EMISSION FACTOR

DOCUMENTATION FOR AP-42

SECTION 2.4, OPEN BURNING

The section was renumbered as 2.5 in the 5th edition 

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1.0 INTRODUCTION

The document "Compilation of Air Pollution Emission Factors" (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new source categories and to update existing emission factors.

This report provides background information to support the emission factors in the open burning of solid waste section of AP-42 (Section 2.4). Specifically, this report provides the basis for adding emission factors for open burning of scrap tires and of inorganic agricultural waste.

The report is divided into the following sections: open burning of scrap tires (Section 2.0), open burning of nonagricultural waste (Section 3.0), open burning of agricultural plastic film (Section 4.0), open burning of organic agricultural waste (Section 5.0), and references (Section 6.0). A copy of the revised AP-42 section is included as Section 7.0. Each section consists of discussions of data sources used to develop the new emission factors, and presentation of the emission factors. The databases containing emissions information from the data sources are presented in Appendices A and B.

2.0 OPEN BURNING OF SCRAP TIRES

Approximately 240 million vehicle tires are scrapped annually. Although viable methods of reclamation exist, less than 25 percent are re-used or re-processed. The remaining scrap tires are discarded in illegal dumps, above ground stockpiles, or landfills.[1] However, it is very costly to cut or shred tires into a condition suitable for landfill disposal. The alternative is to dispose of tires by combusting them. Although open burning of scrap tires is not allowed as a disposal method in many states, it is not uncommon for fires to start at the tire stockpiles.

An analysis performed on the rubber portion of passenger car tires indicated that they are generally comprised of carbon, hydrogen, ash, oxygen, sulfur and nitrogen.[1] Emissions from open burning scrap tires include a variety of organic and inorganic compounds, many of which may pose health risks.

2.1 DATA SOURCES[1]

Qualitative data on the open burning of scrap tires is limited to one recent study funded by the EPA's Air and Energy Engineering Research Laboratory (AEERL). The study identified and quantified the emissions of organic and inorganic compounds from the simulated open burning of tires comprised of rubber only. Steel belted tires were not tested. Emission factors were developed in the report for large "chunks" of tires that are burned, and for smaller slices or "shredded" tires.

Test burns of scrap tires were conducted inside an outbuilding modified for small-scale combustion experiments. Emissions from the tires were transported through a duct to various sampling trains. It was determined that the tests and procedures used to measure the emissions were generally of good quality. However, original raw field data sheets and laboratory data sheets were not provided in the report, nor was the actual time for each test run. For these reasons, a rating of "C" was assigned to most of the emission factors in this reference. An emission factor rating of "D" was assigned to the polycyclic aromatic hydrocarbons (PAH's) emission factors, as AEERL's test report indicates that the volume of each sample was estimated rather than accurately measured.

2.2 EMISSIONS AND EMISSION FACTORS

Emissions from burning scrap tires are dependent on the burn rate of the tire. The AEERL study indicates that a greater potential for emissions exists at lower burn rates, such as when a tire is smoldering, rather than when it is burning out of control. Oxygen transport is the controlling mechanism for sustaining the combustion process, and the gaps between the tire material provides the major avenue of oxygen transport.

Compounds emitted from the open burning of scrap tires include particulate matter, aromatic hydrocarbons, cyclic alkanes, alkenes, dienes, sulfonated compounds, and nitrogenated hydrocarbons. These compounds emitted are grouped into the following categories: organic compounds, PAH's, and particulate metals.

2.2.1 Organic Compounds

Tests for organic emissions from open burning tires were conducted on two successive days. Volatile organic compounds were sampled using a volatile organic sampling train (VOST), and semi-volatile compounds were sampled using a XAD-2 canister. Emission factors (in mg pollutant per kg tire burned) were supplied in the study for tires burned at different rates over the two test days. A weighted average emission factor for each compound was developed using the following equation:

$$\text{Weighted Average} = \frac{EF_1 (BR_1) + EF_2 (BR_2) + EF_n (BR_n)}{BR_1 + BR_2 + BR_n}$$

Where:

$EF_{1,2,...n}$ = Emission factor for each compound for burn rate 1, 2,...n. (mg/kg tire)

$BR_{1,2,...n}$ = Burn rate 1,2,...n (kg tire/hr)

The weighted average emission factors for the measured organic compounds are presented in Table 2-1. Some compounds were measured in both the VOST and XAD-2 samples. For these pollutants the largest values were used as a default value. A database containing emission factors at each burn rate is presented in Appendix A.

Table 2-1

Emission Factors for Organic Compounds from Open Burning of Tires[a]

Emission Factor Rating: C

Tire condition	Chunk[b,c]		Shredded[b,c]	
	mg	lb	mg	lb
Pollutant	kg tire	1000 tons tire	kg tire	1000 tons tire
1,1'biphenyl, methyl	12.71	25.42	0.00	0.00
1h fluorene	191.27	382.54	315.18	630.37
1-methyl naphthalene	299.20	598.39	227.87	455.73
2-methyl naphthalene	321.47	642.93	437.06	874.12
Acenaphthalene	592.70	1185.39	549.32	1098.63
Benzaldehyde	223.34	446.68	322.05	644.10
Benzene	1526.39	3052.79	1929.93	3859.86
Benzodiazine	13.12	26.23	17.43	34.87
Benzofuran	40.62	81.24	0.00	0.00
Benzothiophene	10.31	20.62	914.91	1829.82
Benzo(B)thiophene	50.37	100.74	0.00	0.00
Benzsisothiazole	0.00	0.00	151.66	303.33
Biphenyl	190.08	380.16	329.65	659.29
Butadiene	117.14	234.28	138.97	277.95
Cyanobenzene	203.81	407.62	509.34	1018.68
Cyclopentadiene	67.40	134.80	0.00	0.00
Dihydroindene	9.82	19.64	30.77	61.53
Dimethyl benzene	323.58	647.16	940.91	1881.83
Dimethyl hexadiene	6.22	12.44	73.08	146.15
Dimethyl naphthalene	35.28	70.55	155.28	310.57
Dimethyldihydro indene	5.02	10.04	27.60	55.20
Ethenyl, dimethyl benzene	11.50	23.01	196.34	392.68
Ethenyl, methyl benzene	12.48	24.95	21.99	43.98
Ethenyl benzene	539.72	1079.44	593.15	1186.31
Ethenyl cyclohexene	4.85	9.70	89.11	178.22
Ethenylmethyl benzene	103.13	206.26	234.59	469.19
Ethyenylmethly benzene	0.00	0.00	42.04	84.07
Ethyl, methyl benzene	79.29	158.58	223.79	447.58
Ethyl benzene	138.94	277.87	335.12	670.24
Ethynyl, methyl benzene	459.31	918.62	345.25	690.50
Ethynyl benzene	259.82	519.64	193.49	386.98
Heptadiene	6.40	12.79	42.12	84.24

Table 2-1 (continued)

Tire condition	Chunk[b,c]		Shredded[b,c]	
Pollutant	mg / kg tire	lb / 1000 tons tire	mg / kg tire	lb / 1000 tons tire
1,1'biphenyl, methyl	12.71	25.42	0.00	0.00
Hexahydro azepinone	64.35	128.69	764.03	1528.05
Indene	472.74	945.48	346.23	692.47
Isocyano benzene	283.78	567.55	281.13	562.25
Isocyano naphthalene	10.75	21.51	0.00	0.00
Limonene	48.11	96.22	2309.57	4619.14
Methyl, ethenyl benzene	21.15	42.30	67.05	134.10
Methyl, methylethenyl benzene	35.57	71.13	393.78	787.56
Methyl, methylethyl benzene	109.69	219.39	1385.03	2770.07
Methyl benzaldehyde	0.00	0.00	75.49	150.98
Methyl benzene	1129.80	2259.60	1395.04	2790.08
Methyl cyclohexene	3.91	7.83	33.44	66.88
Methyl hexadiene	15.59	31.18	102.20	204.40
Methyl indene	50.04	100.07	286.68	573.36
Methyl,methylethyl benzene	11.76	23.52	114.33	228.66
Methyl naphthalene	144.78	289.56	122.68	245.37
Methyl,propyl benzene	0.00	0.00	30.14	60.28
Methyl thiophene	4.39	8.78	10.52	21.03
Methylene indene	30.37	60.75	58.91	117.82
Methylethyl benzene	41.40	82.79	224.23	448.46
Phenol	337.71	675.41	704.90	1409.80
Propenyl, methyl benzene	0.00	0.00	456.59	913.18
Propenyl naphthalene	26.80	53.59	0.00	0.00
Propyl benzene	19.43	38.87	215.13	430.26
Styrene	618.77	1237.53	649.92	1299.84
Tetramethyl benzene	0.00	0.00	121.72	243.44
Thiophene	17.51	35.02	31.11	62.22
Trichlorofluoromethane	138.10	276.20	0.00	0.00
Trimethyl benzene	195.59	391.18	334.80	669.59
Trimethyl naphthalene	0.00	0.00	316.26	632.52

[a]Reference 21.

[b]0.00 values indicate the pollutant was not found.

[c]Values are weight averages.

2.2.2 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons were sampled over the two consecutive days using a XAD-2 canister. Emission factors in the AEERL report were supplied for both a XAD-2 extract and its accompanying filter. The total emission factor was calculated by adding the filter and extract values for each day. A weighted average over the two days of testing was calculated using the formula presented in Section 2.2.1.

The weighted average emission factors are presented in Table 2-2. The database in Appendix A contains emission factors for both the XAD-2 extract and filter for the two days of testing.

2.2.3 Particulate Metals

Airborne particulate metals were sampled across two filters at different burn rates on two successive days. The emission factors were summed for the two filters. A weighted average emission factor over the two days was calculated using the equation presented in Section 2.2.1. The weighted average emission factors for the measured metals are presented in Table 2-3. Appendix A contains the emission factors at each burn rate.

Table 2-2

Polycyclic Aromatic Hydrocarbon Emission Factors From Open Burning Tires[a]

Emission Factor Rating: D

Tire Condition	Chunk[b,c]		Shredded[b,c]	
Pollutant	mg / kg tire	lb / 1000 tons tire	mg / kg tire	lb / 1000 tons tire
Acenaphthene	718.20	1436.40	2385.60	4771.20
Acenaphthylene	570.20	1140.40	568.08	1136.17
Anthracene	265.60	531.20	49.61	99.23
Benzo(A)pyrene	173.80	347.60	115.16	230.32
Benzo(B)fluoranthene	183.10	366.20	89.07	178.14
Benzo(G,H,I)perylene	36.20	72.40	160.84	321.68
Benzo(K)fluoranthene	281.80	563.60	100.24	200.48
Benz(A)anthracene	7.90	15.80	103.71	207.43
Chrysene	48.30	96.60	94.83	189.65
Dibenz(A,H)anthracene	54.50	109.00	0.00	0.00
Fluoranthene	42.30	84.60	463.35	926.69
Fluorene	43.40	86.80	189.49	378.98
Indeno(1,2,3-CD)pyrene	58.60	117.20	86.38	172.76
Naphthalene	0.00	0.0	490.85	981.69
Phenanthrene	28.00	56.00	252.73	505.46
Pyrene	35.20	70.40	153.49	306.98

[a] Reference 21.

[b] 0.00 values indicate pollutant was not found.

[c] Values are weighted averages.

3.0 OPEN BURNING OF NONAGRICULTURAL MATERIAL

New emission factors for open burning of municipal refuse and automobile components were not found. The existing emission factors were reassigned an emission factor rating of "D" because field and laboratory data sheets were not provided.

4.0 OPEN BURNING OF INORGANIC AGRICULTURAL PLASTIC FILM

Agricultural waste that is disposed of by open burning includes plastic film that has been used to control ground moisture and weeds. The plastic film is disposed of by burning the film with field crops or gathering the film into piles and then burning it.

A recent study attempted to quantify emissions from burning plastic film. As a result of this study, emission factors have been developed for various organic compounds.

4.1 DATA SOURCES[2]

A study funded by the U.S. EPA on the burning of agricultural plastic film was conducted to determine the pollutants that may be emitted during this activity. A small utility shed equipped with an air-delivery system was used to simulate pile burning and forced-air incineration of 1 pound of plastic film. Emissions were analyzed for combustion gases, volatile, semi-volatile, and particulate compounds.

The study included test burns of plastic film previously used in fields and unused plastic. Sampling was also conducted for used and unused plastic film burned with a forced air convection system to simulate air-curtain incineration. Volatile organic compounds were measured using a VOST sampling train, and semi-volatile compounds and PAH's were measured with the XAD-2 canister. It was determined that the test procedures were generally of good quality. However, original field data sheets and laboratory data sheets were not provided. For this reason arating of "C" was assigned to the emission factors derived from this reference.

4.2 EMISSIONS AND EMISSION FACTORS

As previously stated, the study identified several volatile, semi-volatile, and particulate compounds that were emitted when burning inorganic agricultural waste. The study only quantified emissions from four volatile compounds (benzene, toluene, ethylbenzene, and 1-hexene) and several PAH's.

4.2.1 Organic Compounds

Samples of 20 liters were collected using the VOST sampling train for each charge of plastic burned (0.454 kg). Emissions of benzene, toluene, ethylbenzene, and 1-hexene are reported in concentration values (mg/m^3). An emission factor in terms of milligrams emitted per kilogram burned was calculated using the following conversion:

$$\frac{\text{Emissions (mg)}}{\text{Plastic charge (kg)}} = \frac{(\text{concentration } mg/m^3)(20\ l)(.001\ m^3/l)}{(0.454\ kg)}$$

The emission factors for benzene, toluene, ethylbenzene, and 1-hexene from burning used and unused plastic in piles and with a forced air current are presented in Table 4-1. Concentration values reported in the study are presented in Appendix B.

4.2.2 Polycyclic Aromatic Hydrocarbons

The study provided concentration values ($\mu g/m^3$) for several PAH's. These values were converted to mass flowrates using a typical sampling rate (0.1 m^3/min) and the average sampling time (1 hr) used for the XAD-2 canister. Emission factors in terms of mass emitted (μg) per mass burned (0.454 kg) were calculated using the following equation:

$$\frac{\text{Emissions } (\mu g)}{\text{Plastic charge (kg)}} = \frac{(\text{concentration } \mu g/m^3)(0.1\ m^3/min)(60\ min)}{0.454\ kg}$$

The emission factors for the PAH's measured are presented in Table 4-2. Appendix B contains the concentration values reported in the study.

Table 4-1

Emission Factors for Organic Compounds From Burning Plastic Film[a]

Emission Factor Rating: C

Pollutant	Units	Condition of plastic			
		Unused Plastic		Used Plastic	
		Pile[b]	Forced air[c]	Pile[b]	Forced air[c]
Benzene	(mg/kg plastic)	0.0478	0.0288	0.0123	0.0244
	(lb/1000 tons plastic)	0.0955	0.0575	0.0247	0.0488
Toluene	(mg/kg plastic)	0.0046	0.0081	0.0033	0.0124
	(lb/1000 tons plastic)	0.0092	0.0161	0.0066	0.0248
Ethyl benzene	(mg/kg plastic)	0.0006	0.0029	0.0012	0.0056
	(lb/1000 tons plastic)	0.0011	0.0058	0.0025	0.0111
1-Hexene	(mg/kg plastic)	0.0010	0.0148	0.0043	0.0220
	(lb/1000 tons plastic)	0.0020	0.0296	0.0086	0.0440

[a]Reference 22

[b]Emission factors are for plastic gathered in a pile and burned.

[c]Emission factors are for plastic burned in a pile with a forced air current.

Table 4-2

Polycyclic Aromatic Hydrocarbon Emission Factors from Open Burning of Agricultural Plastic Film[a]
Emission Factor Rating: C

Pollutant	Units	Condition of Plastic			
		Unused plastic		Used plastic	
		Pile[b]	Forced air[c]	Pile[b]	Forced Air[c,d]
Anthracene	(ug/kg plastic film)	7.14	0.66	1.32	0.40
	(lb/1000 tons plastic film)	0.0143	0.0013	0.0026	0.0008
Benzo(A)pyrene	(ug/kg plastic film)	41.76	1.45	7.53	0.00
	(lb/1000 tons plastic film)	0.0835	0.0029	0.0151	0.0000
Benzo(B)fluoranthene	(ug/kg plastic film)	34.63	1.59	9.25	0.93
	(lb/1000 tons plastic film)	0.0693	0.0032	0.0185	0.0019
Benzo(e)pyrene	(ug/kg plastic film)	32.38	1.45	9.65	0.00
	(lb/1000 tons plastic film)	0.0648	0.0029	0.0193	0.0000
Benzo(G,H,I)perylene	(ug/kg plastic film)	49.43	2.11	14.93	0.00
	(lb/1000 tons plastic film)	0.0989	0.0042	0.0299	0.0000
Benzo(K)fluoranthene	(ug/kg plastic film)	13.74	0.66	2.51	0.00
	(lb/1000 tons plastic film)	0.0275	0.0013	0.0050	0.0000
Benz(A)anthracene	(ug/kg plastic film)	52.73	2.91	14.41	1.19
	(lb/1000 tons plastic film)	0.1055	0.0058	0.0288	0.0024
Chrysene	(ug/kg plastic film)	54.98	3.70	17.18	1.19
	(lb/1000 tons plastic film)	0.1100	0.0074	0.0344	0.0024
Fluoranthene	(ug/kg plastic film)	313.08	53.39	107.05	39.12
	(lb/1000 tons plastic film)	0.6262	0.1068	0.2141	0.0782
Indeno(1,2,3-CD)pyrene	(ug/kg plastic film)	40.04	2.78	10.70	0.00
	(lb/1000 tons plastic film)	0.0801	0.0056	0.0214	0.0000
Phenanthrene	(ug/kg plastic film)	60.40	12.56	24.05	8.72
	(lb/1000 tons plastic film)	0.1208	0.0251	0.0481	0.0174
Pyrene	(ug/kg plastic film)	203.26	18.24	58.81	5.95
	(lb/1000 tons plastic film)	0.4065	0.0365	0.1176	0.0119
Retene	(ug/kg plastic film)	32.38	2.91	18.77	3.04
	(lb/1000 tons plastic film)	0.0648	0.0058	0.0375	0.0061

[a]Reference 22.

[b]Emission factors are for plastic gathered in a pile and burned.

[c]Emission factors are for plastic burned in a pile with a forced air current.

[d]0.00 values indicate pollutant was not found.

5.0 OPEN BURNING OF ORGANIC AGRICULTURAL WASTE

No new emission factors were located for this source category. However, the existing emission factors were reassigned an emission factor rating of "D" because the original references, and the corresponding field and laboratory data sheets were not found.

6.0 REFERENCES

1. Characterization of Emissions from the Simulated Open Burning of Scrap Tires, Acurex Corporation, Research Triangle Park, October 1989. U. S. Environmental Protection Agency. EPA-600/2-89-054.

2. Linak, W. P., et al., "Chemical and Biological Characterization of Products of Incomplete Combustion from the Simulated Field Burning of Agricultural Plastic" Journal of Air Pollution Control Association. Vol. 39, No. 6, June 1989.

7.0 AP-42 SECTION 2.4

Section 2.4 of AP-42 is presented in the following pages as it would appear in the document.