DIFFUSION AND EMISSION OF SMOKE FROM AGRICULTURAL BURNING IN HAWAII

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(Received August 31, 1981; revised November 19, 1986)

Abstract. Agricultural burning has been common practice for many years in Hawaii. Cane fields are burnt before harvesting and the crowns of pineapple are cut-off during harvest, left in the field to dry and subsequently burned. While this practice has many advantages, it produces air pollution levels which at least one study finds affect public health. In 1974 open burns of cane and pineapple were simulated in a burn tower where samples were burned while monitoring weight loss and smoke density. From these measurements emission values were calculated. However, because questions were raised as to whether the vigorous field fires can be simulated in a burn tower, a field survey was undertaken and a diffusion model, basically a limited Gaussian line source model, was developed and run using the data collected during the burns. The calculated emission rate for particulates is orders of magnitudes larger than the burn tower rate. This is attributed to dust drawn into the fire. When emission values from a survey of the open burn literature and from the present study were plotted against wind speed, low intensity fires such as grass, straw and pineapple residue fires showed decreased emissions with increasing wind speed while cane fires showed increased emission. This suggests that emission characteristics are different for low and high intensity fires. For low intensity fires increased air flow acts mainly to increase the combustion efficiency producing less particulates. For high intensity fires, such as cane fires, increased air flow results in hotter fires lofting more dust, which is the major pollutant from such fires. Revised emission values are recommended.

1. Introduction

Sugar cane and pineapple fields have been burned on all Hawaiian Islands for many years. This practice has many advantages - insects and rodents are killed by the fire, the ground is fertilized by the burn residuals, less bulk is left to be hauled to the factory and the sugar cane yield is increased. The cane fields are burnt before harvesting while the crowns of the pineapple plant are cut-off during the harvest, left in the field to dry and subsequently burned. The main disadvantage with burning is that it causes air pollution. Plumes from the fires can be seen daily during the burning season (March–December) on most of Oahu. Visibility in the area may be seriously reduced, particularly along roads near burning fields. Property soiling occurs downwind but the main problem concerns public health. Testimony given at a public hearing in 1972 reports that 'the extract of sugar cane smoke can be an allergen' and 'it is highly suggestive that there is a definite relationship of cane smoke to disease' (Sakamaki, 1972). Other testimony (Ames, 1972) reported a 300% increase in respiratory problems in an area affected by the burns during the burn season. Unfortunately no particle size measurements were available. Such measurements would have been valuable since particles of different sizes affect the body in different ways and to different degrees. Furthermore, such measurements might have shown if the particles were predominantly dust which is generally larger than 1 μm or C particles which are generally smaller than 1 μm (Carroll et al., 1977).
Since measurements needed to make field emission estimates are uncertain, difficult and time consuming to make, open burns have been simulated in burn towers. During these tests, which have been shown to reproduce field measurements for slow burning fires such as grass and stubble (Boubel et al., 1969), material is piled on a weighing table in a configuration as close as possible to field conditions and set afire (Gestle and Kemnitz, 1967). The smoke, which is collected by a large inverted funnel above the table, is sampled to determine the amount of pollutant produced by the fire. This value and the change in weight of the burning material are then converted to emission rate.

Darley (1974) conducted such a test for sugar cane and pineapple trash that produced the following emission rate estimates:

For sugar cane trash:

- Suspended particulates: $3.3 \pm 0.7$ kg tonne$^{-1}$ trash burned,
- CO: $32.0 \pm 7.8$ kg tonne$^{-1}$ trash burned,
- Total hydrocarbons: $4.7 \pm 3.7$ kg tonne$^{-1}$ trash burned.

For pineapple trash the emission ranged between the following values:

- Suspended particulates: $2.8-11.3$ kg tonne$^{-1}$ trash burned,
- CO: $35.4-75.3$ kg tonne$^{-1}$ trash burned,
- Total hydrocarbons: $1.7-5.8$ kg tonne$^{-1}$ trash burned.

The ranges reflect fuel and moisture differences and two methods of setting fire to the trash. Based on these emission figures and the 'proportional air pollution model' state agencies decided that agricultural burning was not a major contributor to the pollution load on Oahu and the practice was allowed to continue under a permit system which forbids burning during adverse meteorological conditions. This system is still in effect.

State agencies and the agricultural industry realized that burn tower tests might not adequately simulate the emission during real fires. It was therefore decided that a field monitoring program should be conducted and diffusion modeling undertaken to arrive at emission data for agricultural burning in Hawaii. This article summarizes these efforts (Daniels, 1980).

**2. Field Program**

The field program, which was conducted during the Fall of 1973, was designed to collect data for a diffusion model. Some 25 agricultural fires were sampled. Before each fire as many as 17 high volume particulate samplers were located at accessible locations in the predicted downwind direction during the burn. One of the samplers near the fire was mounted on a trailer in which the following were also continuously sampled: CO, total hydrocarbons, and small particulate density (nephalometer).

A time lapse camera about 5 km away from the fire photographed the smoke in the vertical plane. Another camera was used in a small aircraft flying at about 3 km altitude to take aerial pictures of the plume. Pilot balloon observations were made at an upwind station which also continuously monitored 10 m winds and particulates.