The Air Emissions Impact of Burning Railroad Tie-Derived Fuel

Introduction

Wood is treated with creosote when preparing railroad cross ties (railties) in order to prolong the useful life of the ties by protecting them against insect and fungal attack. Wood exposed to the outdoor atmosphere and in direct contact with soil or water is more prone to decay and therefore usually requires treatment. At the end of their useful life, treated wood products like railties must be landfilled, reused beneficially, or burned for energy recovery. This paper summarizes available information on the air emission impact of burning railties in industrial boilers, specifically those equipped with stokers. A full comparison of the contaminants (trace metals, organics, etc.) in railties with those in traditional fuels such as coal, biomass and fuel oil was carried out earlier and submitted to EPA in support of the Non-Hazardous Secondary Material (NHSM) rule (AF&PA 2013).

A. Testing at an Electricity Generating Unit (EGU) at McBain, MI

Under EPA's supervision, elaborate emission tests were conducted on the Viking Energy, McBain, MI wood-fired stoker (with ESP) when burning chipped creosote-treated railties and several other treated wood wastes (EPA 1994). The test results for chipped creosote-treated railtie burning are summarized in Table 1. The boiler typically fired about 600 tons per day of virgin and recycled untreated wood in chip form. However, a baseline run with 100% untreated wood was not conducted during this study. Table 1 provides a comparison of the mean emissions when firing railties in the McBain boiler against ranges and/or means of emissions from firing 100% untreated wood residues in stoker units with ESPs, the latter being obtained from Boiler MACT and other recent test data that were summarized in NCASI Technical Bulletin No. 1013 (NCASI 2013). Sampling was conducted for dioxins/furans (PCDD/Fs), several polyaromatic hydrocarbons (PAHs), trace metals, particulate matter (PM), HCl, formaldehyde, acrolein, NO_x, CO, SO_2 and VOCs.

A comparison of emissions resulting from burning 29.0 wt% creosote-treated wood (remainder being virgin and recycled untreated wood) in the Viking boiler with emissions from burning 100% untreated wood residues in stoker units (NCASI 2013) indicates that there is no discernible difference due to the addition of railties to the untreated wood fuel. In fact, most emissions when burning creosote-treated wood are lower than the averages for 100% wood burning, including those of PAHs. Emissions of 2-methylnaphthalene from 29% creosote substituted wood burning were comparabale to the maximum values from untreated wood burning. However, the emissions of all other PAHs were closer to the lower end of the range. (NCASI 2005, 2013). This observation is not surprising given that PAH emissions reduce when the robustness of combustion increases. The use of dry fuels with high heat value, like railties, generally improves combustion, thereby reducing products of incomplete combustion like PAHs.

Table 1. Trial Burns of Creosote-Treated Railties in a Wood-Fired Boiler (EPA 1994)

	Baseline Untreated Wood[1]	Creosote-Treated[2, 3]
	Range	**Mean**
Co-firing Rate (% wt)		29.00
Load (lb/hr steam)		157,990
Dioxins (ng/m^3)[4]	0.0017 to 0.375	0.164
PAHs (ng/m^3)		
Naphthalene	14 to 599,295	917.2
2-Methylnaphthalene	50 to 3,679	3,704
Acenaphthene	3 to 10,214	67.7
2-Chloronaphthalene	2.95[5]	1.29
Acenaphthylene	11 to 38,517	38.1
Fluorene	4 to 32,857	145.4
Phenanthrene	11 to 43,071	499.1
Anthracene	4 to 32,857	30.4
Fluoranthene	7 to 13,044	87.0
Pyrene	7 to 32,857	49.9
Benzo(a)anthracene	1 to 445	2.5
Chrysene	3 to 619	2.56
Perylene	1 to 110	0.53
Trace Metals (µg/m^3)		
Arsenic	0.2 to 11.5	ND
Cadmium	0.09 to 1.66	ND
Chromium	0.12 to 11.6	ND
Copper	3.13 to 13.5[5]	13.8
Lead	0.44 to 35.6	ND
Mercury	0.1 to 8.2	0.68
Nickel	0.24 to 18.2	ND
Zinc	20.6 to 872[5]	87.8
	Mean	**Mean**
Part. Matter (gr/dscf)	0.029[5]	0.0087
HCl (mg/m^3)	5.37	ND
Formaldehyde (µg/m^3)	1,255	76.0
Acrolein (µg/m^3)	320	ND
NO_x (ppm)	136	168
NO_x (lb/10^6 Btu)	0.21	0.23
CO (ppm)	765	120
SO_2 (lb/10^6 Btu)	0.011	0.027
VOC (ppm)	11.0	0.8

[1]NCASI TB 1013 - factors available for 100% wood combustion in a stoker unit with ESP in units of lb/MMBtu were converted assuming F factor of 9,280 dscf @ 0% O_2/10^6 Btu, 6% O_2 in stack and 8,400 Btu/lb dry wood; [2]concentrations for the McBain unit are expressed at stack O_2 which varied from 4 to 5%; [3]29% creosote-treated wood, remainder untreated and recycled wood; [4]mass (not TEQ) basis; [5]same as AP-42 Chapter 1.6

B. Pilot-Scale Tesing of Creoste-Treated Wood With Coal

Freeman et al. (2002) conducted a pilot-scale study co-firing creosote-treated woods with coal to provide data for pre-permitting evaluations by utilities interested in co-firing biomass as a means of increasing renewable energy use. The results of these tests are summarized in Table 2. Substances tested for included PCDD/Fs, PAHs, several heavy metals, formaldehyde and other VOCs, HCl and particulates. These emissions represented "uncontrolled" emissions from the combustor "upstream of flue gas cleanup devices."

From the results presented in Table 2, the authors concluded that creosote-treated wood could be successfully co-fired in coal-fired utility boilers at 10% heat input without increases in most air toxic emissions relative to the baseline with 100% eastern bituminous coal firing. Compared to the baseline test results with 100% coal, the results with 10% creosote-treated wood (rest coal) consistently showed lower levels (often non-detectable) of dioxins/furans, PAHs, heavy metals, formaldehyde and other aldehydes, ketones and total hydrocarbons. The slightly higher levels of HCl emissions measured (61 vs 44 ppm) appears to be an anomaly since creosote-treated wood has much lower chlorine levels than most coals, being similar to those in virgin wood fuels (<0.07%).

Table 2. Emissions from Creosote Treated Wood Cofiring with Coal (Freeman et al. 2002)

	Baseline UF Coal	10% Creosote Wood[1]
Flue Gas (dry basis @ 3% O_2)		
SO_2 (ppm)	1209	1120
NO_x (ppm)	574	474
CO (ppm)	92	75
HCl (ppm)	44	61
Total Hydrocarbons (ppm)[2]	2.0	1.6
Particulate (g/dNm^3)	8.9	5.5
VOCs (dry basis @ 3% O_2))		
Acetaldehyde (ppb)	<1.4	<2.7
Acetophenone (ppb)	<1.5	<1.2
Formaldehyde (ppb)	~2.3	2.4
Isophorone (ppb)	<0.21	<0.18
Propionaldehyde (ppb)	<0.53	<0.46
PCDD/Fs (ng/dNm^3 @ 3% O_2)		
Total PCDD/Fs	0.0463	0.0039
WHO TEQs	0.0014	ND
Total PAHs (µg/dNm^3 @ 3% O_2)	0.134	0.079
Heavy Metals (g/MJ)		
Antimony	7.36E-06	6.38E-06
Arsenic	4.21E-04	3.42E-04
Cadmium	5.84E-06	4.65E-06
Cobalt	2.38E-04	1.14E-04
Lead	1.34E-04	9.96E-05
Manganese	1.17E-03	6.68E-04
Mercury	9.18E-06	9.40E-06
Nickel	2.01E-04	1.23E-04
Selenium	6.61E-05	3.96E-05

[1] 10% creosote treated wood, remainder coal; [2] as propane; ND – non-detect

C. Chipped Railroad Tie Burning in a Pulp Mill Bark Boiler

In 2003, a southwestern pulp mill conducted extensive tests on its bark boiler by replacing the entire wood fuel with chipped railroad ties. The boiler was tested with 100% railties for several criteria pollutants, particulate matter (PM), six trace metals (As, Cd, Cr, Pb, Cu and Zn), several semi-volatile organics (SVOCs), PCDD/Fs, and several speciated VOCs. CO, THCs, NO_x and SO_2 were also measured during a baseline test with 100% bark/wood residues (NCASI File Information). These emissions data are compared in Table 3. For comparison purposes, the emission data from this study are compared against mean and range of emissions when firing 100% untreated wood residues in stoker units with ESPs (NCASI 2013). Once again, the emissions data with 100% railtie combustion in a stoker unit are routinely lower than for 100% untreated wood combustion.

Table 3. Criteria and Non-Criteria Pollutants From Burning Railties in a Bark Boiler

		100% Bark	100% Railties	Untreated Wood Range or Mean[5]
RTDF feed rate	tons/hr	0	24.7	
Steam	KPPH	520	430	
CO	ppm@8%O_2	316	117	663
THC as C	ppm@8%O_2	56	7	9.5
NO_x	lb/MMBtu	0.20	0.21	0.21
SO_2	lb/MMBtu	0.00	0.01	0.011
PM	gr/dscf@7%O_2		0.026	--
PCDD/Fs	ng/dscm@7%O_2		5.01E-04[1]	7.21E-03[5]
As	µg/dscm@7%O_2		11.0	0.2 to 11.5
Cd	µg/dscm@7%O_2		4.8	0.09 to 1.66
Cr	µg/dscm@7%O_2		5.8	0.12 to 11.6
Cu	µg/dscm@7%O_2		45.2	3.13 to 13.5[6]
Pb	µg/dscm@7%O_2		107.8	0.44 to 35.6
Zn	µg/dscm@7%O_2		764.7	20.6 to 872[6]
SVOCs				
Naphthalene	µg/dscm@7%O_2		2.98	11.4
Bis(2-ethylhexyl)phthalate	µg/dscm@7%O_2		1.90	0.1
Benzyl alcohol	µg/dscm@7%O_2		4.10	No data
Benzoic acid	µg/dscm@7%O_2		152.4	49.5
All Others[3]	µg/dscm@7%O_2		ND	--
VOCs				
Methyl chloride	µg/dscm@7%O_2		9.34	628.0
Chloroform	µg/dscm@7%O_2		19.97	23.1
Benzene	µg/dscm@7%O_2		38.84	1125.0
Toluene	µg/dscm@7%O_2		4.96	24.2
Xylenes (total)	µg/dscm@7%O_2		4.04	6.0
Ethyl Benzene	µg/dscm@7%O_2		1.35	453.5
Styrene	µg/dscm@7%O_2		1.4	547.6
All Others[4]	µg/dscm@7%O_2		ND	--

[1]I-TEF/89 units; [2]WHO-TEF 2005 units; [3]over a hundred other compounds including phenol, 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, 2,4,6-trichlorophenol, hexachlorobenzene, pentachlorophenol, and several PAHs; [4]over 50 other VOCs including chloromethane, vinyl chloride, carbon tetrachloride, 1,1,2-trichloroethane, trichloroethene, tetrachloroethylene; [5]NCASI TB 1013 - factors available for 100% wood combustion in a stoker unit with ESP in units of lb/MMBtu were converted assuming F factor of 9,280 dscf @ 0% O_2/10^6 Btu and 8,400 Btu/lb dry wood; [6]same as AP-42 Chapter 1.6

The emissions of Cd, Cu, and Pb from 100% railtie burning were higher than the maximum values from untreated wood burning. However, it should be noted that emissions of PM and trace metals are generally a function of the PM control device efficiency. Unless the fuel combusted is believed to contain a particular trace metal in unusually large concentrations (not the case with railties), a comparison of resulting emissions should made with care as it ignores any variability in effectiveness of the control device. It is also worthwhile to note that the 100% railtie substitution scenario is a highly atypical worst-case boundary condition – railtie substitution levels in industrial boilers typically range between 5 and 30%.

D. Emissions from Combustion of Railties in Several EGUs – A 1995 Study

Holtzman and Atkins (1995) reported on air emissions data from the burning of railties in several large independent wood-fired power plants (EGUs) and one coal-fired plant (EGU). The treated wood emissions data from each of the test programs are also compared to emissions from combusting clean wood or coal in these boilers. The wood-fired EGUs ranged in size from 20 to 50 MW, were of a spreader stoker design, and had either a baghouse or ESP for PM control. Table 4 provides an emissions comparison between burning clean wood with and without various levels of railties at 3 different sites, 25 to 50% railties at Site A, 20% railtie at Site B, and 10% railtie at Site C. The emissions measured included criteria pollutants PM, NO_x, CO, SO_2 and THCs, trace metals As, Be, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se and Zn, acid gases HCl and H_2SO_4, PCDD/Fs and several organics. The comparison clearly shows that burning railties at various levels in these stokers along with clean wood had no discernible bearing on the air emissions of most criteria and non-criteria pollutants (SO_2 emissions continued to be negligible but were marginally higher; Among trace metals, only arsenic emissions were somewhat higher).

Table 4. Emissions Comparison of EGUs Burning Clean Wood With and Without Railroad Ties

	Site A		Site B		Site C	
	Clean	25-50%	Clean	20%	Clean Wood	10%
	All emissions are in units of lb/MMBtu					
Particulate Control Emissions Control	MC ESP	MC ESP	ESP	ESP	MC ESP	MC ESP
Heat Input (MMBtu/hr)	339	339	711	681	286	295
Particulate Matter	1.68E-03	1.31E-03	2.63E-02	2.80E-02		
PM - Back Half	9.84E-03	3.94E-03			3.55E-03	6.27E-03
Nitrogen Oxides	1.44E-01	1.22E-01	2.08E-01	2.07E-01	1.96E-01	2.00E-01
Carbon Monoxide	2.65E-01	5.21E-01	4.30E-01	4.04E-01	2.68E-01	1.39E-01
Sulfur Dioxide	2.54E-03	4.07E-02		7.33E-03	2.08E-03	4.30E-02
Hydrocarbons	3.62E-03	5.72E-03			5.07E-03	3.62E-03
Arsenic	1.44E-07	7.97E-07	1.64E-05	3.07E-05		
Beryllium	<2.87E-07	<1.91E-06				
Cadmium	<2.87E-07	<1.53E-06	1.20E-06	1.29E-06		
Chromium	<6.37E-07	<2.87E-06	3.36E-05	4.09E-05		
Hexavalent Chromium	*		Not Tested	1.62E-06		
Copper	1.59E-05	3.51E-06				
Lead	1.59E-05	1.12E-06	9.64E-06	2.20E-05		
Manganese	3.01E-05	1.43E-06	8.59E-05	1.18E-04		
Mercury	3.19E-07	4.30E-07				
Nickel	<2.87E-06	<1.34E-05	3.97E-06	1.98E-06		
Selenium	<2.87E-06	<3.62E-06	5.53E-07	4.36E-07		
Zinc	1.12E-05	4.30E-06				
Hydrogen Chloride			5.60E-05	5.60E-05		
Sulfuric Acid			1.63E-02	2.25E-02		
2,3,7,8-TCDD	7.80E-11	3.51E-11	1.66E-12	3.66E-12		
Acetaldehyde	7.57E-05	2.54E-05	5.11E-04	1.54E-04		
Acrolein			1.85E-04	5.74E-06		
Benzene	2.45E-04	1.55E-04	2.18E-04	2.40E-04		
Benzo(a)anthracene	<5.00E-09	<6.00E-09	2.73E-07	2.82E-07		
Benzo(a)pyrene	<5.00E-09	<6.00E-09	2.98E-07	3.21E-07		
Chlorophenols			1.94E-05	2.11E-05		
Clorobenzenes			1.19E-05	1.28E-05		
Chloroform	<3.64E-05	<2.14E-05				
Chrysene/Triphenylene	<5.00E-09	<6.00E-09	2.98E-07	3.08E-07		
Formaldehyde	2.800E-04	1.32E-04	2.36E-03	7.20E-04		
Naphthalene			7.05E-06	3.28E-06		
Phenol			2.27E-05	4.58E-06		
Toluene	<2.97E-05	<4.49E-05	2.29E-05	3.07E-05		
Dioxins			<6.48E-12	<1.83E-11		
Furans			<2.05E-11	<1.99E-10		

*Blank indicates no data

Table 5 provides an emissions comparison between burning coal with and without railties at low and high loads at a coal-fired EGU. The emissions measured included criteria pollutants PM, NOx, CO, and SO_2, trace metals As, Be, Cd, total Cr, Cr^{+6}, Cu, Pb, Hg, Ni, and Zn, acid gas HCl, PCDD/Fs, PCBs, PAHs, total chlorophenols, and formaldehyde. Once again, most emissions were comparable or lower as a result of co-firing railties in this coal-fired unit (formaldehyde and arsenic emissions were a bit higher).

Table 5. Baseline and Railtie ombustion Emission Test Summary, Hickling Station, East Corning, NY

	Low Load (lb/hr)		High Load (lb/hr)	
Test Parameters	Baseline[c]	Creosote Treated[d]	Baseline[c]	Creosote Treated[d]
Total particulate	35.63	2.06	133.43	5.37
Carbon monoxide (CO)	13.9	12.9	9.9	24.0
Nitrogen oxides (NO_x)	66.6	94.3	206.3	156.3
Sulfur dioxide (SO_2)	686.5	439.6	1436.6	724.5
Arsenic (As)	a	a	1.72E-03	6.24E-02
Beryllium (Be)	a	a	<2.54E-04	<7.04E-04
Cadmium (Cd)	a	a	4.52E-04	1.10E-04
Total Chromium (Cr)	a	a	7.74E-03	5.90E-03
Hexavalent Chromium (Cr^{+6})	a	a	<4.08E-03	5.90E-04[e]
Copper (Cu)	a	a	8.56E-03	8.82E-03
Lead (Pb)	a	a	3.24E-03	1.18E-03
Mercury (Hg)	a	a	2.88E-02	1.33E-02
Nickel (Ni)	a	a	2.58E-03[b]	3.39E-04
Zinc (Zn)	a	a	1.86E-02	3.31E-03
Formaldehyde (HCHO)	a	a	0.012	0.028
Hydrogen chloride (HC1)	a	a	48.7	13.44
2,3,7,8 TCDD Tox. Equiv.	a	a	4.81E-09	1.696E-08
Total PAHs	4.56E-04	<1.26E-02	6.44E-04[b]	<2.12E-02
Total PCBs	a	a	<2.44E-05	<1.23E-03
Total chlorophenols	a	a	9.17E-05	<2.42E-02

Source: Unit 1 Creosote Treated Wood/Coal CO-Fired Feasibility Project

a Indicates no source testing was conducted for these test parameters.

b Estimated emission rate. When 1 or 2 of the 3 sample runs demonstrated emissions below the detection limit, one-half of the detection limit for each of the ND test runs was used to calculate the average emission rate.

c Baseline emissions (coal only) testing performed by Galson Corporation in June 1992.

d Creosote treated wood testing performed by TRC Environmental Corporation in November 1993.

e $Chromium^{+6}$ values were calculated assuming 10% of total chromium was chromium +6.

Summary

The data presented in this paper indicate that the air emission impact of burning creosote-treated railroad ties (railties) along with either virgin, untreated biomass or coal in stokers is not any different than that from the burning of untreated biomass or coal in these units. The organic constituents in the creosote appear to oxidize completely during combustion on the grate and above the grate in such boilers such that the emission of VOCs, SVOCs, PCDD/Fs and other products of incomplete combustion would be similar in magnitude as the baseline fuel. Further, the metals content of the railties are known to be similar to those in virgin wood fuels and thus the trace metals air emission impact of co-firing these fuels in a given boiler would be no different than those measured when firing predominantly untreated wood fuel in the same boiler.

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