Image Cover Sheet

TITLE

NATURE, DISTRIBUTION AND DISPERSION OF CONTAMINANTS IN THE URBAN ENVIRONMENT

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...ture, Distribution and Dispersion of Contaminants in the Urban Environment

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by

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Few of us realize the rapidly growing impact of air pollution on the health of our city populations and on our economy. Dr. Katz, one of Canada's foremost authorities on the subject, here summarizes the studies made by the International Joint Commission over the past four years in the Windsor-Detroit area. Pollution, he points out, cannot be remedied by legal action alone, but technical understanding as to what remedies are economically feasible is needed also.

The rapid growth of our cities has intensified the problem of the contamination of the air by the waste products from combustion of fuels, manufacturing and processing industries, vehicular traffic and other activities of the population. The average human adult, in a day, will consume about two and three-quarter pounds of food, drink four and a half pounds of water and breathe about thirty pounds of air. He may be concerned with the purity of his food and water supplies, but is less fastidious about the air which enters his lungs.

However, the time is fast approaching when some consideration must be given to the quality of the air in our environment. The capacity of the atmosphere to dilute and disperse effectively the vast quantities of contaminants discharged daily over a city or industrial community is not unlimited. This is shown by the increasing incidence of smog and nuisance effects in many cities, and the appearance of pollution problems in urban communities which were relatively free from such influences in the past.

Recent smog disasters, accompanied by illnesses and deaths, at Donora, Pa. in 1948 and London, England in 1952, indicate that when the atmosphere becomes overburdened with solid, liquid and gaseous waste products the result may be not merely a nuisance but can constitute a serious menace to our health.

In order to control effectively and economically the extent of pollution in our urban areas, and to minimize the possibility of unpleasant effects, it is necessary to know as much as possible about the physical and chemical properties of these wastes. We must learn how they are distributed through the atmosphere by the prevailing air currents, and the influence of topographical and meteorological factors on their accumulation and dispersion.

Recent advances in science and engineering technology have made it possible to control most stack emissions at the source to the extent that they do not constitute a nuisance to the surrounding community. The extent of such control is limited only by economic considerations, and by how much we are willing to pay for reasonably clean air.

Nature of Contaminants

In our urban and industrial communities the atmosphere serves a natural function as a means of disposal of waste effluents. There is no reason to question this practice until the amount of waste products released becomes too much or the stack discharges constitute a visible nuisance. The combustion of coal results in the release to the air of carbon dioxide, water vapour, carbon monoxide, sulphur dioxide, oxides of nitrogen; organic compounds such as hydrocarbons, oxygenated derivatives and acids; as well as tarry material of indefinite composition, soot and fly ash.

Liquid and gaseous fuels may be burned more efficiently so that there is much less soot but they still release a variety of organic vapours and gases, including methene, acetylene, phenols, alcohols, aldehydes and ketones in addition to sulphur dioxide, ammonia and oxides of nitrogen.

The contribution to this problem from the general activities of the public must not be underrated. Thus, in a city where half a million

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automobiles, trucks and busses are operated, there may be consumed a daily total of 1 million gallons of gasoline and oil, releasing nearly 1 billion cubic feet of exhaust gases.

In order to determine the extent of atmospheric pollution in an urban area it is convenient to measure the rate of dustfall, the concentration of suspended particulates or aerosols and the concentration of sulphur dioxide. These quantities serve to assess the pollution on a preliminary basis. Provided continuous testing or sampling methods are employed, one can gain an insight into the variations in the levels of contamination introduced by changes in weather conditions and other factors, at different periods of the day and seasons of the year.

Such measurements have been in progress for a number of years in the Greater Windsor-Detroit area in connection with an international air pollution investigation, in accordance with the terms of a joint reference submitted to the International Joint Commission by the Governments of Canada and the United States in January 1949. The area under investigation lies on both sides of the Detroit River for a distance of about 30 miles and extends to about 15 miles inland from the river.

The overall estimated population is about three million, of which about 160,000 is on the Canadian side. This region is the third largest industrial area in North America. The total annual consumption of solid fuel for industrial and domestic purposes is estimated at about 15 million tons on the U.S. side and about 650,000 tons on the Canadian side. Approximately 430,000 tons of sulphur dioxide are discharged to the atmosphere annually from the combustion of solid fuels alone. This total is increased appreciably by the sulphur dioxide liberated from liquid and gaseous fuels.

Additional sources of industrial wastes include operations associated with the automotive industry, power plants, rubber, chemical, metallurgical, oil refining and numerous other plants. During the navigation season there is also the problem of smoke and fly ash from the Great Lakes vessel fleets which make about 30,000 passages of the Detroit River in transporting 120 million tons or more of cargo, consisting of iron ore, coal, grain and limestone.

Table I. Mean Values for Dustfall in Greater Windsor Area in Tons per Square Mile per Month

Area	Dustfall: Total Solids	Components of Deposited Material: Water Insoluble	Water Soluble	Tar	Other Combustible Matter	Ash	pH water soluble fraction
— Test Period: August — December 1951 —							
Industrial	92.2	69.2	21.1	1.48	21.0	45.9	[illegible]42
Industrial—residential	53.9	45.0	11.0	0.62	13.[illegible]	28.7	[illegible].31
Residential—semi-rural	35.9	26.9	8.8	0.61	11.[illegible]	16.1	[illegible].31
— Test Period: May — September, 1952, Non-heating season —							
Industrial and residential	36.1	31.4	4.3	1.23	10.3	21.3	5.9
Residential — semi-rural	18.8	16.7	2.1	0.81	3.5	11.3	7.3
— Test Period: October 1952 — February 1953, Heating season —							
Industrial and residential	92.1	69.1	22.9	1.70	13.5	52.0	5.1
Residential — semi-rural	53.0	40.8	12.3	2.59	8.2	30.0	5.8

Table II. Mean Dustfall in Tons per Square Mile per Month for Various Cities

No.	City	Year	Monthly Mean	Reference
1	Detroit	1946	51.7	Detroit Department of Buildings and Safety Engineering.
		1950	59.8	
		1951	62.1	
		1952	64.1	
		1953	72.1	
2	New York	1953	67.5	New York State Chamber of Commerce
3	Chicago	1947	61.2	Nos. 3-6, McCabe, L. et al. Ind. Eng. Chem. 41, [illegible] (1949)
4	Cincinnati	1946	34.0	
5	Los Angeles	1948	33.3	
6	Rochester	1942	26.4	
7	Pittsburgh	1951	45.7 (insoluble matter only)	City of Pittsburgh, Dept of Public Health Report 1951.
8	Toronto		31.7-54.2	Allcut, E.A., Eng. J. (Canada) [illegible] 154 (1947).

Table III. Concentrations of Suspended Particulate Matter (Micrograms per Cubic Metre) in the Atmosphere of Greater Windsor, Ontario

Area	Test Period	Number Sampling Stations	Range of Concentration	Mean for all Stations
High pollution	Oct. 24 – Dec 5, 1951	8	36–467	210
Moderate pollution	" " "	16	1–556	150
Low pollution	" " "	2	3–214	80
High pollution	Aug. 7 – Sept. 17, 1952	5	27–718	247
Moderate pollution	" " "	3	22–568	170
Low pollution	" " "	2	3–257	107

(a) Dustfall

The larger particles of dust, fly ash and soot settle out of the atmosphere fairly rapidly. Such particles range in size from over 100 microns down to about 5 microns. Most of the mass of material collected in dustfall receptacles is over 44 microns in size (325 sieve mesh, Tyler). Dustfall records, which are usually expressed as total solids in tons per square mile per month, afford an indication of the extent of contamination from such relatively large particles over a city.

The data in Table I indicate the dustfall rates for various areas of Greater Windsor and the nature of some fractions of this deposited material. The mean values are derived from a total of twenty stations distributed throughout the various areas. The industrial-resi

Table IV. Rise in Mean Daily Concentrations of Suspended Particulate Matter (Micrograms per Cubic Metre) During Two Smog Periods in Windsor Area

Date 1952	Daily Mean for 10 Sampling Sations
August 22	95
August 23	151
August 24	205
August 25	282
August 26	288
August 27	275
August 28	245
August 29	56
September 7	90
September 8	281
September 9	392
September 10	500
September 11	410
September 12	303
September 13	164
September 14	71

dential stations were located in the most heavily populated and industrialized zone, which lies close to the Detroit River. The residential-semi-rural stations were located at distances of about 4 to 15 miles from the Detroit River.

The rate of dust deposition rises considerably during the heating season with the increase in use of fuel for domestic and industrial space heating purposes. Coal for domestic purposes is burned much less efficiently and the waste products are emitted from much shorter stacks, on the average, than the combustion products of industrial solid fuel. Furthermore, many of the industrial stacks are equipped with fly ash receivers and dust collectors. In the outlying residential-semi-rural area of Greater Windsor, the dustfall rate is about one-half of that in the heavily populated and industrial section. The average dustfall in the latter area during the heating season is about 92 tons per sq. mile per month.

The rates of deposition at some of the most heavily polluted stations have ranged as high as 100 to 150 tons per sq. mile per month during the heating season. In one or two months of the year the rate has risen as high as about 200 tons per sq. mile. The water-soluble fraction in these shows a relatively high sulphate content and greater acidity. The content of tar and combustible organic matter shown in Table I is related to the amount of soot, carbon and incompletely burned waste products deposited with the dust and fly ash.

Table II indicates the monthly mean rate of dustfall in certain other cities of North America. The Detroit records show a rise from about 52 tons in 1946 to 72 tons in 1953. The rates are comparable to those of New York and Chicago. The lowest values in the table are shown by Los Angeles, Cincinnati and Rochester. Los Angeles is troubled with a persistent smog problem which has been under intensive investigation during the past five years[10]. However, [illegible] all the fuel used in this area consists of gas and oil, although large quantities of refuse and trash are also burned in domestic incinerators.

There is some conflict of opinion as to the reliability of comparisons of dustfall in different cities. This is due largely to the fact that various types of dustfall containers are in use and methods of exposure are not uniform. In the Windsor area the dustfall containers used are of the same type as those employed in the Detroit area, a design which was developed by City of Detroit engineers after wind tunnel tests of various models.

However, the data shown in Table II provide a fair comparison because the results are in line with the mean values to be expected for cities of comparable size and coal consumption. Wherever solid fuel has been replaced by liquid or gaseous fuel for domestic space heating, there has been a considerable drop in the city dustfall rate. Effective smoke abatement has also resulted in a decrease in dustfall.

It is difficult to ascertain accurately the fraction of the dustfall rate in cities which is due to natural sources, such as wind-blown sand, soil particles, pollen and vegetation. However, the dustfall in rural areas remote from urban communities ranges from less than five to about 15 tons per sq. mile per month. This is confirmed by the results for the stations at 8 to 15 miles distant from the Detroit River in the Greater Windsor area.

Suspended Particulate Matter

Although aerosols include, by definition, all solid and liquid par-

Table V. Mean Sulphur Dioxide Concentrations in Parts per Billion of Air for Each Month of the Year, September 1950-January 1953.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
— near centre of Windsor, Ontario —												
1950									74	71	63	91
1951	73	88	76	107	122	47	70	88	93	119	104	149
1952	121	143	82	90	89	70	116	120	109	134	102	200
1953	127											
Mean	107	116	79	99	106	59	93	104	92	108	90	147
— McGregor, Ontario, 15 miles South of Detroit River —												
Year	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1950									10.0	12.0	11.0	27.0
1951	1.5	3.0	3.2	0.8	3.3	3.9	1.2	3.9	3.5	3.5	5.0	10.0
1952	10.0	1.9	4.3	5.7	4.5	6.3	5.0	5.0	15.0	7.0	6.0	13.0
1953	8.0											
Mean	6.5	2.5	3.7	3.3	3.9	5.1	3.1	4.5	9.5	7.5	7.3	16.7

ticles in the diameter range from about 100 microns down to 0.01, the suspended impurities in the atmosphere which influence visibility, stain or soil walls, textiles and other exposed surfaces, and penetrate into the lungs are in the size range of less than about 5 microns. The amount of light scattering or reduction in visibility depends more on particle size and refractive index of the material, than on the number of particles per unit volume.

The size range which is most effective for obscuration of visibility is the diameter from 0.3 to 0.6 micron for liquid aerosols. Visibility may also be reduced by small particles which absorb light. Below 5 micron size, the particles begin to penetrate into the lungs after passing through the respiratory tract, but when their size becomes less than 1 micron, the retention of such particles in the lung decreases. Only a small fraction of the very small particles is retained in the lung (7).

Suspended impurities are collected for measurement by filtration through paper or other membranes, by electrostatic or thermal precipitation, or by use of impinger or impaction devices. The concentration is influenced markedly not only by the mass rate of emission and nature of industrial and other activities in a given area, but also by various meteorological factors.

In the Windsor-Detroit area daily fluctuations in the levels of suspended particulate matter have been investigated intensively by use of the High Volume Sampler of a type similar to that developed by the U.S. Atomic Energy Commission (9). As in the case of settled dust, the values tend to increase in proceeding from the outlying areas towards the centre of the populated and industrial section.

Table III indicates the range in concentration and the mean values for various pollution areas in Greater Windsor during surveys carried out on a continuous basis for 6-week periods in 1951 and 1952. The two stations in the low pollution area were located about 8 and 15 miles from the heart of Windsor, at Tecumseh and McGregor, Ont. respectively.

In Table IV there is indicated the rise in the concentration of atmospheric suspended matter during two smog periods in the Greater Windsor area. During these events the levels rose markedly over four-day periods at all the sampling stations, even those at points 8 and 15 miles distant, and then subsided as meteorological conditions became more favourable for dispersion. These smogs were accompanied by a marked reduction in visibility and complaints of eye irritation.

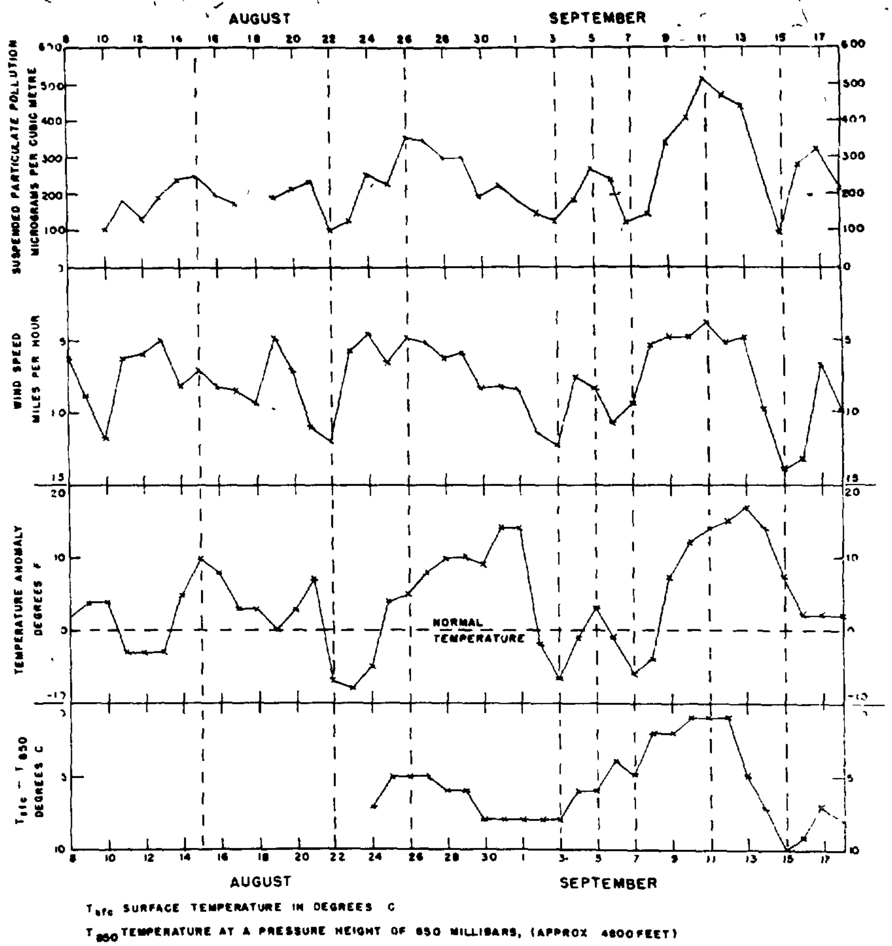

Fig. 1. Variation of suspended particulate pollution in the Windsor-Detroit area during the period August 8 to September 17, 1952, with wind-speed, temperature anomaly, and temperature gradient.

Similar surveys of suspended particulate matter carried out by the U.S. Public Health Service in Detroit (4) reveal higher atmospheric loadings than those found for Windsor. A six weeks' survey in Detroit with 31 sampling stations during May 7 to June 17, 1951, indicated a range of median values of 121 to 357 micrograms per cubic metre from the least polluted to the most heavily polluted areas, with maximum values ranging from 351 to 1,009.

Comparisons with other cities are difficult because of a lack of data gathered by comparable technique. Cholak (3) has presented results for Cincinnati (1946-51) which show a mean value of 370 micrograms per cubic metre for the city as a whole, 420 for the industrial and commercial areas, and 180 for the rural areas near the city. The median size range of suspended particles in the Windsor-Detroit atmosphere is about 0.9 micron for samples collected by the thermal precipitator or standard impinger and evaluated by standard microscope counting techniques, which do not include particles smaller than 0.2 micron.

The inorganic fraction of the suspended dust has been studied intensively in the Windsor-Detroit area by methods of spectrographic analysis. About 20 metallic elements have been found in varying amounts. The most abundant are calcium, silicon, aluminum and iron. Next in order of abundance are magnesium, lead, copper, zinc and manganese. Elements which were found in small quantities only were titanium, tin, molybdenum, barium, nickel, vanadium, chromium, cadmium and beryllium (8).

A considerable number of crystal line compounds have been identi fied in the Windsor suspende particulates by X-ray diffractio studies. These include calcium car bonate, alpha-quartz, gypsum, am monium chloride, magnetite, hema tite, cadmium carbonate, nicke fluoride, graphite and carbon. Th

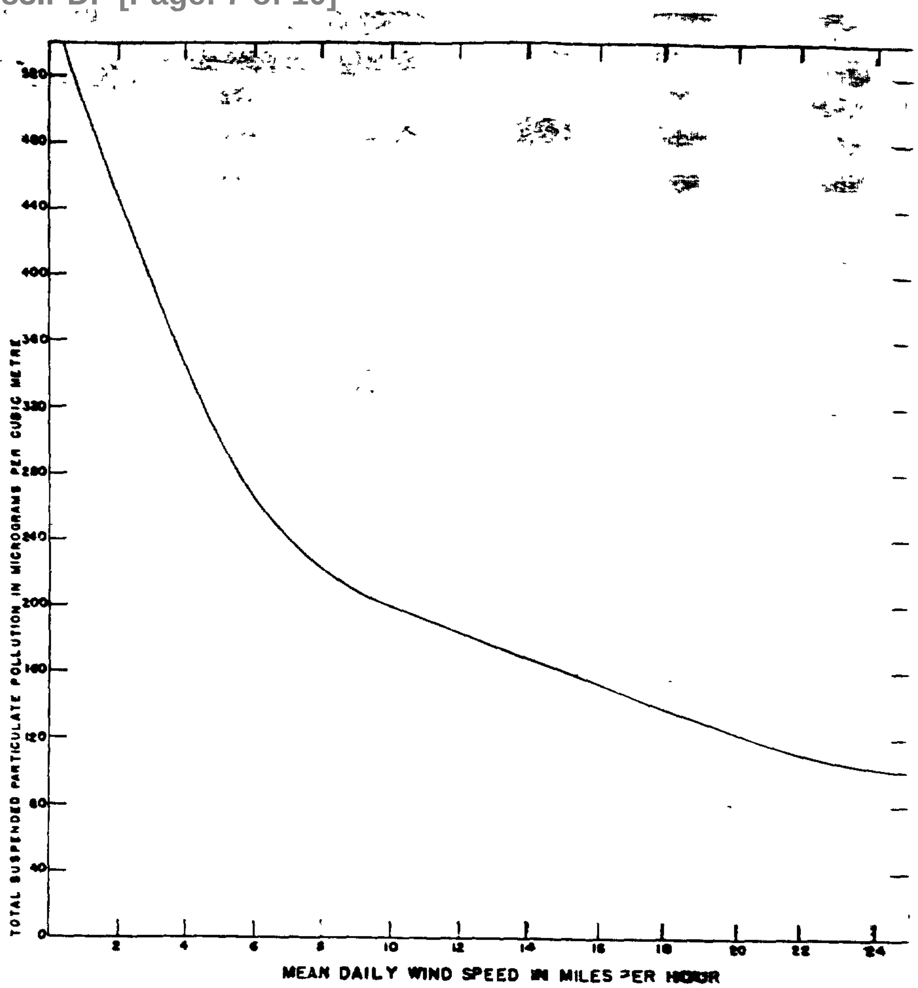

Fig. 2. Regression of suspended particulate pollution in Windsor area on mean wind-speed from observations on 74 days during period August 11 to December 31, 1953.

shape and size factors of suspended impurities have been studied by the electron microscope. Sub-micron particles show a tendency to agglomerate. This is particularly evident in carbon, which was the most widely distributed constituent. Carbon particles formed distinctive filaments consisting of individual units in the size range of 0.05 to 0.2 micron (14).

Suspended particulate matter consists of about 60 to 75 percent carbon and a complex mixture of organic matter. The nature of this fraction in the Windsor atmosphere is under investigation at the present time. In contrast to this, the settled dust consists largely of ash and material of inorganic origin.

Sulphur Dioxide and Other Impurities

Atmospheric sulphur dioxide levels have been investigated continuously for several years by recording analyzers at four to five stations in the Greater Windsor area. In view of the large amount of solid fuel used in the Windsor-Detroit area, the sulphur dioxide content of the atmosphere is of considerable importance in assessing the extent of the pollution load in various sections of this region.

The average monthly concentrations at a sampling station near the centre of the industrial part of Windsor and at McGregor, Ont. a semi-rural district 15 miles south of the Detroit River, are shown in Table V. There is a considerable difference in the mean values for these two areas, the sulphur dioxide pollution in Windsor being about 18 to 25 times greater than that registered at McGregor. The overall mean values in parts per billion for the Windsor and McGregor stations were as follows:—

	1951	1952
Windsor—		
industrial area	84.7	114.7
McGregor	3.6	6.1

The maximum 30-minute average concentration in Windsor during the test period 1951-1952 reached a value of 1.45 parts per million. The maximum over the same period at McGregor was 0.876 parts per million.

Mean sulphur dioxide concentrations reported in the literature for other city areas within recent years are, as follows, in parts per billion (3):—

Cincinnati (1947-51)	
Industrial and commercial areas	64
Residential area	44
Rural	37
Baltimore (1950)	
Industrial area	74
Rural	23
St. Louis (1937)	
Warm months	127
Cold months	250
Cold months (1950)	41
Cleveland (1949-50)	
Industrial area	42
Donora (1949)	150
Yonkers, N.Y. (1936-37)	32
Los Angeles (1949-50)	
Days of good visibility	50
Days of reduced visibility	200

The increased use of natural gas, liquid and solid fuel of low sulphur content for space heating has been reflected in a progressive decrease in the average sulphur dioxide concentration of the atmosphere in a number of cities, such as St. Louis, Cincinnati, Pittsburgh and Salt Lake City.

Other impurities which have been found in the Windsor atmosphere, as in other city areas, include aldehydes, oxides of nitrogen, ammonia and chlorides.

Influence of Meteorological Factors on Dispersion

Although the total amount of contaminants discharged to the atmosphere over a city or industrial area may remain constant from day to day, the concentration of impurities per unit volume of air will vary widely because of changing meteorological conditions imposed by the weather. This is especially true where topographical features such as mountain valleys and large bodies of water are absent.

At Trail, B.C., Donora, Pa. and Los Angeles, the topographical features tend to complicate the influence of meteorological factors on the dispersion of contaminants. No such complications are evident in the Detroit River area, however. The terrain is relatively flat and the river valley is shallow. The influence of Lake St. Clair and Lake Erie is only minor in character. The dispersion of contaminants in this area is governed by weather correlations consistent with diffusion theory.

Raymon (1) has analyzed the findings of a six weeks' joint study of suspended particulate matter in the Windsor-Detroit area, carried out by our Windsor staff and the U.S. Public Health Service in the late summer of 1952. Twenty sampling stations were operated continuously and the daily mean values of particulate pollution were related to the observed weather.

Correlation of Meteorological Factors

The results of this correlation are presented graphically in Fig. 1. The daily values for three weather elements have been plotted underneath the day to day fluctuations in the levels of particulate pollution. These elements are the daily mean wind speed in miles per hour, the daily temperature anomaly defined as the difference between the daily mean temperature and the normal temperature, and lastly, the daily value of the difference between surface temperature and the temperature at a pressure of 850 millibars. The pressure region of 850 millibars corresponds roughly to an altitude of 4,800 feet above mean sea level.

The dispersal of atmospheric contaminants by air currents is usually accomplished by dilution laterally on wind movements and by diffusion vertically through convection currents. This process is assisted or inhibited by the "lapse rate". The lapse rate is defined as the rate of decrease of air temperature with height. Large lapse rates induce convection currents, whereas small lapse rates inhibit such currents. It is evident therefore that large lapse rates should coincide with reduced pollution levels whereas small lapse rates favour the accumulation of pollutants.

The temperature anomaly is considered as an index of the lapse rate. In the Great Lakes region it is generally true that lapse rates are large during unusually cold weather, and small during unusually warm weather. A large lapse rate would be indicated by a relatively large negative temperature anomaly, whereas a small lapse rate would be indicated by a large positive temperature anomaly.

The curves in Fig. 1 indicate clearly the phase relationships of the above three weather elements. Light winds, small lapse rates and above normal temperatures coincide with high pollution loadings of the atmosphere or lead to high pollution levels. Strong winds, large lapse rates and below normal temperatures reduce pollution rapidly.

The strong influence of the wind speed in this region on the total suspended particulate pollution is illustrated by the curve in Fig. 2. This curve represents the regression of the daily mean value for suspended particulates on the daily mean wind speed in Windsor. These pollution concentrations represent the average results of two sampling stations located in a heavy and moderate pollution area respectively, in measurements on 74 days during the period August 11 to December 31, 1953. There is a much greater effect on the absolute concentration of suspended matter by changes in the diffusion process at low wind speeds than at high wind speeds.

Other factors which have been found to affect the levels of pollution are changes in wind direction, frontal passages and precipitation. Marked reduction in the level of pollution is associated with cold frontal passages over the area. A cold front may be defined as the leading edge of an advancing mass of cold air that is displacing and passing under warmer air. Precipitation also tends to reduce the level of pollution, although it is difficult to isolate specifically the influence of rainfall because of the frequent coincidence of cold frontal passages and higher wind speeds with rain.

Daily Cycle of Pollution

During the period Feb. 26—June 26, 1952, measurements were made of the hourly variation in the concentration levels of fine suspended matter near the centre of Windsor, by means of a modified Owens pollution recorder. (9, 13). This instrument yields a series of spots or stains around the periphery of a filter paper disk. The intensity of these spots is a measure of the concentration of suspended solids or smoke in the atmosphere and the results are evaluated by an optical method. The data have been plotted for each hour of the 24-hour day and reveal a marked diurnal trend, as shown in Fig. 3.

The level of suspended matter increases during the night and early morning hours until a peak is reached at 7.00 a.m. Thereafter the concentration decreases rapidly until the minimum value is attained about 3.00 p.m. This cycle is probably closely related to the diurnal variation in wind turbulence and temperature lapse rate. It is known that, in clear weather, turbulence reaches a maximum about the

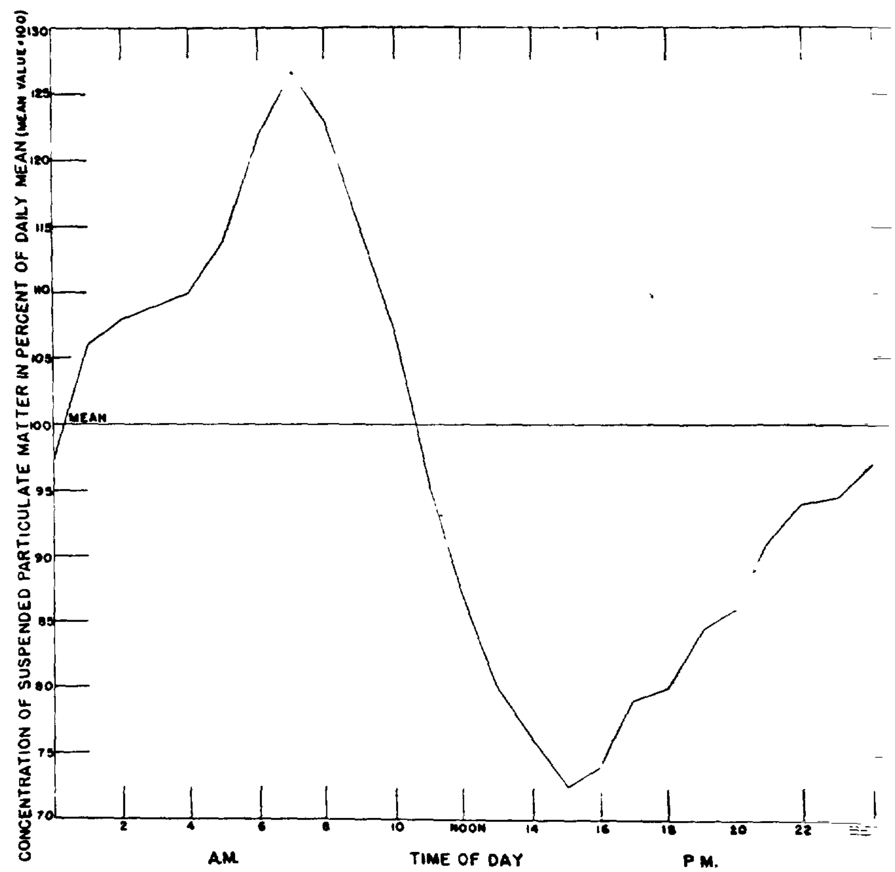

Fig. 3. Daily cycle of suspended particulate pollution in Windsor. Test period February 26 to June 26, 1952.

decays after sundown and during the night.

The daily and seasonal cycles of sulphur dioxide pollution in Windsor are indicated in Figs. 4 and 5 over the test period September 1950 to January 1953. In the fall and winter months there are well-defined maxima in the pollution levels during the morning period from 8.00 to 9.00 and 9.00 to 10.00 o'clock, respectively. During the spring and summer seasons the relation is more complex with peaks in the daytime and a lowering of the concentration levels during the night hours up to about 5.00 a.m.

There is evidence that turbulence, which consists of the two co-variables of wind velocity and temperature gradient, has somewhat similar but by no means identical effects on the concentrations of sulphur dioxide and suspended particulates. Air pollution studies by the Department of Scientific and Industrial Research in England (5) indicate that some of the causes which do not operate similarly on smoke and sulphur dioxide are due to the following:

(a) differences in rate of emission, because sulphur dioxide is always present in the flue gases from solid fuels whereas smoke is produced by inefficient combustion.

(b) proportionately more sulphur dioxide than smoke is emitted from industrial chimneys; there are differences in place of emission and in the height of emission.

(c) smoke and sulphur dioxide are removed from the atmosphere at different rates; small particles of suspended smoke are removed by collision or impaction with surfaces and obstructions whereas sulphur dioxide is removed by absorption by water and vegetation as well as by chemical reaction with other impurities.

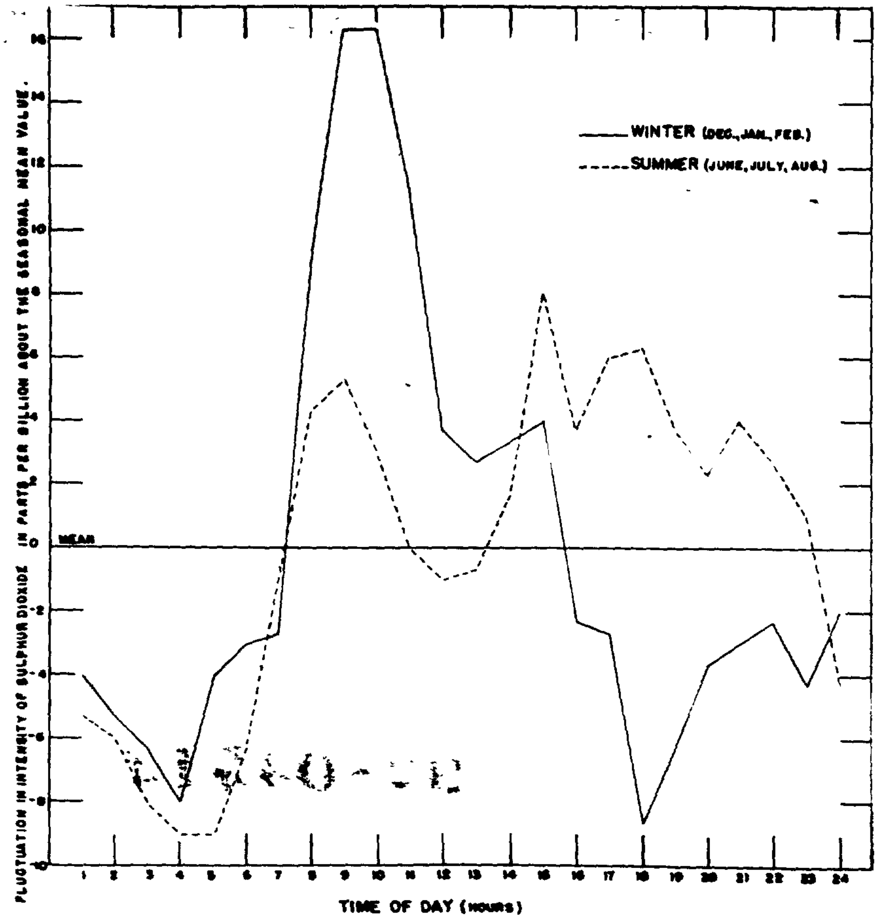

Fig. 4. **Daily cycle of sulphur dioxide pollution in Windsor during winter and summer seasons.**

Influence of Adverse Factors — The Los Angeles Problem

The Los Angeles pollution problem represents an excellent example of the limitations imposed on natural air cleaning processes by adverse meteorological and topographical factors. The Los Angeles area consists of a basin hemmed in on three sides by mountains that limit the lateral movement of the land and sea breezes. The air circulation is further limited by the presence of an inversion layer known as the Pacific Inversion, which consists of a warm air mass above cooler air, extending aloft from the California coast far out into the Pacific ocean. On many days of the year, this inversion layer drops to about 3,000 feet or lower, below the level of the mountains, effectively sealing the basin and preventing the vertical diffusion of the polluted air.

The result is a recurrent haze and smog accompanied by eye, nose and throat irritation, reduced visibility, and economic losses in crop damage and rapid deterioration of rubber (6, 11). The major pollutants in the Los Angeles area are believed to be due to organic products from the daily combustion of about 45,000 tons of gasoline, fuel gas and oil, and about 4,000 tons of household rubbish. Excluding carbon monoxide and dioxide, at least 1,800 tons of impurities are emitted daily from industrial and public sources, including the exhaust fumes from about two million motor vehicles (11).

Reactions Between Atmospheric Contaminants

It is known that gaseous contaminants such as ammonia and sulphur dioxide may react after release to the atmosphere, or oxidation of sulphur dioxide, nitric oxide and other oxidizable compounds may take place in the air, especially in the presence of sunlight and catalytic impurities. Recent investigations into the Los Angeles smog problem have shown that during smogs there is a considerable increase in the concentration of ozone or "oxidant" material, coincident with the severe cracking of rubber, eye irritation and crop damage. The ozone or "oxidant" material is not found at night but begins to form simultaneously throughout the Los Angeles basin in the smoggy atmosphere shortly after dawn. The oxidant concentration reaches a peak which coincides generally with the period of highest intensity of the smog or least visibility in daylight hours. (6, 11).

These facts have led to several interesting theories on the photochemical formation of ozone from impurities in the atmosphere by the action of sunlight. These include the photolysis and photochemical activation of nitrogen dioxide, sulphur dioxide, aldehydes, ketones.

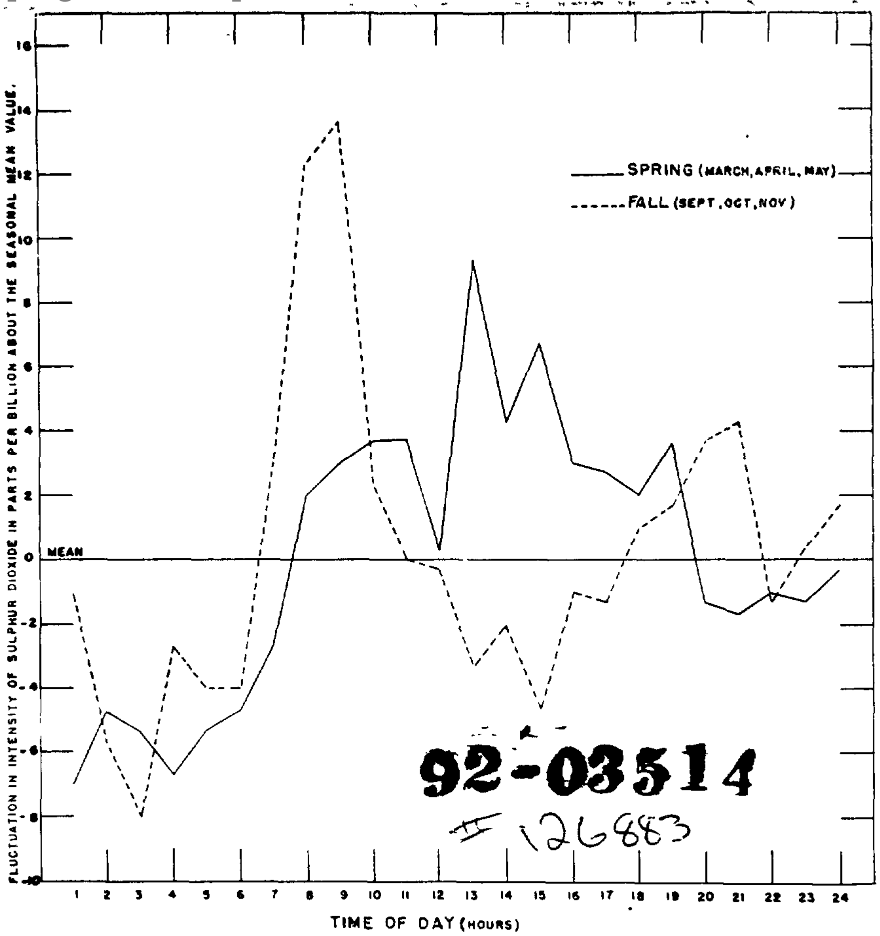

Fig. 5. Daily cycle of sulphur dioxide pollution in Windsor during spring and fall seasons.

and organic free radicles. Ozone can be formed as a by-product in most of these reactions. The ozone thus formed may react readily with olefins and other constituents of smog forming organic peroxides, aldehydes and acids. (2, 6).

It is interesting to note that most of the impurities involved in these reactions are present in other city atmospheres besides the Los Angeles air. The principal difference is that, in other city areas, natural air cleaning processes are more effective in dispersion of the contaminants, so that their persistence in the atmosphere is not as prolonged as in the Los Angeles area.

Conclusions

It is apparent that the impurities in a city atmosphere are extremely complex and varied. They represent the waste products of all human activities in the area, including both industrial and public operations. The problem created by exhaust gases from vehicular traffic is in some large cities, such as Los Angeles, overshadowing that of the effluents from industry. The possibility of interaction of some of the contaminants to form products which are more harmful than the original wastes is an additional complicating factor in attempts at control.

Control measures in a given area will depend not only on the mass rate of emission of particular contaminants, but also on the capacity of the atmosphere to disperse and diffuse such impurities effectively under the prevailing meteorological conditions. Measures suitable for an area which is adversely affected by topography and persistent inversion conditions need not be applicable where the geographical location and weather factors are more favourable.

Experience in the Los Angeles area and elsewhere has indicated that a pollution problem cannot be remedied by legal machinery alone. Unless there is adequate technical understanding, a knowledge of cause and effect and the remedies are feasible economically, the problem will remain. In Los Angeles County the troublesome smog is still present in spite of drastic limitations on industrial emission of dust, fumes, smoke and sulphur dioxide.

In London, England the in[illegible]ient combustion of bituminous coal for domestic space heating presents an unsolved smoke nuisance. It is probable that future remedies will include city and community planning in relation to location of industrial and residential areas, decentralization of industry and more extended use of land for public parks, gardens and wooded areas to prevent overcrowding of sources of emission.

As air pollution becomes of increasing importance in cities and industrial communities, forecasting of major smog periods will be an essential service. This could prevent the occurrence of a disastrous or unpleasant episode by providing time for the institution of relief measures. Recent studies on the correlation of pollution with weather factors in the Windsor-Detroit area indicate the feasibility of predicting pollution levels.

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