soluble.

For the CH_4 1-hour maximum concentrations listed in Table 11, the main characteristics for these high values are that they occur during the early morning and late evening hours, with southerly wind directions, and at a high relative humidity.

For the RHC 1-hour maximum concentrations listed in Table 11, there do not appear to be any characteristic correlation with the correspondong conditions.

For the CO 1-hour maximum concentrations, the main characteristics are that these high values correspond to the mid-morning hours, northerly wind directions, and high relative humdities.

Any analysis of the data is retrospective in nature and reveals past and not future events. However, reasonable approximations to future behavior can be made based on past experience. For example, it was noted in the above analysis of the 1-hour maximum concentrations that some pollutants and gases had peak concentrations at certain times of the day. This is not fortuituous, but is the result of a combination of systematic variations of meteorological conditions and emission sources. Consequently, it seems reasonable to suspect that some of the pollutants and gases would follow a daily cycle. Emission sources, for example, might be expected to follow a daily routine of operations with some sources peaking at certain times of the day and/or with peak demands occurring with the season. In addition, meteorological conditions that follow a certain pattern include, night and day, higher air temperatures in the afternoon hours with corresponding increased sunlight intensity, higher relative humidities in the morning hours, and higher wind speeds in the afternoon. Obviously, there will be variations in these conditions, so

that if a definite pattern emerges for an air pollutant or gas it might
be concluded that it follows a systematic variation in its daily cycle.
Conversely, some air pollutants and gases may have no pattern so that
irregular, or random variations occur during a day.

One way of depicting a daily profile is to plot on regular
coordinate graph paper, a typical day's observations, *i.e.*, *the 1-hour*
average concentration against time of day. The problem with this
method is in choosing a typical day as representative of all other
days. Another way would be to average the concentrations of all the
1-hour averages, for a given hour, and plot the results against the
time of day. This idea has merit and might be worth looking into at
another time. A more elegant and simpler method is to determine, for
a given day *in which all* 24 1-hour average concentrations are avail-
able, the time of day in which the highest 1-hour average concentration
occurred. This would be done with all days in which data were avail-
able, the results tabulated, and the data plotted as the number of
times the highest 1-hour average occurred at a given time of day. The
results of the tabulations of the NRL air quality data, using this
procedure, are shown in Figs. 1-8 for O_3, NO, NO_2, CO, SO_2, THC, CH_4,
and RHC, where the ordinate is the number of occurrences of the highest
1-hour average concentration occurring in a given day, and the abscissa
is the time of day (00 is midnight, 12 is noon, and 23 is 11 p.m.).

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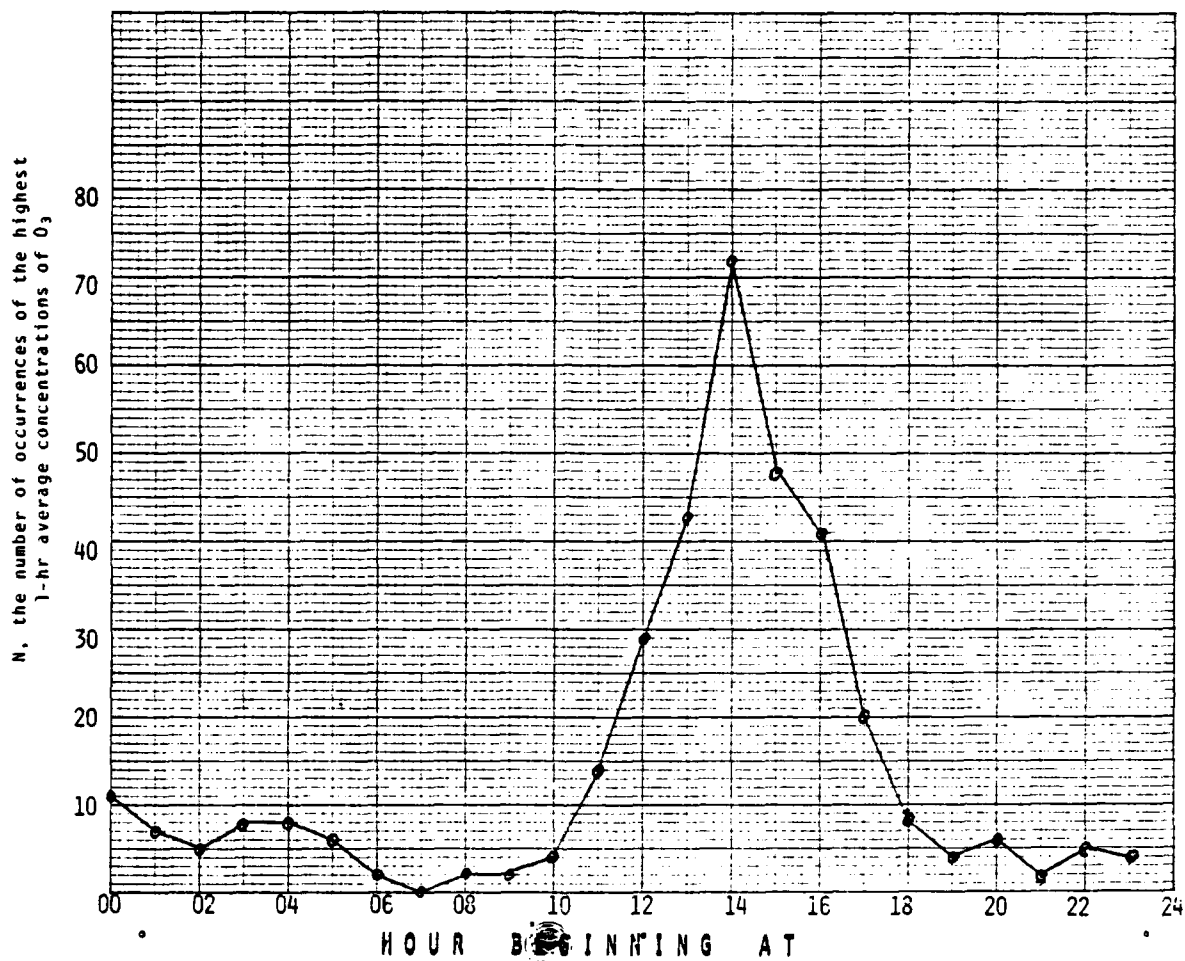
Fig. 1. - N, the number of occurrences of the highest 1-hr average
concentrations of O_3 of each day during 1979 as a function
of the time of day.
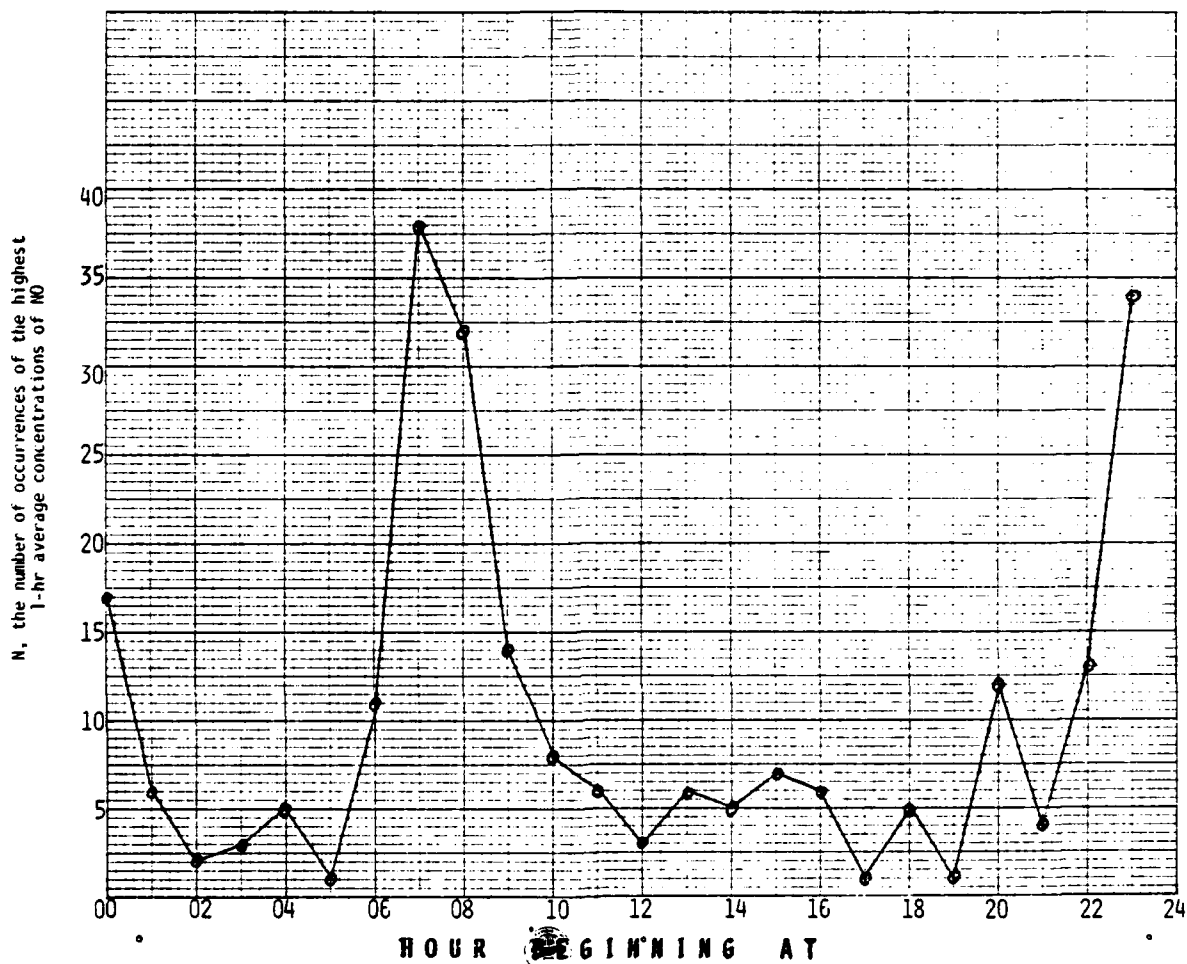
Fig. 2 -   N, the number of occurrences of the highest 1-hr average
            concentrations of NO of each day during 1979 as a function
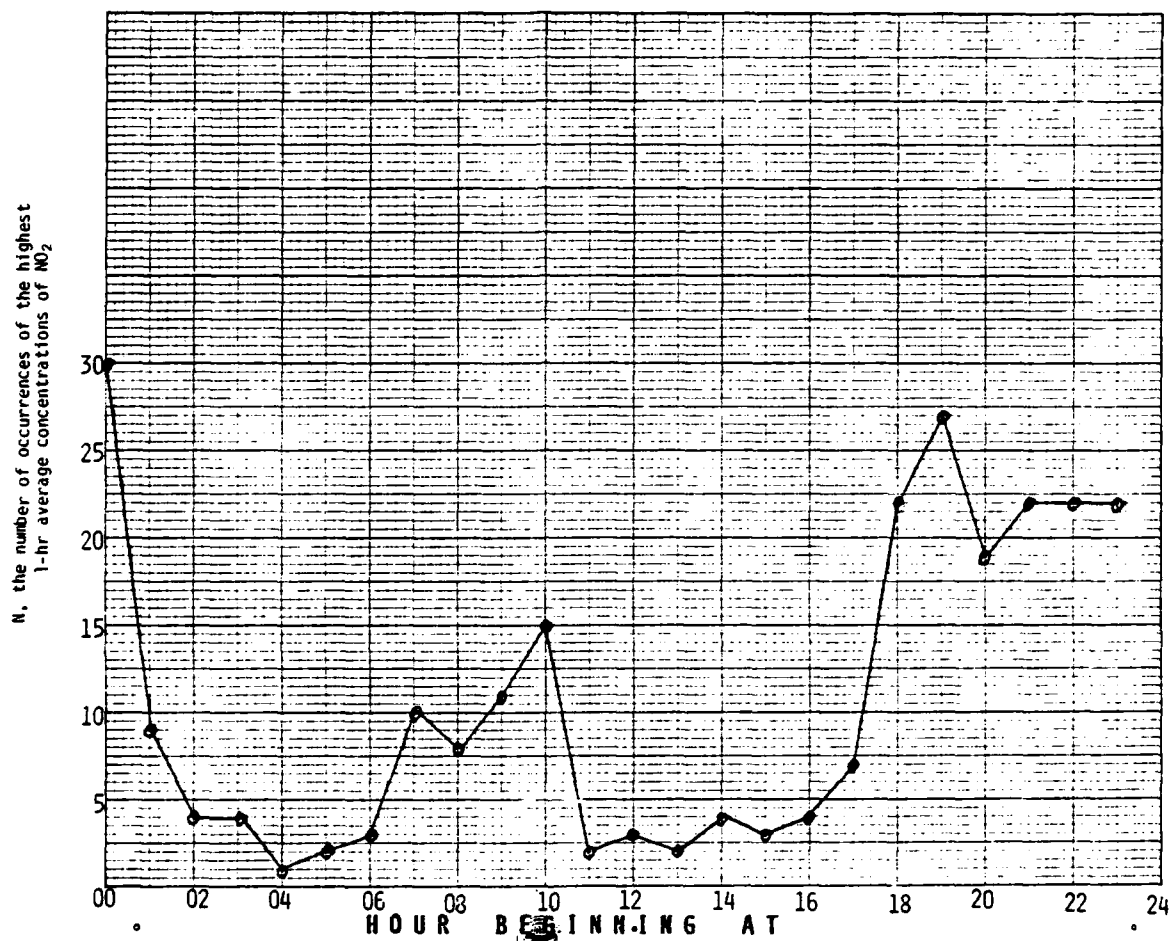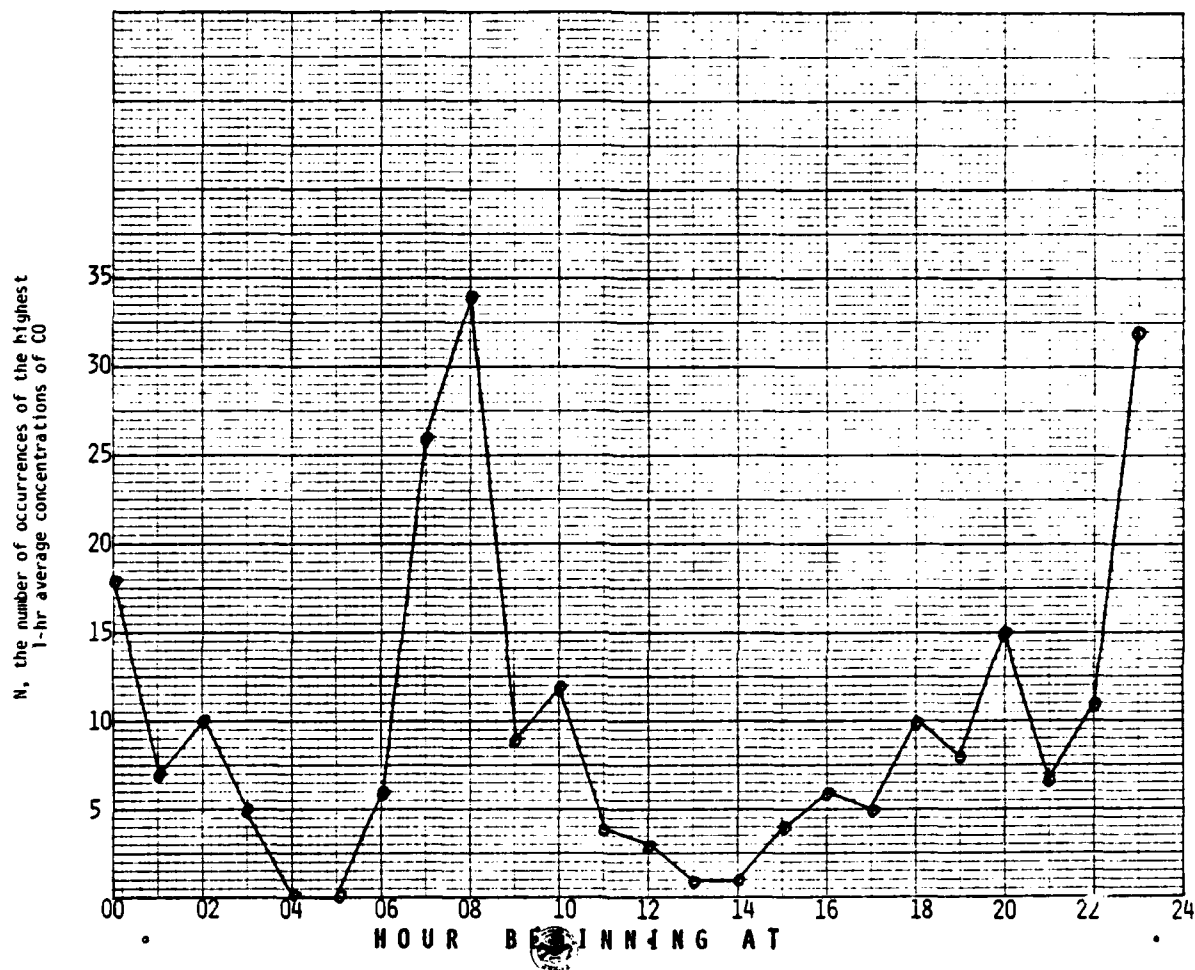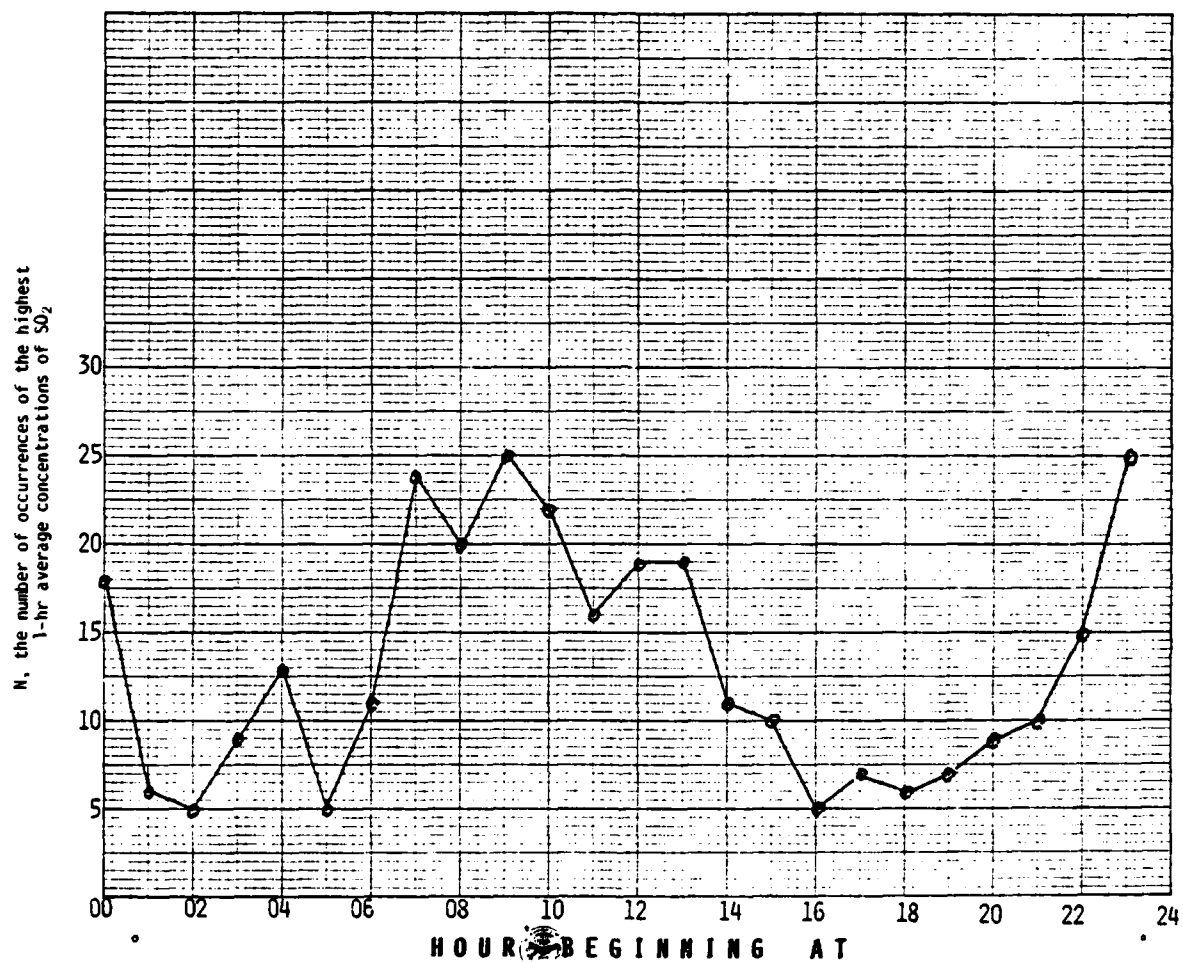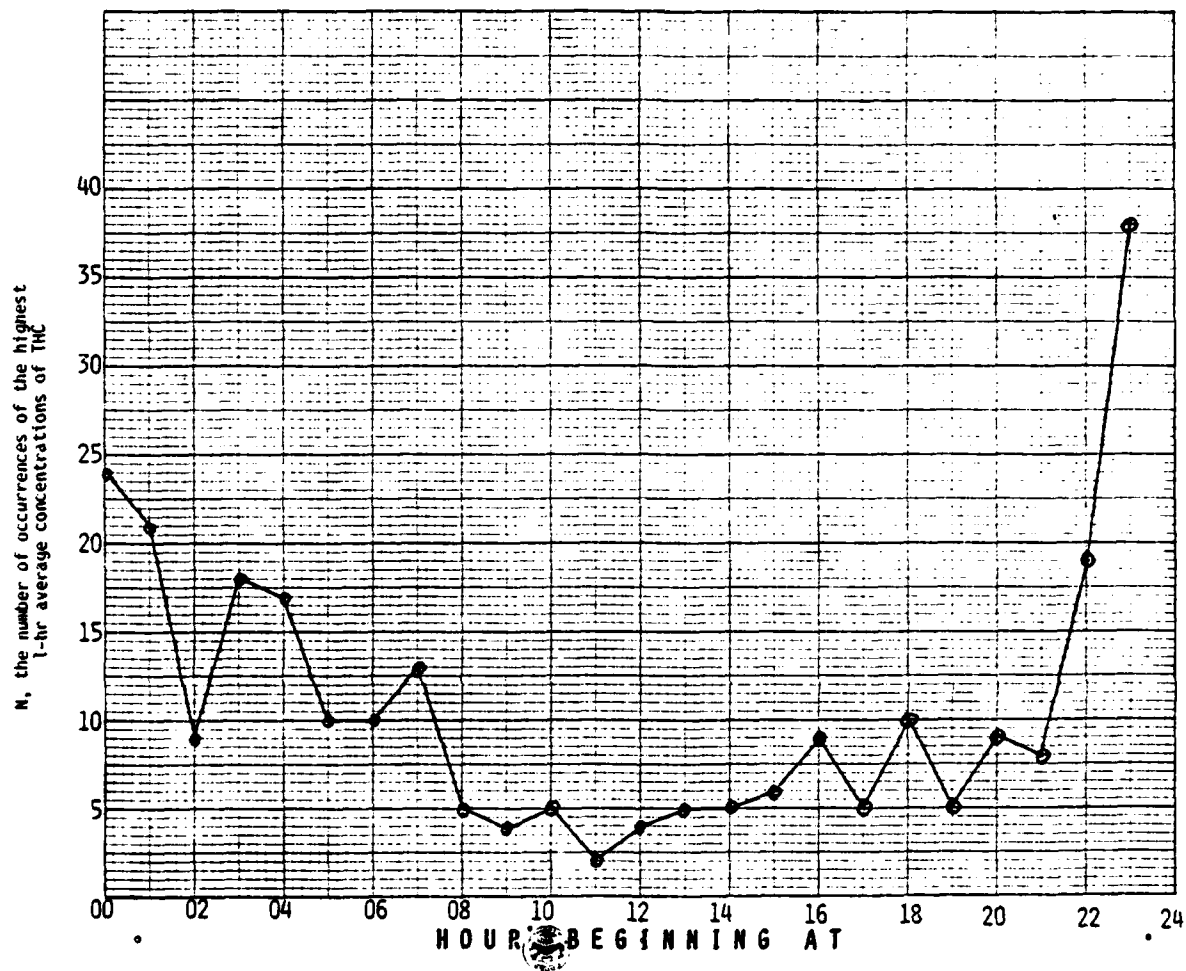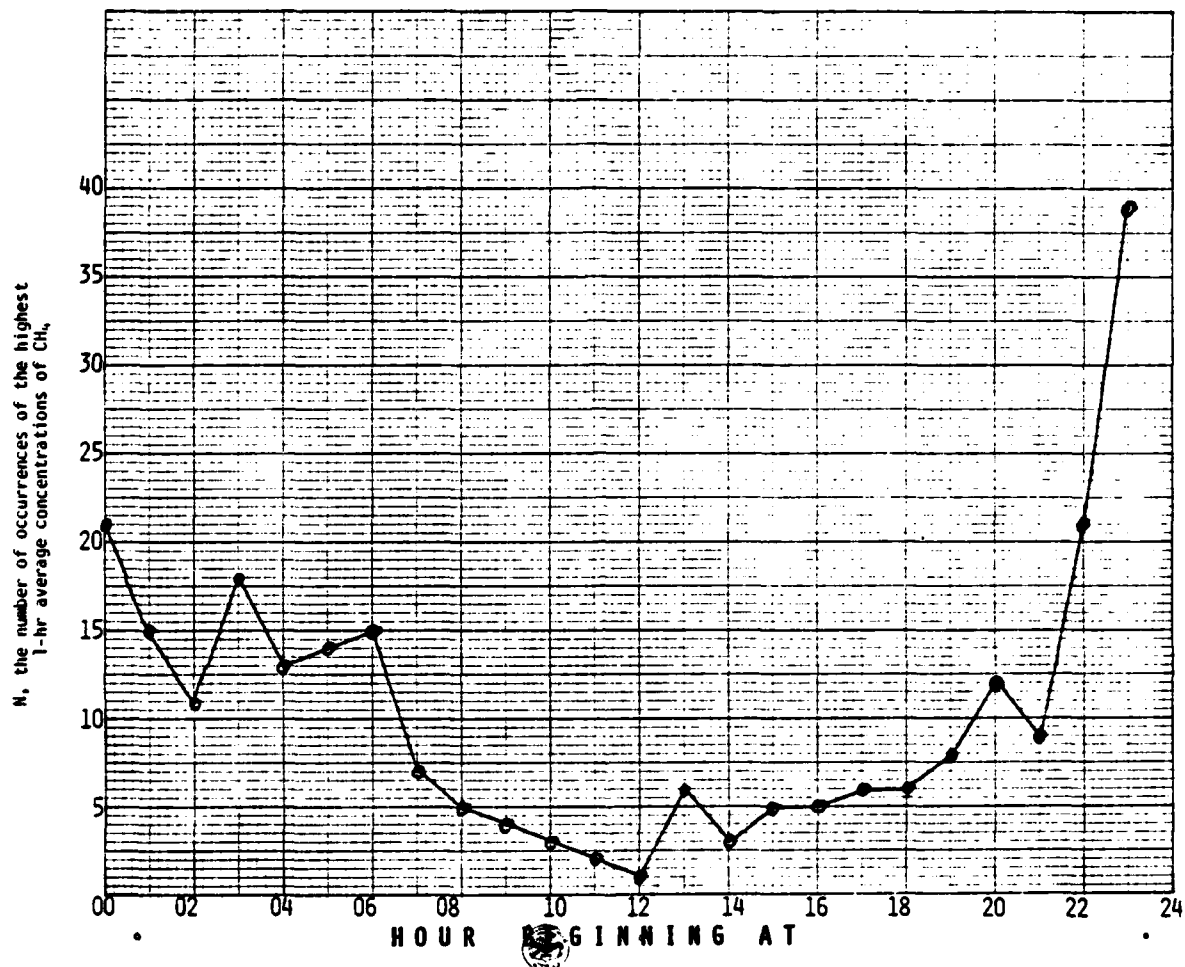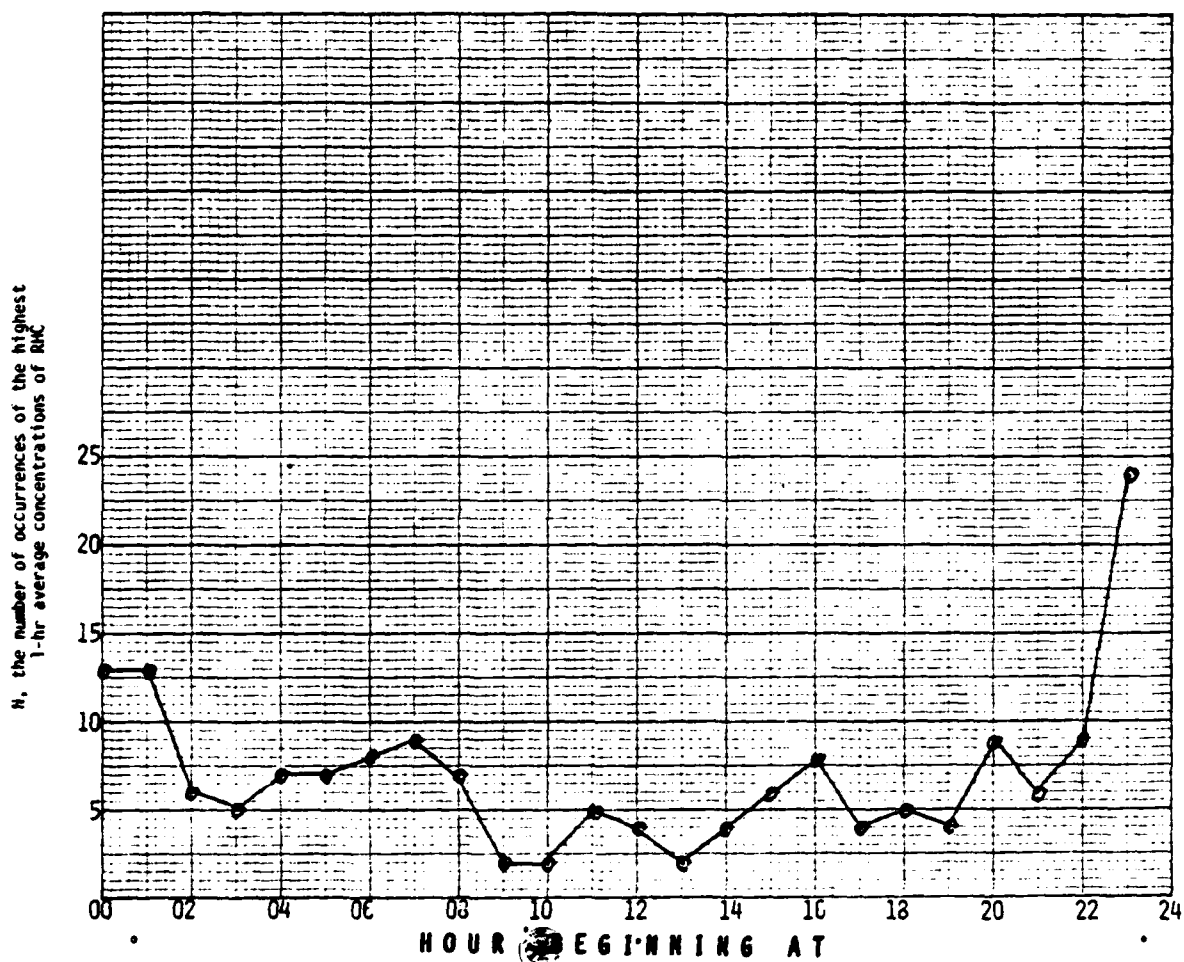   of the time of day.

Fig. 3 -   N, the number of occurrences of the highest 1-hr average
concentrations of NO_2 of each day during 1979 as a function
of the time of day.

Fig. 4 -   N, the number of occurrences of the highest 1-hr average concentrations of CO of each day during 1979 as a function of the time of day.

Fig. 5 - N, the number of occurrences of the highest 1-hr average concentration of SO_2 of each day during 1979 as a function of the time of day.

Fig. 6 -   N, the number of occurrences of the highest 1-hr average
            concentration of THC during each day of 1979 as a function
            of the time of day.

Fig. 7 – N, the number of occurrences of the highest 1-hr average concentrations of CH_4 of each day during 1979 as a function of the time of day.

Fig. 8 -   N, the number of occurrences of the highest 1-hr average
concentrations of RHC of each day during 1979 as a function
of the time of day.

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Inspection of the figures reveals that there are, in a broad
sense, three distinct characteristic daily profiles for the air pol-
lutants and gases. One type is shown by O_3 with a single peak occur-
ring in the afternoon hours with the maximum at 2 p.m. Another
characteristic profile is shown by NO, NO_2, CO, and SO_2, which have
two daily peaks, one in the mid-morning hours and the other in the
late evening and early morning hours. The third characteristic daily
profile is shown by THC, CH_4, and RHC, and is a U-shaped curve with
the highest concentrations occurring in the late evening and early
morning hours. The curves in the figures are not as smooth as might
be desired, but this is a result of, and why they are called, system-
atic variations. Consequently, the single peak, double peak, and U-
shaped daily profiles are examples of the pollutant concentration
behavior to be expected of the air quality data. It should be
emphasized that these curves pertain only to the NRL air quality data.
However, similar shaped curves should be closely followed by the data
collected at other air monitoring stations.

Other type curves that might be produced by other substances
present in the atmosphere are: a daily curve with three or more peaks,
and a daily curve with no peaks, i.e., a simple horizontal straight
line. Examples of this curve would be the nitrogen and oxygen concen-
tration data. These gases are the predominant and permanent gases
present in the atmosphere. In any case, it is felt that any trace
substance present in the atmosphere, and especially those emitted by
human activity, or formed in the atmosphere by chemical reactions,
will fall into one of three characteristic profiles shown by the NRL
air quality data. This is an important conclusion because any change
in the characteristic curve would mean a drastic change in meteorological
conditions or in emission sources.

The chief disadvantage of the characteristic curves shown in
Figs. 1-8 is that the concentration values are not given. However,
work on the problem is continuing.

The O_3 peak occurring during the afternoon hours, as shown
in Fig. 1, is due to the favorable conditions for the formation during
this period, i.e., sunlight, and the precursors RHC and NO_2. At other
times of the day, maximum O_3 concentrations are likely due to long
distance transport of this pollutant from other metropolitan areas,
or a tropospheric-stratospheric exchange. However, the highest O_3
concentrations always occur in the afternoon hours. Lower concen-
trations at other times are due to the high reactivity of O_3 with
other substances.

The NO curve in Fig. 2 can be considered as a classic
example of the double peak profile. It will be noted from inspection

of the figure that the mid-morning peak corresponds to the morning rush hour traffic period and to the human activities normally going on at this time. The combined late evening and early morning peak which occurs with NO, and all other gases with the exception of O_3, is not, as one might expect, associated with the evening rush hour traffic. The reasons for this peak are not clear but some possibilities are: long distance transport, bypass of pollution controls on certain combustion systems, concentration buildup in the surface-based temperature inversion layer, or a byproduct of chemical reactions occurring during this time period. These possibilities also apply to the other gases that have peaks in the late evening and early morning hours.

The double peak profile for NO_2, as shown in Fig. 3, is not so smooth as that for NO, but is easily recognizable. It is fortunate that NO_2 does not have a single peak curve in the morning hours because this would ultimately result in higher O_3 concentrations, or smog symptoms, than are now shown. Also, a comparison of Figs. 2 and 3 shows that the morning NO_2 peak occurs at a later time than the morning NO peak. This occurs because of the slow oxidation of NO to NO_2, which takes time, and the reaction of NO with reactive hydrocarbons, with some NO_2 being formed. It should be pointed out, however, that NO_2 is also formed directly in high temperature combustion processes which use fossil fuels (coal, fuel oil, gasoline, natural gas). Normally, NO_2 has low concentrations during the afternoon hours, when O_3 concentrations are high, because it is consumed in the photochemical reaction scheme to produce O_3. As the sun goes down, the photochemical series of reactions ceases and the NO_2 concentration increases; this may be another reason for the late evening and early morning NO_2 peak (as shown in Fig. 3).

It is noteworthy that the CO double peak profile, shown in Fig. 4, closely resembles the NO_2 curve in Fig. 2. This is not fortuitous but suggests that the sources of these two gases are similar. Also, the morning CO peak corresponds to the morning rush hour traffic period as for NO. It is generally agreed that motor vehicle exhaust emissions are the principal source of CO in urban atmospheres. Other combustion sources also contribute to the CO in the atmosphere and their influence may be felt at other times of the day. This is a point worth re-emphasizing because at different times of the day different emission sources will, or might, bias the air quality data. It is also postulated that CO concentrations are lower in the afternoon hours because of reactions with the highly reactive hydroxyl free radical (OH). This free radical would tend to be lower in the nighttime hours and in the colder winter months. The hydroxyl radicals are formed by the reaction of water vapor with excited oxygen atoms, which, in turn, are formed by the photolysis of O_3.

The double peak profile for SO_2, shown in Fig. 5, is not as smooth a profile as one would like and could be subject to a different interpretation. However, the double peak profile for this pollutant is evident upon closer inspection of the curve. The first peak is extended from the morning to the early afternoon hours and covers a wide range of time. One reason for this is the close proximity of a coal-fired electric power plant, the NRL heating plant, and other nearby power plants. In the later afternoon hours, SO_2 concentrations are low because of the reaction of this pollutant with O_3.

The U-shaped curves for THC, CH_4, and RHC, as shown in Figs. 6, 7, and 8, respectively, are, in a general sense, closely alike. Note that the number of peak concentrations do not coincide with the morning and evening rush hour traffic periods. High concentrations do occur at these time periods but not as many times as in the late evening and early morning hours. Low concentrations of these gases, especially in the late morning and evening hours, suggest a good mixing of the gases in the atmosphere, a breakup of the surface-based temperature inversion layer with increased dilution, and dispersion, or a participation in the photochemical sequence of reactions.

AIR QUALITY STANDARDS

To protect human health and welfare, federal air quality standards have been issued for a number of air pollutants. The standards for those air pollutants measured at the NRL air monitoring station are listed in Table 12. The main change from previous years is the relaxation of the O_3 standard from 0.08 ppmv to 0.12 ppmv. Included in the table is the number of times these standards have been exceeded at NRL. By the old O_3 standard, this number would have been 112. In any case, this is not a bad showing for the NRL air environment if the air quality standards are used as a guide, but improvement in air quality is certainly required and constant vigilance is necessary. However, it should be remembered that the weather in 1979 was not as favorable for O_3 formation as in other years. In fact, the possibility always exists that more favorable meteorological conditions, such as low relative humidity, strong sunlight, minimal cloud cover, and a stagnating high pressure system could trigger a sever air pollution episode and, especially, since the precursors for oxidant formation, reactive hydrocarbons, and nitrogen dioxide are always present in the atmosphere. It should also be remembered that lower concentrations of air pollutants may exert a subtle, or as yet unrecognized, effect on human health and welfare.

Table 12 National Ambient Air Quality Standards in ppmv and Times Exceeded				
				Times Exceeded at NRL
SO_2	0.03 (aam)*	-	primary	0
	0.14 (24-hr)	-	primary	0
	0.50 (3-hr)	-	secondary	0
CO	9 ppmv (8-hr)	-	primary-secondary	1
	35 ppmv (1-hr)	-	primary-secondary	0
O_3	0.12 ppmv (1-hr)	-	primary	0
			secondary	12
RHC	0.24 ppmv (3-hr)	-	primary-secondary	70
NO_2	0.05 ppmv (aam)*			0

*annual arithmetic mean

ODOR NUISANCE AT NRL

One of the most immediate and recognized aspects of air pollution, besides the visibility degradation of the atmosphere, is odor pollution. Most people find, by common consent, that some odors, from specific facilities, are obnoxious and offensive. Odors from such facilities may cause headaches, nausea, vomiting, a general sense of discomfort, and a lowering of work performance. Other symptoms may appear such as loss of appetite, nervousness, and irritation of the eyes, nose, and throat. Some familiar examples of facilities that produce the odors that cause such symptoms are diesel buses and trucks, canneries, oil refineries, rendering plants, and sewage treatment plants. Each have their own characteristic emissions, but the common point is that these odors are a nuisance. Unfortunately, there are no odor pollution standards available to be enforced, so that the only recourse is by citizens' complaints and/or by use of public nuisance laws. In most cases, the subjective nature of the odor problem makes it difficult to enforce. Usually, one must appeal to the better nature of the offender in the spirit of fostering better community relations.

As yet, there is no fundamental theory of smell, and no basic odor detection device is available. No detector could come close to the odor detectability of the human nose with respect to extremely low concentrations, but some specific detectors have been developed for specific odorous sources. For example, hydrogen sulfide (H_2S), a common odorous compound from sewage treatment plants, can easily be detected by some modern instrumentation.

Odor preception varies with the individual and will depend on age, environment, experience, health, race, and sex. It will also depend on the quality, strength, and the occurrence of the odor. Another possibility of odor perception is that one can be programmed to like or dislike certain smells. Most people have a normal sense of smell, but a few are odor-blind. There is another group of people who find all odors offensive, while others have only a partial sense of smell. In addition, some people have an exaggerated sense of smell and there is still another group whose sense of smell is stimulated by outside, non-odorous stimuli. Most people at the Laboratory will fall into one or more of these categories (10, 11).

Normal people can differentiate among several thousand odors, while an expert can differentiate several times that number. Usually, the compounds emitting these odors are organic in nature and in gaseous form. Solids and liquids, as such, do not emit odors. In addition, some odorous compounds are offensive at low concentrations and pleasant *at higher concentrations*, while for some other compounds the converse is true. In any case, odors range from pleasant to obnoxious and there is no good way to describe or classify them.

Odor perception is a part of everyday experience and starts at birth. As a consequence, every person lives in an odor-adapted environment. At times, this environment may be altered by the intrusion of foreign substances into the atmosphere, thereby creating an odor nuisance problem. Such intrusions occur at NRL. Because of the infrequent occurrences of these intrusions, there is not enough time for odor adaption to occur so that the smells are considered as offensive.

For the NRL air environment, these odorous intrusions are suspected to originate from the sewage treatment plant next door to the Laboratory. From this facility, odors are emitted from decomposing organic wastes, i.e., the bacterial breakdown products of fats and nitrogen and sulfur organic compounds (proteins). Consequently, odors are associated with sewage and sludge. The compounds from these wastes include organic acids, alcohols, aldehydes, amines, ammonia, carbon dioxide, carbon monoxide, hydrogen sulfide, mercaptans, methane, and sulfides. A combination of the odorous components is typical of sewage plant type odors. Usually, hydrogen sulfide is considered to be the compound most usually identified with sewage-type odors.

However, a mixture of various compounds results in the characteristic odor commonly identified with this type of facility. This odor has been described as cabbage-like, fecal, nauseating, obnoxious, offensive, rancid, or strong (12).

Odor control at the sewage plant is by chlorination treatment, a method that is usually effective. In addition, other measures, such as domed canopies, are used to contain odors. In any case, odor control is an expensive technology and only tried and true methods have been used. Consequently, any odors escaping from the facility must be considered as part of the "normal odor environment".

Finally, because of the ready identification of odors from the sewage plant, odors from other sources have been presumed to be due to this facility. These other sources have been found to be: painting opererations, solvent release from caulking materials used on the external parts of buildings, and solvent release from the slow-setting concrete formulations.

FUTURE PLANS

The work of the NRL air monitoring program will continue. In addition, a report will be published on a 5-year summary of the NRL air quality data collected from the years 1975-1979.

SUMMARY

The variables measured and recorded at the NRL air monitoring station include ozone (O_3), sulfur dioxide (SO_2), nitric oxid NO), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (RHC), carbon monoxide (CO), air temperature, relative humidity, wind direction, and wind speed. The air quality data analyzed from these variables is for the calendar year 1979. The main features in the report include representative yearly and monthly concentration averages, the maximum concentrations of various time-averages of interest, prevailing wind directions in decreasing order of percentage of occurrence, the number of times the federal air quality standards were exceeded, and trends and character-istics of pollutant behavior in the atmosphere. One of the main points in the report is that the pollutants and gases measured at NRL follow one or the other of three daily characteristic profiles: single peak, double peak, or U-shaped curves over the 24-hour period. In addition, a brief description of the odor nuisance problem at the Laboratory is described.

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