



Project Summary

Mutagenicity of Emissions from the Simulated Open Burning of Scrap Rubber Tires

P. M. Lemieux and D. M. DeMarini

Discarded automobile tires have become a serious health concern, largely because the growing number of stockpile fires has focused attention on the potentially harmful products of incomplete combustion (PICs) emitted into the atmosphere from uncontrolled burning of scrap tires. This report describes a follow-up to a small-scale combustion study that was designed to collect, identify, and quantify the products emitted during the simulated open combustion of scrap tires. During the previous study, it was found that total estimated emissions of semi-volatile organics ranged from 10 to 50g/kg of tire material burned. Mono- and polyaromatic hydrocarbons were the predominant emission products identified. For the follow-up study described in this report, the extracts from this study were subjected to bioassay directed fractionation to determine mutagenic potencies of the extracts. The results from these bioassay studies were then compared to data from other conventional combustion sources indicate relative potencies of the emissions from uncontrolled burning of tires. The fractionated extracts were then subjected to further gas chromatography/mass spectroscopy (GC/MS) analysis to determine the classes of compounds giving the highest mutagenic potencies. In addition, a sample from an actual tire burn was subjected to the same bioassay analyses to determine the relevance of the initial small-scale simulations to actual field samples from a full-scale tire fire.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study is a follow-up to a study performed for the EPA's Control Technology Center (CTC) to characterize emissions from the simulated open burning of scrap tires. The full report of the results from the initial study is available. For clarity, a summary of the initial study is included in this report.

Summary and Conclusions

Characterization of Emissions

The primary goal of this project was to characterize potentially harmful emissions from the simulated open burning of scrap tires. The simulation was necessarily crude, because it would be extremely difficult to match the burning of the equivalent of two tires with a 6 million tire, full-scale, stockpile fire. Nevertheless, the study allowed the investigators to identify and measure gaseous emissions and directly relate this information to a mass burn rate. This task was accomplished by accurately measuring dilution volumes, sample volumes, and weights of tire material combusted.

The dilution air added to the burn hut was used not only to control known volumes introduced, but also to simulate am-



bient conditions. It is probable that the same types of compounds identified during this study are emitted during an actual fire, but whether the average gaseous concentrations and estimated emissions are comparable is uncertain. A comparison with limited data collected at a Winchester, Virginia, fire by the National Institute for Occupational Safety and Health (NIOSH), indicates that reasonable agreement exists within several measurement areas. Many of the same compounds were identified in actual plume samples. Particularly good agreement exists in polycyclic aromatic hydrocarbon (PAH) plume measurements. NIOSH reported that ambient concentrations of total PAHs are generally within the same order of magnitude as average gaseous concentrations obtained during testing. Measurements of carbon monoxide (CO) and metals also indicate similar agreement. Both lead and zinc measurements show similar values in both gaseous and relative concentrations between the two metals. It may be reasonable to assume that the estimates obtained during this study may be within an order of magnitude of emissions realized from actual stockpile fires.

The results from the airborne metals portion of the study were inconclusive. Maximum values were presented, often based on detection levels. Emissions of lead and zinc may reach significant quantities. Chemical analysis of the flyash reveals that zinc comprises nearly 50% of the total residue. Evidently, the other metals known to be contained in tires remain in the ash residue. Although no attempt was made to analyze ash residue, significant quantities of metals present in the ash could potentially be leached out into groundwater systems, posing another major problem.

The values obtained by on-line analyzers for normal combustion gases showed that, as burn rate increased, the amount of CO, sulfur dioxide (SO₂), and unburned hydrocarbons also increased. High burn rate conditions were not fully evaluated, so greater quantities of these gases, particularly SO₂, may be emitted during a stockpile fire. Tires contain a significant amount of sulfur, so high emissions of SO₂, while likely only a minor contributor to the acid rain problem, could have significant local consequences.

This study was designed to identify the potential chemical hazards from tire fires on a small-scale, simulation basis. The study reveals the potential for the emission of great amounts of organic compounds, primarily aromatics, some of which may be extremely harmful. Although the

estimates of average gaseous concentrations and estimated emissions are crude, the trends presented in regard to burn rate may be helpful in directing further research and control efforts. The fact that the shredded (5 X 5 cm cubes) condition resulted in a lower burn rate than the chunked (one-quarter to one-sixth of whole tires) condition indicates that the gaps between the tire material provide the major avenue of oxygen transport. Oxygen transport appears to be a major if not the controlling mechanism for sustaining the combustion process. This fact could have advantageous implications for those attempting to combat tire fires. It may be possible to fill the gaps between tires with a foam inhibitor, potentially suffocating the fire from within.

The extreme complexity of the organic emissions confounded attempts to quantify all compounds present. In fact, only around 10 % of the chromatographic peaks were identified, although most of the organic mass was identified. This suggested that a different approach to emissions measurements, one that applies to complex mixtures, might be useful. The CTC provided additional funding to examine the complex mixtures resulting from simulated open combustion of scrap tires with the bioassay-directed fractionation technique. The relative potency of the emissions could then be compared to other well-characterized combustion sources.

Mutagenicity of Emissions

In general, the mutagenic potency of the semi-volatile organics (those collected on XAD resin) was similar for chunked or shredded tires. However, the mutagenic potency of the particulate organics (those collected on filters) was 2-10 times greater than that of the semi-volatile organics. Chunked tires produced more potent organics as assayed in the presence of S9, but shredded tires produced more potent organics as assayed in the absence of S9. This difference is a reflection of the different classes of chemical mutagens that likely were produced under the two combustion conditions. Based on additional data, these results suggest that the particulate organics from chunked tires contain more PAHs than are present in the effluent produced by shredded tires. This is likely due to the greater burn rate that was achieved with chunked tires, leading to the production of PAHs.

In general, the mutagenic emissions factors (revertants/kilogram of tires or revertants/megajoule of heat) were similar for the semi-volatile organics produced by chunked or shredded tires as assayed in

the presence or absence of S9. The mutagenic emission factors for the particulate organics were much greater than those for the semi-volatile (XAD bound) organics.

The average of the chunked and shredded particulate mutagenic emission factor for the open burning of tires as assayed in Salmonella strain TA98 in the presence of S9 was compared to that of other combustion emissions. The results showed that the mutagenic emission factor for open tire burning is the greatest of any other combustion emission studied previously. For example, it is 3-4 orders of magnitude greater than the mutagenic emission factors for the combustion of oil, coal, or wood in utility boilers. Table 1 illustrates the mutagenic emission factors derived from this study.

Interestingly, the mutagenic emission factor for the open burning of tires was most similar to the values for the open burning of wood (in residential fire places) and plastic (in agricultural fields). These open burning conditions are characterized by poor combustion parameters, resulting in elevated levels of PICs and, thus, elevated mutagenic emission factors. Open burning, regardless of the feed stock or fuel, appears to result in greater mutagenic emission factors than does controlled combustion as provided by various types of incinerators or boilers.

The high-pressure liquid chromatography (HPLC)-generated mutagrams were similar for the particulate organics resulting from the open burning of either chunked or shredded tires. This suggests that there were only minor differences in the chemical composition of the two effluents. Chemical analysis of selected mutagenic HPLC fractions identified PAHs has a major contributor to the mutagenic activity of the organics. In addition, oxygenated PAHs, such as anthraquinone, and various aromatic compounds that contained ring nitrogens, such as acridine, were also present in mutagenic fractions.

The mutagenic potency of the unfractionated particulate organics in various strains of TA98 in the absence of S9 showed that little of the mutagenic activity was due to mononitroaromatics, but as much as two-thirds of the mutagenic activity (in the absence of S9) was due to either dinitroaromatics or other types of nitroarenes or aromatic amines that require metabolic conversion to arylhydroxylamines and then esterification in order to be mutagenic.

Through the auspices of colleagues at McMaster University in Hamilton, Ontario, Canada, we were able to obtain samples

of particulate organics from the effluent of a large open tire burn that occurred during 2 weeks in Hagersville, Ontario, in February 1990. This real-world sample had a similar mutagenic potency as did the EPA sample. In addition, the mutagram contained several of the same mutagenic fractions (particularly the PAH-containing fraction) as did the EPA mutagram, and the Canadian sample also showed evidence that various types of nitroarenes or aromatic amines were present as in the EPA sample. Chemical analysis also showed great similarity between the Canadian and EPA samples.

Based on these chemical and biological measurements, the EPA tire burn simulated reasonably well a major real-world tire burn of the type experienced in Hagersville, Ontario. This conclusion should provide some confidence in extrapolating from the EPA simulated tire burn to real-world tire burns.

Considering (a) the relatively high mutagenic potency of the particulate organics, (b) the high mutagenic emission factors, and (c) the presence of many mutagens/carcinogens, especially PAHs, in the effluent from the open burning of tires, such burns pose a genuine environmental

and health hazard. Because of the frequent occurrence of unwanted combustion at tire piles, and the potential environmental and health risks posed by such combustion, prudence would suggest that such piles be reduced or eliminated in size and number. Used tires may be recycled, used in asphalt for roads, or incinerated under controlled condition in combustion devices for cogeneration of power. Any of these uses would appear to be preferable to the environmental and health risks posed by the open burning of tires.

Table 1. Mutagenic Potencies and Mutagenic Emission Factors of DCM-Extractable Organics in TA98^a

Day	Condition	Burn rate (kg/h)	Filt. EOM ^b (%)	S9	XAD (revertants per)				Filter (revertants per)			
					µg	m ³	Kg of fuel x 10 ⁵	MJ of heat	µg	m ³	Kg of fuel x 10 ⁵	MJ of heat
1	Chunk	9.4	4.5	+	2.2	1536	14.88	42690	12.0	403608	873.61	2506387
				-	1.9	1326	12.85	36866	2.3	77358	167.44	480385
	Shred	1.1	22.6	+	0.7	623	0.17	487	4.3	29335	484.23	1389255
				-	1.0	890	0.25	717	8.9	60716	100.25	2875455
2	Chunk	3.5	6.8	+	2.1	1573	18.76	53822	10.4	192379	1036.52	2973775
				-	1.4	1049	12.51	35891	2.3	42545	229.23	657660
	Shred	1.3	16.7	+	4.3	4726	59.26	170016	7.0	61397	769.25	2206978
				-	8.9	9781	122.65	351822	7.0	61397	769.25	2206978

^a DCM = dichloromethane

^b EOM = extractable organic matter

D.M. DeMarini is with the U.S. EPA, Health Effects Research Laboratory, Research Triangle Park, NC 27711.

Paul M. Lemieux is the EPA Project Officer (see below).

The complete report, entitled "Mutagenicity of Emissions from the Simulated Open Burning of Scrap Rubber Tires," (Order No. PB92- 217 009/AS; Cost: \$19.00; subject to change) will be available only from:

National Technical Information Service

5285 Port Royal Road

Springfield, VA 22161

Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Air and Energy Engineering Research Laboratory

U.S. Environmental Protection Agency

Research Triangle Park, NC 27711

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Official Business
Penalty for Private Use
\$300

EPA/600/SR-92/127

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35