AIR POLLUTION IN THE CHRISTCHURCH METROPOLITAN DISTRICT

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SUMMARY: A brief outline of the history of air pollution measurements in Christchurch is given with an outline of the factors which influence them, such as climate, fuels used, topography, etc. A short discussion on the D.S.I.R. survey and other more recent work follows.

From the present data, it seems that sulphur dioxide levels have remained relatively constant and smoke in the central city area has decreased, whereas in the residential areas it has remained relatively constant. Levels in the months of June and July are now far removed from those in London.

HISTORY

The earliest reported work was done by Gray at Lincoln in 1884–1888 and 1907–1909 and was published in 1889 and 1910 respectively. In this work the dissolved solids in rainwater were measured and were found to be about 50 mg./m^2 day. It is interesting that this figure is very close to the current level 70mg/m^3/day.

During the early 1930s C. J. Barwell and C. Coleridge Farr on behalf of the Christchurch Sunlight League, made measurements on the precipitation of solid matter (unpubl. rept.).

The first truly scientific studies were started by the Department of Scientific and Industrial Research in June 1954. These recorded the levels of sulphur dioxide in the centre of Christchurch. In August 1956 the survey was extended to the suburbs and measurements made of deposited matter and smoke. A summary of the results is given by Wilkinson (1959).

TOPOGRAPHY AND CLIMATE

Christchurch is situated at about latitude 45°S. on the Canterbury Plains. To the south are the hills of Banks Peninsula and the Port Hills; to the north-west and west are the foothills of the Southern Alps. On average, Christchurch would be about 50 feet above sea level. In summer, ventilation is good, calm days being fairly rare. However, in winter, from May to August, calm days are common. From latest data it appears that temperature inversions occur on about 60% of winter days, even with wind speeds of up to 7–8 knots.

Of the total degree-days approximately half occur in the months of June and July (1,000–1,100). Frost occurs on about 35 days in these two months. These factors lead to a high heating load and this, associated with calm days and inversion conditions (which gives poor ventilation rates approximately half those of London), make this time the peak for air pollution.

In winter and summer anticyclones generally proceed from Australia to New Zealand and these tend to become slow-moving or stationary in the Tasman Sea during winter and the Pacific Ocean during summer. It is, perhaps, fortunate that they do not usually become stationary over the Canterbury Plains (although there is always the possibility of this happening) — especially in winter when such a situation would be associated with extreme levels of pollution.

POLLUTANTS AND THEIR SOURCES

The principal pollutants in and around Christchurch are divided into two classes: visible pollution such as smoke, dust and grit; and invisible pollution such as sulphur dioxide, nitrogen oxides and carbon oxides. All processes in which a fossil fuel (coal or oil) is burned produce carbon dioxide; and to a greater or lesser extent, dependent on use, nitrogen oxides and carbon monoxide. The extent to which sulphur oxides are emitted depends solely on the range of sulphur content of the fuel and it is safe to assume that at least 90% of the sulphur will be emitted to the atmosphere in the form of its oxides. Smoke is produced when combustion is not complete, dust and grit originate primarily from industrial boiler plants and are carried away in the flue gases.

Dealing with the visible pollution, the sources of smoke in Christchurch in order of quantity produced are as follows:

(a) The domestic open fire;
(b) Industrial combustion;
(c) Incinerators for the disposal of wood waste;
(d) Heavy trucks, buses and cars.

Legislation has been passed (the Smoke Restriction Regulations 1964) to limit (b) and (c) and the decrease from these sources is starting to be noticeable. Pollution by motor vehicles is controllable under a section of the Transport Act, but although prosecutions have been made, a more stringent approach is necessary to effect the improvement desired. No legislation exists to control the emissions from (a).

With regard to invisible pollutants, most of the work in Christchurch has been concentrated on sulphur oxides. Reduction in these can be achieved only by limiting the quantity of sulphur in fuels and ensuring that the flue gases are dispersed through a chimney stack of height sufficient not to cause unpleasant concentrations in the vicinity and not to add markedly to existing background levels of pollution. Carbon monoxide from motor vehicle exhausts is the next most significant gaseous pollutant; but, as a result of legislation enacted overseas, improvements in the modern engine should lead to reduced local emissions from this source.

Other pollutants commonly found in the atmosphere are lead from combustion of petrol and smelting operations, hydrocarbons from motor vehicles, fluorides from fertiliser manufacture and numerous very local pollutants from industrial processes, such as odour from a meat works, ammonium and zinc chlorides from galvanising plants, and so on. In other words, the atmosphere is the "garbage can" for any unwanted gaseous effluent, just as lakes, rivers and the sea have been for liquid effluents.

With the urban and industrial development of Christchurch, the increasing demand for energy has put a steadily increasing load on the atmosphere; although with modernisation and use of different fuels the overall situation is not as bad as it might have been. For example, domestic coal consumption has risen from 53,000 tons in 1957 to 75,000 tons in 1966; but coal consumption by the railways fell from 66,000 to 47,000 tons and in 1969 will fall to less than 10,000 tons as a result of the rapid conversion to diesel fuel. In addition, industry and fuel technology have advanced rapidly and management is now becoming very aware of the fact that smoke up the chimney is profits down the drain and this is possibly the greatest incentive for improvement.

MEASUREMENT AND CONCENTRATION OF POLLUTANTS

The methods used in Christchurch for the measurement of pollutants are the same as those applied by the Warren Springs Laboratory in England. This standardisation has been made so that direct comparison with British results may be made. The conditions found here are from the same general source (domestic open fires) so results can be compared. Results from the United States monitoring networks are not necessarily measured in the same manner or from the same type of source (automotive and industrial), so extreme care must be taken when making comparisons.

Sulphur dioxide concentrations have been measured continuously, using the measurement of change in conductivity of a solution of hydrogen peroxide brought about by the formation of sulphuric acid, according to the following reaction:

$$H_2O_2 + SO_2 = H_2SO_4$$

Measurements were made daily by titration of the sulphuric acid with standard alkali. Monthly measurements were made by using lead peroxide candles which are in the form of a porcelain cylinder around which is wrapped 100 sq. cm. of tapestry cloth impregnated with lead peroxide which reacts with the sulphur dioxide to form sulphate which is determined gravimetrically at the end of the period.

Continuous or daily monitoring determines concentration in parts per hundred millions (p.p.h.m.) or microgrammes per cubic metre (ug./m^3); monthly results or sulphonation values are expressed in mg./100 cm^2/day. A rough conversion may be made by multiplying this by 100 to give ug./m^3. In this way monthly or annual averages may be compared, but that different methods have been used must always be born in mind when doing so.

Smoke is measured optically by the amount of light reflected from a paper filter through which has been drawn approximately 60 cubic feet of air through an area 1 inch in diameter (Wilkinson 1959). From this it is possible to calculate the amount of smoke in ug./m^3. This method is extended so that by the use of a special type of sampler an average smoke concentration over 1–2 hour periods, as well as over 24 hours, may be obtained.

Measurements have also been made of the total particulate matter in the atmosphere by drawing between 100–300 cubic metres of air through a pre-weighed glass fibre filter and weighing it afterwards. This method may also be used in the analysis of dust in the vicinity of industrial plants. Other pollutants may be measured if required.

From 1955–1957 measurements were made by the D.S.I.R. (Wilkinson 1959) which showed that the annual average sulphur dioxide concentrations were as follows:

SO_2 in ug./m.^{3}	Annual	Summer	Winter
City	76	26	127
St Albans	33	11	55
Spreydon	42	14	70
Huntsbury	8	3	12

The ratio of summer to winter levels is also shown in this table. The average winter smoke level during this period was 330 ug/m^3. in the central city area.

In 1960 a report was begun by the D.S.I.R. on air pollution for the Air Pollution Advisory Committee of the Christchurch Regional Authority (Anon. 1966).

For this report, measurements were made at 25 selected sites in the Christchurch Metropolitan Area from 1960 to 1964. To supplement this report, a survey of fuel-use was made and analysed in terms of the contributions made by domestic, industrial and vehicular combustion. Associated surveys included in the report were, fuel burning habits in Riccarton and Sydenham (by the University of Canterbury), Air Pollution and Health in Christchurch (de Hamel 1966).

Since 1964, measurements of sulphur dioxide and smoke have been made by the D.S.I.R. at Government Buildings, Worcester Street, in the centre of the city; and in the winter of 1969, measurements of smoke, sulphur dioxide and particulate matter were made by the Health Department at National Radiation Laboratory, Victoria Street; at Riccarton, the Wigram Air Base, and at Hornby. In addition, two-hourly smoke levels were measured at the National Radiation Laboratory, at Riccarton and at Rangiora and Kaiapoi.

SULPHUR DIOXIDE AND SULPHONATION

The area of highest concentration of sulphur dioxide is found in the central city and is extended outwards in the form of wedge towards Moorhouse Avenue and encompasses the area from Addington through Sydenham. The average winter levels range from 80–115 ug./m^3. However, with the conversion of the railways to diesel power, the extent of this area needs to be re-established.

No substantial change in the overall level of sulphur dioxide has been measured in the past nine years; although, from examination of the results from the city centre and allowing for seasonal variations, there appears to be a slight downward trend in the concentration of this pollutant.

SMOKE

The areas of highest concentration now appear to almost encircle the centre of the city; the emphasis changing from the southern area to residential areas of Merivale, St. Albans and Shirley. From measurements made in 1969 and since 1964, it has been apparent that smoke levels in the developing area of Hornby have increased, whereas there has been a marked decrease in the central city area. In 1969 the variations in smoke concentration over two-hourly periods throughout the day have been measured for the first time. It is striking that on all days, regardless of the weather, there is a large increase in smoke from 4 p.m. to 12 midnight and also a smaller increase from 6 a.m. to 10 a.m. On 90% of the days, the peak concentration is between 8 p.m.–10 p.m. On one occasion a level of 1,260 ug/m.^{3} was reported and on several occasions levels of $>$1,000 ug./m.^{3} have been recorded. These levels are 6–7 times the winter monthly average; and as this is about seven times the annual average, peak winter concentrations of at least 50 times the annual may be expected.

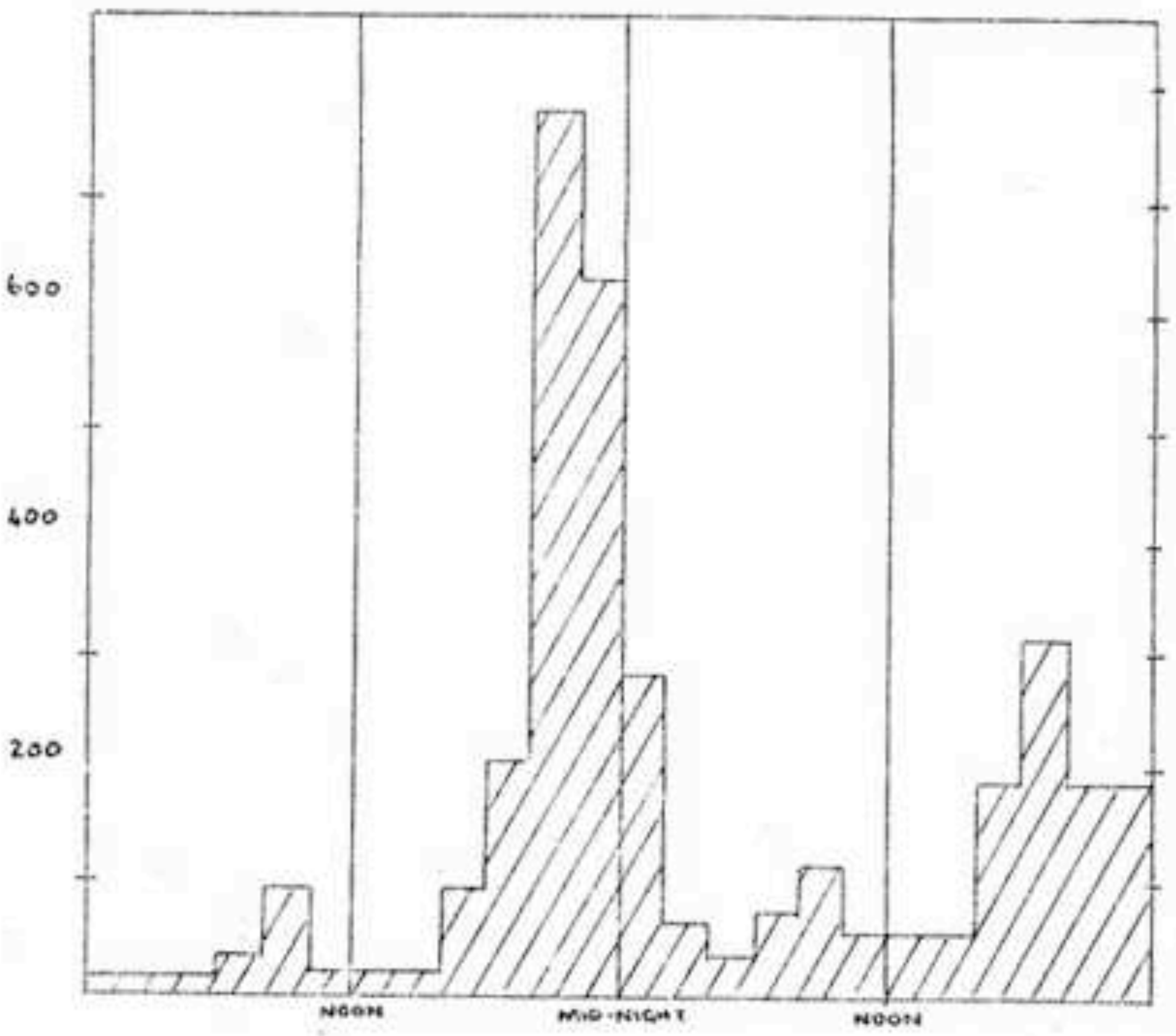

FIGURE 1. *Typical winter diurnal smoke pattern, Christchurch.*

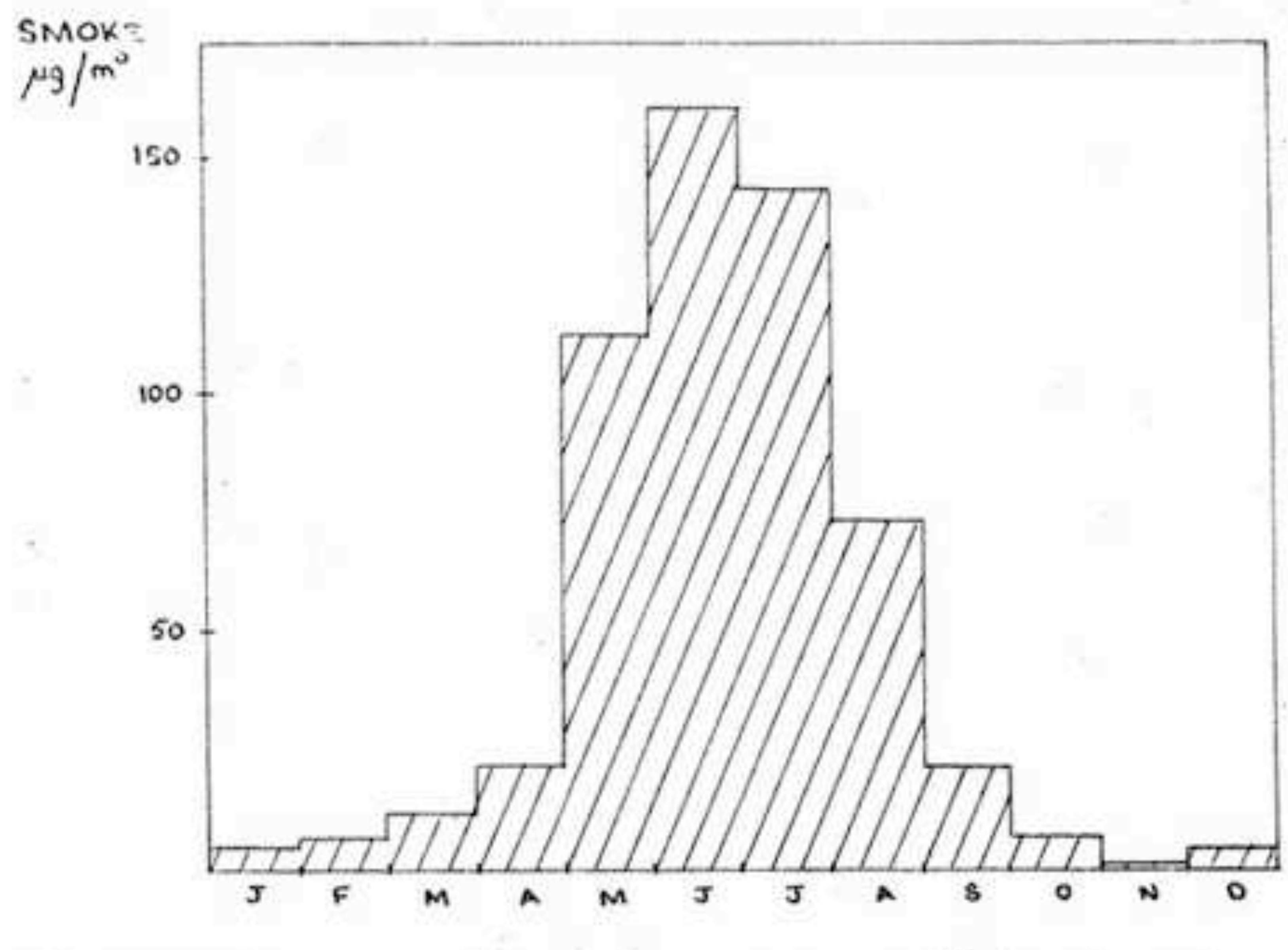

FIGURE 2. *Annual smoke pattern, Christchurch.*

CONCLUSIONS

From the topographical and climatic conditions in Christchurch it is evident that there exists a situation conducive to the increase of pollutants in the atmosphere, especially on calm days such as occur frequently in winter. Peak levels occur in June and July. All fuels contribute to this pollution, but as Christchurch is still largely dependent on coal for space-heating in winter, it will be the inefficient burning of this fuel which is the prime cause. Approximately 70,000 tons of coal are burnt on the domestic open fire annually, most of this in winter. The smoke is discharged at a very low level, usually not more than 15–16 feet above the ground. From data obtained on the two-hourly smoke sampler, peak levels occur in the early evening. Until such time as better and cleaner methods of heating are widely introduced, this state of affairs will continue in winter.

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