Preliminary Report

Project No. 10.039

EVALUATION OF THE IMPACT OF LEAF BURNING--

PHASE I: EMISSION FACTORS FOR ILLINOIS LEAVES

for

State of Illinois

Institute for Environmental Quality

309 West Washington Street
Chicago, Illinois 60606

from

Statewide Air Pollution Research Center
University of California, Riverside

Ellis F. Darley
Plant Pathologist

August, 1975

Evaluation of the Impact of Leaf Burning--

Phase I: Emission Factors for Illinois Leaves

Introduction

In order to determine the emissions from buring various species of tree leaves, arrangements were made between the Illinois Institute of Environmental Quality and the University of California, Riverside (UCR) to burn leaves in the UCR burning tower. The tower had been developed for the purpose of determining pollutant emissions from agricultural and forest burning.

Some 36 fires from four types of leaf samples have been completed. Considerable amounts of data have yet to be processed but the principal emission factors have been calculated. This preliminary report serves to submit these data to the Institute.

Methods

The final report will give details of the facilities in the tower and the methods of its operation. Briefly, the tower is an inverted metal cone set over a burning table 8 feet in diameter. The table is set on a scale so that fuel weights can be monitored. The arrangement of the tower and table are such that open burning conditions are simulated but the smoke plume is channeled so that adequate gas and particulate samples can be taken. Concentrations of carbon monoxide, carbon dioxide, hydrocarbons are recorded continuously throughout the fire. The air flow and temperature at the sample site are also monitored continuously. A modified HIVOL particulate sampler is used to isokinetically collect particulate matter throughout the fire.

From the data on gas concentration, temperature, air flow, weight of fuel lost and weight of particulate collected, yields of CO, hydrocarbon and particulate were calculated in terms of pounds of pollutant per ton of fuel burned.

Samples of three species of tree leaves, red oak, sugar maple and sycamore, as well as a composite sample, were sent to Riverside. After a few preliminary burns using 12 and 6 pounds of leaves piled in a cone, and either stirring or not stirring the pile during the burn, it was decided to use 6 pounds of leaves for all subsequent fires and to stir the pile several times during the fire. When a pile is ignited, the flame moves over the surface rather quickly and then goes out. If the pile is not stirred, it will remain in a smoldering condition for an hour or more. If it is stirred just before the flame goes out, unburned leaves are brought to the surface and the flame again spreads over the exposed leaves. By successively stirring the leaves while a little flame was left, a 6 pound pile of dry leaves burned down in about 12 minutes.

Piles were ignited as quickly as possible with two small propane torches, igniting the entire periphery at the bottom of the pile. Each stirring was done with a pitchfork by turning the pile from the bottom two or three times and maintaining the pile in as near a cone shape as possible.

Each leaf fuel was burned at three moisture levels determined on a dry weight basis. The low level was the air-dry moisture existing in the leaves at the time the sample was burned and was generally between 9 and 12 percent. Having thus determined the moisture content

of the air dry leaves, the amount of water to be added to a 6 pound sample of leaves to bring the moisture to a predetermined higher level could be calculated. The 6 pound leaf sample was placed in a large polyethylene bag and the desired amount of water was sprayed onto the leaves in 3 to 5 aliquots, stirring the leaves between each spraying. The bag was sealed and allowed to equilibrate for about 16 hours; the leaves were rolled around within the bag several times during that interval. Just before the leaves were placed on the table, a sample was taken for moisture determination.

Based on experience with cereal grain straws, we assumed that we could select 20 percent for a medium moisture level and 40 percent for the high level. This was done with red oak and the piles burned satisfactorily, although it was somewhat difficult to keep the flame going at the 40 percent moisture level. It was therefore decided to reduce the high level to 30 percent moisture for subsequent samples and for sugar maple the 20 and 30 percent samples were prepared at the same time. The 20 percent samples burned much slower than the comparable sample of red oak. For the 30 percent samples, it was necessary to use the propane torch after each stirring in order to keep the pile aflame. For the medium and high moisture fires of the sycamore and composite leaves it was decided to burn the 20 percent samples first. Depending on how these burned, we would go on up to 30 percent for the high sample, or reduce the moisture level to 15 percent, thus making the 20 percent sample the high moisture level.

In addition to determining total particulate yields, a Sierra Instrument Company HIVOL 5-stage cascade impactor was used to determine particle size distribution. The impactor was set up near the top of the tower so that samples were taken just above the opening of the stack. Operating at 55 cubic feet per minute gave an adequate sample in the relatively short time the leaves burned. The data are yet to be processed through the computer but two red oak samples were calculated by hand in order to give an idea of the particle size distribution.

Results

Emissions of Particulate, Carbon Monoxide and Hydrocarbons:--The emissions of particulate, CO, and hydrocarbons at the three moisture levels are given in terms of pounds of pollutant per ton of leaves burned in following table. In addition, the weight of leaves loaded on the table and the pounds of weight loss are also given.

The first two red oak fires at 12.8 and 12.9 percent moisture were test fires to help determine loading and stirring patterns and are not comparable to subsequent fires. But the data are included for informational purposes. Stirring was either delayed or erratic and the intervals were not noted. The apparent reduction in emission of CO and hydrocarbon are due to the stirring procedures and not to the change in loading.

For particulate emissions, sycamore leaves produced the least at the low moisture level (30.8 pounds), increasing to 74 pounds at the higher moisture level. Sugar maple produced somewhat more particulate

Emissions of Particulate, Carbon Monoxide, and Hydrocarbons from Burning Illinois Leaves.

Leaf species	% Moist., dry wt. basis	Lbs. Weight		Emissions, lbs./ton of leaves burned		
		Loaded	Loss	Part.	CO	HC
Red Oak	12.8	12.0	11.0	89.6	158.3	49.3
	12.9	6.0	4.6	81.2	117.1	27.9
	10.6	6.0	5.6	59.2	137.5	25.5
	10.6	6.0	5.5	70.6	137.1	30.2
	20.7	6.3	5.5	89.3	127.2	27.6
	21.3	6.4	5.8	67.6	139.3	31.2
	43.0	7.2	6.4	142.9	144.5	42.8
	40.0	7.4	6.9	135.8	136.1	37.8
Sugar Maple	10.4	5.8	4.6	38.5	127.7	20.7
	10.4	5.8	4.6	43.1	125.7	20.1
	21.8	6.7	5.5	65.3	111.1	33.3
	22.5	6.3	5.2	53.3	97.3	28.1
	32.2	7.0	5.7	59.8	97.2	30.9
	33.7	7.1	5.8	59.3	87.7	28.1
Sycamore	11.7	6.2	4.8	30.7	88.6	17.5
	10.7	6.2	5.0	30.9	94.8	17.9
	21.5	6.1	4.3	56.3	100.7	26.1
	20.8	6.3	5.1	46.6	102.0	24.1
	32.4	6.7	5.6	74.1	118.8	35.9
	30.0	6.7	5.5	74.4	111.9	35.4
Composite sample	9.6	5.5	4.3	48.3	79.0	24.5
	9.9	5.8	4.1	51.4	84.0	25.6
	17.7	6.2	4.7	77.9	81.0	27.0
	16.8	6.1	4.8	70.5	82.4	25.4
	21.2	6.3	4.2	126.5	117.4	37.7
	21.0	6.2	3.4	91.4	98.0	31.6

at the low level (40.8 pounds) but increased only to about 60 pounds at the high level. However, the medium moisture level in this species produced 59 pounds. Red oak produced the most particulate at all moisture levels, ranging from almost 65 pounds at the low range to about 140 pounds at the high level. The composite ranged from 50 pounds at the low level to about 109 pounds at the high moisture level. Thus in all fuels there was an increase of particulate with increase in moisture. The increase was more than two fold for red oak, sycamore, and composite and about 66 percent for sugar maple. Thus for particulate, the pollutant which receives the greatest public attention, sugar maple would rank the cleanest of the fuels burned to date.

The results of CO emissions were less consistent. Moisture appeared to have no effect in red oak, and caused only a slight increase of CO yield in sycamore and the composite leaves. CO actually decreased with increase in moisture in sugar maple. Red oak fires produced substantially more CO than the other species.

Hydrocarbon yields were more nearly uniform between species. Within species there was always an increase in hydrocarbon with an increase in moisture. This was most apparent in sycamore (two fold increase) and least in the composite leaves (36 percent increase).

In comparing tree leaves with a variety of field crop residues, the emissions of particulate and hydrocarbon from dry leaves is somewhat higher, while the emissions of CO from the two sources is more nearly comparable. For all dry leaf samples, the average of particulate and hydrocarbon was 47 and 23 pounds, respectively, per ton of fuel burned. Yields for field crops is about 17 and 11 pounds, respectively.

CO yields from dry leaves averaged about 109 pounds while that from field crops averaged about 120 pounds per ton of fuel burned.

Particle size distribution:--The size distribution was calculated for the first two fires of red oak leaves. The mass median diameter was 0.72 micron. Eighty-five percent of the particles were less than 2 microns, and 65 percent were less than 1 micron. In comparison with particulates from burning rice straw, particles from oak leaves are somewhat larger. About 85 percent of particles from rice fires were less than 1 micron, and the mass median diameter was less than 0.2 micron.

INTERIM REPORT

EVALUATION OF THE IMPACT OF LEAF BURNING

PREPARED JOINTLY BY THE

ILLINOIS INSTITUTE FOR ENVIRONMENTAL QUALITY
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

AUGUST 1975

CONTENTS

APPENDICES

Introduction

This is a preliminary report of the work completed on an investigation of the health effects of leaf burning. It is composed of a description of the entire project design, reports on portions of the work which are completed, and estimates of the time required for the completion of the remaining work.

Background

Certain legislative history regarding regulation of leaf burning is contained in the Agency Report, "A Field Study On the Effect of Leaf Burning on Ambient Air Quality" (Appendix I). In summary, on September 14, 1974, the Board found the record developed on the Agency proposal (R73-5) to regulate the burning of leaves lacking in certain medical and biological evidence necessary for its adoption. The work described herein is intended to provide additional evidence in this and other areas.

Statement of Need

Specific areas of need were described in the Board opinion of September 20, 1974 on R73-5. These are summarized below:

A) Emission factors for the primary pollutants (AP-42) were based on composite mixtures of leaves, branches, grass, etc. and are not based on the burning of leaves only.

B) Emission factors for certain known and suspect carcinogens (certain polynuclear aromatic hydrocarbons) were based on composite mixtures of leaves, branches, grass, etc. and are not based on the burning of leaves only.

C) The record was not deemed sufficient to determine the "quantity" and "duration" of leaf burning contaminants in a geographic area.

D) The record was not deemed sufficient to determine what "quantity" and "duration" of such contaminants would or would not be injurious.

Based on the above factors, additional information contained in the Board opinion, and other sources of information, the following study was designed.

Study Design

Meetings and discussions occurred between the Institute and the Agency to establish objectives for the proposed study. Areas of need were identified, alternative solutions were discussed, and the following methodology was established. It should be recognized that funding for the work was limited and was a constant consideration. The study design agreed upon is described briefly below.

A representative sample of Illinois leaves was to be collected by a biologist or forester. As it was not known to what degree emission factors would vary according to the species of leaves burned, "pure" samples of species of leaves common to Illinois were to be gathered. Also, a composite mixture of a number of species of leaves common to Illinois was to be composed.

A portion of the leaves were to be used by the Agency in field studies to better understand the concentrations (quantity) and duration of certain pollutants resulting from leaf burning. It was decided that the pollutants monitored would be those for which there exists sufficient medical and biological data on the concentrations (quantity) and duration of exposure to such pollutants, recognized to be hazardous to health. The pollutants chosen to be monitored were those for which National Ambient Air Quality Standards exist. Certain pollutants were not included because of the nature or small amount of the particular pollutant expected to be released. Consequently it was determined that monitoring would be conducted for particulate matter, carbon monoxide, and hydrocarbons. Carbon dioxide was also monitored.

The remainder of the leaves were to be used for the development of emission factors for Illinois leaves only. Chamber studies were to be conducted and emission factors developed for certain pollutants. As the health effects of the particulates would be dependent on the amount of particulate matter in the respirable size range, the particle size distribution was to be determined.

The Board opinion made clear the uncertainty which exists in the area of health effects attributable to exposure to polycyclic organic material (POM). Certain POM's have been detected in the smoke from leaf and landscape burning and cited as being carcinogenically active. The question

of what concentrations and duration of these materials will produce cancer in man appears to be largely unanswered at this point. However, it was noted that, "the NAS asserts that epidemiologic and experimental data are not adequate to set a limit on carcinogenic polynuclear hydrocarbons below which there will definitely be no tumorigenic responses in humans. In light of the serious health implications involved, an attempt to develop emission factors from leaves alone, for certain select POM's was deemed to be desirable. It was recognized that evaluation of the health data in light of the statuatory requirements was the responsibility of the Board. Identification of the specific POM's in leaf smoke which were cited as being active carcinogens would be necessary for such a consideration. These were:

Chrysene
Benz (a) anthracene
Benzo (a) pyrene
Benzo (e) pyrene

Status Report

The Institute contracted with Dr. G. L. Rolfe and Mr. J. M. Edgington, University of Illinois, for the collection, drying, and fumigation (necessary) for shipment to California) of the leaves. Three species of leaves common to Illinois (Red Oak, Sugar Maple and Sycamore) plus a composite sample were collected. A short report on the collection of the leaves, "Species Selection for Leaf Burning Experiments", is contained in the Agency report.

The field study has been completed and a detailed report describing the results of that work has been prepared (Appendix I).

The emission factors developed by Dr. E. F. Darley, University of California, Riverside, have been received and included in this report (Appendix II). A short progress report containing the methodology used in developing the emission factors is expected within a week.

Additional work was done by Dr. Darley, the results of which have not been received. The particulate size distribution has been delayed due to problems with the computer routine. It is expected that this informaion will not become available for at least three to four weeks. The results of grab samples taken to get an idea of the amounts of total and non-methane hydrocarbons generated are expected to be received at that time along with a

final report incorporating all of the work done in California. A copy of the Statement of Work for the work done in California is contained in this report (Appendix III).

The analysis of the POM's (benzo (a) pyrene, etc.) is being done by Battelle labs under contract with the Federal EPA. Twelve absorbers were constructed and sent to California for use by Dr. Darley in the burns. It was requested that those POM's described in the Board opinion as having been detected in the smoke from leaf and landscape burning and cited as carcinogenically active, be included in the analysis. The analysis will include at least 15 potential carcinogens. Estimated cost of the support provided by the US EPA through Battelle labs is $3,000. A final report on the work done by Battelle was promised for the week of August 18th. As soon as the results are received, they shall be transmitted to the Board.

Final Report

Upon receiving all the portions of the work described, a final report containing all the new information developed will be prepared. It is expected that the final report will be completed in 4 to 6 weeks. The additional information presently not available will be transmitted to the Board as soon as it is received.