EMISSION COMPARISONS

Prescribed Burning

vs.

Mechanical Treatment

Darwin L. Bennett

Forest Fire Division, Michigan
Department of Natural Resources

January 1974

Many reports have been written by prominent researchers comparing forest fuel emissions to gasoline and diesel emissions. These comparisons are always listed by pounds of material emitted per ton of fuel burned (one ton forest fuel vs. one ton liquid fuel). These comparisons are somewhat meaningless when presented in this manner. For instance, there is more than one ton of forest fuel consumed per acre burned in most prescribed fires; and one ton of gasoline or diesel fuel (about 250 gallons), when burned in a large tractor for site management, will treat much more than one acre of land.

A study of the amount of forest fuel consumed by prescribed fires in jack pine slash during the fall of 1972 in Michigan revealed an average of 4 tons/acre. Equipment treatments (rolling chopper, tree cutter) show on the average that one ton of gasoline or diesel fuel will treat 40 acres of forest land. A burn treatment on 40 acres would consume 160 tons of forest fuel, a mechanical treatment on 40 acres would consume one ton of liquid fuel. We now have a relationship which is more meaningful and understandable.

Department of Health
Air Pollution Control Data

AVERAGE EMISSION COMPARISONS
40-Acre Treatment of Forest Land

Emissions	40 Acres 160 Tons Forest Fuel	250 Gal. 1 Ton Gasoline	250 Gal. 1 Ton Diesel Fuel
Particulate Matter	1100#	70#	4#
Carbon Monoxide	8000#	900#	56#
Hydrocarbons	800#	130#	10#
Oxides of Sulfur	*	2#	7#
Oxides of Nitrogen	**	50#	93#
Alehydes (HCHO)	***	3#	1#
Organic Acides (Acetic)	***	1.5#	1#

* Forest fuels contain very little, if any, sulfur.

** Prescribed fires in forest fuels do not reach the temperatures necessary to emit these products.

*** These products are emitted in prescribed fires but figures are not available.

All combustibles produce emissions when burned. How serious the threat of each emission, whether alike or different, from each combustible to air quality is not completely known. This writing is an attempt to compare the different emissions and to determine their possible effect on air quality. It should be noted that neither prescribed burning nor mechanical treatment on state lands, alone or together, pose a great threat to air quality in Michigan. The intent is to consider or compare both methods of treatment on a one to one basis. Both methods emit so-called pollutants and should be placed in their proper perspective, one to the other, when air quality is considered.

During the process of decay, nutrients are released to the soil while hydrocarbons and gases are released into the atmosphere. If there were 160 tons of vegetative matter on 40 acres of ground and no additional material was added to it yearly, at some point in the future, dependent upon varying environmental conditions, this litter would totally decompose. This is a natural process. Another somewhat natural process would be for man to burn the 160 tons of material. The carbon monoxide (8000#) and hydrocarbons (800#) emitted from the burn would be near that emitted from natural decay, but over a much shorter time period, approximately two hours. An additional emission would occur from burning which is not produced to any degree during decomposition; that is, particulate matter.

As mentioned earlier, the burning of forest fuels is a natural phenomenon. The emissions from burning vegetative matter are not new or unusual to our atmosphere. The tremendous ability of the atmosphere to cleanse itself of these natural emissions is well documented.[1] Therefore, prescribed burning under proper conditions poses no real threat as an air polluter by itself. Problems arise, however, when the additional man-caused emissions,

---

(1) Hall, Alfred J. -- 1972-Forest Fuels, prescribed fire, and air quality. USDA Pacific N.W. Forest & Range Experiment Station, Forest Service, 44 pp.

such as those from gasoline and diesel engines are added to this system, especially in localized atmospheres around cities. All of the pounds of pollutants listed under the man-made liquid fuels are foreign to the natural system. Even the particulate matter--CO and hydrocarbons--which are also emitted from burning forest fuels, must be considered foreign and therefore excess, because naturally there are no gasoline or diesel engines. Our atmosphere in many ways can be compared to a stream. It has the ability to handle the natural load of pollutants plus a given excess of man-made pollutants without any appreciable damage. But, as we have already found out, there is a limit to the man-caused pollutants that a natural system can handle and still remain in balance.

PARTICULATE MATTER

The "particulate matter" emissions are measured in microns (one thousandth of a millimeter). They range from 50 to 0.002 microns in size. Particulates, depending upon size, can remain suspended from a few seconds to several months. The smaller particles have the ability to mix with other pollutants in the air to form more harmful substances.

The only real concern resulting from prescribed fire emissions in Michigan may be the particulate matter. The total impact of these particulates on air quality is not really known. Little is known of the various sizes and amounts produced from forest fuel combustion. It is known that a large percentage of these solids are too heavy to remain suspended for any length of time and they fall out of the smoke plume almost immediately as ash. These large particles, either separately or as a conglomerate of smaller particles mixed with the water vapor, make up the visible smoke. They do pose a problem in the immediate fire area by reducing visibility. There are, however, some very small particles which remain suspended for a longer period of time.

What percentage of the total particulate load the very small particles comprise and how long they remain suspended is an unanswered question.

In comparison, the particulate load from the gasoline and diesel fuels is much smaller (1/16th to 1/200th that of forest fuel emissions). That there are extreme load differences is very obvious, but which load has a more lasting effect on our air quality is more difficult to determine.

The liquid fuels, due to the extreme heat and pressure under which they are burned, produce particulates of a smaller size than open burning. These smaller particles will affect air quality for a longer period of time due to their ability to remain airborne longer. More information is needed, to determine the effects on air quality the very small-sized particulates actually pose.

CARBON MONOXIDE

Aside from carbon dioxide, not considered a pollutant, carbon monoxide constitutes in weight the largest percentage of air pollution components regardless of source. Its toxic nature has long been recognized and high urban concentrations from automobile exhausts have long been accepted as dangerous to health. Yet the background levels of CO in the atmosphere remain fairly constant, at 0.02 to 0.05 parts per million. There are many theories which attempt to explain the short life of CO in the atmosphere. Experts agree that somewhere a CO "sink" does exist. It has been suggested by several that the soil may be a major sink. Considerable work has been done showing consumption of CO by various species of bacteria and lower fungi. Tests have also shown CO to oxidize to CO_2 in the troposphere at a rate of 0.05 percent per hour, day or night. This calculates to a lifetime of less than one-third of a year.

This level reduction of CO also occurs in forest fuel combustion. Samples taken in one fire showed CO concentrations as high as 8000 ppm; but at 5,000 feet in the smoke plume, the gas was diluted to ambient conditions. Ground level samples 60 feet from the fire were 40 ppm, and 150 feet away, decreased to 10 ppm. As a basis of comparison, industrial health standards allow human exposure to average levels of 50 ppm over an 8-hour day.

HYDROCARBONS

In chemical terms, hydrocarbons are compounds composed only of carbon and hydrogen. In "air pollution" circles, the term also includes oxygenated derivatives.

Hydrocarbons are extremely widespread in the plant world in volatile oils, waxes, and resins. Their close relations--hydrocarbons partially oxidized--are familiar to us in thousands of plant odors. A few of these are turpentine, pine oil, peppermint oil, citronella oils, oils of lemon and orange, and a host of others. So it comes as a surprise to a chemist that "hydrocarbons" are reported in various tables of publications on emission factors and inventories as all lumped together and carrying the implied label of being generally harmful, especially when one considers the fact that these chemicals are routinely emitted by plants.

This implication arises probably from the following facts. Unsaturated hydrocarbons are produced by incomplete combustion of organic fuels, especially petroleum fuels and coal. By unsaturated, it is meant the absence of hydrogen atoms in the molecule from adjacent carbon atoms, so situated that the hydrocarbon has high affinity for oxygen or other elements in order to saturate itself. If such substances, usually small molecules, are formed in the presence of much sunlight and materials capable of giving off oxygen easily, we get photochemical oxidation, which can cause much trouble in our larger cities.

Actual data on emissions of hydrocarbons from combustion of forest fuels are scarce. It is expected that the hot fire produces fewer total hydrocarbons than does the cooler one. Composition samples of hydrocarbons collected from active fires indicate that very small quantities of a number of potentially photochemically reactive hydrocarbons are present. Whether hotter fires produce a greater percentage of the unsaturated hydrocarbons, even though totally a smaller amount is produced, is not known. Until accurate measurements are made upon fuels of known composition, under well-controlled conditions of combustion, products from flaming foliage can be only speculative. Hall reports, "All things considered, it seems to me that the probable total evaluation of hydrocarbons from burning forest fuels is probably higher than values reported. But the relative importance of this matter, as far as photochemical smog is concerned, seems to be very small."(1)

SULFUR AND NITROGEN OXIDES

The "oxides of sulfur and nitrogen" can mix in the atmosphere with water vapor to form deadly sulfuric and nitric acids. The sulfur oxide produced from the burning of coal in Great Britain, with chemical change, is destroying the marble in the statues, buildings, etc. The famous "smog" of Los Angeles is also a specialized phenomenon. The ingredients in Los Angeles smog are sunlight, nitric oxide (NO), and hydrocarbons of low molecular weight that are components of automobile exhaust. These hydrocarbons have a high capacity to combine with oxygen or ozone, and produce the PAN (Peroxyacyl-nitrates), which are eye-irritating and injurious to health and vegetation. These may be isolated cases, but they do point up the seriousness of these oxides when in concentration.

Oxides, being gases, remain airborne and do not fall out unless a chemical change occurs. What is not known, when comparing the emissions from different fuels, is how the individual emissions rate as polluters. We may find that two pounds of sulfur, or 50 pounds of nitrogen oxides, are more damaging or have more potential to do damage than any other emission being compared.

According to the graph on page 4-3 of "Control Techniques for Nitrogen Oxide Emissions from Stationary Sources" (U.S. Department of Health, Education and Welfare, 1970), the formation of NO_x does not occur until a temperature of 2800° Fahrenheit is reached. Beaufait, during his prescribed fire research in the Upper Peninsula of Michigan in jack pine slash fuels, recorded a maximum temperature of 1750° F. There is always the possibility that prescribed fire in Michigan may for some short period of time reach a temperature of 2800°F., but the probability of this occurring is very low.

Sulfur and its compounds can be dismissed as an emission in forest fuel combustion because sulfur is almost entirely absent from forest fuels.

ALDEHYDES AND ORGANIC ACIDS

Figures are not available from the Michigan Department of Health on aldehyde and organic acid emissions from forest fuels. Presently, no legislation is in effect or has been proposed for these emissions. Both of these products are emitted through natural decomposition. How these products react in the atmosphere to sunlight, moisture, mixing ambient air, etc., is not known.

The State of Michigan does have ambient air quality standards. These standards were established by the Federal government for the protection of human health. In general, the ambient air conditions in the rural areas of the state are well below the established standards (listed in parts per million or milligrams per cubic meter). Even the air within our large cities seldom exceeds these standards, and then only under unusual conditions (such as a prolonged atmospheric inversion). The areas in which the compared forest and grassland treatments are applied remain miles away from our large cities. Almost all of these treatments are done in the upper half of the Lower Peninsula, and in the Upper Peninsula. In these areas it is very doubtful that testing would reveal contaminants relating to either burning or mechanical treatment in excess of the present standards.

This should in no way excuse the fact that these treatments do emit atmospheric contaminants. It is, however, an attempt to bring into perspective the impact of these emissions on Michigan's total air quality program.

Those opposed to prescribed burning say, "Treat the area mechanically and avoid all that air pollution!" They don't realize that the emissions which are not visible, from the machines doing the mechanical treatment, have an impact on air quality just as those emissions from burned forest fuels. The magnitude of the impact from either technique can vary. In an attempt to relate the importance of each emission, the listing below shows the average toxicity threshold limit values established for Michigan Industrial Hygiene over an 8-hour day.

AVERAGE EMISSION LOAD ALLOWED PER 8-HOUR DAY *

Emissions	Parts Per Million
Aldehydes	2
Organic Acids	2
Oxides of Sulfur	5
Oxides of Nitrogen	5
Carbon Monoxide	50
Hydrocarbons	500

Particulate Matter - 10 Milligrams Per Cubic Meter

* It must be mentioned that the most significant air pollution problems in Michigan relate to particulates, odor and sulfur dioxide.

The days prescribed fire can be effectively used during a normal weather year will range from 20 to 40. These effective or "ideal" burning days are also the days when good atmospheric mixing occurs. Fuel combustion is enhanced by entrained air moving along the ground into the fire. The smoke emitted is forced upward by this air movement and heat to form a chimney-like appearance. This process is called thermal lift. These smoke plumes may reach five- to ten-thousand feet in the air before being dispersed by the winds aloft. The burning time, regardless of the size of the area being treated, lasts from one to three hours.

Mechanical treatment, conversely, can be done under all atmospheric conditions. The length of time necessary to mechanically treat an area is dependent upon tree density and size, terrain, snow depth, etc. The number of days necessary to treat 40 acres with one machine would range from four to eight. Eighty acres would take twice as long. Because of time, it becomes necessary for these machines to operate on days when there is very little atmospheric mixing, or even during atmospheric inversions. The emissions from these machines may remain near the ground for some time.

SUMMARY

The differences which must be considered when comparing prescribed fire and mechanical treatment with regard to air quality are:

1. Fire is a natural phenomenon; emission from man-made machines is not. (Machine emissions could be considered foreign material in the atmosphere.)
2. Machines, due to their intense heat and pressure, emit additional contaminants which are not found in forest fuel smoke and may be more harmful.
3. Natural decomposition will release almost the same kind and quantity of emissions as burning will, except for particulate matter which is of immediate nuisance concern in Michigan.
4. Particulate emissions or visible smoke may be the greatest concern from burning. This nuisance factor can be reduced

considerably by burning when fuel combustion and upper atmospheric air movement, for adequate smoke dispersal, is ideal.

The limited knowledge about "air pollution" may be the single most important factor which will determine whether we as a public agency are able to use prescribed fire as a wildlife habitat and forest management tool. This often highly emotional concern seems to be disregarded when considering the alternatives to burning. It must be understood, however, that the alternative methods do emit pollution. Also, in many ways, this pollution is different from forest fuel smoke and possibly just as detrimental. At best, the emissions from both types of treatment (burning and mechanical), should be equally considered when determining forest treatments. At present, neither treatment appears to violate the Michigan Air Quality Standards when used with good judgment.