The air pollution potential of slash burning in southwestern B.C.

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Considerable adverse publicity is directed in British Columbia at the practice of slash burning because of the smoke created. The criticism reflects the public's growing awareness of air pollution.

The forest industry, too, is concerned. At the annual meeting of the Western Forestry and Conservation Association held in Vancouver, B.C., December 2 - 4, 1970, a resolution was passed urging " — the Minister of the Department of Transport to make funds available to the Fire Weather Service to provide adequate staff and research so that they can achieve their maximum contribution to smoke management programs."

Smoke pollution from the burning of logging slash presents problems quite different from those originating from industrial sources. Firstly, many of the toxic substances harmful to human health that are present in emission from industrial sources are absent in the smoke from burning cellulose. Secondly, since slash burning takes place in unpopulated areas, air pollution is of little concern in the immediate vicinity of the emission source, but rather the problem occurs after the smoke has spread to urban or resort areas. Here the public find it objectionable not because of detrimental effects to health or property, but because of aesthetic considerations. Even in the unpopulated areas problems arise, however, since the layers of smoke in the lower levels of the atmosphere present a distinct hazard to aircraft flying under visual flight regulations. This is particularly true in the mountainous terrain of British Columbia.

Since slash burning is a planned activity which can be completed in relatively short periods of time, the accompanying smoke pollution problem may be amenable to solution through simply restricting burning to those periods when atmospheric conditions are favourable for the natural dispersal of smoke.

To investigate the feasibility of this approach, a brief study was made on the slash burning that took place from mid-August to mid-October 1970 in the Vancouver Forest District of British Columbia. An

attempt was made to measure the capacity of the atmosphere for smoke dispersal during this period, and to relate this quantity to the observed frequency of slash burning. About 95% (70,000 acres) of the total slash burning in this district in 1970 was conducted during this two-month period.

Meteorological aspects of atmospheric dispersion

Transfer of pollutants through the atmosphere depends almost entirely on meteorological and topographical factors. Two of the most important parameters in studying the dilution of atmospheric pollutants are the depth of the mixing layer and the low level wind flow.

The mixing or convective layer can be briefly defined as the layer of air next to the ground in which active vertical mixing takes place. The temperature in this mixing layer decreases at a rate of 5.0°F per 1000 ft, referred to as the **dry adiabatic lapse rate**. The depth of the mixing layer can be estimated from vertical temperature profiles observed at nearby upper air reporting stations and values of surface temperatures in the area. The procedure is shown in Figure 1.

The depth of the mixing layer undergoes a pronounced diurnal variation in accordance with daily surface temperature changes. During the day, heat-

Fig. 1. A is the estimated depth of the mixing layer (4300 ft) for Cassidy Airport obtained from its surface temperature and the upper air temperature profile at Quillayute. B is the depth of the mixing layer at Quillayute (1300 ft).

Fig. 2. Percent cumulative frequency distribution of Ventilation Indices using temperature profiles from Quillayute upper air ascents and Quillayute 4 pm surface temperature (solid line) and Cassidy Airport maximum temperature (dotted line). Total of 59 observations in August 16 - October 18, 1970.

Fig. 3. Percent cumulative frequency distribution of Ventilation Indices using temperature profiles from Port Hardy upper air ascents and Port Hardy 4 pm surface temperature (solid line) and Cassidy Airport maximum temperature (dotted line). Total of 62 observations in August 16 - October 18, 1970.

ing of the ground usually establishes a well-mixed surface-based layer, the depth of which depends on both the surface temperature and the temperature of the air aloft. After the time of maximum surface temperature the mixing layer gradually decreases in depth, usually completely disappearing at night. This normal diurnal variation is superimposed on the characteristic vertical temperature structures associated with day-to-day airmass changes over the area.

Wind speed is perhaps the most important parameter in smoke dispersal. Strong winds increase the area over which pollutants are dispersed thereby reducing pollutant concentrations; furthermore, higher wind speeds increase mechanical turbulence and this results in a deeper layer of active vertical mixing.

A simple index called the **Ventilation Index** combines mixing depth and wind speed to rate the potential of the atmosphere to disperse atmospheric pollutants. This Ventilation Index (VI) used by some agencies in the western United States (Fire weather and air pollution talk presented to the Utah Cooperative Fire Fighter's Association, 1969, by Mr. L. P. Mallory, U.S. Weather Bureau, Salt Lake City, Utah) is calculated by multiplying the depth of the mixing layer in feet by the mean wind speed in the mixing layer in knots, and dividing the product by 100

$$VI = (\text{mixing depth} \times \text{mean wind speed}) / 100$$

The following standards have been applied by some fire control agencies in Utah to regulate issuing burning permits:

less than 200	absolutely no burning
200 to 600	generally no burning, but exceptions allowed for short period, low yield burns
greater than 600	burning permits issued (and often issued down to an index of 500)

Estimation of pollution potential for the Vancouver Forest District

In the autumn, high pressure areas with light winds often stagnate over B.C. The large scale subsidence accompanying these weather systems produces a vertical temperature profile which inhibits the formation of a deep mixing layer. Since most slash burning takes place in the autumn when the above conditions are most prevalent, a high accumulation of pollutants may be expected to occur periodically.

An estimate of the pollution potential of the atmosphere during the period of slash burning was obtained by calculating the Ventilation Indices for Quillayute, Washington, (south of the District), and Port Hardy, B.C. (in the north of the District), the nearest upper air reporting stations. The indices were calculated from the 4 pm LST observations because these data provided the best indication of the maximum daily values of the index.

Both stations are situated on the coastline, and their surface temperatures are therefore strongly influenced by the cold ocean water. As a result, the maximum temperatures recorded there are generally lower than those observed further inland; accordingly, the Ventilation Indices are also lower. Experience suggests that the maximum temperature from Cassidy Airport (in the south of the District)

Fig. 4. Percent cumulative frequency distribution of daily average Ventilation Indices for Vancouver Island for the period August 16 - October 18, 1970.

Fig. 5. Percent cumulative frequency distribution of average Ventilation Indices for Vancouver Island for the 25 days companies burned slash.

should provide a more typical estimate of the temperatures at locations away from the immediate effects of the ocean. Two additional sets of indices were calculated by combining the winds and temperatures from the two upper air reporting stations with the maximum surface temperatures observed at Cassidy Airport. It was felt that the resulting indices would be representative of the forested areas in the northern and southern parts of the Vancouver Forest District.

Figure 2 shows the cumulative frequency distribution of the two sets of Ventilation Indices obtained by combining Quillayute upper air sounding data with, in one case, the Quillayute surface temperatures, and, in the other, with the Cassidy Airport maximum temperatures. If the Utah standards have some applicability to southern B.C., then the frequency distributions indicate rather unfavourable pollution dispersal conditions persisted during the period. For Quillayute over 60% of the days had an index less than 200 and about 85% of the days had an index below 500. The substitution of Cassidy Airport maximum temperatures resulted in only a slight overall increase in the indices. The largest differences between the two sets of indices occurred at low VI values; for example, when the index was calculated using higher airport temperatures, there were approximately 15% fewer days in the range below 200.

The stabilizing effect of the cold water off the northern end of Vancouver Island is clearly illustrated by the large number of days with an index less than 100 at Port Hardy (Figure 3). The substitution of Cassidy Airport temperatures produced a marked change in the distribution. A comparison of the cumulative frequency distributions suggests that a value of the VI less than 200 may occur twice as often along the immediate coast as at locations further inland.

The two sets of indices obtained by combining the maximum temperatures at Cassidy Airport with the upper air data from Port Hardy and Quillayute were averaged to provide an approximation of the overall conditions in the forested areas of the Vancouver Forest District. About one third of the days had an index less than 200 and only about one quarter of the days had indices greater than 500 (Figure 4).

Values of the VI greater than 500 - 600 do not necessarily preclude smoke pollution. During some anticyclonic weather situations, the depth of the mixing layer persists at 4,000 - 8,000 feet for a period of several weeks. If the mean wind speed in the layer is 10 knots or higher, the associated VI will be fairly high. Even so, smoke could gradually accumulate in the mixing zone, forming smoke layers aloft, thereby creating a nuisance to the public and a possible hazard to aircraft operations.

Although the VI does not provide a complete description of the pollution potential, it can nevertheless be very useful. It can be obtained relatively easily and incorporates the two parameters used in nearly all air pollution studies.

Slash burning operations related to the Ventilation Index

A list of daily slash burning activities, provided by the B.C. Forest District Office, showed 25 days in the two-month period from mid-August to mid-October when one or more companies carried out slash burning. Although the above information was limited, it provided a convenient means of identifying the days which were operationally suitable for slash burning, but without regard to smoke pollution.

Restricting slash burning to days with a VI over 200 would have decreased by 40% the number of days otherwise suitable for slash burning (Fig. 5). Restricting burning to days with a VI greater than 500 would have reduced the number of suitable days by 80%.

Conclusions

Since records of the total area of slash burned each day were not available, an indication of the relative amount of daily burning that took place was obtained by noting the number of individual companies burning each day. By defining a "company-slash-burning-day" as a day when one company burned slash, we obtain a total of 187 company-slash-burning-days in the two-month period. On this basis, about 50% of all slash burns occurred when the VI was less than 200, and 80% of the burns occurred when the VI was less than 500.

For the period studied, most slash burning took place under atmospheric conditions not conducive to the natural dispersal of smoke. However, during this two-month period only a small number of the total days had indices greater than 500 (Fig. 5). Indeed, a comparison of the curves in Figures 4 and 5 indicates that the frequency distribution of the Ventilation Indices for slash burning days and for all days in the period are closely parallel. This suggests that the air pollution potential is not taken into consideration in slash burning practice. It also suggests that regulating prescribed burning to minimize the ensuing smoke pollution would require a considerable increase in operational planning, since the addition of a smoke management restraint would decrease the number of days suitable for burning to a fraction of the number presently used. Under these circumstances, in order to accomplish the required amount of burning, companies might find it necessary to modify current slash burning practices by burning in other periods of the year.

A proper smoke management program would, of course, consider many other factors in addition to the VI, for example the location of the fire with respect to population centres. If smoke pollution from slash burning is to be studied seriously, it is recommended that detailed records be kept of the date and extent of all prescribed burning conducted in the province.

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