THE DISPOSAL OF RAILWAY CROSS TIES
(AN INTERNAL REPORT)

by

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INTRODUCTION

Regional office personnel were concerned that the open burning of railway ties, particularly those treated with pentachlorophenol could result in unacceptable atmospheric emissions, possible emissions of polycyclic organic matter (POM) was of particular concern.

Upon investigation it became evident that this concern was not limited to one region; that it had nationwide implications. The purpose of this report is to support the Regions in their dealings with the railways, the provincial governments, and miscellaneous groups, by providing background information.

In addition to the pentachlorophenol treated ties it became evident that creosote treated ties were also of concern. Initially, adequate data did not surface. Consequently it became necessary to generate data internally; two railway tie burning experiments were conducted, one for pentachlorophenol and one for creosote treated ties.

GENERAL INFORMATION

Since about 1958 two types of treated ties have been used, creosote and pentachlorophenol. Before that time, all ties were treated with creosote. In 1982, Canadian National Railways purchased 2.2 million ties, about 700,000 of which were treated with pentachlorophenol. Canadian Pacific Railways indicated they purchased 2.1×10^6 creosote treated ties in the same year.

The preservative for creosote ties consists of a 50% creosote, 50% no. 6 oil treatment solution while pentachlorophenol preservative consists of a 97% carrier and a 3% PCP solution. Only softwood ties are treated with PCP whereas both hardwood and softwood ties are treated with creosote.

Ties last about seven years in heavy use and are discarded when they no longer can hold a spike. On spur lines, tie lifespan may be 25 years or more. In the past they were removed by a machine in three pieces, thus removing their potential resale value. More recently a tie extractor machine is being used which removes the tie in one piece, in this condition they are readily saleable.

Methods of disposal in use in Canada presently include abandonment by the track, stockpiling, landfill, burning by the track, refurbishing, and extraction in one piece for sale or reuse.

Several criteria must be met before the ties are allowed to be burnt, e.g. they must be burnt a minimum distance from population centers, there must be a low probability of grass fires, etc. Appendix A presents the guidelines currently in force in Ontario, and several western provinces with respect to open burning.

PROBLEM AREAS

Several problem areas have arisen in the course of the study:

(i) the quantitative analysis of the emissions from the burning of the ties was difficult to complete due to heavy concentrations of other compounds present. In addition, when the analysis was completed, the results weren't consistent. Likely the samples taken were contaminated by chemicals which were released from the chimney. The apparatus had previously been used to measure the efficiency of wood stoves at low excess air which would promote the build up of creosote on the chimney. This is elaborated on in the section detailing the experiment.

(ii) the railway companies have not been as cooperative as it had been hoped they would have been. It may be that the type of information which we seek is not readily available. Mrs. L. Boisjolie of the Quebec regional office is liasing with the companies in an effort to fill in the gaps.

TIE DISPOSAL METHODS

BACKGROUND

This section develops the environmental considerations, market analyses (where appropriate) and costs per tie for each tie disposal method under study.

Methodologies and sample calculations of disposal costs are presented for each disposal alternative. It is taken from the report entitled, "The Disposal of Discarded Railroad Wood Crossties", prepared by Dolby and Associates for the Association of American Railroads, April, 1984. Although the data is not Canadian in origin it can be expected to approximate the Canadian situation.

Disposal costs for the study are developed in accordance with the following criteria:

1) Labor rates for track personnel include wages and fringe benefits, and are based on 1981 rates obtained from the AAR, escalated to Second Quarter 1983 dollars.

2) Work equipment rates are derived from the "Schedule of Equipment Rental and Other Rental Rates For Use Between Carriers", published by the General Managers Association of Chicago on 1 July 1981. Daily rental rates represent the maximum charge for a twenty-four hour period and apply only for the days the equipment is actually rented. All rental rates include the cost of repairs, lubricating oil, fuel, electricity and other supplies.

3) Transport costs are dependent on a number of variables, including hauling distance, number of loaded rail cars per move and car maintenance and depreciation charges. Representative transport costs have been developed, based on figures obtained from the AAR finance department that are most reflective of a railroad's typical on-line costs.

4) Daily production rates for removal of scrap ties from the right-of-way are based on an average of six hours of work per day, with an average of two hours per day for travel time to and from the job site and train delays. Tie removal gangs are assumed to operate independently from tie installation gangs. It should be noted that reduced costs and reduced track occupancy time could possibly be realized by including tie disposal work as part of the operation of the tie installation gang. This approach was not taken for this study, due to the variety of possible tie gang configurations that are used by individual railroads.

The tie pick-up method selected for this study includes the use of a small tie crane to pick up and assemble ties for banding, and a larger crane for picking up the bundles, loading them in a car and handling the car. Another possible method would be the use of a work train with a crane capable of working from the top of gondolas. Cranes are available which are capable of moving along the tops of gondolas loading or unloading ties.

When tie pick-up and removal in large volumes becomes more of a common practice, a greater need will arise for new, specialized equipment to do this work. It is likely that equipment manufacturers will respond to these needs by building specialized machinery to complete the pick-up and loading tasks at a reduced cost of operation. Most of the tie handling equipment currently available is designed primarily for unloading new ties along the right-of-way and for tie installation purposes.

SALE

ENVIRONMENTAL CONSIDERATIONS

The sale of scrap railroad ties for use in landscaping for contracting applications is not regulated by federal, state, provincial, or local environmental protection agencies.

MARKET ANALYSIS

Telephone interviews with contractors and landscaping firms were conducted to gather retail and wholesale market information during March 1983. This data is summarized in Table I. A three-tiered market, based on timber quality, was found to exist in most areas.

The top grade of scrap timber is free from splits, shakes and/or attached metal, has four good sides and commands the greatest resale value. The best wood normally becomes available by selecting the best ties from branch line abandonments or from main line track rehabilitation. These ties are suitable for re-use in light density branch lines, or may be sold at retail landscaping outlets for construction of retaining walls. On a nationwide basis, the strongest market exists for the best quality timber; most retailers reported that many more top grade ties could be sold if available.

Medium grade ties typically have two or three good sides, and occasionally contain some metal that has not been removed, such as a spike. Residential customers purchase these ties for edging flower beds, creating borders around driveways or building planter boxes. The largest demand occurs during spring and early summer, and will exceed supply if local railroad abandonment and/or rehabilitation activity has been slack during the previous autumn and winter months. A severe shortage of medium grade timber was reported in Los Angeles, Boston, Atlanta, Charlotte and Seattle, while an abundant supply was found in the cities of Miami, Houston and Denver, largely due to recent abandonment activity.

The lowest grade of secondhand ties, constituting the balance of the market, includes wood having no more than one or two good sides. These ties are often severely plate cut and may contain unremoved scrap metal. Tie butts (ties cut into three pieces) also fall into this category. The retail market for these "cull" ties is extremely poor, and likely to remain as such since little use has been found for them other than for burning as fuel. The disposal problem is considerable, given the large quantity of cull ties and the cost of removing them from the right-of-way. In some cases, contractors will clear sections of the right-of-way of all discarded cross ties, but generally, this will occur only in areas of very high demand for ties.

Generally, high quality secondhand timber is in demand virtually everywhere, and can be readily sold by wholesalers and retailers. There are seasonal fluctuations in demand, however.

Theft of cross ties removed from track (with or without the implied consent of the railroad) can have a significant impact on the local landscape market, due to the fact that the thief can use or sell ties at a lower price than the contractor who has to purchase his ties. Retail prices are generally highest in large cities such as Miami and Los Angeles, as well as in the northeast part of the country. In the midwest and southwest an oversupply exists due to recent rail abandonment and rehabilitation work; much of this oversupply is of the cull variety, presenting the greatest disposal problem.

TABLE I SALE PRICE/TIE*

Region	State	County	City	Retail Price Range	Wholesale Price Range
S E	FL	Dade	Miami	$12 - $15	$7 - $9
N E	ME	Cumberland	Portland	$11	$7 - $9
N E	PA	Philadelphia	Philadelphia	$8	$4 - $5
S E	NC	Mecklenburg	Charlotte	$7 - $10	$6 - $8
S E	MS	Hinds	Jackson	$7 - $10	$5 - $6
M W	IL	Cook	Chicago	$7 - $9	$3 - $4
S W	TX	Harris	Houston	$8.50	$3 - $4
S W	CA	Los Angeles	Los Angeles	$14	$8 - $10
N W	WA	King	Seattle	$8	$6
N W	MT	Yellowstone	Billings	$6	$3 - $4
N W	CO	Denver	Denver	$8 - $9	$3 - $6
M W	MO	St Louis	St Louis	$7 - $10	$3 - $5
N E	MA	Middlesex	Boston	$10 - $15	$6
M W	WI	Dane	Madison	$4.50 - $8	$3 - $4
		NATIONAL AVERAGE PRICE RANGE		$8.43 - $10.11	$4.79 - $6.14
			AVERAGE PRICE	$9.27	$5.47

* SOURCE: Telephone interviews with contractors, landscaping firms and retailers

COST/TIE FOR REMOVAL OF WHOLE TIES FROM RIGHT-OF-WAY

LOAD TIES IN CARS

Operation 1 - Band whole ties in bundles of 25 ties.

1 Tie handler with 2 push cars	$96/day
2 Track laborers	$126/day each
1 Operator	$137/day

Procedure: Move down the right-of-way, loading whole ties on the push cars with the handler. When the cars are loaded, stop and unload and band the ties in bundles of 25 ties, and leave them on the right-of-way. Assume a production rate of 3 bundles per hour for six hours per day. Assume this work is accomplished separately from the tie gang. It may be more economical to accomplish this work as part of the tie gang depending on a railroad's maintenance practices and the availability of track occupancy times.

$$\frac{\$96/\text{day} + (2 \times \$126/\text{day}) + \$137/\text{day}}{450 \text{ ties/day}} = \$1.08/\text{tie}$$

Operation 2 - Load bundles in a gondola.

1 Burro Crane or equivalent	$269/day
2 Track laborers	$126/day each
1 Operator	$137/day
1 Foreman	$144/day

Procedure: The Burro crane moves down the track with a car and loads the bundles. Assume a production rate of 75 ties/hour (3 bundles) for 6 working hours per day. The Burro Crane loads 2 gondolas per day and sets them in a siding when loaded. The foreman is in charge of operations 1 and 2.

$$\frac{\$269/\text{day} + (2 \times \$126/\text{day}) + \$137/\text{day} + \$144/\text{day}}{450 \text{ ties/day}} = \$1.78/\text{tie}$$

Total Loading Cost: $1.08/tie + $1.78/tie = $2.86/tie

TRANSPORT TIES TO DESTINATION

Assume a 300 mile on line move requiring 14 days to complete in company owned cars with 225 ties in each car. Compute the average actual cost to the railroad using a transportation cost of $.011/Net Ton (NT) mile and a maintenance and depreciation cost of \$4/car day[1]. If the ties move off one railroad onto another railroad (through interchange) these costs will be much higher due to the need to charge tariff or contract rates.

Car Movement Cost:

$$\frac{\text{180 lbs./tie x 450 ties x 300 mi. x \$011/NT mi.}}{\text{2000 lbs./NT x 450 ties}} = \text{\$.30/tie}$$

Car Maintenance and Depreciation Cost:

$$\frac{\text{2 cars x 14 days x \$4/car day}}{\text{450 ties}} = \text{\$.25/tie}$$

Total Transportation Cost:

$$\text{\$.30/tie + \$.25/tie} = \text{\$.55/tie}$$

COST/TIE FOR CROSS TIE BUTT REMOVAL

LOAD TIES IN CAR

Operation 1 - Stack tie butts in piles along right-of-way.

1 tie handler, 2 push cars	\$96/day
2 track laborers	\$126/day each
1 operator	\$137/day

Procedure: Move down the right-of-way loading tie butts on the push cars. When the cars are loaded, unload the butts in a pile along the right-of-way. Assume a production rate of 360 ties (1,080 butts) per day.

$$\frac{\text{\$96/day + (2 x \$126/day) + \$137/day}}{\text{360 ties}} = \text{\$1.35/tie}$$

Operation 2 - Load tie butts into a car.

1 foreman	\$144/day
1 Burro Crane	\$269/day
2 track laborers	\$126/day each
1 machine operator	\$137/day

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[1] Costs computed by the AAR Economics and Finance Department

Procedure: The Burro crane moves down the right-of-way with a car and loads the piles of tie butts. Assume a production rate of 60 ties per hour (180 butts) for six hours. An alternate method would be to load the butts in the cars using a conveyor system with a work train.

$$\frac{\$144/\text{day} + \$269/\text{day} + (2 \times \$126/\text{day}) + \$137/\text{day}}{360\ \text{ties/day}} = \$2.23/\text{tie}$$

Total Loading Cost: \$1.35/tie + \$2.23/tie = \$3.58/tie

Transport Costs = \$ .55/tie

FUEL

ENVIRONMENTAL CONSIDERATIONS

REGULATIONS:

Considerable regulatory uniformity was discovered upon review of stationary source air quality legislation for the 49 states surveyed. The Canadian provinces seemed to have less uniformity. Each state maintains standard opacity limits for wood burning incinerators, typically 20% or É1 on the Ringelmann Scale. This is also true of some, but not all Canadian provinces. Particulate emissions regulations vary considerably among the states and provinces, depending on incinerator size and rate of charging input. Most commonly, particulates are limited to 0.1 grains per dry standard cubic foot of air, corrected to 12% CO_2.

Construction and/or operating permits for new installations are required in each state. Technical considerations subject to review and approval may typically include the following:

1.) Submission of site plan, construction plan, operating plan
2.) Review of new Source Performance Standards (NSPS)
3.) Use of Best Available Control Technology (BACT)
4.) Use of multiple combustion chambers; specification of minimum operating temperature for primary and secondary chambers
5.) Analysis of percent destruction of odors and percent completeness of combustion
6.) Air quality impact assessment and review; compliance with particulates and opacity emissions criteria
7.) Demonstration of "environmental acceptability" to assure adequate public health protection
8.) Review of performance data from similar facilities
9.) Control of fugitive dust
10.) Testing for toxic or carcinogenic emissions
11.) 30-day public comment and review period

A summary of state and provincial emission regulations for stationary wood burning sources is presented in Table II.

EMISSION DATA:

A literature search was conducted to further assess the current state of the art in the control of emissions from stationary wood burning sources. Tests to evaluate air pollutants emanating from the incineration of railroad ties were recently performed in Pennsylvania, Wisconsin, Vermont and New York. Results of these tests were reviewed and are summarized below.

At the Boiler Erection Company plant in Ambler, Pennsylvania, shredded railroad ties were burned in an Energy Recovery Group, Inc. horizontal combustor/waste heat boiler arrangement to determine stack emissions for particulates, opacity and hydrocarbons. The boiler burned creosote treated ties that had been pulverized into chips by primary (minus four inch screen) and secondary (minus one inch screen) shredders. The fuel was stored in a large screw feed hopper before entering the boiler. The boiler was rated at 10,000 lbs. of steam per hour (maximum input of approximately one ton of scrap ties per hour).

Test results indicated that visual emissions (expressed as percent opacity) were less than 5%, well below the Pennsylvania state limit of 20%. Non-condensible hydrocarbons from the escaping exhaust gases were at low levels, signifying good combustion. Particulate emissions were on the order of 0.9 lbs. per million Btu's of heat input, exceeding the state limit of 0.4 lbs. for a charging rate of 2.5 to 50 million Btu's per hour. It was later determined that by increasing the burning time to maximize percent completeness of combustion and by using a commercially available dry scrubber of at least 70% efficiency, particulate emissions could probably be reduced to acceptable levels.

In New York State, the Procter and Gamble Company obtained state and local permit approvals to construct a 240,000 lb./hr. wood burning boiler at its manufacturing facility on Staten Island. The new boiler will replace an existing gas and oil fired boiler, and will supply steam heat to meet the plant's total process and electrical power requirements. Wood fuel is to be supplied by local manufacturers and service firms who normally dispose of their waste wood to landfill sites. Primary pollutants from the wood burning operation include particulates, CO, NO_x and HC. A restriction was placed by Procter and Gamble in the supplier contracts on "coated and/or pressure treated wood such as railroad ties, etc."[1] The self-imposed Procter and Gamble restrictions were designed to speed up the permitting process and to avoid further conjecture (due to insufficient emissions data) on the burning of treated wood products.

In Burlington, Vermont, a wood burning facility is currently in operation at the Moran Station Municipal Power Plant of the Burlington Electric Light Department.

The station is designed to burn mixed hardwoods. Whole trees are shredded in forest locations and then hauled by truck to the plant site for incineration.

A feasibility study was conducted by the Moran Station in conjunction with the Vermont Agency for Environmental Conservation (AEC) to determine the environmental impacts of burning scrap ties as fuel. After considerable investigation, the agency decided to prohibit cross tie incineration, primarily because the Moran facility is aging and is not designed to handle emissions from treated wood. The siting is also a factor, as the plant is located in a metropolitan area classed as non-attainment for certain pollutants, particularly carbon monoxide. However, CO emissions were not one of the major concerns. The Vermont AEC believes that there is a lack of sufficient evidence on the impact of burning treated wood - hence, the inappropriateness of issuing permits for either an existing or a new facility. The state wants more evidence on possible toxic contaminants. The Vermont AEC is also very concerned about the acceptability of such an installation due to intense interest in the state on environmental issues.

In LaCrosse, Wisconsin, the Northern States Power Company is currently operating a wood burning incinerator/boiler at its French Island Power Plant. This facility, capable of handling sawdust and mill wastes as well as treated wood products, uses the largest fluidized bed chamber in the country. The fluidized bed combustor allows for the efficient burning of a non-uniform blend of fuels - for example, treated and untreated wood.

On December 14, 1982, a stack test was conducted at French Island on emissions from a burn of 100% shredded railroad ties. The average heat input rate was 156.4 million Btu/hr. The average particulate emission concentration for the test was 0.09 lb. per million Btu of input, below the state allowable limit of 0.15 pounds applicable to this type of source. Visual emissions (opacity) peaked at a 12% reading. The emission rate for phenols was measured at 0.17 lb./hr. Allowable phenol limits for this flue gas were not previously established. The CO emissions were high, signifying a less than desirable percent completeness of combustion.

A second test was conducted on May 25, 1983, for a fuel mix of 60% hogged railroad ties and 40% untreated bark and sawdust (by Btu value). A redesigned overdraft air

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[1] "Permitting a Wood-burning Boiler in a Major Metropolitan Area", Foster, Kathye L., and Scherr, R.C., Control Technology News, August 1982, p. 872f

system and carbon monoxide analyzer unit were added in this test to improve combustion and to reduce and monitor the reduction of carbon monoxide emissions. Particulate emissions fell to 0.023 lbs. per million Btu of input. CO stack emissions ranged from 191 - 249 ppm, depending on moisture content. Hydrocarbons and simple phenolic compounds were not detected. Aldehyde and benzene concentrations were reported to be quite low. The Wisconsin Department of Natural Resources believes that the results of this test are satisfactory enough to permit the French Island plant to burn a mix of up to 80 percent cross ties.

On August 27, 1981 G and S Mills in Massachusetts tested a wood burning furnace burning cross ties that had been cut in half. The furnace burned 100 lbs. of ties per hour for 3 1/2 hours. The stack emissions were in compliance with the air pollution regulations in most states. The particulate emissions averaged .321 lb. per million Btu input which is not in compliance with the regulations in Massachusetts.

In addition to the recent tests sited above, data is available from a test conducted in 1975 at the York-Shipley plant in York, Pennsylvania. A fluidized bed incinerator with a capacity of 751 pounds of cross ties per hour was tested. The incinerator flue gas was routed through a multiple pass heat recovery boiler. The stack emissions were in compliance with the environmental regulations in effect at the time of the test with the exception of the particulate emissions which were measured at one lb. per million Btu input. The ash content of ties is higher than the ash content of clean untreated wood and the fly ash collector proved to be incapable of handling these large quantities of ash.[1]

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[1] "The Disposal of Discarded Railroad Wood Cross ties - A Study of Alternatives," A. Jay Dolby, AAR, Washington, DC., December 1975

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR)

State	Summary of Regulations
Alabama	* For existing facility: need scrubber or electrostatic precipitator -testing would not be required for railroad ties For new facility: * C&O permit would be required * Emissions: 0.1 grains particulates; 20% opacity * Bact needed for > 250 tons/year of any one pollutant
Alaska	* Emissions: for wood burners > 50 mmBtu/hr.: 0.15 grains particulates; 30% opacity * C&O permits needed: may require extensive testing (stack test, monitoring equipment, emissions standards, volatile organic compounds) * Must comply with federal PSD standards for > 250 tons/year of pollutants
Arizona	* Emissions: 0.2 grains particulates; 20% opacity * C&O permits required for new facility; must submit drawings and specs.; must investigate 1st time operations; may require stack test or test results from a similar burn
Arkansas	* C&O permits required for new facility * Emissions: 0.3 grains particulates for < 200 lb./hr.; 0.2 grains particulates for > 200 lb./hr.; 20% opacity
California	* Emissions: 0.1 grains particulate; 20% opacity * C&O permits; bact, check offsets stack emissions; exemptions for cogeneration facilities
Colorado	* Emissions: 0.1 grains particulate; 20% opacity * C&O permit; review plans and specs.
Connecticut	* Emissions: for wood fuel burning sources with energy recovery - 0.1 lb./mmBtu; for incinerators without heat recovery - 0.8 lb./mmBtu; 20% opacity; SO_2 - 1.1 lb./mmBtu (= 1% sulfur fuel) * C&O permits required; site study; emission rates and concentrations (ambient impact)
Delaware	* Normally allows "pathological" type incinerators, i.e., human, animal and organic wastes - must be studied case-by-case

* See index of abbreviations where necessary

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

<table>
<tr><th>State</th><th>Summary of Regulations</th></tr>
<tr><td>Delaware (cont'd)</td><td>* Emissions: 20% opacity; particulates:
<table>
<tr><th>Charg. Rate (lb./hr.)</th><th>Mass Emiss. Rate (lb./hr.)</th></tr>
<tr><td>100</td><td>0.2</td></tr>
<tr><td>200</td><td>0.4</td></tr>
<tr><td>300</td><td>0.6</td></tr>
<tr><td>400</td><td>0.8</td></tr>
<tr><td>500</td><td>1.0</td></tr>
<tr><td>1000</td><td>2.0</td></tr>
<tr><td>2000</td><td>3.5</td></tr>
<tr><td>3000</td><td>5.0</td></tr>
</table>
* Incinerators must have minimum operating temp. of 1400 degrees F</td></tr>
<tr><td>Florida</td><td>* C&O permits required for > 250 tons/year particulates
* Emissions: max. 20% opacity < 50 tons/day; 5% opacity > 50 tons/day</td></tr>
<tr><td>Georgia</td><td>* For < 8 mmBtu/hr. input, no permit required
* C&O permit required for > 8 mmBtu/hr.; review size; input; control equipment; site plan; multiple chambers; maintain 1500 degree F in secondary chamber; 1000 degree F in primary chamber
* Visible emissions: 20% opacity; < 50 tons/day; -0.1 grains particulates; > 50 tons/day - 0.0 grains particulates</td></tr>
<tr><td>Hawaii</td><td>* Not included in this study</td></tr>
<tr><td>Idaho</td><td>* Emissions: 0.2 grains particulates corrected to 8% CO_2; 20% opacity
* Construction permits required; bact; PSD determination</td></tr>
<tr><td>Illinois</td><td>* Emissions: existing site - 0.2 grains particulates; new site - 0.10 grains particulates < 2,000 lb./hr.; 0.07 grains particulates 2,000 - 60,000 lb./hr.; 0.05 grains particulates > 60,000 lb./hr.
* C&O permits; public hearing, meet zoning requirements</td></tr>
<tr><td>Indiana</td><td>* Emissions: for > 200 lb./hr. of charge, 0.3 lb. particulates per 1,000 lbs. of dry exhaust gas at standard conditions corrected to 50% excess air; opacity - 40% in attainment areas, 30% in non-attainment areas
* C&O permits required: < 25 tons/year - simple registration letter; > 25 tons/year - permit process: subject to "new source review", i.e., public participation and 30 day review period</td></tr>
</table>

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

State	Summary of Regulations
Iowa	* Emissions: 40% opacity; > 1,000 lbs./hr. - 0.20 grains particulates; < 1,000 lbs./hr. - 0.35 grains particulates * Need construction permit, but no operating permit * Need secondary combustion chamber control equipment, test results
Kansas	* Emissions: 20% opacity; < 200 lb./hr. - 0.3 grains; 200 to 20,000 lb./hr. - 0.2 grains; > 20,000 lb./hr. - 0.1 grains * C&O permits required: stack tests, meet emissions criteria, PSD review, limit operating hours, advise of capacity
Kentucky	* Emissions: 40% opacity (existing sources); 20% opacity (new facility); particulates: 500 lb./hr. to 50 tons/day - 0.1 grains; > 50 tons/day - 0.08 grains * C&O permits required; depending on size, may need public hearing, site study, PSD review (applies to major sources, i.e., > 100 tons/year of pollutants)
Louisiana	* Emissions: 20% opacity; 0.1 grains particulates * C&O permit required: performance tests, site study, multiple combustion chambers, test organic by-products
Maine	* Emissions: max. 0.3 lb. particulates per million Btu for > 150 million Btu/hr. * C&O permits: air emission license, site location study
Maryland	* Emissions: 0.03 grains particulate; 20% opacity in rural areas; zero opacity in metropolitan areas * For "specific by-product" incinerators, must have burning rate of 1 ton/hr., must burn 2 tons/day minimum
Massachusetts	* 0.1 grains particulate * 0.55 grains sulfur per million Btu * Construction permit; siting requirements; public hearing
Michigan	* Emissions: 20% opacity; particulates: 0.30 lbs. per 1,000 lb. stack gas corrected to 50% excess air * Must "demonstrate environmental acceptability" - health/welfare regulation - concerned about possible carcinogens from burning treated wood * C&O permits both required: stack tests; breakdown of air contaminants to show no adverse effects on public health

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

State	Summary of Regulations
Minnesota	* Emissions: for > 100 lb./hr. of charge, 0.1 grains particulates; 20% opacity (existing facility); 10% opacity (new-NSPS standards) * C&O permits both required: define construction characteristics; design capacity; type of mat'l; Btu input; chamber design; control tech.; review EP toxicity; particle sizing; analysis of heavy metals and SO_2
Mississippi	* Emissions: 0.2 grains particulates; annual emissions < 100 tons/year * Need construction application; test for organic by-products; PCB levels
Missouri	* Emissions: 0.2 grains particulate for > 200 lb./hr. (new); 0.3 grains particulate for < 200 lb./hr. (existing) * Construction, but not operating permit req'd: review design capacity, number of chambers, previous tests
Montana	* Emissions: 0.08 grains particulate > 50 tons/day; 0.10 grains particulate < 50 tons/day; 20% opacity * C&O permit: air quality permit required
Nebraska	* Emissions: for > 1 ton/hr. - 0.1 grains particulate and 20% opacity * C&O permits both required: description of unit; stack parameters; test data on similar units
Nevada	* Emissions: opacity must not exceed 20%; < 2,000 lb./hr. -3 lbs./ton particulates; < 2,000 lb./hr. - $E = 40.7 \times 10^{-5}C$, where C = rate of charge, lb./hr. E = allowable emissions in lbs./hr. * Limited hours of operation; must report yearly charging rate * Must be multi-chambered design * > 50 tons/day - NSPS applies; use bact
New Hampshire	* Emissions: 20% opacity; particulates: > 50 tons/day - 0.08 grains * C&O permits both required: appropriate particulate control; opacity monitoring; O_2, NO_x, CO monitoring; PSD review
New Jersey	* Emissions: 20% opacity; 0.1 grains particulate, including ash * Need C&O permits; case-by-case basis; check site selection; preservatives used

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

State	Summary of Regulations
New Mexico	* Emissions: 20% opacity; particulate limits only for > 50 tons/day - 0.08 grains * Construction permits required: for > 10 lb./hr. or 25 tons/year, must achieve complete combustion, primary and secondary chamber design
New York	* Emissions: opacity 20%; allowable particulates: $E = \frac{1.0}{P^{0.22}}$ where E = permissible emissions in lbs./mmBtu and P = total heat input in mmBtu's/hr. * C&O permits required: review size, location, terrain, diffusion analysis test
North Carolina	* Emissions: 0.2 lb./hr. particulates per 100 lb. of charge; 0.08 grains CO and volatile organic compounds * C&O permits: soils test, completeness of combustion, RCRA compliance
North Dakota	* Emissions: 20% opacity; particulates: input 50 lb./hr. -1.74 lb./hr.; 1000 lb./hr. - 2.40 lb./hr. $E = .0252R^{0.67}$ for > 1000 lb./hr. R = refuse burning rate (lb./hr.) E = emission rate (lb./hr.) * C&O permits both required: 1) review of similar performance tests, 2) control tech. depends on size
Ohio	* Emissions: for existing site 0.1 lb. particulate per 100 lbs. charge; 20% opacity * For new site more stringent requirements; C&O permits both required; if major source, PSD review, bact; if not a major source, need modeling, bact, public notice & hearing
Oklahoma	* Emissions: 20% opacity; particulates for new facility > 250 mmBtu/hr. input - 0.1 lbs./mmBtu * C&O permits both required: submit engineering data, review size, location, PSD requirements, stack data, fugitive dust control, bact
Oregon	* Emissions: 20% opacity; 0.05 grains particulates in non-attainment area; 0.10 grains particulates for rural or attainment area * C&O permits both required: must burn more than 30 million Btu/hr. (or > 25,000 lb. steam/hr.) in rural areas. For > 250 tons/year of emissions, must meet NSPS highest and best practical treatment and control required

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

State	Summary of Regulations
Pennsylvania	* Emissions: 20% opacity; 0.1 grains particulate * C&O permits called "plan approval" needed: use bact, study location, emissions, number of combustion chambers
Rhode Island	* Emissions: 20% opacity; particulates: < 2000 lb./hr. - .16 grains; > 2000 lb./hr. - .08 grains * Construction permits: incinerator design - need afterburners, must be multi-chambered, min. 1400 degrees F operating temp., review physical dimensions, method of loading, if > 250 tons/year, must comply with PSD regs. and bact, need AQI statement
South Carolina	* Emissions: 20% opacity; 0.516 per million Btu input particulates * No noxious odors * C&O permits both required: review of previous designs, review by licensed P.E.
South Dakota	* Emissions: 20% opacity; 0.3 lb./mmBtu particulates * C&O permits required: site study, stack tests, specify control tech., submit construction plan, show schematic of process
Tennessee	* Emissions: 20% opacity; particulates: max. 0.2% of charging rate for < 2000 lb./hr.; 0.1% > 2000 lb./hr. * C&O permits: PSD review, air quality monitoring, bact
Texas	* Emissions: 20% opacity; particulates based on gas outflow chart * C&O permits: state rates of discharge, frequency of operation, incinerator specs. and emissions
Utah	* Emissions: 20% opacity; particulates - 0.08 grains * bact, NSPS standards * Construction permits needed: submit plans and specs. for engineering review, 30 day public comment, volatile organic compounds
Vermont	* Emissions: opacity - constructed before 1970 - 40%, after 1970 - 20%...for no more than six minutes in 1 hour; particulates (mass emissions): built before 12-5-77 0.45 grains (> 90 HP), built after 12-5-77 -A) 90-1300 HP -0.20 grains; B) > 1300 HP - 0.10 grains * C&O permits required: PSD review in clean air areas, determine if major or minor source, if major (more stringent than federal standards), need bact review, determine effects on ground level air quality
Virginia	* Emissions: 20% opacity; 0.14 grains particulates * C&O permit required: NSPS review for > 250 mmBtu/hr., bact required on all new units, stack tests - submit data on similar units

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

State	Summary of Regulations
Washington	* Emissions: 20% opacity; 0.1 grains particulates * Need construction, but not operating permit: bact, notice of construction, public hearing
West Virginia	* Emissions: 20% opacity; 0.1 grains particulate * C&O permits both required plus solid waste permit: limitation of access to site, fully enclosed burning, submit design plans, assure adequate public health protection
Wisconsin	* Emissions: 0.5 lb. particulate per million Btu (new); 0.6 lb. particulate per million Btu (existing); ASME stack emission requirements * C&O permits both required; location and start-up, fuel and sulphur content, analysis of toxicity, completeness of description
Wyoming	* Emissions: 20% opacity; particulates: 0.2 lb. per 100 mmBtu input without heat recovery; 0.1 lb. per mmBtu input with heat recovery * C&O permits both required: estimate of emissions, stack test, modeling analysis, completeness of combustion of wood and creosote, size and location of unit

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

Province	Summary of Regulations
Alberta	* Emissions: maximum 40% opacity for 6 minutes in one hour; particulates - for wood waste burners in rural area, maximum 0.6 lbs. per 1,000 lbs. of effluent air, adjusted to 50% excess air in urban areas, maximum rate is 0.2 lbs. * C&O permits both required; must examine design, operation and efficiency of each unit
British Columbia	* Emissions: particulates - new unit, 0.1 grains/DSCF - existing unit, 0.2 grains/DSCF; opacity limit = É1, Ringelmann (20%) * C&O permits required; must examine emissions, ambient air quality, ash disposal plans, pollution control equipment
Manitoba	* Incinerator regulations are under review; currently: emissions: opacity limit is 40% for any one point in time, and not more than 20% for more than 4 minutes; 0.1 grains particulate limit * C&O permits both required for new facility under the "clean environment act", must: A) limit emissions as above, B) if within Winnipeg city limits, comply with city by-laws
New Brunswick	* Emissions: 500 milligrams/cubic meter particulate unit; 20% opacity (É1 Ringelmann) * C&O permits required; must obtain an "approval to construct"; conduct stack test within 90 days; use Canadian Standards Association materials and construction criteria, (similar to ASTM standards) as guidelines for new municipal incinerator installation
Newfoundland	* Emissions: no opacity criteria; particulate criteria - (point of impingement standards): 120 micrograms/cubic meter for a 24 hour period; 70 micrograms/cubic meter as a geometric mean * Operating permit required; must examine size of unit, location, maintenance procedures; must prove to the Dept. of Environment that the products of combustion would not pose a public health problem
Nova Scotia	* No specific particulate or opacity criteria; case-by-case review is required * Must have C&O permits (operating permit is important); permit requirements vary according to location
Ontario	* Emissions: general regulation for opacity - for any combustion process - 20% or É1 Ringelmann scale; particulates - point of impingement standard - maximum 100 mg/m^3* for any 1/2 hour period * Micrograms per cubic meter * C&O permits required for new facilities: give details of type and quantity of material to be burned, dimensions of stack, temperature of burn

TABLE II EMISSIONS REGULATIONS (STATIONARY INCINERATOR) (CONT'D)

Province	Summary of Regulations
Prince Edward Island	* A new incinerator would need to meet federal environmental protection service standards; particulates and opacity same as federal standards * Would need permit for "refuse" type incinerator
Quebec	* Emissions: general regulation for any combustion process - 20% opacity - 600 mg/nm^3 corrected to 12% CO_2 * Applications must be submitted
Saskatchewan	* No particulate or opacity criteria * Operating permit required: must examine design, operation and efficiency of each unit

MARKET ANALYSIS

The economic feasibility of burning wood wastes as an energy source is an option that is becoming increasingly attractive, especially for industries that generate their own wood waste materials. Public utilities that supply electrical power to metropolitan areas are also becoming users of wood fuels. Studies have indicated that switching to waste wood incineration and heat recovery is economically attractive for certain industrial and power plant applications if waste woods are available in sufficient quantities.

Wood burning boiler/incinerator systems are beginning to replace or supplement existing gas or oil fired units in situations where the cost of burning low Btu fuels is economically competitive with other forms of energy. The steam heat generated and recovered from burning these fuels may be used to satisfy space heating requirements, to supply process heat for various industrial applications, or to run a turbine to generate electricity. Recent environmental studies have confirmed the feasibility and acceptability of burning treated wood wastes such as shredded cross ties, either in combination with untreated waste wood or as a sole fuel source.

The market for sale of whole scrap ties and tie butts as fuel to existing wood burning facilities is currently very underdeveloped. Several problem areas must be more fully addressed before significant progress can be achieved in expanding this market. The major concerns include:

1.) Variability in the value of scrap ties as fuel from one location to another
2.) Ability of the railroads to make commitments to meet user supply requirements on a long term basis
3.) Collection and dissemination of accurate and up-to-date information on the environmental impacts of treated wood incineration and heat recovery
4.) Comparative economics of transport costs for on-line, off-line and company material moves.

The estimate of revenue that may be potentially generated from this disposal technique is based on an average price paid in 1983 for low Btu wood fuel. If revenue were calculated as if waste wood fuel were to replace conventional fuels such as oil or natural gas, which are much more expensive on cost per Btu basis, it would have a very positive effect on the net cost or profitability of this disposal scenario.

To initiate further investigations into the economics of this method, railroads might consider the test installation of a tie burning power plant for provision of process steam or space heating to a diesel shop, maintenance shop, or similar facility.

COST/TIE TO BURN AS FUEL

The tie butts are removed from the right-of-way and transported to the location of the incinerator according to the procedures described on p. 10. When the ties arrive at the incinerator, they are unloaded onto the ground, picked up and shredded, blown into a silo and fed into the incinerator as needed. The incinerator is assumed to operate 24 hours a day with an input of 19,200,000 Btu/hr.

Load Ties in Cars, Transport, Unload Ties

Operation 1 - Load tie butts (see Section 2.24).	\$3.58/tie
Operation 2 - Transport the tie butts to the incinerator (see Section 2.23).	.55/tie
Operation 3 - Unload the tie butts from the gondolas.	

Unloading crane	\$ 96/day
2 laborers	252/day
1 crane operator	137/day
1 foreman	144/day

Procedure: A small crane with a grapple unloads the ties onto the ground. Two laborers assist in unloading the ties. The foreman supervises the tie unloading as well as the shredding and incineration. Assume that the company incinerating the ties will be required to pay railroad maintenance-of-way union rates of pay. The unloading cost is highly dependent on the size of the facility since this operation can be made more efficient by purchasing special cars or car unloading systems.

$$\frac{\$96/\text{day} + \$144/\text{day} + \$137/\text{day} + (2 \times 126/\text{day})}{700 \text{ ties/day}} = \$.90/\text{tie}$$

Total Cost of Ties Delivered and Unloaded:

$$\$3.58/\text{tie} + \$.55/\text{tie} + \$.90/\text{tie} = \$5.03/\text{tie}$$

Shred Ties and Store in Silo

Operating Cost - Labor and Equipment

$$\frac{\$96/\text{day} + \$137/\text{day} + (2 \times \$126/\text{day})}{700 \text{ ties}} = \$.69/\text{tie}$$

Utility Cost - Electricity

$$\frac{(0.066/\text{KWH}^{1} \times 60 \text{ kw/hr.})}{100 \text{ ties/hr.}} = \$.04/\text{tie}$$

Maintenance Cost - Labor, Materials and Other

$$\frac{\$6790/\text{yr.}}{140{,}000 \text{ ties/yr. (incinerator capacity)}} = \$.05/\text{tie}$$

Annual Capital Recovery Cost

$$\text{Shredder } \frac{\$170{,}000 \times .2127}{\$140{,}000} = \$.26/\text{tie}$$

$$\text{Storage Silo } \frac{\$40{,}000 \times .2127}{\$140{,}000} = \$.06/\text{tie}$$

Total Cost of Shredding and Storage:

$.69 + $.04 + $.05 + $.26 + $.06 = $1.10/tie

Incinerate Ties and Recover Heat

1 incinerator/boiler unit (19,200,000)	$500,000
1 operator	$137/day

Procedure: Shredded wood is fed by auger from the storage silo into the incinerator and burned. The incinerator provides heat to operate the boiler. Assume the system operates 24 hours per day 365 days/yr. with an input capacity of 19,200,000 Btu/hr.

Incinerator Capacity

$$\frac{19{,}200{,}000 \text{ Btu/hr.}}{(6{,}356 \text{ Btu/hr. wet})(180 \text{ lb./tie})} = 16.8 \text{ ties/hr.} = 140{,}000 \text{ ties/yr.}$$

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[1] Commercial rate for electricity, Philadelphia, PA, 7/1/83

Operating Cost (Labor)

$$\frac{137/\text{day} \times 3 \text{ shifts/day} \times 365 \text{ days/yr.}}{140{,}000 \text{ ties/yr.}} = \$1.07/\text{tie}$$

Utility Cost - Electricity

$$\frac{123 \text{ kwh} \times \$.066/\text{kwh}}{16.8 \text{ ties/hr.}} = \$.48/\text{tie}$$

Maintenance Cost - Repairs and Cleaning

$$\frac{\$5{,}400/\text{yr.}}{140{,}000 \text{ ties/yr.}} = \$.04/\text{tie}$$

Annual Capital Recovery Cost

$$\frac{\$500{,}000 \times .2127}{140{,}000 \text{ ties/yr.}} = \$.76/\text{tie}$$

Total Incinerator/boiler Cost:

$$\$1.07 + \$.48 = \$.04 = \$.76 = \$2.35/\text{tie}$$

Total Cost of Energy From Ties
Used as a Fuel:

$$\$5.03 + \$1.10 + \$2.35 = \$8.48/\text{tie}$$

PRIVATE LANDFILL

ENVIRONMENTAL CONSIDERATIONS

In most states (37 of 49 surveyed)[1] a construction and/or operating permit is required to create a new landfill site on privately owned property. Five states review private landfill applications on a special case basis. Seven states (Alabama, Arkansas, Arizona, Florida, Nebraska, New Mexico, and Montana) do not require a permit. In all cases, landfills must be operated in a manner that will not create a public nuisance to schools, hospitals and residential or commercial areas.

Many states require completion of some of the following tasks prior to issuance of a construction and operating permit for a new landfill site. The more stringent states may require fulfillment of all of these conditions.

1.) Conduct a site study - investigate soils, geology, hydrology of proposed location; prepare a site contour map and plan view
2.) Investigate the effects of the fill on water quality (groundwater, surface runoff water balance), using groundwater monitoring wells or related test methods
3.) Define the size and boundaries of the fill site; indicate the proposed quantity of wastes to be buried
4.) Submit an operation plan - indicate excavation procedures, site access, method of progressive soil cover, liner and thickness specifications, fill closure and reclamation procedures, fencing standards for site boundaries, and the fill inspection schedule
5.) Demonstrate compliance with local solid waste, zoning and water quality regulations
6.) Submit lab analyses of leachates expected to emanate from the treated wood samples
7.) Provide evidence that the seasonal high water table level is at least five feet below the bottom of the disposal site (site must not be above an aquifer or on a flood plain)
8.) Locate the fill site a minimum of 75 feet (horizontal distance) from the nearest stream
9.) Provide diversionary drainage around the fill site
10.) Furnish a list of the equipment expected to be used at the fill site
11.) File an environmental impact statement
12.) Attend a public hearing

For a listing of permit requirements by state, see Table III.

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[1] See Table III

TABLE III PRIVATE LANDFILL

State	Summary of Regulations
Alabama	* Don't normally need permit; only if state has a problem with the site
Alaska	* Need permit - site study, investigate leachates and water quality
Arizona	* No permit if not a hazardous waste - state would like to be advised of landfill size and location
Arkansas	* No permit required (ties not normally disposed into landfills)
California	* Need permit - file environmental impact statement, land use description; must meet waste discharge and site requirements for local areas
Colorado	* Need permit: check surface drainage, fugitive dust, access to site
Connecticut	* Need solid waste permit for more than five tons per year; also need water discharge permit; concerned with leachates & water quality
Delaware	* Must prove to state that ties are not contaminated with PCB's before permit is issued
Florida	* No permit; "Disposal of one's own waste on one's own property from one's own activity" is permissible
Georgia	* Need permit: submit operational plan, indicate sequence and depth of fill
Hawaii	* Not included in this study
Idaho	* Need solid waste disposal permit: study of surface and groundwater migration, water balance
Illinois	* Need permit: hydrological/geological study, examine toxicities, pH, leachates, dust control, security measures
Indiana	* Permit required: "solid fill" landfill policy is not as stringent as sanitary fill; need set of plans, schematic and narrative of operation, local zoning compliance
Iowa	* Need "construction and demolition" permit - submit excavation and fill procedures; closure of fill
Kansas	* Don't need permit if demonstrated that creosote would not contaminate groundwater

TABLE III PRIVATE LANDFILL (CONT'D)

State	Summary of Regulations
Kentucky	* Special case review basis
Louisiana	* Need solid waste permit, including water quality review
Maine	* Need permit: subsurface investigation; must not be on aquifer or flood plain
Maryland	* Industrial waste permit required: requirements not as stringent as for sanitary landfill permit; subject to local approval
Massachusetts	* Permit required: must be approved by a city or town board of health; not likely to approve RR ties in new landfill
Michigan	* Need permit: quantity, location, soils and geological evaluation, analysis of leachates, comply with county solid waste management plans
Minnesota	* Must go through "co-disposal permitting program"; treated wood must be reviewed by an approved lab and by state staff
Mississippi	* Need permit: site selection/geological study
Missouri	* Need permit: "demolition landfill", site plans, location and contour maps, surface water diversions, progression of fill, closure of fill
Montana	* No regs. for private property
Nebraska	* Special case review
Nevada	* Apply for a special sanitary landfill permit - must have four feet of native soil between bottom of pit and high groundwater level
New Hampshire	* Permit needed: groundwater protection (site specific); guideline of six feet above seasonal high groundwater, 75 feet from nearest stream; groundwater and drinking quality at boundary of site considered
New Jersey	* Need permit (registration statement); site review, file environ. health & impact statement
New Mexico	* No permit required
New York	* Depends on creosote content - must demonstrate that groundwater is not affected, then would get a permit

TABLE III PRIVATE LANDFILL (CONT'D)

State	Summary of Regulations
North Carolina	* Need "demolition site" permit; determination of quantity to be disposed
North Dakota	* Would need permit; must know quantity, soils and geological site conditions
Ohio	* Need permit - classed as "demolition material" - site study, operation plan, closure of fill
Oklahoma	* Must be permitted as "other industrial waste"; examine groundwater pollution from leachates
Oregon	* Need "land use clearance" permit; submit plans, soil and groundwater studies, leachate tests
Pennsylvania	* Need permit - geological/soils analysis, leachate collection and testing; must have monitoring well below and above fill; public nuisance and public health review
Rhode Island	* Need permit: submit engineering plans and operating plans, conservation easement, groundwater studies
South Carolina	* State must be advised of intent to bury; examine groundwater and surface runoff
South Dakota	* Can be buried without a permit, but must be reviewed by state for water quality
Tennessee	* Need permit - geological evaluation, public notice, site boundary and operating plans, drainage study
Texas	* Need permit for hazardous waste: EPA procedures, liner type and thickness specs.
Utah	* Need solid waste permit - site study, daily or weekly covering, operation plan
Vermont	* Need permit - examine groundwater table, horizontal distance from streams, access, closure, 10 feet minimum distance from bottom of pit to high groundwater level
Virginia	* Classed as demolition debris - need permit - must be buried in an accessible area; separation between water table and waste (optimally 5 feet); diversionary drainage; progressive soil cover; operation plan; statement of equipment and personnel on site; closure plan

TABLE III PRIVATE LANDFILL (CONT'D)

State	Summary of Regulations
Washington	* No state level regs.; comply with local solid waste regs. (locality, toxicity)
West Virginia	* Need permit - class 3 inert waste - site evaluation (soils and geology, hydrology), detailed construction and operating plans
Wisconsin	* Need license: site plan, soil and groundwater analysis, excavation review, public hearing, plan of operation, on-site inspections
Wyoming	* Need permit: description and map of area, soils and geology of site; operation plan; site reclamation plan

TABLE III PRIVATE LANDFILL (CONT'D)

Province	Summary of Regulations
Alberta	* Approval is required; have received no requests to date; would investigate on a case-by-case basis
British Columbia	* Regulated by federal government on railroad right-of-way
Manitoba	* Permit required
New Brunswick	* Permit required
Newfoundland	* Not allowed; a licensed landfill would be required
Nova Scotia	* Method not used; the province has had no problems
Ontario	* Regulated by the federal government on railroad right-of-way; if a landfill is a problem, they complain to the federal authorities
Prince Edward Island	* Not regulated by the province
Quebec	* Regulated by the federal government on railroad right-of-way, but must also comply with provincial regulations
Saskatchewan	* Not regulated by the province

COST/TIE FOR LANDFILL DISPOSAL SMALL SITE ON RIGHT-OF-WAY

Operation 1 - Remove tie butts from the right-of-way. The operation, procedure and cost for removing the tie butts from the right-of-way is the same as given on p. 10.

Total Handling Cost/Tie: $3.58/tie

Operation 2 - Place ties in landfill.

1 unloading crane	$115/day
1 crane operator	$137/day
2 laborers	$252/day
1 dozer operator	$137/day
1 dozer	$173/day

Procedure: Ties are unloaded out of the gondolas directly into the landfill site which has been excavated by the dozer. Using the dozer, they are distributed in the landfill. Cover material is then placed on top of the fill site and graded. The cost is based on cover material being available from material removed when the site was excavated. Assume favorable soil conditions, i.e., no ripping or blasting of rock required.

Cost:

$$\frac{\$115 + \$137 + \$252 + \$137 + \$173}{360 \text{ ties/day}} = \$2.26\text{/tie}$$

Total Cost/Tie for Landfill Disposal:

$$\$3.58\text{/tie} + \$2.26\text{/tie} = \$5.84\text{/tie}$$

The costs developed in this section do not take into account the additional expenses that may be incurred in obtaining landfill permits. Given the recent trend toward increased state regulatory control of the creation of new disposal sites, it is likely that in some cases these additional costs will be prohibitive. Often, permitting procedures are lengthy and complex, requiring a great deal of time and research effort to complete.

COST/TIE FOR LANDFILL DISPOSAL - LARGE SITE

The tie butts are removed from the right-of-way and transported to a "highly engineered" disposal site.

Procedure: Engineering studies are conducted and the site is designed including groundwater monitoring, leachate collection, use of liners, daily cover and a site closure plan. Assume a 20 acre site, 40 feet deep, where 75% volume utilization is achieved. This site, if used exclusively for cross ties, will hold 632,323 tons or 7,025,807 ties.

Operation 1 - Load tie butts (see Section 2.24). = $3.58/tie
Operation 2 - Transport the tie butts to the landfill (see Section 2.23). = $.55/tie
Operation 3 - Unload the tie butts from the gondolas (see Section 2.23). = $.90/tie
Operation 4 - Landfill ties.

$$\frac{\$11.12/\text{ton}[1] \times 632{,}323\ \text{tons}}{7{,}025{,}807\ \text{ties}} = \$1.00/\text{tie}$$

Total Cost to Landfill (Large Site):

$3.58/tie + $.55/tie + $.90/tie + $1.00/tie = $6.03/tie

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[1] Source - WI Dept. of Natural Resources - Solid Waste Division includes capital, operation and maintenance costs of landfill

OPEN BURNING

ENVIRONMENTAL CONSIDERATIONS

The practice of open burning for the disposal of used railroad ties is generally regarded by state environmental protection offices as undesirable. Of the 49 states surveyed,[1] 27 states reported specific prohibitions on the open burning of scrap railroad ties. Twenty-two states will permit open burning of scrap ties on a conditional basis. Conditions vary widely, but may typically include several of the following factors:

1.) Must demonstrate opacity compliance
2.) Must burn in rural areas
3.) Must burn during favorable meteorological conditions
4.) Must burn during daylight hours
5.) Must comply with local fire laws
6.) Must burn material originating on the premises
7.) Must burn a minimum specified distance from nearest residence or public facility
8.) Must not constitute a public nuisance or hazard
9.) Must prove no other viable disposal method is available

No state permits free and unconditional open burning for disposal of this type of waste.

Ground level open burning of railroad ties can be affected by many variables, including wind, temperature of the surrounding air, moisture content of ties and tie butts and compactness of the pile. Generally, the relatively low temperatures associated with open burning increase the emission of particulates, carbon monoxide and hydrocarbons and reduce the emission of nitrogen oxides. Sulfur oxide emissions are directly proportional to sulfur content of the refuse, and are usually negligible for scrap cross ties. EPA emission factors for open burning of wood refuse are presented below.[2]

Pollutant	lb./ton	lb./tie*
Particulates	17	1.53
Carbon Monoxide (CO)	50	4.50

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[1] See Table IV

[2] "Compilation of Air Pollutant Emission Factors" - Second Edition, U.S. Environmental Protection Agency

Pollutant	lb./ton	lb./tie*
Hydrocarbons (CH_4)	4	0.36
Nitrogen Oxides	2	0.18
Sulfur Oxides	Neg.	Neg.

* Calculated based on EPA emission factors
Assume average wt. of scrap tie = 180 lbs.

Open burning is widely regarded as a public nuisance with numerous drawbacks, particularly the production of offensive odors and dense smoke, the emission of incompletely combusted wastes and the creation of a fire hazard. Regulations at the county and city levels are typically even more stringent than at state levels.

Ironically, despite apparently overwhelming disapproval for open burning at the state and local levels, 17.8% of all secondhand cross ties removed from track in 1980 were reported by area to have been burned in the open. It is likely that the railroads conducted much of this activity in geographically remote areas. Furthermore, ties and tie butts are often gathered and burned by track men to create warming fires during cold weather months. The current trend toward progressively tighter regulation of this disposal method will undoubtedly reduce the number of ties burned in future years.

The State of Maine, Department of Environmental Protection has recently entered into a formal agreement with the Maine Central Railroad Company, known as the "Joint Memorandum of Understanding". Public hearings were held to revise the existing state regulations prohibiting the open burning of creosote-impregnated objects. Both parties agreed to enter into a five year scrap tie disposal study, beginning in 1983, which will address environmental and economic impacts of open burning as well as all other disposal methods currently available. Other methods include, but are not limited to, burial or landfill, sale to private contractors, incineration (hogged, chipped or whole), or a combination of the foregoing. Other Maine railroads are invited, but not compelled, to participate in the study.

Specific goals of the Maine open burning program include the following:

1.) Laboratory analysis - railroads will report to the Maine Department of Environmental Protection (DEP) the details of lab analyses of the actual combustion products resulting from the open burning of scrap ties. The Maine Central Railroad Company had burn tests conducted during the latter part of 1983. The used ties were burned in a 55 gallon drum with a hood and stack arrangement to facilitate sampling. The emissions were analyzed for toxic semivolatile organic compounds and the results were compared with results from a similar burn using red oak firewood and a burn using new ties[1].

2) Air monitoring study - the DEP and the railroads will determine the impact of open burning of scrap ties on air quality
3) Alternate disposal methods - the railroads will assess the following methods of scrap tie disposal in a report to the DEP:
    a. Sale of ties for landscaping
    b. Sale to private contractors
    c. Use as fuel for industrial boilers or incinerators
    d. Burial along the right-of-way
    e. Landfill in municipal solid waste facilities
    f. A combination of the aforementioned
4) Interim open burning - a limited amount of open burning may take place during the study period, under the following conditions:
    a. A permit must be obtained from DEP
    b. Burning must take place in a rural setting, more than 1,000 feet from the nearest residence
    c. Burning hours shall be 9 AM to 4 PM only
    d. No more than 50 ties may be burned in any pile at any one time
    e. Burning activity shall cease upon the receipt or knowledge of any formal complaints.

In July 1983 the Minnesota Pollution Control Agency, in cooperation with the Burlington Northern Railroad, conducted tests to determine emissions from open burning of cross ties. An air sampling study was designed to measure extractable organic matter and polycyclic organic matter (POM). POM is a large group of chemicals formed from two or more benzene rings. Core samples of the test cross ties were analyzed for pentachlorophenol (PCP) and polychlorinated biphenol (PCB), and ash samples were leach tested for these materials and heavy metals. The purpose for the tests was to establish

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[1] "Potential Emissions From Open Burning of Railroad Ties", E.C. Jordan Co., Portland, ME, March 2, 1984

data on open burning emissions from which a health assessment of exposure to the smoke could be performed.

High volume particulate air samplers were situated at various locations so as to get an idea of the downwind, crosswind, and vertical variation in pollutant concentration in order to develop approximate emission factors. Test burns were set up to simulate typical railroad burning practices. A burn of raw, green wood was conducted for comparison purposes.

Results of the tests show that high total suspended particulate (TSP) concentrations (552-1062 mgm^3) above background are experienced downwind of all test conditions. Similar cyclohexane extractable fractions were found at levels of 85-150 mg/m^3.

Ash samples were subjected to the EPA EP Toxicity Test. All samples were found to be within the interim levels of ten times the primary drinking water standards.[1]

The following data is taken from the report and summarizes the emission test results:

Parameter/burn number	1	2	3	4	5
material burned	ties	ties	ties	ties	ties
date of burn	7/6/83	7/7/83	7/7/83	7/13/83	7/13/83
sample time	2 hours	2 hours	1 hour	1 hour	1 hour
sampler location	hi cent.	lo cent.	lo cent.	hi cent.	lo cent.
TSP, micrograms per cubic meter (mg/m^3)	675	953	991	1219	709
TSP above background, mg/m^3	591	777	806	1062	552
Cyclohexane extract, mg/m^3	85	136	150	110	NA
Benzo (a) pyrene, nanograms per cubic meter, (ng/m^3)	*	650	10	490	280
Benzo (a) anthracene, ng/m^3	-	1200	NQ	930	860
Crysene, ng/m^3	*	140	NQ	-	660

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[1] Railroad Tie Disposal Report by Minnesota Pollution Control Agency Staff, August 15, 1983

Parameter/burn number	1	2	3	4	5
Dibenzanthrecene, ng/m^3	*	240	NQ	370	330
O-Phenylenepyrene, ng/m^3	*	60	NQ	150	70

* Sample submitted for re-analysis

NQ Below quantification limit

TABLE IV OPEN BURNING

State	Summary of Regulations
Alabama	* Treated railroad ties not permitted to be burned
Alaska	* Would require permit: one-time only basis, if allowed at all; must be no other alternatives; must be best available technique; must burn cleanly
Arizona	* Prohibited for treated railroad ties
Arkansas	* Must have permit: need to demonstrate emissions compliance, not a public nuisance, and no other viable means to dispose
California	* No state regs.; regulated locally
Colorado	* Prohibited
Connecticut	* Permission to burn depends on air quality control regions, i.e., attainment vs. non-attainment; railroad ties not favorably regarded; permits issued for a one-day period
Delaware	* Permitted for burning of wood products if site is suitable; must file application stating location and type of material to be burned; must be between 8 AM and 6 PM in summer, 10 AM and 4 PM in winter
Florida	* Prohibited for railroad ties
Georgia	* Generally not permitted - depends on location (certain counties)
Hawaii	* Not included in this study
Idaho	* Not permitted for treated timbers in non-attainment areas
Illinois	* Prohibited for railroad ties
Indiana	* Not permitted
Iowa	* Prohibited
Kansas	* Generally prohibited; may approve railroad ties on limited basis in rural areas
Kentucky	* Prohibited in cities of more than 8,000 population (non-attainment areas), no permit required in rural area (less than 8,000 population), but must notify regional air pollution office of intent to burn
Louisiana	* Prohibited for railroad ties

TABLE IV OPEN BURNING (CONT'D)

State	Summary of Regulations
Maine	* Currently not permitted; will be permissible under certain conditions when railroads and dept. of environmental protection sign "memorandum of understanding"
Maryland	* Not permitted in Baltimore and Washington areas: regs. enforced by county health departments; need county permits, rural areas - permit requirements: 1) no practical disposal alternative; 2) meet local fire laws; 3) material must originate on premises; 4) dense smoke prohibited; 5) min. 1,500 ft. from nearest structure or heavily traveled highway
Massachusetts	* Prohibited
Michigan	* Railroad ties prohibited
Minnesota	* Opposed to issuing permits for burning of railroad ties: can obtain permit if proven that other disposal methods are an economic burden
Mississippi	* Permitted on case-by-case basis; must determine if fire hazard; must be 500 yards from nearest residence
Missouri	* Prohibited for railroad ties
Montana	* Prohibited for railroad ties
Nebraska	* Not permitted for railroad ties
Nevada	* Only permitted in spring and fall for two-week period; railroad ties discouraged
New Hampshire	* Not permitted
New Jersey	* Case-by-case basis; must be "only viable disposal method"; prohibited for cross ties
New Mexico	* Not permitted for railroad ties, except if can't be disposed of by any other method
New York	* Prohibited for railroad ties
North Carolina	* Prohibited for cross ties
North Dakota	* Permitted during daylight hours, favorable meteorological conditions, one mile minimum distance from nearest airport

TABLE IV OPEN BURNING (CONT'D)

State	Summary of Regulations
Ohio	* Could be permitted in rural areas - must be burned between 10 AM and 4 PM; days of burning depend on local air quality
Oklahoma	* Prohibited for railroad ties
Oregon	* Prohibited for railroad ties
Pennsylvania	* Prohibited in "air basins" (Philadelphia and Pittsburgh); in rural areas smoke can't drift beyond owner's property limits
Rhode Island	* Prohibited
South Carolina	* Prohibited
South Dakota	* Prohibited, except for rural areas (no permit required)
Tennessee	* Would possibly permit on an interim basis
Texas	* Prohibited
Utah	* Prohibited for railroad ties
Vermont	* No open burning permitted
Virginia	* Not permitted
Washington	* Permitted on case-by-case basis; normally permitted for one-time burning
West Virginia	* Not permitted for railroad ties - classed as open dump, which is prohibited
Wisconsin	* Case-by-case basis, or where "best and only way" to dispose; must burn before fire season
Wyoming	* Prohibited for railroad ties

TABLE IV OPEN BURNING (CONT'D)

Province	Summary of Regulations
Alberta	* Not allowed without written approval; each year each railroad applies to burn a certain number of ties; each year each railroad must achieve at least a 10% reduction in the number of ties burned the year before
British Columbia	* A permit is required
Manitoba	* Railroads can burn ties on their own property except within the city limits of Winnipeg
New Brunswick	* Permit is required; this method is discouraged, but it is still approved in remote areas; New Brunswick is having problems with railroads using this disposal method
Newfoundland	* Not allowed; Newfoundland is having problems with railroads using this disposal method
Nova Scotia	* Requests to use this method are reviewed on a case-by-case basis; open burning is allowed outside populated areas; Nova Scotia has had only one or two problems with open burning
Ontario	* Open burning on the railroad right-of-way is regulated by the federal government; it is discouraged by the province, and if a problem occurs, they complain to the federal authorities
Prince Edward Island	* This method is not used, and therefore not regulated; ties are given away
Quebec	* Must have permit to burn; permits are not issued during the summer months
Saskatchewan	* No formal permit process; permission is required; allowed only in rural areas

COST/TIE FOR OPEN BURNING

Operation 1 - Stack tie butts in piles along the right-of-way

1 tie handler, 2 push cars	\$96/day
2 track laborers	\$126/day each
1 operator	\$137/day
1 foreman	\$144/day

Procedure: The tie handler moves down the track loading the tie butts on the push cars. The ties are unloaded in a pile at a suitable location and ignited by the trackmen.

$$\frac{\$144/\text{day} + \$96/\text{day} + 2 \times \$126/\text{day} + \$137/\text{day}}{725 \text{ ties/day}} \quad = \quad \$.87/\text{tie}$$

AIR CURTAIN DESTRUCTOR

ENVIRONMENTAL CONSIDERATIONS

An air curtain destructor (Figure 1) is a set of machinery averaging 40 feet in length, designed to feed forced air over an enclosed mass of burning biomass wastes. The enclosure consists of a modularly constructed combustion chamber lined with high density refractory tiles. A high volume air handling unit, consisting of a blower, feeder pipe, and plenum, delivers a controlled amount of air at high velocity across the length of the chamber. The unit may be powered by an electric, gasoline or diesel motor.

Air curtain destructors are designed primarily for stationary installations. Units are top loading and can be placed in ground or above ground. A site study and analysis of soil conditions is required prior to in ground placement. Normally, one week is required for construction time and set-up, using a machine operator and three laborers. Units may be relocated by re-casting and inserting new concrete footings. Designers are currently investigating the concept of a fully portable unit; however, mobile destructors are presently not available on the market.

The use of the air curtain destructor is generally regarded by state environmental agencies as slightly more desirable than the open burning technique for cross tie disposal. Ten states will issue permits for their operation; nineteen states permit them to be set up on a conditional basis. Ten states explicitly prohibit the use of air curtain destructors for burning treated ties. Ten other states have no applicable regulations either restricting or permitting their use, and would review applications for their operation on a case-by-case basis. Many states require some of the following conditions to be satisfied prior to issuance of a permit for set-up and operation of an air curtain destructor:

1.) Compliance with state and local emissions criteria for particulates and opacity
2.) Determine if any volatile organic compounds are present
3.) Compliance with minimum distance restrictions from nearest residence
4.) Notification of time and place of burn; if mobile, time and place of movement
5.) Limitation of burning to daytime hours during favorable meteorological and air quality conditions
6.) Preference for use in rural areas
7.) Compliance with solid waste and zoning regulations (state and local)
8.) Demonstration that no other disposal method is viable

9.) Use of approved equipment, operating technique, and qualified personnel

10.) Evidence of high percent completeness of combustion of preservative compounds

Table V summarizes the regulatory procedures for each state.

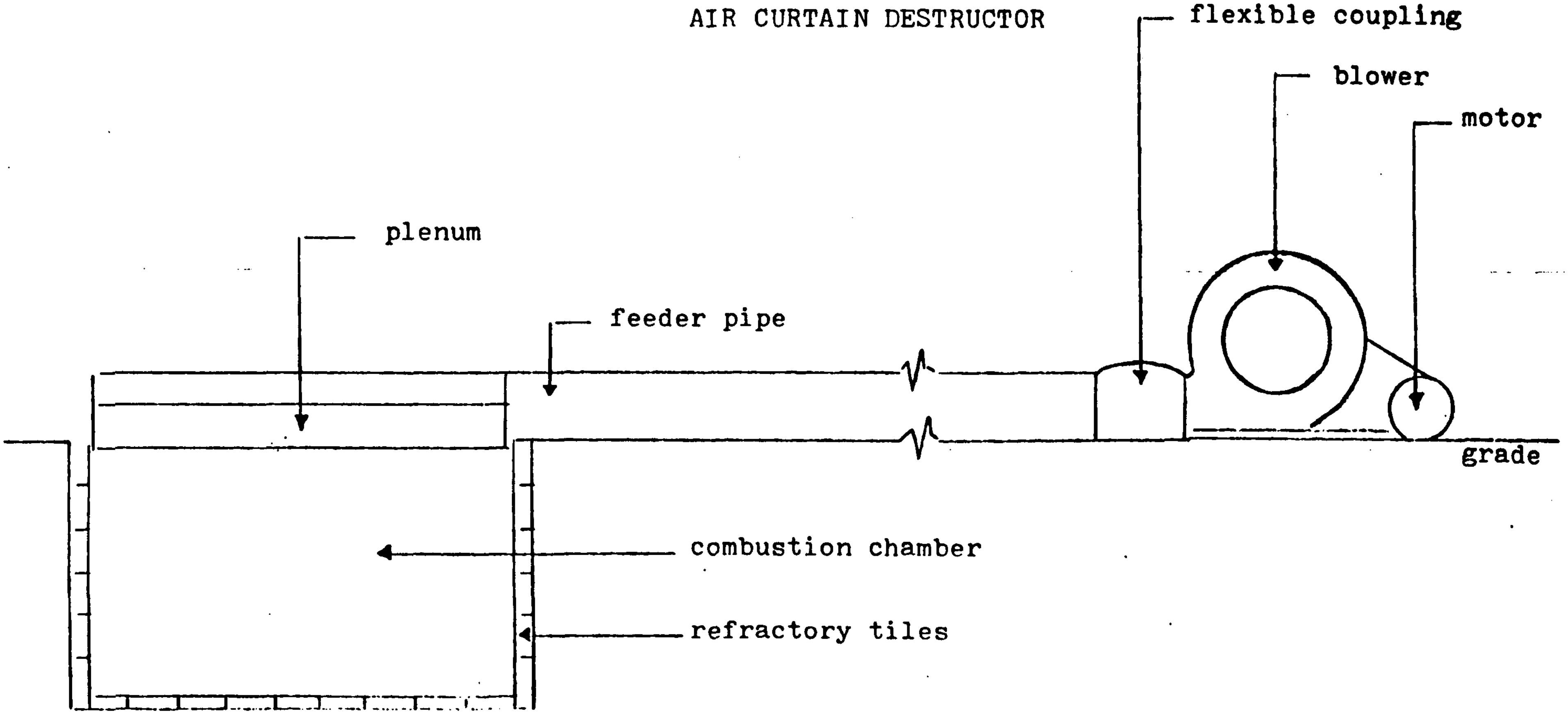

FIGURE 1 AIR CURTAIN DESTRUCTOR

TABLE V AIR CURTAIN DESTRUCTOR

State	Summary of Regulations
Alabama	* Not permitted
Alaska	* Tests have shown ACD's to be inadequate - would have to apply for approval of use
Arizona	* Tests have shown ACD's to be inadequate - would have to apply for approval of use
Arkansas	* Subject to agency review - have been recommended for land clearing purposes - must examine volatile compounds
California	* Prohibited
Colorado	* Normally not permitted
Connecticut	* No regulations
Delaware	* No specific regulations
Florida	* Permit required; site specific, subject to local zoning
Georgia	* Only permitted for clean-up around destruction sites; must be mobile - their use is generally discouraged
Hawaii	* No pertinent regulations
Idaho	* Permitted for "bulky wastes", provided less than 20% opacity and more than 500 feet from any residence
Illinois	* Prohibited for railroad ties
Indiana	* Discourages their use except for large land clearing operations. Might be considered for railroad ties; subject to review
Iowa	* Prohibited
Kansas	* Treated as open burning: permitted for land clearing - must make application for exemption from open burning regs.
Kentucky	* No specific regs.
Louisiana	* Would probably be permitted for railroad ties - don't need permit, but must inform state of intent to burn
Maine	* No specific regs.

TABLE V AIR CURTAIN DESTRUCTOR (CONT'D)

State	Summary of Regulations
Maryland	* No specific permit required for ACD treated as an open fire (see open burning regs.)
Massachusetts	* Prohibited
Michigan	* Railroad ties prohibited
Minnesota	* No regs.
Mississippi	* No regs.
Missouri	* No regs.
Montana	* Must review - concerned with combustion of preservatives
Nebraska	* Practice not encouraged; case-by-case basis
Nevada	* No regs.
New Hampshire	* Not permitted
New Jersey	* Permit required - case-by-case basis based on incineration codes and stack emissions criteria, must achieve high percent completeness of combustion
New Mexico	* Can burn ties if opacity does not exceed 20% after start-up
New York	* Prohibited for railroad ties
North Carolina	* Permit required: study site selection, opacity and stack emissions
North Dakota	* Preferred to open burning; must burn during daylight hours and favorable weather conditions; must be one mile from nearest airport
Ohio	* Could be permitted in rural areas; must burn between 10 AM and 4 PM; must check ambient air quality before burning
Oklahoma	* Permissible - must obtain C&O permit: submit design and state measures taken to preserve air quality; observe smoke emissions
Oregon	* The practice is discouraged, but not prohibited - need letter of approval and special case review
Pennsylvania	* Permitted for native vegetation; must approve site and equipment selection

TABLE V AIR CURTAIN DESTRUCTOR (CONT'D)

State	Summary of Regulations
Rhode Island	* No specific regs.
South Carolina	* If opacity criteria of 20% is met, can use ACD; need permit; must not emit visible particles falling outside property limits
South Dakota	* Permitted only at landfills; source must be in compliance with air and solid regs.; need solid waste permit
Tennessee	* Need permit - 20% opacity compliance, review pit design and siting criteria for city areas
Texas	* Must first be reviewed
Utah	* Permit needed: examine quantities, location, time of year, dispersion characteristics of air
Vermont	* Not permitted
Virginia	* Permitted on site specific basis (attainment areas only); must meet air ambient standards
Washington	* Permit required: must meet opacity (20%) and particulate (0.1 grains) criteria
West Virginia	* Permitted - must designate hours of operation; 500 feet minimum distance from residence
Wisconsin	* No regs.
Wyoming	* Permitted on case-by-case review; must be in public interest; there must be no other disposal means available; specific hours of operation, location

TABLE V AIR CURTAIN DESTRUCTOR (CONT'D)

Province	Summary of Regulations
Alberta	* Not allowed; the province observed tests of this method and disapproved it
British Columbia	* A permit is required
Manitoba	* A permit is required
New Brunswick	* Requires a permit; not permitted in highly populated areas
Newfoundland	* None currently used; requests for permits would be considered; would be looking for sufficient emission control
Nova Scotia	* This method is not currently used; would require a permit
Ontario	* Regulated by the federal government on the railroad right-of-way; if a unit were a problem, they would complain to the federal authorities
Prince Edward Island	* Air curtain destructors are not used, and therefore not regulated
Quebec	* Not regulated
Saskatchewan	* Permit required

COST/TIE FOR AIR CURTAIN DESTRUCTOR

The tie butts are removed from the right-of-way, transported to a stationary air curtain destructor and unloaded.

Operation 1 - Remove from right-of-way	$3.58
Operation 2 - Transport to incineration site	.55
Operation 3 - Unload tie butts (See Sect. 2.33).	.90
Total Handling Cost:	$5.03/tie

Operation 4 - Burn ties in Air Curtain Destructor.

Air Curtain Destructor

1 tie crane	$115/day
1 operator	$137/day
2 laborers	$252/day

Procedure: The tie crane feeds the ties into the stationary refractory lined combustion chamber. The ties are control burned under a curtain of forced air. Ash is removed weekly with a front end loader and trucked to a fill site. The unit operates for 200 days/year.

Production rates:		ties/year
20' unit: 7 tons/hr. x 6 hrs./day x 200 days/yr. x 11 ties/ton	=	92,400
30' unit: 10 tons/hr. x 6 hrs./day x 200 days/yr. x 11 ties/ton	=	132,000
40' unit: 15 tons/hr. x 6 hrs./day x 200 days/yr. x 11 ties/ton	=	198,000

Labor and Equipment		Annual Costs ($)
($137/day + $252/day + $115/day) x 200 days/yr.	=	100,800
Electricity		
20' unit: 23 kw/hr. x 0.16/kwh x 8 hrs./day x 200 days/year	=	5,888

30' unit: 30 kw/hr. x 0.16 kwh x 8 hrs./day x 200 days/year = 7,680

40' unit: 37 kw/hr. x 0.16/kwh x 8 hrs./day x 200 days/year = 9,472

Maintenance (including ash removal)

20' unit	2,000
30' unit	2,500
40' unit	3,000

Capital Costs (including ACD and Combustion Chamber and Site Preparation)

20' unit	66,200
30' unit	83,680
40' unit	106,575

Salvage Value (12 year life)

20' unit	2,000
30' unit	3,000
40' unit	4,000

Annual Capital Recovery Costs

20' unit ($66,200 - $2,000) (.2127) = 13,655

30' unit ($83,680 - $3,000) (.2127) = 17,161

40' unit ($106,575 - $4,000) (.2127) = 21,818

	cost/tie ($)		
Summary of Costs	20'	30'	40'
Labor and Equipment			
20' unit: 120,800 / 92,400	1.09		
30' unit: 100,800 / 132,000		.76	
40' unit: 100,800 / 198,000			.51
Electricity			
20' unit: 5,888 / 92,400	.06		
30' unit: 7,680 / 132,000		.06	
40' unit: 9,472 / 198,000			.05

	cost/tie ($)		
Summary of Costs (Cont'd)	20'	30'	40'
Maintenance			
20' unit: 2,000 / 92,400	.02		
30' unit: 2,500 / 132,000		.02	
40' unit: 3,000 / 198,000			.02
Annual Capital Recovery Cost			
20' unit: 13,655 / 92,400	.15		
30' unit: 17,161 / 132,000		.13	
40' unit: 21,818 / 198,000			.11
Total Cost to Burn:	1.32	97 .47	.69
Total Handling Cost:	5.03	5.03	5.03
Total Cost:	6.35	6.00	5.72

SHREDDING ALONG THE RIGHT-OF-WAY

ENVIRONMENTAL CONSIDERATIONS

Possible leachate contamination of ground and surface water along the right-of-way is the principal area of environmental concern for this disposal method. Twenty-one states have no specific regulations or provisions applicable to this procedure. Thirteen states indicated the need to treat shredding and dispersal on a case-by-case basis. Fifteen states would attempt to exercise some degree of regulatory control over the solid waste and water quality impacts of particle dispersal.

State regulatory bodies are interested in some of the following aspects:

1) Review of the placement of shredded ties (particle locations, demonstration of shredding and dispersal method)
2) Compliance with groundwater and surface water quality standards (leachate tests for non-point sources)
3) Compliance with local solid waste disposal regulations, particularly in urban areas
4) Investigation of the possibility of the presence of toxic contaminants
5) Investigation of the geology, elevation and boundaries of the proposed disposal areas.

Shredding and dispersal along the right-of-way has several disadvantages. Wood chips have a tendency to wash into ditches and other drainage structures during heavy rains. Chips tend to accumulate in areas of restricted flow and may merge with vegetation, debris, and other waste, clogging longitudinal and transverse track drainage. In dry areas, the probability of a fire starting along the right-of-way can be greatly enhanced.

In addition, because crosstie removed from track may be embedded with stones and spikes, tie plates, and anti-splitters can often be found in the wood, portable shedding equipment has been found to require frequent maintenance. Because of this problem, and those previously mentioned, few railroads are now using this equipment.

Table VI summarizes the regulatory procedures for each state.

TABLE VI SHREDDING ALONG THE RIGHT-OF-WAY

State	Summary of Regulations
Alabama	* Will generally control non-point sources, but not concerned about shredded ties
Alaska	* No regulations - not concerned about contamination of groundwater, unless runoff violated water quality standards - would want to review the placement of shredded ties, but no testing necessary
Arizona	* Have ground and surface water standards, but this application would not present a problem
Arkansas	* No current provisions
California	* Regulated: monitor leachates, check geology of site; shredding and disposal treated as special case
Colorado	* For shredding and disposal, run leachate test
Connecticut	* Must check water quality (ground and surface) standards for various locations; may need DEP permit, depending on location; state must review on case-by-case basis
Delaware	* Must comply with leachate concentration limitations for non-point sources
Florida	* Regulations for new construction of "discharge facilities"; need site study and water quality determination
Georgia	* Local ordinances apply; case-by-case review basis
Hawaii	* Not included in this study
Idaho	* Broad non-point source regulations governing water quality; no specific stormwater regs.
Illinois	* No regs.
Indiana	* Subject to solid waste regs.; not an area of primary concern
Iowa	* Land disposal rules apply: must address the likelihood of contamination
Kansas	* No specific regulations - possible restrictions in urban areas
Kentucky	* Special case review basis

TABLE VI SHREDDING ALONG THE RIGHT-OF-WAY (CONT'D)

State	Summary of Regulations
Louisiana	* No specific regulations
Maine	* Regulated - need site investigation
Maryland	* No specific regulations
Massachusetts	* No regs.
Michigan	* Need variance to prove no groundwater contamination; review at regional level
Minnesota	* Concerned about water quality and potential groundwater contamination
Mississippi	* No regs.
Missouri	* No regs. in rural areas
Montana	* No regs., but special case for shredding and disposal
Nebraska	* No regs.
Nevada	* No regs.
New Hampshire	* No regs.; case-by-case study
New Jersey	* Regulated: check elevation, storm drain ponds, site classification, water quality
New Mexico	* No applicable regs.; case-by-case review
New York	* Not a solid waste problem; runoff water quality should be checked
North Carolina	* Would need special determination of shredding and disposal
North Dakota	* No applicable regs.
Ohio	* No applicable regs.
Oklahoma	* Case-by-case review - need to test and substantiate (unprecedented situation)
Oregon	* Must examine water quality to check for detrimental effects on runoff and groundwater
Pennsylvania	* No specific regs. on shredded wastes

TABLE VI SHREDDING ALONG THE RIGHT-OF-WAY (CONT'D)

State	Summary of Regulations
Rhode Island	* No permit required - considered a "segregated solid waste"
South Carolina	* Case-by-case basis - no specific regs.
South Dakota	* Must conduct literature search - to examine detrimental effect to surface and groundwater contamination
Tennessee	* Concerned about volumes, EP toxicity, PCP concentration - case-by-case review basis
Texas	* Regulated in undeveloped areas; shredding and disposal not permitted if classed as a hazardous waste
Utah	* No regulations
Vermont	* No specific regulations
Virginia	* Special case review to analyze protection of environment and health
Washington	* No regulations
West Virginia	* Leachate control not required; would want a demonstration of method
Wisconsin	* No regulations
Wyoming	* Would require a disposal permit; special case study basis

TABLE VI SHREDDING ALONG THE RIGHT-OF-WAY (CONT'D)

Province	Summary of Regulations
Alberta	* This method is not used; if permission were requested, the province would investigate the request; local approval by local fire authorities would be required
British Columbia	* Regulated by federal government on railroad right-of-way
Manitoba	* Would ask for detailed information and consider on a case-by-case basis
New Brunswick	* Has not been used; would consider approving this method if tie chips were kept away from streams
Newfoundland	* Not allowed due to leachate considerations
Nova Scotia	* A request for this method would be considered; the province would be concerned around stream and watershed areas
Ontario	* Regulated by the federal government on railroad right-of-way; if it became a problem, the province would complain to the federal authorities
Prince Edward Island	* This method is not used and therefore not regulated
Quebec	* No specific regulations
Saskatchewan	* Not regulated by the province except in response to citizen complaints

COST/TIE FOR SHREDDING

Operation 1 - Pick up and shred ties; disperse chips along right-of-way

1 tie shredder - rail mounted

1 operator	\$137/day
1 laborer	\$126/day

Procedure: Tie shredder moves along right-of-way, picking up ties and/or tie butts, feeding them into shredder mechanism and dispersing shredded chips along the right-of-way. Assume a conservative production rate of 420 ties/day. Actual processing rate depends on operator proficiency, as well as the age, condition and distribution of scrap ties or tie butts along the right-of-way.

$$\frac{\$137/\text{day} + \$126/\text{day}}{420\ \text{ties/day}} \quad = \quad \$.63/\text{tie}$$

Fuel

((6 gal./hr. x 6 hrs./day) +
(5 gal./hr. x 2 hr./day))
x \$1.20/gal.[1]
420 ties/day = \$.13/tie

Shredder Maintenance

Mechanic	\$137/week (1 day/week)
Parts	\$200/week
	\$337/week

$$\frac{\$337/\text{week}}{420\ \text{ties/day} \times 5\ \text{days/week}} \quad = \quad \$.16/\text{tie}$$

Annual Capital Recovery Cost

Capital Cost = \$75,000
Capital Recovery Factor = .2127
Salvage Value = \$75/ton x 16 tons = \$1,200

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[1] Fuel price obtained from "Traffic World", June 27, 1983, p. 41

Assume 12 year life, interest rate at 18.5%

CR = ($75,000 - $1,200) (.2127)

CR = $15,697

$$\text{CR per tie} = \frac{\$15{,}697}{420 \text{ ties/day} \times 200 \text{ days/yr.}} = \underline{\$.19/\text{tie}}$$

Total Shredding Cost:

$.63 + $.13 + $.16 + $.19 = $1.11/tie

MOBILE INCINERATOR

ENVIRONMENTAL CONSIDERATIONS

For the purposes of this study, a mobile incinerator is defined as an incinerator mounted on a truck, trailer, or rail car which is capable of being moved and set up at multiple locations along the right-of-way to burn discarded ties. The practice of mobile incineration of scrap railroad ties is virtually non-existent. This is primarily due to the size and complexity of the equipment. Of the 49 states surveyed, 20 states reported no specific regulations or provisions for portable incinerators. Mobile units would be treated on a special case review basis in five states. The remaining 24 states expressed interest in maintaining some regulatory control over this method of disposal. Advance notice of the time and place of incinerator movement was commonly reported to be of state and local concern. A few states have modified the mobile units to comply with stack emissions criteria for stationary sources. Hours of incineration are sometimes specified. Favorable meteorological conditions must exist prior to burning in some states. Minimum distances from the nearest residence are occasionally predetermined.

Very few firms offer equipment suitable for adaption to railroad use. Without chipping the ties, incinerators would have to be very large to accommodate whole ties or tie butts. The length of time needed to destroy these large pieces may have an adverse effect on productivity.

Table VII summarizes the regulatory procedures for each state.

TABLE VII MOBILE INCINERATOR

State	Summary of Regulations
Alabama	* No specific provisions
Alaska	* No provisions
Arizona	* Must notify of time and place of movement; would review first time operation
Arkansas	* Same provisions as for stationary incinerators
California	* No regs.
Colorado	* Must notify state of relocation
Connecticut	* Special case review basis
Delaware	* Need permit; case-by-case review; no specific regs.
Florida	* Must have permit; notify state whenever unit is moved and comply with district regs.
Georgia	* No regulations - would be reviewed on special case basis
Hawaii	* No pertinent regulations
Idaho	* Portable sources must be registered; opacity must not exceed 20%
Illinois	* No regulations
Indiana	* Notify health department and fire department; burn during daylight hours, notify of time and place of movement; favorable meteorological conditions; comply with opacity regs. (no particulates criteria)
Iowa	* No specific regulations
Kansas	* Same regs. as for stationary incinerator; notify state 10 days prior to movement
Kentucky	* Case-by-case review at permits department
Louisiana	* Can use mobile unit between 8 AM and 5 PM, 1,000 feet minimum distance from any residence; must limit hydrocarbons, favorable meteorological conditions needed
Maine	* Need operating permit and air emission license

TABLE VII MOBILE INCINERATOR (CONT'D)

State	Summary of Regulations
Maryland	* No mobile incinerators currently operating; no specific regulations
Massachusetts	* No regs.
Michigan	* No provisions - mobile units treated the same as stationary incinerators - need site approval for each location
Minnesota	* Need permit; report time and place of relocation, NSPS review
Mississippi	* Need permit for each site; minimum 150 feet from unit to nearest residence; site inspection
Missouri	* No regs.
Montana	* No regs.
Nebraska	* When unit is moved, must give 30 days prior notice
Nevada	* Must report new location 30 days prior to move
New Hampshire	* No special provisions, but each site must be permitted
New Jersey	* Case-by-case basis; notify of time and place of burning
New Mexico	* No special provisions, except for 20% opacity limit
New York	* Treated as stationary source
North Carolina	* No provisions
North Dakota	* No special provisions
Ohio	* Permits issued for portable sources; notify of time and place of movement; meet permanent source emission limits; location depends on size of facility
Oklahoma	* Subject to same permitting requirements as for stationary source
Oregon	* No special provisions; would have to add a new category for portable wood burners
Pennsylvania	* Permitted only on special case basis, when no other disposal methods available
Rhode Island	* No special provisions

TABLE VII MOBILE INCINERATOR (CONT'D)

State	Summary of Regulations
South Carolina	* No provisions
South Dakota	* No provisions
Tennessee	* Must obtain new permit for each move
Texas	* Need permit; advise of time and place of movement
Utah	* Need permit and engineering review
Vermont	* Same permitting process as for stationary incinerator
Virginia	* No special provisions
Washington	* No regs.
West Virginia	* No special provisions
Wisconsin	* No special regs.; would need operating license
Wyoming	* Need permit; monitor operation and time and place of movement

TABLE VII MOBILE INCINERATOR (CONT'D)

Province	Summary of Regulations
Alberta	* Same regulations as a stationary incinerator; the province uses federal emission guidelines
British Columbia	* A permit is required
Manitoba	* Permit required for all emission sources; no existing laws are specifically for mobile sources
New Brunswick	* Would require a permit; would not be permitted in highly populated areas
Newfoundland	* None currently used; requests for permits would be considered
Nova Scotia	* None are currently used; would require a permit
Ontario	* Regulated by the federal government on the railroad right-of-way; if a unit were a problem, they would complain to the federal authorities
Prince Edward Island	* Mobile incinerators are not used and therefore not regulated
Quebec	* No specific regulations; this method is not used
Saskatchewan	* A permit is required; the province uses the federal emission guidelines

COST/TIE FOR INCINERATION

Mobile incinerator units are not currently being used for tie incineration on the right-of-way. No suitable unit could be found to use as a basis for developing cost data.

RECONSTITUTED TIES

An interest in recycling discarded crossties was stimulated in the early 1970's by forest industry projections that a shortage in timber supply available to the railroad industry was seen by the end of the century. Several inventors and entrepeneurs offered solutions to this problem and a railroad industry committee was formed to work with these ideas. AAR and its members, the U.S. Department of Transportation, and the U.S. Department of Agriculture worked with the forest products industry to develop ideas which would in some manner reuse crossties. A 'reconstituted' timber cross tie was proposed which would make use of shredded creosote treated ties mixed with waterproof resins to create a new tie. The group evaluated various proposals and offered suggestions about the necessary qualities of the products in order for them to be comparable with the new wood crosstie. Some ties were produced on a test basis and subjected to laboratory and in-service testing on North American railroads. Many of these tests are still underway.

Reconstituted ties have been subjected to extensive in track testing at the AAR's Transportation Test Center (TTC) in Pueblo, Colorado. A total of 85 ties were examined after 717 million gross tons (MGT) of in-service loading (typically, a wood tie will last for about 1,200 MGT). Of the 85 ties tested, 10 ties were in good condition, 10 were plate cut, and the remainder experienced some degree of shear failure or delamination due to improper placement of longtitudinal reinforcing bars inside the ties. Generally, plate cutting was not evident on ties that were fitted with tie pads under the tie plate.

A second generation of ties has recently been installed at TTC. These have been reinforced with longitudinal bars made of tropical hardwood having a square cross sectional design. The Atchison, Topeka & Santa Fe and the Union Pacific Railroads are testing approximately 1,000 and 600 second generation ties, respectively, in main line track to monitor their in-service performance characteristics. Railroads in Canada, Japan, France, Germany and Great Britain are also testing reconstituted ties.

Studies have been performed by Cedrite Corporation, Portland, Oregon, designers of reconstituted ties, to assess the feasibility of constructing a full scale production plant in Kansas City, and in Alberta, Canada. Capital requirements for annual production of 1.4 million reconstituted ties is on the order of $30,000,000, with final production costs estimated at $23 to $24/tie. These ties may eventually be produced on a large scale commercial basis, if it can be demonstrated that they are competitive with conventional ties from a cost and service life point of view. In the future, railroads may decide to enter directly into contracts with particle board tie manufacturers, and to deliver scrap ties to a production site in exchange for reconstituted ones. The economics may be such that the railroads would be required to absorb only the cost of tie pick-up and loading. Transportation costs will vary, depending on distances from various tie removal sites, to the manufacturing facility. It is likely that payment of these charges would be negotiated between railroads and the manufacturer.

Once a tie production facility becomes fully operational, rail cars could be loaded with scrap wood, moved to the tie plant and unloaded with newly manufactured ties, thus minimizing empty back haul moves. This recycling process may eventually assure railroads of a steady supply of ties at a reasonable cost, while simultaneously addressing the tie disposal problem.

A reference list of firms and testing agencies currently working toward further research and production testing of reconstituted ties has been compiled, as follows:

Firm or Agency	Location
Cedrite Corporation	Portland, Oregon
Cosgrove Industries	Hakensack, NJ
AAR, Transportation Test Center	Pueblo, Colorado
Forest Produces Laboratory	Madison, Wisconsin
Webster Tie Company	Winona, Minnesota

Two FAST reports have been issued relative to the testing of reconstituted ties. They are:

1.) "Performance of Laminated and Reconstituted Wood Ties" TN 79-06 December 1978
2.) FAST Engineering Conference - 1981 Proceedings, "Results of Standard Wood Tie and Manufactured Tie Experiments at FAST", L.C. Collister, p. 57ff.

TABLE VIII TABULATION OF STATE ENVIRONMENTAL REGULATIONS FOR ALTERNATE DISPOSAL METHODS

Method		Totals
I.	OPEN BURNING	
	Prohibited for railroad ties	27
	Permitted conditionally for railroad ties	22
		49
II.	AIR CURTAIN DESTRUCTOR	
	Permitted for railroad ties	10
	Prohibited for railroad ties	10
	Permitted conditionally for railroad ties	19
	No regulations	10
		49
III.	PRIVATE LANDFILL	
	Permit required	37
	Permit not required	7
	Special case review	5
		49
IV.	SHREDDING ON RIGHT-OF-WAY	
	No specific regulations or provisions	21
	Special case review	13
	Regulated as solid waste or for water quality impact	15
		49
V.	MOBILE INCINERATOR	
	No specific regulations or provisions	20
	Special case review	5
	Regulated	24
		49
VI.	STATIONARY INCINERATOR	
	Construction and/or operating permit required for new facility	49
		49

DIOXINS, BASIC FACTS

With the exception of the quantity of dioxins originating from the combustion of pentachlorophenol treated ties, the subsequent sections on dioxins originated in the Federal government report, Dioxins in Canada: The Federal Approach, a publication originating with the Interdepartmental Committee on Toxic Chemicals, 1983.

Major sources

Dioxins are a group of 75 compounds (congeners). Specific dioxins are identified by the total number of chlorines (one to eight) and the numerical position of the chlorine atoms in the compound. Dioxins are not chemicals that we intentionally manufacture or for which we have any use. They are by-products formed during production of other organic chemicals, or during the general combustion of organic material.

Chemicals Containing Dioxins:

Pentachlorophenol and tetrachlorophenol were manufactured in Canada and are used as wood preservatives (about 3 million kg per year). They are contaminated with hexa, penta, and octachlorodibenzo-p-dioxins at the parts per million level.

2,4,5-trichlorophenol contains 2,3,7,8-TCDD. Although registered for use in Canada, there is now no Canadian supplier. It was never manufactured in Canada but was used as the starting product to manufacture 2,4,5-T. It was also used as a disinfectant.

2,4,5-T is a herbicide containing 2,3,7,8-TCDD. It is registered for specific forestry uses in Canada but only about 500 kg are used annually. It is restricted to use in forestry applications and used under provincial authority.

2,4-D is a herbicide used extensively in the prairie provinces (about 4.5 million kg per year). It contains various dioxins, including some tetrachlorodibenzo-p-dioxins, but not 2,3,7,8-TCDD.

Other chemicals, such as Triclosan and Hexachlorophene, are known to contain dioxins. Other pesticides, such as Dicamba and MCPA, are closely related to dioxin containing chemicals and are scheduled for investigation.

Waste Dumps

These can be sources of dioxins, particularly those associated with disposal of wastes from 2,4,5-trichlorophenol manufacture. The only confirmed Canadian area of concern is the Great Lakes region with the current emphasis on the Niagara River which is affected by U.S. landfills. Some concern has been raised and investigations are underway at landfills at Elmira, Ontario where Uniroyal produced 2,4,5-T and 2,4-D in the past, and where dioxins were found in groundwater of one of several test wells at the site. Other potential problem areas include the Detroit River, the St. Clair River and the Saginaw Bay in Lake Huron.

Combustion

Incineration, particularly of municipal garbage and chlorinated industrial waste, produces trace quantities of dioxins if the combustion temperature is not high enough. The large portion of the dioxins are adsorbed into fly ash and are removed by electrostatic precipitators, but some are emitted, adsorbed to particles or as gases. The majority are the higher chlorinated dioxins (less than 1% is 2,3,7,8-TCDD). There are many other potential combustion sources, including natural sources such as forest fires and human activities such as smoking. This raises the probability that a detectable background level of dioxins exists in industrialized nations today.

Quantities Entering Canadian Environment

The quantitative assessment of input from the various sources is only at a rudimentary stage of development and open to considerable refinement. In 1981, the NRC estimated 9.2 kg of dioxins from 2,4-D, 1500 kg from pentachlorophenol (including tetrachlorophenol) and 13.4 kg from municipal incinerators. On the basis of current compliance to regulations, 2,4-D (with a use pattern of 4500 tonnes and 3 dioxins at 10 ppb) gives a total environmental input of 0.14 kg (a 98% reduction). The contribution of 2,3,7,8-TCDD from 2,4,5-T (with a use pattern of 500 kg and manufacturers levels of 10 ppb) gives a total environmental input of 5 mg (5×10^{-6} kg). By comparison, 2,3,7,8-TCDD contained in the Niagara waste dumps is estimated as 45 kg in Love Canal and 2.23 tonnes in Hyde Park. The S-area and 102nd Street dumps contain similar quantities of 2,4,5-trichlorophenol wastes but of unknown 2,3,7,8-TCDD content.

The total potential load from penta/tetrachlorophenol remains largely the same as estimated at 1500 kg. This does, however, require some clarification. First a large portion of that total is octachlorodibenzo-p-dioxin, which is not considered very toxic. The more problematic hexa- and heptadibenzo-p-dioxins isomers contribute 430 kg of the total. The fraction of this total that actually contaminates the environment or contributes to human exposure is unknown. Certainly a large portion would be expected to remain in the treated wood. As a result of an intensive wood preservation plant study, planned for 1984, the various contributions and losses of dioxins will become clearer.

Combustion represents a much more complex assessment because of the various possible sources and wide variety of fragmentary values available. NRC has estimated the contribution from municipal incinerators as 6.7 kg precipitated as fly ash and an equal amount emitted. On the basis of preliminary Environment Canada results (to be available later), the NRC estimates for emitted dioxins appear high. However, within the range of total data available, dioxins contained on emitted fly ash could contribute anywhere from less than 1 up to 50 kg total dioxins per year. Such variation can also be expected for precipitated fly ash which is usually disposed of in land-fill. How much dioxin escapes from these land-fills by leaching and enters the environment is unknown. It is not readily bioavailable in the form of fly ash.

voir p.86

Based on the railway tie combustion experiment undertaken by Environment Canada at the CANMET laboratory of Energy, Mines and Resources, the quantity of dioxins and furans (all isomers) emitted from the combustion of pentachlorophenol treated ties is less than .077 kg. (See the section on the railway tie combustion experiment for details). Emissions from creosote ties are unknown at this time, but will be included when available.

Other incineration sources are under investigation for their contributions to this total, both as solid wastes and as emitted particles. Of these sources, sewage incinerators would appear to be a source with a potential of 4-13 kg emitted per year on the basis of the limited data available. Forest fires have perhaps the largest potential of natural sources. Using limited data on wood burning, an estimate of possible inputs from forest fires is 160 kg per year. Even though forest fires would seem to represent a significant natural source, an equal quantity of dioxin could come from urban-related incineration and combustion process.

Environmental Concerns

2,3,7,8-TCDD is relatively persistent and evidence now exists that in soils the half-life may exceed 10 years. Data for other dioxins do not exist but it has been predicted that dioxins with less chlorine will have a shorter half-life whereas dioxins containing more chlorine will have much longer half-lives. Dioxins have very low water solubilities but a much higher affinity for fats and proteins. Consequently, they bioaccumulate and are much more easily detected in biological samples than in water. Dioxins have been detected in some samples of fish, some raw water from the Great Lakes, human tissue, bird eggs across Canada, and soils and sediments around wood preservation plants.

There is no evidence of recurring problems from the low environmental levels of dioxins encountered at present in the Canadian environment. The reproductive failure of several fish-eating bird colonies on the Great Lakes in the early 1970s has been attributed to 2,3,7,8-TCDD, but these problems are not encountered today.

Fishery Concerns

Dioxins are readily bioaccumulated and, as a consequence, 2,3,7,8-TCDD has been reported in several species of commercial and sport fish. As a result of the significance of fish as a human food source, both in Canada and as an export commodity, environmental contamination with dioxins has threatened the viability of the commercial and sport fishery of the Great Lakes as witnessed by the incorrect assumption by Japanese importers that Lake Erie smelt were contaminated with dioxins.

In addition, there is some evidence that 2,3,7,8-TCDD, at relatively high water concentrations (100 times the levels so far detected), can affect the survival and growth of the early stage of certain species. Whether this has an impact on the stocks of fish in Canada is unknown at present.

Health Concerns

Health concerns over dioxins stem from laboratory animal studies that indicate several dioxins have extreme, acute toxicity and that some have effects at very low levels when exposure is lengthy. Long-term, low-level exposures in animal studies have resulted in reproductive dysfunction and carcinogenic effects.

In man, the major health concern is over continuous or intermittent, low-level exposure. Acute lethality is not a major concern as environmental levels in fish, water and air are one million to 100 million times lower than acutely lethal effect levels in laboratory animal species tested. The only confirmed effects in humans are chloracne and some biochemical and neurological disorders.

Effects such as reproductive failure, birth defects and increased cancer rates have been claimed in connection with events such as the Seveso, Italy, explosion, spraying of Agent Orange in Vietnam and communities sprayed with 2,4,5-T in the U.S. These reported effects remain, however, unsubstantiated at the present time. Numerous confounding factors and, in some cases, small numbers of exposed subjects made meaningful scientific interpretation of these cases impossible.

2,3,7,8-TCDD is considered to be the most toxic of the dioxin congeners. Estimates of the toxicity of the other dioxins have been made, based on the structure, i.e. the number and position of chlorine atoms on the molecule, and the relative activities of some of these other dioxins in enzyme induction and toxicity trials. Predictions of toxicity for those dioxins available for testing have been reasonably accurate. As predicted, 1,2,3,7,8-pentachlorodibenzo-p-dioxin and two hexachlorodibenzo-p-dioxin congeners have the highest acute toxicity after 2,3,7,8-TCDD. Octachlorodibenzo-p-dioxin is far less toxic than both 2,3,7,8-TCDD and hexachlorodibenzo-p-dioxin. These structure-activity relationships may also be useful in predicting carcinogenicity. The mixtures of hexachlorodibenzo-p-dioxin congeners tested proved to be carcinogenic at concentrations 10 times higher than those determined for 2,3,7,8-TCDD.

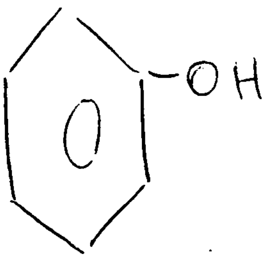
More than 800 workers have been exposed to dioxins in industrial accidents. Chloracne and some neurological disorders (which disappear after a few years) have been observed in many of these exposed workers. Because of the long latent periods often associated with cancer, it is difficult to draw definite conclusions. The earliest well-documented case of human exposure resulted from an accident in 1949 in which 250 workers were exposed and 122 cases of chloracne were reported; so far, 32 deaths (versus 46.4 expected) have occurred in this group with no apparent increase in deaths from malignant neoplasms. In other studies, an increase in soft tissue sarcomas (3 out of 105 workers, 2.86%, versus 0.07% ion the general population) has been reported. These studies neither prove nor disprove the carcinogenicity of dioxins for man.

CHEMISTRY OF PHENOLS, DIOXINS AND FURANS

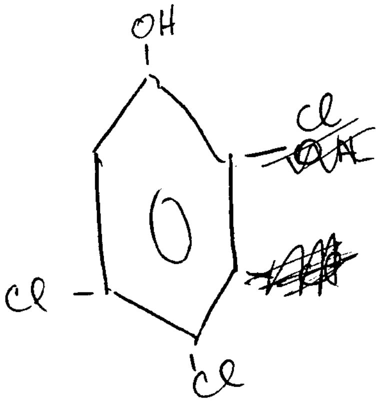
Phenols

A phenol is the general name given to that class of compounds which have a hydroxyl group attached to a benzene ring.

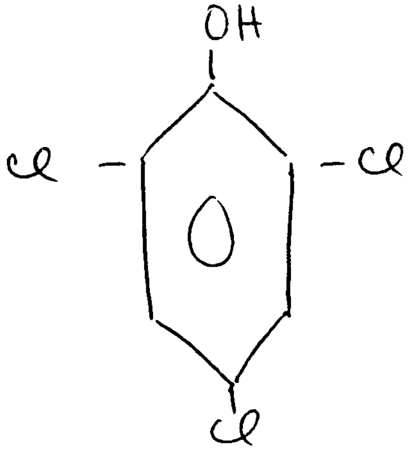
Pentachlorophenol has five chlorines attached as well as the hydroxyl group. Chlorophenols are named under the International Union of Pure and Applied Chemistry convention of the hydroxyl group assuming the number 1 position, and numbering clockwise around the benzene ring. The chemical structure of the most common chlorophenols as well as phenol are shown below.



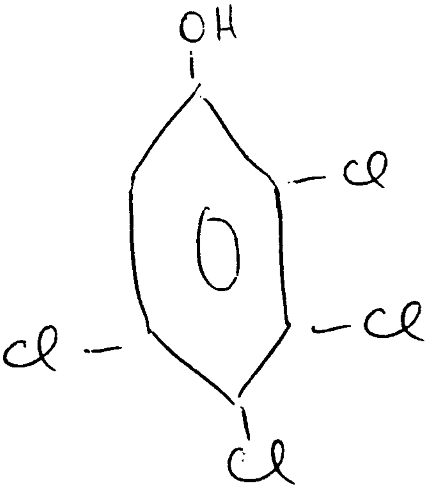
Phenol



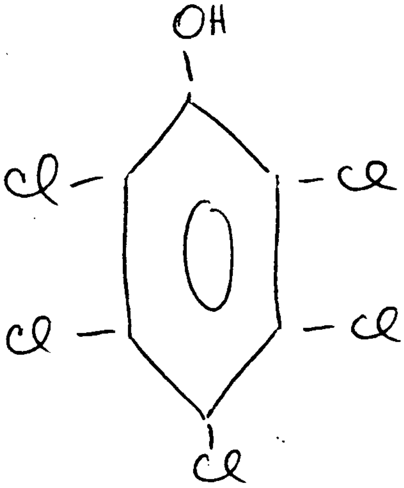
2,4,5 Trichlorophenol



2,4,6 Trichlorophenol



2,3,4,5 Tetrachlorophenol



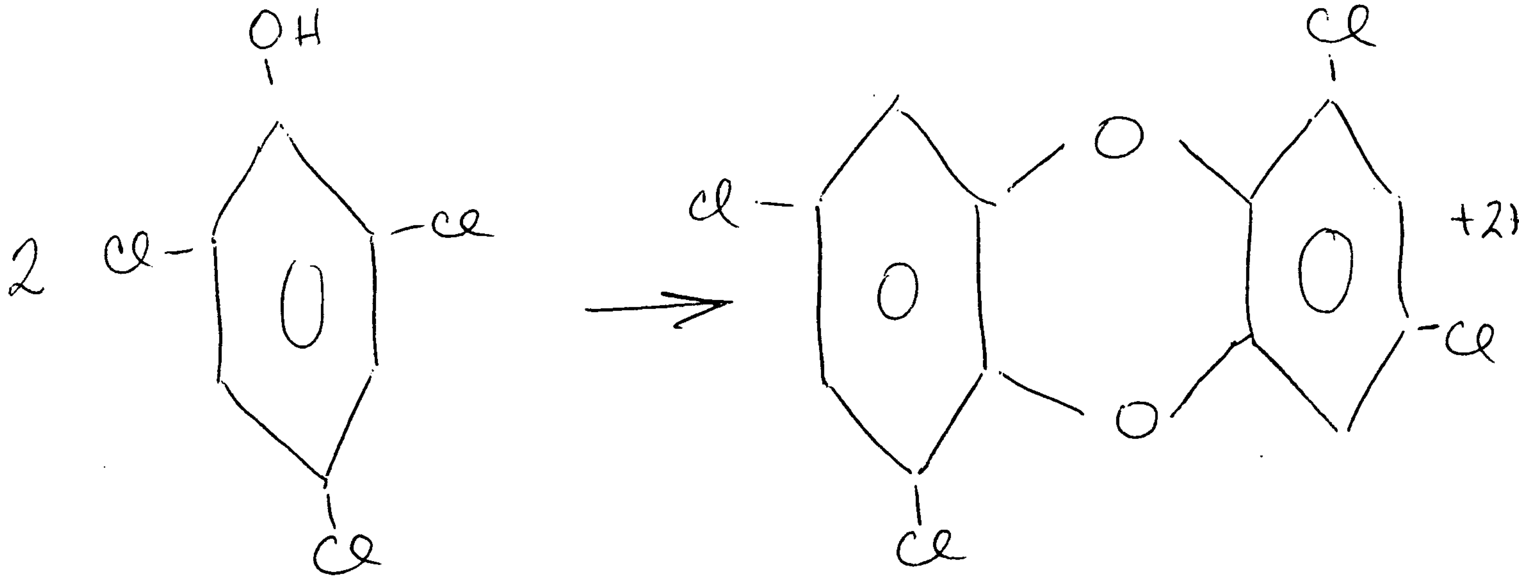
Pentachlorophenol

Dioxins and Furans

Dioxins and furans are of interest in the disposal of railway ties since they are present initially in the pentachlorophenol as impurities to a small degree and secondly they can be formed to a significant degree during the combustion of railway ties if combustion is not carried out under strict conditions. The conditions needed for their formation are not well defined.

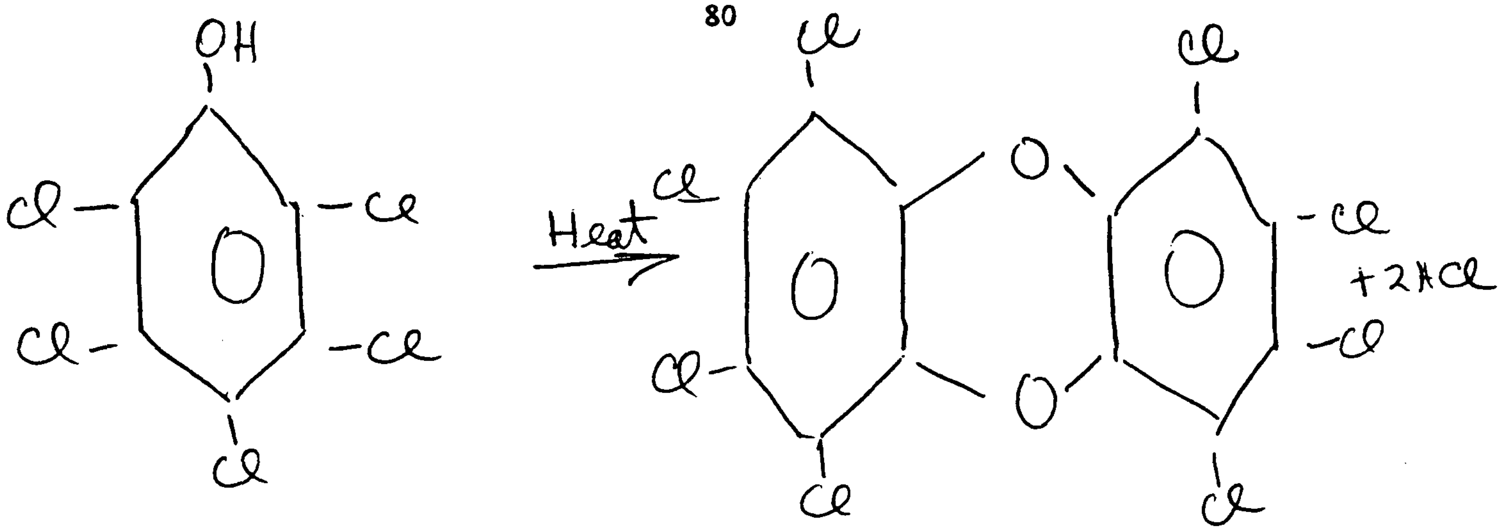
However, it is known that low temperature combustion and short residence times promote the formation of dioxins and furans.

The following reactions indicate some of the reactions by which it is hypothesized dioxins and furans are produced from phenols.



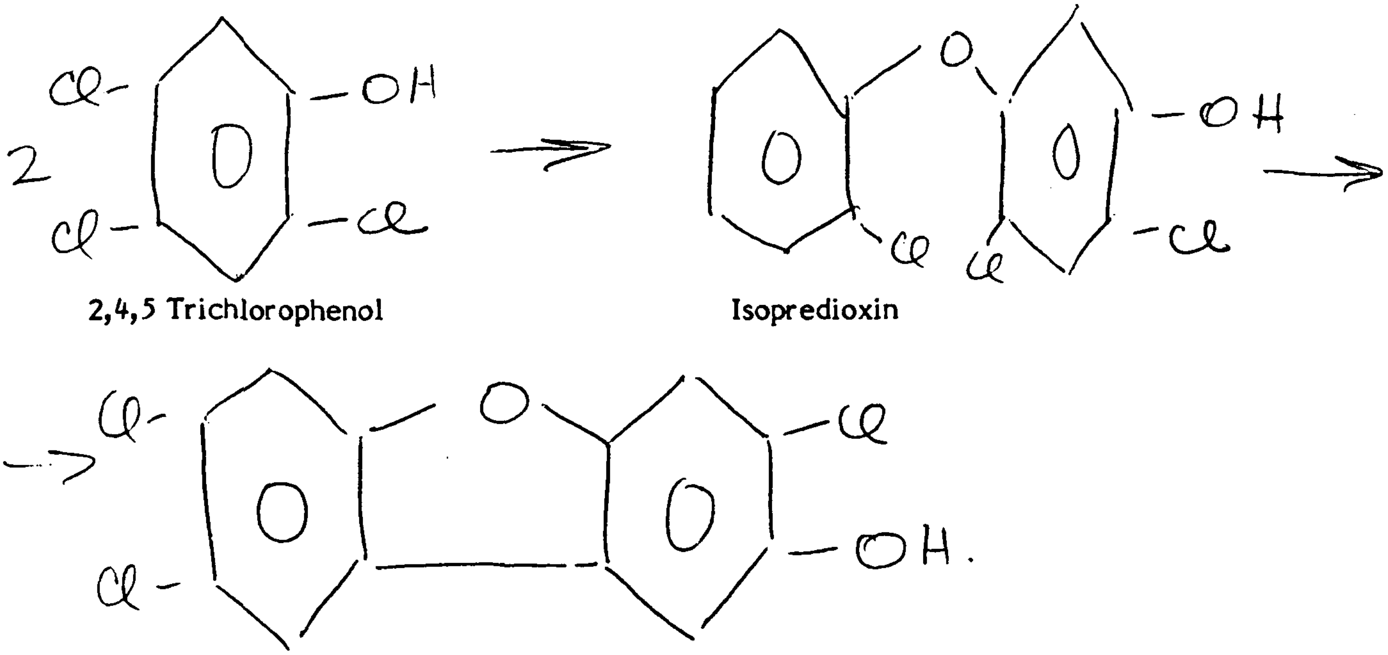
2,4,6 Trichlorophenol

1,3,6,8 Tetrachlorodibenzo-p-dioxin



Pentachlorophenol

octachlorodibenzodioxin



2,4,5 Trichlorophenol

Isopredioxin

Furan

CHRONIC AND ACUTE HUMAN EXPOSURE TO PENTACHLOROPHENOL

Acute intoxication with PCP and its salts is an uncommon occurrence; however, a number of fatalities have been reported. Postmortem samples of serum, tissues and urine from individuals who died from PCP intoxication have contained between 20 and 140 ppm of PCP in tissue and 28 to 26 ppm PCP in urine. Six cases of occupationally exposed pest control operators in Hawaii whose urinary PCP exceeded 10 ppm were reported. The highest value recorded was 36 ppm. It is possible that tolerance to PCP might develop with continued exposure, which would account for a lack of obvious symptom in the heavily exposed pest control operators (1).

There was an unfortunate incident in which 20 infants in a small hospital in St. Louis developed an unusual illness which was severe in 9 cases and lethal in 2 cases. The illness was traced to the misuse of a laundry product which contained sodium pentachlorophenate. Postmortem tissue samples of one of the children who died contained 21 to 33 ppm PCP. The serum levels of PCP in another infant ranged from 118 ppm prior to a blood transfusion to 31 ppm the next day. Serum levels of PCP in 6 exposed, asymptomatic infants ranged from 7 to 26 ppm. Concentrations of PCP in diapers used in the nursery ranged from 109 to 172 ppm. Serum values of PCP in two healthy control infants were 69 and 459 ppb respectively.

A study of 80 industrial workers who were exposed to sodium pentachlorophenate and 2,4,5-trichlorophenoxy acetic acid showed a variety of symptoms including chloracne, porphysia, cretanea tarda disorders in porphyrin metabolism, fat metabolism and carbohydrate metabolism, as well as neurological lesions. The workers were exposed to a number of compounds in the industrial environment. Although some of the effects may have been due to PCP the major causative agent was believed to be 2,3,7,8-tetrachlorodibenzo-p-dioxin.

There have been two reports of PCP intoxication intermediate between general chronic exposure and lethal or nearly lethal exposure. Four families in Japan became weak and suffered from throat and skin irritation after drinking and bathing in water that contained 12.5 ppm PCP, a case was reported in which a man bathed his hands in a PCP solution for 10 minutes while cleaning a paint brush. Pain in the man's hands caused him to stop. Two days later his urine showed 236 ppb of PCP. One month elapsed before the urinary PCP for this individual had returned to "background" levels, i.e. 17 ppb.

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(1) Rango Rao, K., Pentachlorophenol, Chemistry. Pharmacology and Environmental Toxicology, Plenum Press, New York, N.Y., p. 354.

SOURCES OF CHRONIC HUMAN EXPOSURE TO PENTACHLOROPHENOL

Four possible sources of PCP are : (1) natural formation of PCP in the environment, (2) PCP appearing as the result of metabolism of other chlorinated compounds, (3) formation of PCP in water chlorination systems, and (4) intake of PCP as a result of human activities.

The suggestion that PCP is a natural compound in the environment seems reasonably unlikely. There is no evidence that PCP is a natural metabolite of any organism.

Pentachlorophenol was the major metabolite of hexachlorobenzene in rats, in rat urine there was nearly twice as much PCP as hexachlorobenzene. In rat urine there was nearly twice as much PCP as hexachlorobenzene. Fecal excretion was dominated by hexachlorobenzene with some pentachlorobenzene. The fact that hexachlorobenzene has not been detected in human urine suggest that metabolism of hexachlorobenzene should be only a minor contributor to the human PCP load.

It has been suggested that the chlorination of phenol in water supplies in sewage effluents may be responsible for the wide occurrence of PCP. It was reported that chlorination of 1 ppm of phenol in water with 10 ppm of chlorine leads to the production of 10 ppb of PCP. Although these results are interesting, it seems quite unlikely that this route would substantially contribute to the human PCP burden. A concentration of 1 ppm of phenol in water is intolerable from the point view of taste, in fact humans can detect phenol in water in the ppb range. The perchlorination of phenol with hypochlorite must require photochemical activation, a situation which is not generally obtainable in water treatment or sewage chlorinaters.

In a spot survey of selected items from the food chain, PCP residues were found in powdered dry milk, soft drinks, bread, candy bars, cereal, noodles, rice, sugar, and wheat. The concentration ranged from 1 ppb to 0.1 ppm. The presence of PCP residues in all the grain and sugar products tested would be consistent with the storage of these products in PCP treated wooden storage containers.

The estimated annual production of PCP is 200 million pounds world-wide. Roughly 80% of the annual production is used for the preservation of wood. Surface treatment of wood with PCP is used for preservation during shipment. Pressure treatment with PCP and its derivatives is used to induce long term stability of wood that is used in exposed or wet environments. Other uses of pentachlorophenol take advantage of its antifungal, antibacterial and contact defoliant properties.

PENTACHLOROPHENOL CONTAMINATION WITH DIOXINS

Most pentachlorophenol preparations are contaminated to a greater or lesser extent with hexachloro-, heptachloro- and octachloro dibenzodioxins. Concern about dioxin contamination is based primarily on the extremely high toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Although other dioxins are less toxic than TCDD, their presence in materials that are produced in large quantities and distributed throughout the environment are, nevertheless, of concern. The concern stems not only from their toxicity but also from their persistence and potential for biological magnification.

The concentrations of tetra-, hexa-, and octachlorodioxin found in samples of pentachlorophenol obtained from Swiss manufacturers in 1973 ranged from less than 10 to 250 ppb for TCDD, less than 30 ppb to 10 ppb for HCDD, and 1.5 to 370 ppm for OCDD.

Manufacturers of pentachlorophenol have been aware of problems associated with dioxin contamination of their products and have gone to considerable lengths to decrease the concentrations of dioxins in the commercial material. Two reports from Dow Chemical Company indicate that their recent products contain less than half a part per million of HCDD and the concentration of OCDD ranged between 2 and 16 ppm.

TOXICITY OF PENTACHLOROPHENOL

The fact that lethal concentrations of pentachlorophenol in human biofluids have ranged from 20 to 190 ppm is consistent with observations of pentachlorophenol toxicity in other mammalian species. The question of an appropriate safety margin for long term exposure to toxic substances is a subject of considerable debate. If an appropriate safety margin were a factor of 10^{-3}, current human exposure to pentachlorophenol appears to be right at that safety margin. A number of scientists maintain that in the case of mutagenic substances there is no appropriate safety margin and permissible concentrations of mutagens in the environment should be below the parts per trillion level that is, in the concentration region corresponding to only a few molecules per cell.

The major effect of PCP on biological systems is not directly related to its mutagenicity. PCP is known to be an uncoupler of oxidative phosphorylation and it has been shown to alter the electrical conductivity of membranes. The fact that PCP is a broad spectrum biocide may be largely due to its influence on membrane properties and oxidative phosphorylation.

The toxic effects of PCP can not be divorced from the effects of the polychlorodioxins that contaminate commercial formulations. It has been shown that commercial PCP had significantly larger effect on induction of liver enzymes, specifically aryl hydrocarbon hydroxylase, in rats than the reagent grade compound. The difference was ascribed to the presence of polychlorodioxins in the commercial PCP. The dioxin concentrations in the commercial PCP used were 8 ppm HCDD, 520 ppm heptachlorodioxin and 1380 ppm OCDD. The fact that the dioxins are considerably less water soluble than PCP and thus subject to a much larger biomagnification makes this finding ominous for exposure to PCP from commercial sources.

Studies have indicated a very general human exposure to pentachlorophenol at concentrations ranging between 1 and 100 ppb. These compounds are 10^{-3} to 10^{-4} of the lethal concentration for this compound in the environment. The most likely sources for human exposure to pentachlorophenol are the food chain and direct contact with PCP-treated wood products. Contamination of the food chain is probably related to pentachlorophenol treatment of storage structures for food products. Another possible source of PCP contamination is the metabolism of hexachlorobenzene obtained from environmental sources.

In view of studies that suggest that pentachlorophenol is mutagenic or at least a comutagen, it seems likely that current human exposure to pentachlorophenol poses a significant health hazard (1).

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(1) Rango Rao, K., Pentachlorophenol, Chemistry. Pharmacology and Environmental Toxicology, Plenum Press, New York, N.Y., p. 359.

EPS RAILWAY TIE COMBUSTION EXPERIMENT

Concern was expressed by the Northwest Regional Office that the disposal of railway ties could be a significant environmental problem. In particular there was concern expressed that the open field combustion of ties could be exposing railway workers in particular and the population in general to dioxins and pentachlorophenol. Consequently the decision was made to analyze the combustion products of ties for these contaminants.

The test was run, July 5-7, 1983, at the CANMET Research Center at Bells Corners, Ontario (just outside Ottawa). The research lab was already set-up to check the combustion efficiency of stoves and consequently it was readily adaptable to the Environment Canada source sampling teams needs.

The railway ties were new ones which were defective and were supplied compliments of CNR. They were combusted in stoves with the doors open, to approximate to the fullest extent possible, open burning. The smoke was very sooty, it could be classified as a very dirty fire.

In all thirty-seven samples were taken, several of these were subsequently combined. Because of the large quantities of impurities present, it was very difficult to analyze for the polychlorinated dibenzodioxin and polychlorinated dibenzofuran present. A new procedure had to be developed.

The analysis indicated that the first test, which was a test run that utilized only raw wood, had the highest emissions. Each successive test, which utilized ties, had lower emissions. This would be consistent with contaminants being vapourized from the chimney. It is hypothesized that previous tests run by CANMET at low excess air during which the efficiency of stoves was being measured, would have contributed to the formation and collection of creosote on the flues. Emissions from the combustion of the pentachlorophenol treated ties, in nanograms be kilogram of dry wood, ranged from a high of 493 to a low of 29.

The accuracy of the experiment could be affected by the following:

(i) low velocities in the flue and a small stack diameter precluded the use of isolzinetic/proportional sampling and traversing. The sampling rate was superisokinetic to collect enough volume for furan and dioxin detection. Under this sampling mode, the reported concentrations may be less than actual.

(ii) the chimney was creosote coated. CANMET while testing the efficiency of wood burning stoves on the same apparatus used very low excess air. This results in the formation of creosote which lined the chimney. In this experiment, in which a large excess of air was used, there was higher temperatures which would result in the boiling off of the creosote. Measured emissions would likely be higher than the actual in this case.

donc la creosote formerait les dioxines? ↓ hypothèse non prouvée.

(iii) the flowrate in the chimney was back calculated. By measuring the oxygen in the flue gas, the carbon dioxide and the weight of the wood burned, the excess air can be calculated. However, the CANMET apparatus was normally used for low excess air. At the high excess air of this experiment, a degree of uncertainty is introduced.

Although the aggregate effect of the foregoing uncertainties can not with any meaning, be quantitatively estimated, a qualitative judgement may be made. For the purpose of estimating a range of dioxin and furan emissions, two scenarios are presented.

Scenario I

Assumptions:

(i) use the highest PCDD and PCDF emission rate from the PCP burning, 493 ng/kg dry wood,

(ii) one-half of the ties purchased each year in Canada replace PCP ties which are destroyed by open burning (2.15×10^6 ties).

Using the above assumptions, the following emission emerges:

$$2.15 \times 10^6 \times \frac{160}{2.2} \times \frac{493 \times 10^{-9}}{1000} = .077 \text{ kg}$$

(No. of ties) x (Wt. per tie, kg) x (emissions per kilogram) = total weight emitted

Scenario II

Assumptions:

(i) use the lowest emission rate, 29 ng/kg of dry wood,

(ii) one-tenth of the ties purchased each year, in Canada, replaced PCP ties which are destroyed by open burning, 430,000 ties.

Using the above assumptions, the following emission emerges:

$$430{,}000 \times \frac{160}{2.2} \times \frac{29 \times 10^{-9}}{1000} = .0009 \text{ kg}$$

The PCP ties were initially found to contain a total of 455,000 nanograms of polychlorinated dibenzodioxin and polychlorinated dibenzofuran per kilogram of wood. The amount of PCDD and PCDF released in the smoke varied between 29 and 493 nanograms per kilogram of dry wood. This indicates a destruction efficiency of between 99.89 and 99.99%.

?

FUTURE WORK

The results of the creosote railway tie burning experiment have yet to be received, and will have to be incorporated in this report.

Future tie burning experiments, preceded by a thorough cleaning of all flues, are a distinct possibility. To date, a very frugal approach has been taken. All field testing, and to the extent possible, laboratory analysis, has been scheduled during lulls. As a consequence, costs have been very low. Future work will be carried out in the same vein.

Communications will be kept open with the American Association of Railways, pertinent information will be forwarded.

An assessment profile will be completed and forwarded to senior management as part of a decision making package, thus following the accepted procedure. Normally a directive is issued as a consequence of this profile; this will define HQ involvement. A number of options are open, a guideline could be issued, regulations (unlikely), liaison with Health and Welfare for the purpose of assessing health risks, a code of good practice or possibly withdrawal.

CONCLUSIONS AND RECOMMENDATIONS

1. The results of the pentachlorophenol treated railway tie burning experiment indicate that polychlorinated dibenzodioxin and polychlorinated dibenzofuran are released in very low levels under combustion conditions which were intended to approximate open burning. If two million PCP treated ties were disposed of by this method, only a combined total of .077 kg of PCDD and PCDF would be emitted, this includes all isomers. Although there are other health effecting compounds emitted, the probability of respiratory cancer developing from these has been estimated to be quite low, appendix B outlines the experiment which led to these conclusions.

2. Leaving the broken ties by the track, although practiced to some degree at present, should be dissuaded. It is an eyesore and cannot be carried out indefinitely.

3. Landfill is acceptable but not the most desirable method of disposal. Public opinion is growing against the landfill of toxic substances, there is a feeling this is simply putting the problem off to the future. There is an economic penalty associated with this method.

4. Promising disposal methods:
   - (a) incineration under controlled conditions incorporating the use of heat produced. However, at present it appears there is an economic penalty associated with this method.
   - (b) grinding and reconstitution. An Alberta based company is currently planning on starting an operation to make these.
   - (c) removal of the ties in one piece and their subsequent sale. The recent introduction of a mechanized tie extractor which removes the ties in one piece has made this one of the most desirable disposal techniques. Under most conditions there is an economic gain associated with it.
   - (d) refurbishing, currently practiced to some degree in Canada. Prime ties can be reused, usually on spur lines.

APPENDIX A

Provincial Railway Tie Burning Criteria

Government of Canada Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

DRAFT/ÉBAUCHE

DISTRIBUTION

Chief
Air Pollution Control
EPS, Western & Northern Region
Edmonton

SECURITY - CLASSIFICATION - DE SÉCURITÉ

OUR FILE - NOTRE RÉFÉRENCE
4510-55/C24

YOUR FILE - VOTRE RÉFÉRENCE

DATE
May 9, 1983

SUBJECT OBJECT RAILWAY TIE BURNING

The attached tie burning authorization from Alberta Environment is for your information.

A. Cam Edwards, P. Eng.

Att.

ACE/lcb

DISTRIBUTION:

E. Wituschek	B. Jank
J. Kozak	J. Witteman
D. Pilon/B. Nadon	H. Gavin
J. McDonald	→ W. Sullivan

FOR INTERNAL USE ONLY

Alberta
ENVIRONMENT
Environmental Protection Services
Standards and Approvals Division
Air Quality Branch 403/427-5872
Water Quality Branch 427-5888
Telex 037-2006 TWX 610-831-2636
9820 - 106 Street
Edmonton, Alberta, Canada
T5K 2J6

DRAFT/ÉBAUCHE

April 29, 1983

C.P. Rail
#400, 125 - 9th Avenue, S.E.
CALGARY, Alberta
T2G 0P6

Cam
For your info.
F.W.

ATTENTION: Mr. J.A. Inshaw, P.Eng.

Dear Sir:

Enclosed, please find Letter of Authorization No. 83-LA-004. Since you are the first to apply this season, perhaps it is a good time to come to terms with the future tie burning program.

As you are aware, the railways had agreed to a progressive reduction in the number of ties burned each year. It was intended that an "accounting" system be set up hopefully based on a 5 year or so projection of tie burning requirements. In October 1981, Mr. R. Morrish sent us a projection of the total ties to be burned in 1982 (to the end of April 1983) of 325,000. We have been using this as a base year and a base figure along with past authorizations to "assign" authorization for the number of ties to be burned in each division by successively reducing each year by 10% (see attached schedule and copies of letters to other divisions).

We note that there has been only one authorization (82-LA-014) for your division and it was for approximately 2500 ties. This is obviously not a realistic figure to start on so we request that you provide a projection (considering other divisions) on which we could base future authorizations.

Thank you for your help and cooperation. If you have any questions, please call me at 427-5872.

Yours truly,

F. Witthoeft

F.V. Witthoeft, P.Eng.
Air Quality Branch
Standards and Approvals Division

FOR INTERNAL USE ONLY

FVW/cc

cc: Mr. Stroick, Superintendent - C.P. Calgary

bcc: J. Lack
G. Peck
S. Dobko

Alberta
ENVIRONMENT

LETTER OF AUTHORIZATION

DRAFT/ÉBAUCHE

AUTHORIZATION NO. 83-LA-004

FILE NO. 83-SA-190

WHEREAS

Canadian Pacific Railways
#400, 125 - 9th Avenue, S.E.
CALGARY, Alberta
T2G 0P6

ATTENTION: J.A. Inshaw

has, pursuant to Section 6, of The Clean Air (General) Regulations of The Clean Air Act, applied to the Director of the Division of Standards and Approvals for authorization to

burn railway ties

NOW THEREFORE

this authorization is issued subject to the terms, conditions and requirements attached hereto.

Edmonton April 29, 1983

FOR INTERNAL USE ONLY

DIRECTOR OF STANDARDS AND APPROVALS DIVISION

AUTHORIZATION No.
83-LA-004

TERMS, CONDITIONS AND REQUIREMENTS ATTACHED TO LETTER OF AUTHORIZATION

1 Subject to section 2., the burning of railway ties shall take place only along those sections of CP right-of-way located:

(a) in the Loggan Subdivision between Calgary and Banff National Park, and

(b) in the Red Deer Subdivision between Calgary and Wessex.

2 No ties shall be burned within 5 miles of a city or within 2 miles of a town, village or hamlet, or in the vicinity of a highway when the wind is blowing towards the highway.

3 A responsible person shall be in attendance at all times that ties are burning.

4 Permission from the local fire department must be obtained prior to burning.

5 The Office of the Director of the Division of Pollution Control of the Department of the Environment located in Edmonton (427-5893 during regular office hours, and 1-800-222-6514 during non-office hours), shall be notified at least twenty-four hours in advance of burning.

6 Should the burning result in smoke emissions which are deemed excessive by the Division of Pollution Control, the fire shall be extinguished immediately.

7 This Letter of Authorization expires April 30, 1984.

April 29, 1983

J. DEFIK, DIRECTOR

DRAFT/ÉBAUCHE

SCHEDULE OF C.P. TIE BURNING APPROVAL (10% Annual Reduction)

Division	To April 30/83 (Approx.)	To April 30/84 (Approx.)	To April 30/85 (Approx.)	To April 30/86 (Approx.)
- C.P. Total (my letter of October 5, 1981)	325,000	302,000	272,000	245,000
- Alberta South (Lethbridge) (my letter of December 2, 1982 to Kubik)	78,000	70,000	63,000	57,000
- Alberta South (Medicine Hat) (my letter of October 19, 1982 to Peters)	110,000	99,000	89,000	80,000
- Alberta South (Calgary) (my letter of April 29, 1983 to Inshaw)	? (47,000 by difference)			
- Alberta North (my letter of August 25, 1982 to Green)	90,000	81,000	73,000	66,000

FOR INTERNAL USE ONLY

f.w.

Environment Canada
Environmental Protection

Environnement Canada
Protection de l'environnement

25 St. Clair Avenue East
7th Floor
Toronto, Ontario M4T 1M2

Telephone: (416) 966-5840

DRAFT/ÉBAUCHE

Your file Votre référence

Our file Notre référence
4510-55/C24-1
4510-55/C34-3

June 10, 1983

Mr. W. Sullivan
Environment Canada
Renewable Resources Extration and
Processing Division
13th Floor, Place Vincent MA.
Ottawa

Dear Mr. Sullivan:

Re: Disposal of Railroad Wood Cross Ties

As per your request to Mr. Jim Smith, enclosed are 2 copies of CN Rail's Track Burning Guidelines as established by the Prairie Regional office as of April 21st, 1981 and by Ontario Region as of May 1st, 1981.

Should you have any further queries, do not hesitate to call.

Sincerely,

Jean Patrice

Jean Patrice Auclair
Environmental Design Officer
Federal Programs Division

FOR INTERNAL USE ONLY

c.c. J. Smith, EPS

1659

R INTERNAL USE O

Regl. Engineering, Winnipeg, 21 April 1981

3715-3

Control of Grass Fires and
Tie Burning on Right of Way

Mr. E. R. Trask	Track and Roadway Engineer	Saskatoon
Mr. R. Gregory	Track and Roadway Engineer	Saskatoon
Mr. J. J. Pomor	Track and Roadway Engineer	Winnipeg
Mr. D. J. Benzies	Track and Roadway Engineer	Winnipeg
Mr. J. D. Bennett	Track and Roadway Engineer	The Pas
Mr. W. Salamon	Track and Roadway Officer	Thunder Bay

The following should be your guideline in the control of grass fires and tie burning on the right of way:

1) Burning of tie butts and grass is to be restricted to early Spring and late Fall and should be authorized by permit from the appropriate Government agencies as required. Permit requirements vary from Province to Province.

2) All right of way burning is prohibited in "built up" urban or municipal areas. Ties are to be hauled away from these areas.

3) Burning must be done only under the direction of a line supervisor and at all times must be under the control of line forces (at least a foreman in charge). All fires must be out before the end of the work shift. The distance along the track being burned must not exceed that which can be controlled by the forces; this must be determined by judgment with no set maximum.

4) Tie butts being burned must be kept to small piles - no more than 3 feet high with a maximum of 30 tie butts.

5) Burning ties must be kept at least 15 feet from the end of track tie. Greater distances should be maintained where practical to do so.

Please ensure that all your line supervisors are instructed accordingly.

RAFT/ÉBAUC

For: P. J. MacDonald
Regional Chief Engineer

RWT:vf

cc: Mr. J. H. Pike, Co-Chairman, Winnipeg Transportation Safety and Health Committee, Transportation, Winnipeg

<u>Attention: P. J. Marquis</u>

This refers your letter dated 6 April, file 4470-24

FOR INTERNAL USE ONLY

GREAT LAKES REGION
ENGINEERING
GUIDELINES TO CONTROL THE BURNING OF OLD TRACK TIES

At some locations on this Region, it is permissible to dispose of old ties and tie butts by burning. To avoid hazards to passing trains, particularly those carrying dangerous commodities, the following guidelines must be adhered to when burning ties or any debris for the purpose of cleaning of the right-of-way.

1. *No burning is to be done within yard limits. No burning is to be permitted within the limits of a Municipality such as a city, town or any built-up area. As a general rule, burning is not to be done any where within Metro Toronto and Environs. No burning is to be done where trains may be forced to stop such as at the apprcaches to diamond crossings, interlocking plants and passing tracks. As a general rule, no burning will be permitted within one mile of a switch leading to a passing track.*

   Other locations where all burning is prohibited at all times will be designated by the appropriate Engineering Officer after consultation with his Transportation counterpart or as otherwise outlined herein.

2. *Burning is to be carried out only when the fire hazard is low and preferably when the ground has some snow cover. Burning should only be carried out between 1 November and 30 April.*

3. *Before any burning is undertaken local Engineering Supervisors will inform:*

   (a) The Ontario Ministry of Natural Resources (MNR) to identify the location of Restricted Burning Zones within the territory. If the planned burning area falls within a restricted zone, a permit to burn shall be obtained from M.N.R.

   Note: The local M.N.R. office is listed in the Blue Pages of the local Telephone Co-Directory

   (b) Where a planned burning site does not fall within a restricted zone, permission to burn should be obtained from the Industrial Abatement Section of the appropriate Regional or District, Ontario Ministry of the Environment Office. An official burning permit may not necessarily be issued by the Ministry but consent from authorized Ministry staff should be obtained.

   Note: The local M.O.E. is listed in the Blue Pages of the local Telephone Co-Directory.

   (c) Inform the local Transportation Officer of the intention to burn. The Transportation Officer will have the preogative to request postponement or rescheduling of the burning operation based on his judgement of the impact on expected traffic.

4. *Piles of old ties or tie butts must be kept small. That is, not more than 10 whole ties or 30 tie butts in any pile to be burned.*

5. *Avoid burning a series of piles out of face and maintain at least 300 feet between adjacent burning piles. Thus if the density is such that there is a pile of old ties every 60 feet, only every fifth pile may be burned at any one time and adjacent piles may not be ignited until the neighbouring pile has been extinguished.*

6. *Piles of burning ties must be placed at least 25 feet clear of all tracks and burning must always take place on the side of the right-of-way away from the telegraph pole line.*

7. *Personnel must be assigned to watch over burning ties and must maintain vigil until the fire is extinguished.*

DRAFT/ÉBAUCHE

Office of Regional Chief Engineer
Toronto, Ontario
(Rev.) May 1981

OR INTERNAL USE ONLY

Reg'l. Engineering, Winnipeg, 21 April 1981

3715-3

Control of Grass Fires and
Tie Burning on Right of Way

Mr. E. R. Trask	Track and Roadway Engineer	Saskatoon
Mr. R. Gregory	Track and Roadway Engineer	Saskatoon
Mr. J. J. Pomor	Track and Roadway Engineer	Winnipeg
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DRAFT/ÉBAUCHE

For: P. J. MacDonald
Regional Chief Engineer

RWT:vf

cc: Mr. J. H. Pike, Co-Chairman, Winnipeg Transportation Safety and Health Committee, Transportation, Winnipeg

<u>Attention: P. J. Marquis</u>

This refers your letter dated 6 April, file 4430 24

FOR INTERNAL USE ONLY

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ENGINEERING
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DRAFT/ÉBAUCHE

Office of Regional Chief Engineer
Toronto, Ontario
(Rev.) May 1981

APPENDIX B

Preliminary Results - Combustion of PCP-Treated Ties

Government of Canada Gouvernement du Canada

MEMORANDUM NOTE DE SERVICE

TO / À
Mr. W. Sullivan
Renewable Resources & Process Extraction
13th Floor, P.V.M.

FROM / DE
Project Engineer
Source Testing Unit
Pollution Measurement Division
Room 104, RRETC

SECURITY - CLASSIFICATION - DE SÉCURITÉ

À
TO W. Sullivan

OUR FILE/NOTRE RÉFÉRENCE
4030-6-2
OCT 23 1984

YOUR FILE/VOTRE RÉFÉRENCE
DOSSIER No
FILE No. 4730-9

DATE
October 18, 1984

2819

SUBJECT / OBJET **PRELIMINARY RESULTS - COMBUSTION OF PCP-TREATED TIES**

Attached are the dioxin and furan emission results from the combustion of PCP-treated railway ties in a wood stove (1983). A final report will follow at a later date.

The combustion tests for the PCP-treated ties were conducted at EM&R's CANMET facility in Bells Corners. Ties were burned in the Acorn Ranger wood stove manufactured by Selkirk. In order to simulate the open field burning of these ties, the wood stove was operated with the door open. In total, four runs were conducted - three from the combustion of PCP-treated ties and one run burning untreated B.C. fir. The B.C. fir run was conducted to determine the baseline emissions from the combustion of untreated wood.

The sampling conditions at this site were less than ideal. Low velocities in the flue and and a small stack diameter precluded the use of isokinetic/proportional sampling and traversing. The sampling rate was superisokinetic to collect enough volume for dioxin and furan detection. Under this sampling mode, the reported concentrations may be less than actual.

The most intriguing result of the tests was that the highest emissions were measured during the baseline run, i.e. "untreated" B.C. fir.

The higher results in the baseline run may be attributable to two factors:

1. The untreated wood contained dioxin or high levels of chlorine which is typical of coastal lumber. A sample of B.C. fir sawdust is presently being analyzed for dioxin content.

2. Another possibility is that the dioxin was already present in the stove and flue lining before the tests were conducted. Creosote may have accumulated from successive burns of wood with the stove operating in the air-tight mode. This dioxin "pool" was released during our baseline run.

.../2

For your convenience, the emissions have also been reported in terms of the amount of wood fed to the furnace. These values should be regarded as estimates since the emission factor is based on the measured concentration (unknown accuracy) and the stack gas flowrate (estimate). As stressed on previous occasions, the results should be considered qualitative in nature.

At best, these tests confirm the presence of dioxins and furans from the combustion products of PCP-treated ties. Hopefully, the combustion of these ties in a wood stove (door open) simulated the open burning conditions. If you are planning any more emission testing with railway ties, I recommend that you give some thought at looking at PAHs also.

I understand that the ASD is presently processing the samples from this summer's program with the creosote ties. Indications are that the results will be available within a few weeks. If you wish, I could send you a preliminary summary for the creosote ties and incorporate both surveys into one final report.

Please do not hesitate to contact us if you have any questions or comments regarding the sampling results.

Dominic Cianciarelli

Dominic Cianciarelli

DC/jf

Attachment (1)

c.c. - R.B. McCaig
- P.K. Leung

PRELIMINARY SUMMARY OF RESULTS

COMBUSTION OF PCP-TREATED TIES IN A WOOD STOVE

GENERAL DATA								
Run Number	1		2		3		4	
Date (1984)	July 4		July 5		July 6		July 7	
Fuel Burned	B.C. Fir		PCP-Treated Ties					
Test Duration (min)	120		180		135		180	
Total Sample Vol(m3)	1.753		1.894		1.103		1.867	
Dry Wood Burned(kg)*	16.7		20.6		16.7		16.1	
STACK GAS CHARACTERISTICS								
Flowrate (m3/min)*	2.5(est)		3.87		2.55		2.22	
Temperature (°C)*	321		400		380		320	
Oxygen (%)	16.2		15.6		16.0		15.5	
Carbon Dioxide (%)	5.1		4.9		5.1		5.4	
Excess Air (%)*	n/a		548		317		385	
DIOXIN AND FURAN CATCHES (DIOXIN/FURAN)								
Front-Half (ng)	60.0	69.2	9.4	8.8	5.4	5.6	0	0
Back-Half (ng)	13.8	17.4	16.8	18.8	5.2	3.8	4.8	2.2
Total (ng)	73.8	86.6	26.2	27.6	10.6	9.4	4.8	2.2
EMISSIONS (ESTIMATED)								
Conc. (ng/m3)	42.1	49.4	13.8	14.6	9.6	8.5	2.6	1.2
Rate (ug/h)	6.315	7.410	3.212	3.384	1.470	1.304	0.343	0.157
(ug/run)	12.63	14.82	9.636	10.151	3.308	2.934	1.027	0.471
Factor (ng/kg dry wood)	756	887	468	493	198	176	64	29

* These values were taken from EM&R outputs. Flowrates and excess air are calculated.

- All volumes given at dry and standard conditions (25°C and 101.3 kilopascal)

- Oxygen and carbon dioxide values represent averages of O2 and CO2 readings taken at 15-minute intervals.

APPENDIX C

Open Burning of Creosote Treated Rail Ties: A Case Study In Health Risk Assessment

84-102.6

Open Burning of Creosote Treated Rail Ties: A Case Study in Health Risk Assessment

Dennis Becker
Gary Eckhardt
John Seltz

Minnesota Pollution Control Agency
Roseville, Minnesota

Tim Johnson

Bay West, Inc.
St. Paul, Minnesota

For Presentation at the 77th Annual Meeting of the
Air Pollution Control Association
San Francisco, California June 24-29, 1984

Introduction

Approximately 22 million railroad ties are replaced annually across the United States. These railroad ties are replaced because they are deteriorated physically due to mechanical stressing, decomposition by bacterial action, and weathering. The replacement of these ties has created a continually expanding disposal problem in certain areas because the ties are often abandoned along the railroad right-of-ways.

Several years ago, the common practice of the railroads for disposing railroad ties was to either sell the whole railroad tie (which was subsequently used for landscaping) or to open burn them if they had no scrap value. With the ban of open burning practices, unusable ties were left along the railroad right of ways. This accumulation accelerated with the use of new removal equipment which split the ties into three pieces thereby minimizing the number of ties usable for landscaping.

Because of the large numbers of ties that are accumulating and because the open burning of railroad ties is the most cost-effective method of disposal (not considering health effects), it is of interest to determine the potential health impacts associated with the open burning of railroad ties. This study is an attempt to assess these health impacts.

Wood preservative systems in common usage today are of three types: creosote, pentachlorophenol, and metal salts. According to the Burlington Northern Railroad, a local contract wood preserver, and the American Wood Preservers Association's journals, railroad ties are universally treated with creosote and not pentachlorophenol or metal salts. The Burlington Northern Railroad, for example, uses a solution of 30% creosote in fuel oil in its pressure treatment facilities.

Incomplete combustion of vegetable matter gives rise to carbon monoxide, other gases some of which are mucous membrane irritants, and respirable particulates containing irritating and /or carcinogenic compounds. The carcinogenic components of this particulate matter are expected to lie in its polycyclic organic matter (POM) content. POM is a large group of chemicals formed from two or more benzene rings. POM compounds identified as carcinogens generally contain four or more benzene rings. The most well known constituent of this chemical class, benzo(a)pyrene, contains five benzene rings. Because the POM content of wood smoke is high and because the addition of creosote (which owes its preservative properties to polycyclic compounds) likely increases the POM emissions, the POM emissions from burning ties were selected as the critical risk from open burning of creosote treated wood.

An air sampling study was designed to measure extractable organic matter and POM concentrations in particulates resulting from burning crossties and to determine "emission factors" for these substances so that air pollutant modeling can be conducted to analyze other exposure/receptor scenarios. Health risk assessment techniques were used to estimate cancer risk from carcinogens detected in the particulates.

Experimental Methods

Railroad tie test burns were conducted at the Carlos Avery Preserve north of the Twin Cities. The Burlington Northern Railroad provided discarded "butt" ties for the various burns. These tie pieces were picked up from the Burlington Northern right of way near Wyoming, Minnesota.

Air monitoring was conducted to measure ambient concentrations of total suspended particulate (TSP), selected POM, and to determine the fraction of particulates extractable by cyclohexane (CEF). The air samplers were configured downwind of the burning piles to get an idea of the downwind, cross wind and vertical variation in pollutant concentration in order to develop approximate emission factors.

Six high volume particulate air samplers were arranged in a baseball diamond configuration (see Figure 1). All air inlets were located 3 feet above ground with the exception of site #4 (co-located with site #3) which was located 16 feet above ground. The ground elevation varied less than 2 feet over the study area and was generally lower away from the fire.

Particulate samples were collected on 8" x 10" preweighed glass fiber filters (Whatman EPM-2000) meeting Environmental Protection Agency specifications for pH and purity. Sample flow rates were approximately 40 CFM (cubic feet per minute). After sample collection, filters were folded, wrapped in aluminum foil and stored in a refrigerator or ice chest. Exposure to light was minimized. The day after sampling, filters were equilibrated for 1 hour at 45% RH (relative humidity) and weighed. Samples were reweighed after an additional 3 hour equilibration period. The additional equilibration resulted in less than a 4% decrease in the apparent weight of collected particulate matter. After weighing, filters were forwarded to the Minnesota Department of Health laboratory for POM and CEF analysis.

Meteorological data were obtained using a portable meteorological station. An adjustable wind sector switch was used to determine the approximate time that the wind was in a 45 degree sector from the fire to the center of the sampler grid. Gasoline powered generators, located to minimize exhaust contamination, were used to power equipment requiring AC power.

Field Sampling Methodology

Meteorological conditions were relatively constant during the study period. The wind direction was from the south with wind speeds generally ranging from 10 to 15 miles per hour.

For each burn, approximately 24 tie pieces were piled in an orderly fashion, doused with approximately 1/2 gallon of #2 fuel oil and ignited with a railroad flare. This procedure simulates practices of Burlington Northern. The burn piles were approximately 4 feet high, and 16 feet in circumference at 2 feet above ground. It is estimated that each pile contained approximately 1500 pounds of creosote treated wood. One burn of green untreated wood was conducted for comparison purposes. The tree branch material burned consisted of approximately 2/3 spruce tops and 1/3 mixed hardwood branches. Approximately one full pickup load of green wood was burned.

For the first 30 minutes of each tie burn, large quantities of black smoke were emitted, after which white smoke, characteristic of untreated wood combustion was emitted. After approximately 2 hours, the pile volume was reduced by at least 70% and most combustion appeared to be of a charcoal burning nature. A few coals remained 24 hours after a burn. Sequential one-hour samples were taken during burn #4 to examine the temporal change in emissions during a burn.

The green wood burn resulted in large amounts of white smoke. The fresh nature of the green wood made it difficult for the fire to burn through to completion. The green wood burn was sampled for one hour only for this reason.

Lab Analyses Methodology

Air filters were stored as received in a freezer until extracted. One quarter of the filter was cut into strips and soxhlet extracted in cyclohexane for 16 hours. The extract was then dried and concentrated. Acetonitrile was added and the mixture heated to drive off the remaining cyclohexane. The sample was filtered and water was added to yield a desired ratio of water and the acetonitrile mixture. A portion of the sample mixture was injected into a Rainin Microsorb C-18 column in a Perkin Elmer Series 4 reverse phase HPLC (High Performance Liquid Chromatograph) interfaced with a Perkin Elmer 3600 data station. The column was solvent programed from 40 to 100% acetonitrile in water. Fluorescence detection with confirmation at 254 nanometers (nm) and 280 nm was employed.

With each set of filters analyzed, an additional filter was spiked with 16 POM compounds at the 1-2 microgram per filter level. The average recovery was 87% with an average standard deviation of 18%. The most heavily loaded filter from each test burn was analyzed in duplicate. The duplicates agreed within 30% of each other except for chrysene and benz(a)anthracene which have retention times so close that separation is very difficult.

The cyclohexane extractable fraction (CEF) of collected particulates was determined in a manner similar to the soxhlet extraction described above from a separate 1/4 piece of the filter.

Results

Five sample sets were obtained: two two-hour tie burns, consecutive one-hour samples during a two-hour tie burn, and a one-hour tree waste burn sample. The results from one of the two hour tie burns are included in Table I to give an idea of the spatial variation in concentration. As noted in Figure 1, the samplers to either side of the smoke plume were brought closer to the center line in successive burns. Only in burns 3 and 4 did these samplers receive any significant TSP impact. A compilation of data from the highest impacted monitor at each burn follows in Table II.

POM compounds included in the Table II were selected on the basis of carcinogenic potential.[1] Several lighter polycyclics were also detected, but not reported here. In addition to being less carcinogenic, these lighter molecules are not retained well on high volume sample filters.[2]

The results demonstrate that high TSP concentrations were experienced downwind for all test burns. Similar CEF levels were also experienced. A notable difference is evident however, upon comparison of POM levels resulting from the tie burns and the tree burn. POM levels in the emissions from the tie burns are much higher than in the tree waste burn. This is most likely a result of the creosote content of the ties, but may also be a function of the combustion temperature and moisture content of the different materials. In comparing the first and second hour samples of the last tie burn (burn #4), an apparent decay in all indicators occurs from the first to second hour. The decrease, however, was not as large as suspected based upon the change in the observed smoke plume from the first hour to the second.

Analysis

Calculation of Emission Rates

One of the objectives of the study was to determine the 'typical' emissions that come from a burn of railroad ties. Knowing the emission rate and the attendant meteorological factors, one can then predict concentrations of particulates for various meteorological conditions and different burn situations. For example, it is common practice for the railroads to burn multiple piles of ties simultaneously with one person tending the fires.

TSP emission rates were back calculated using conventional Environmental Protection Agency (EPA) plume rise and dispersion modeling algorithms. In general, the effective plume height is the sum of the physical pile height, flare height and non-flare height. The flare height is defined in Beychok's Fundamentals of Stack Gas Dispersion.[3] The non-flare plume rise is defined according to Brigg's equations for bent-over buoyant plumes.[4] For this study, it was determined that Brigg's equations alone best described the observed plume rise during the test burns, especially at the relatively short downwind distances considered in this paper.

Atmospheric dispersion calculations utilize Gaussian dispersion algorithms. These algorithms are incorporated into EPA's CRSTER and MPTER dispersion models.[5,6] This study utilized Brigg's plume rise equations and MPTER's rural dispersion coefficients.

Table I. Railroad tie open burning test data. Burn #2, sample run #2. Ties burned 7/7/83 from 10:45 A.M. to 12:45 P.M.

Parameter/Site	#1	#2	#3	#4	#5	#6
Total Suspended Particulate, ug/m3	193	176	953	645	181	437
Naphthalene, ng/m3	nq	nq	nq	nq	nq	nq
Acenaphthylene, ng/m3	nq	nq	800	186	nq	255
Fluorene, ng/m3	nq	nq	nq	nq	nq	nq
Acenaphthene, ng/m3	nq	nq	3067	2182	nq	601
Phenanthrene, ng/m3	nq	nq	120	29	nq	26
Anthracene, ng/m3	nq	nq	28	9	nq	10
Fluoranthene, ng/m3	nq	2	473	55	nq	64
Pyrene, ng/m3	nq	5	580	87	nq	71
Chrysene, ng/m3	nq	nq	140	29	nq	205
Benz(a)anthracene, ng/m3	-	-	1200	353	-	240
Benzo(b)fluoranthene, ng/m3	nq	2	613	217	nq	262
Benzo(k)fluoranthene, ng/m3	nq	1	167	68	nq	99
Benzo(a)pyrene, ng/m3	nq	nq	653	273	nq	276
Dibenz(a,h)anthracene, ng/m3	nq	nq	247	434	nq	226
O-phenylenepyrene, ng/m3	nq	nq	62	57	nq	48
Benzo(g,h,i)perylene, ng/m3	nq	nq	80	51	nq	51
Cyclohexane extractable, ug/m3	-	-	136	-	-	-

Average Ambient Temperature - 84 degrees F, Average Wind Direction - South,
Average Wind Speed - 13 mph

nq = not quantifiable, - = no analysis performed
ug/m3 = micrograms per cubic meter; ng/m3 = nanograms per cubic meter

Table II. Selected data from highest impact sampler of each burn.

Parameter/Burn Number	#1	#2	#3	#4	#4
Material burned	Ties	Ties	Trees	Ties	Ties
Sample collection time, hours	2	2	1	1	1
Wind speed, mph	10	13	15	11	11
Wind direction	S	S	SSE	SSE	SSW
Sky	Fair	Fair	Fair	Fair	Fair
Site number, highest TSP	3	3	3	4	3
TSP, ug/m3	594	953	991	1219	709
TSP above background, ug/m3	503	777	806	1062	552
Cyclohexane extract, ng/m3	na	136	150	110	na
Chrysene, ng/m3	---	140	nq	---	660
Benz(a)anthracene , ng/m3	960	1200	---	930	860
Benzo(b)fluoranthene, ng/m3	720	610	nq	660	520
Benzo(a)pyrene, ng/m3	410	650	10	490	280
Dibenz(a,h)anthracene, ng/m3	180	240	nq	370	330
O-phenylenepyrene, ng/m3	74	60	nq	150	70

na = no analysis, nq = not quantifiable, --- no data

Table III. Calculated emission rates.

Burn/Calculated Emission Rate, lbs/hr	
1	9
2	5
3[a]	29
4	11 (average of first and second hourly rates)

[a] Burn 3 was conducted for green brush

Table IV. Maximum projected one-hour TSP impacts (ug/m3) downwind of 1 and 5 piles of burning railroad ties.

Downwind Distance, meters	1 Pile Burn Downwind Impact	5 Pile Burn Perpendicular Wind Impact	5 Pile Burn Parallel Wind Impact
200	72	72	253
1000	21	35	91

Table V. Measured polycyclic organic matter compounds.

POM Compound	Carcinogenicity[9]
1. Napthalene	-
2. Acenaphthylene	-
3. Fluorene	-
4. Acenapthene	-
5. Phenanthrene	-
6. Anthracene	-
7. Fluoranthene	-
8. Pyrene	-
9. Chrysene	+
10. Benz(a)anthracene	+
11. Benzo(b)fluoranthene	++
12. Benzo(k)fluoranthene	-
13. Benzo(a)pyrene	+++
14. Dibenz(a,h)anthracene	+++
15. O-phenylenepyrene	+
16. Benzo(g,h,i)perylene	-

+ = carcinogenic
+++, ++ = strongly carcinogenic
- = not carcinogenic

Table VI. Calculated cancer risks.

Scenario/Parameter	Receptor distance, meters	TSP, ug/m3	CEF, ug/m3	4 hour total dose, ug CEF	Equiv. cont. conc., ng/m3	Excess risk, resp. cancer
1 pile, maximum concentration	200	72	10	35	.068	1/40,000,000
	1000	21	3	10	.019	1/140,000,000
5 piles, maximum concentration	200	253	37	120	.230	1/12,000,000
	1000	91	13	44	.086	1/31,000,000
5 piles, maximum concentration, once per five years exposure	200	253	37	120	3.22	1/860,000
	1000	91	13	44	1.20	1/2,214,000

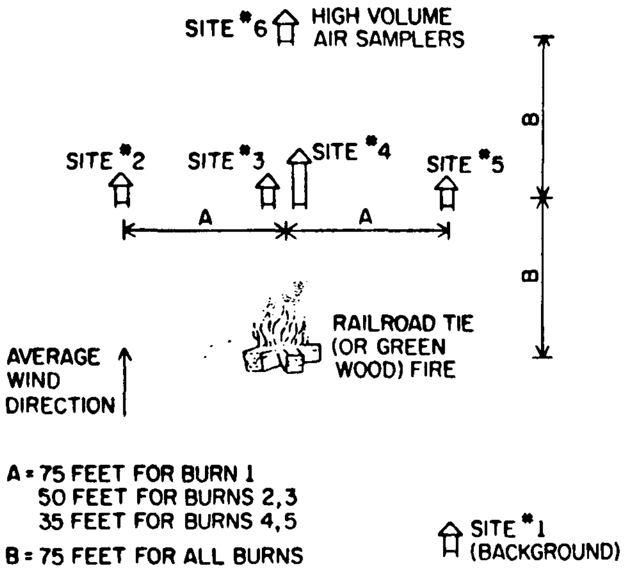

FIGURE 1. AIR SAMPLING CONFIGURATION

Emission rates were back calculated using the above modeling procedure, together with on-site meteorological data and TSP data. A wind direction optimizing routine was employed for each test burn to minimize the average of the five site emission rates estimates. Finally, average emission rates for each test burn presented in Table III reflect moderately unstable atmospheric conditions resulting from ground level turbulence close to the burn piles. An average emission rate of 8 lbs/hr for burns 1,2, and 4 was calculated.

To ensure reasonable emission rates, a simple crosscheck was performed. Approximately 1500 pounds of ties were burned for each test burn. Assuming that all wood was consumed during that two hour period, a particulate emission factor can be derived by multiplying the average projected emission rate of 8 pounds per hour times two hours to give 16 pounds of particulates emitted in the two hour period. This amounts to a particulate generation rate of about 21 pounds per ton of wood burned. As a comparison, typical rates for various types of wood consumed in wood stoves are in the 10 to 100 pounds per ton range.[7] Typical emission factors for open burning of agricultural and leaf waste are also in the 10 to 100 pounds per ton range.[8] These calculated rates seem to be reasonable.

Using the established emission rate of 8 pounds per hour and MPTER's rural dispersion coefficients, downwind 1-hour TSP concentrations were projected for single and multiple pile burns. Multiple pile burn impacts were projected for two situations: 1) the wind blowing parallel to the centerline of the multiple piles and 2)the wind blowing perpendicular to the centerline of the multiple piles. The distance between piles was considered to be 100 meters since this is the approximate distance that a worker can easily maintain multiple pile burns.

For reasons of brevity, only maximum one-hour TSP concentration impacts at 200 and 1000 meters downwind of the emission source are presented. Table IV shows projected worst-case impacts for a single pile burn and worst-case impacts for a 5 pile burn when the wind is either perpendicular or parallel to the centerline of the piles. In general, worst case impacts at 200 and 1000 meters occur with wind speeds of 20 and 8 mph respectively.

It is noteworthy that when the wind blows perpendicular to the centerline of piles separated by 100 meters, there is insufficient horizontal dispersion to result in significant plume overlap at a downwind distance of 200 meters. However, at 1000 meters the overlap of multiple plumes results in a total impact which is about 66% greater than that due to a single pile. If winds blow parallel to the centerline of 5 piles, then total impacts at 200 meters and 1000 meters are 251% and 335%, respectively, greater than a single pile impact.

Risk Assessment

Open burning of discarded creosote treated railroad ties results in the emission of a dense plume of black smoke containing gases and particulates on which are adsorbed a complex mixture of POM. Following exposure to these emissions, potential adverse health effects include irritation of mucous membranes and, in the long term, cancer.[9] Among the mixture of POM compounds are several known and suspected human carcinogens such as benzo(a)pyrene (B(a)P) and dibenzo(a,h)anthracene, and several co-carcinogenic compounds such as pyrene and fluoranthene. Table V presents the approximate relative carcinogenicity of the sixteen POM compounds analyzed in this study.

The objective of this assessment is to estimate the risk of mortality due to lung cancer that may result from a defined exposure to railroad tie open burning (RTOB) emissions.

Establishment of Risk Factor. Probably the best characterized POM mixtures are the emissions from coke ovens. Excess incidence of lung cancer among coke oven workers has spurred epidemiologic studies of the coke oven worker population and resulted in a quantitative risk estimation by the EPA Carcinogen Assessment Group (CAG).[10] Using epidemiologic data from coke oven workers in Allegheny County, Pennsylvania and exposure data according to job category, the EPA CAG estimated the lifetime risk of lung, bronchial, and tracheal cancer mortality from a lifetime continuous exposure of 1 microgram per cubic meter benzene soluble organic (BSO) to be 9.25E-4 or 1 in 1081 persons so exposed (The BSO fraction results from solvent extraction of collected particulates and evaporation of the solvent - benzene). The EPA considers the unit risk, which is based on a linear, nonthreshold model, to be a "rough, but plausible upper-bound estimate(s) of risk."

Creosote, like coke oven emissions, is a product derived from coal and therefore it is not unreasonable to suspect some similarity in the POM component of the railroad tie open burning (RTOB) emissions.

Comparisons of RTOB emissions with coke oven emissions indicate that RTOB emissions would be about 40% as potent as coke oven emissions. Analytical data from a coke oven plant reveals B(a)P to be present to the extent of 1.9 micrograms per milligram of particulate matter (mean value) whereas this study shows 0.714 microgram B(a)P per milligram for RTOB particulate or about 40% as much B(a)P per milligram as in coke oven emissions.[11] Additionally, comparison of the concentration of B(a)P in the benzene soluble organic fraction (BSO) of particulate from a coke oven facility and B(a)P CEF from this study are 7,031 micrograms B(a)P per gram BSO and 4390 micrograms B(a)P per gram CEF, respectively. Concentrations of B(a)P in CEF for this study are about 62 % of those found at a coke oven facility. Furthermore, a comparison of relative amounts of carcinogenic POM compounds between this study (for compounds 9, 10, 11, 13, 15 from Table V) and that found in coke oven work atmosphere suggests close similarity in POM profile.[8] On the strength of these comparisons, it can be concluded that coke oven emissions are similar to RTOB emissions and that RTOB emissions are about 40% as potent as coke oven emissions with respect to carcinogenicity. This assumes that carcinogenic compounds present in coke oven emissions other that those analyzed in this study are also present in RTOB emissions. A further assumption is that the mass of cyclohexane extractable organic material is equivalent to the BSO, although there is evidence suggesting that the CEF mass is actually less than the BSO mass.[12,13]

Size distribution analysis was not performed on the particulates collected on the high-volume sampler filters. It was assumed that all particulates fall in the respirable size range.[14,15]

Two scenarios have been envisioned for human exposure to RTOB emissions. Both involved examination of projected concentrations of particulate that would occur at six different atmospheric stability classes and at windspeeds ranging from 2 to 20 miles per hour. The first exposure scenario involves the projected maximum particulate concentration at 200 meters and at 1000 meters from a single burning pile of tie butts (Table VI). Open burning regulations in Minnesota require a distance of at least 600 feet between the fire and occupied residences. The second scenario involves the projected maximum particulate concentrations obtained at 200 meters and 1000 meters from the nearest of 5 burning piles arranged 100 meters apart along a straight length of track and parallel to the wind direction.

For purposes of risk estimation, the concentrations of TSP used for the various scenarios are those which result from projections based on two hour sampling of the burning tie piles. The concentrations measured in the two hour tie burns are assumed to persist for 4 hours.

To determine risk of lung cancer from these exposure concentrations, the EPA unit risk factor of 9.25E-4 per microgram BSO per cubic meter can be applied. There is, however, a disparity in the exposure situation for RTOB which can be characterized as an acute, short term exposure of undefined length as opposed to the EPA unit risk factor which assumes lifetime continuous exposure to the carcinogen. To get around this disparity, an accumulated acute dose was calculated and then translated into a continuous air concentration which would result in the same accumulated dose over 70 years. The EPA unit risk factor (divided by 2.5 to account for the 40% potency consideration) is applied to the continuous concentration in order to derive a lifetime risk of lung cancer mortality. This method assumes that exposure to an acute, short term dose will not result in a greater incidence of lung cancer than the same total dose fractionated over a period of 70 years. Animal studies involving carcinogenic POM compounds have demonstrated that where the total dosage is the same, small, repeated doses are more effective in eliciting cancer than a large single dose.[16,17]

A period of 4 hours (breathing air in the middle of the plume) was chosen as the length of exposure from which an accumulated dose can be calculated. Table VI summarizes the exposure scenarios and risk levels calculated from the data.

An alternative method of assessing the risk would entail focussing attention on benzo(a)pyrene (B(a)P) since there is much relevant data regarding the dose-response characteristics of B(a)P in animals for both acute and chronic exposures. A study reports a 4% lifetime excess incidence of respiratory system cancer in Syrian golden hamsters following single intratrachael instillations of 5 mg B(a)P and 45 mg ferric oxide.[18] The human risk of exposure to 120 ug CEF (containing 5.28E-4 mg B(a)P) is 2.7E-8 or 1 in 37,000,000, assuming linear dose-response and applying a factor of 0.113 to extrapolate human dosage (Interspecies dose conversion is accomplished by relating body surface area and weight).[19] 120 ug CEF corresponds to a single exposure to maximum RTOB emissions from the 5 pile scenario. A major drawback of making a risk estimate based upon B(a)P is that it represents only a portion of the carcinogenic content of RTOB emissions. Considering that the B(a)P risk probably represents an underestimate of risk, risk calculated from the EPA unit risk factor (1/12,000,000) and the risk calculated from B(a)P animal data (1/37,000,000) compare favorably.

<u>Discussion</u>. Lifetime risk of mortality from lung cancer from single, short term exposures to RTOB emissions appears insignificant at distances of 200 meters or more. The risk rate for exposure to the maximum concentration for a lifetime is 0.014 or 1/73 (37 ug/m3 x 9.25E-4/2.5). Although high for a short period of time, following cessation of exposure, the risk would be expected to diminish. Averaged over a lifetime, risk would appear small, as the calculations of lifetime risk imply. If, however, exposure were to occur periodically, risk would increase. For example, if burning were to take place every five years, the risk estimates would have to be changed by a factor of 14 (70 years/5 years). With the five pile, maximum concentration at 200 meters, the risk level would be 1 in 860,000. If the exposure period is longer than four hours or the frequency of exposure is greater, then the risk increases. The calculated risk would also increase if larger piles (greater than 1500 pounds ties/pile) were burned.

Consideration should be given to the fact that this estimate does not take into account additive contributions to risk of lung cancer mortality from POM components in wood-stove, fireplace or vehicle emissions. This study also did not attempt to address additive or synergistic effects from other airborne contaminants.

Considering the number of assumptions made and the lack of a reliable method of assessing risk of cancer due to an acute exposure, the estimates could be off by a factor of ten (high or low). Uncertainties in the risk levels calculated are expected to arise primarily from underlying uncertainties in: (1) carcinogenic potency of RTOB emissions; (2) the cancer incidence expected due to an acute exposure versus that resulting from a chronic exposure of the same total accumulated dose; (3) the projected ambient concentrations and (4) persistance of maximum predicted concentrations.

Conclusions

High concentrations of TSP result immediately downwind from the open burning of railroad ties or green wood. POM emissions from the burning of creosote treated wood are higher than from the burning of green wood. Many POM compounds present in the TSP are considered carcinogens. If one considers lifetime accumulated dose as the best indicator of cancer risk, one time acute exposure at sufficient separation distance probably results in an insignificant risk whereas multiple exposures may present unacceptable risks.

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NOTE TO EDITORS

APPENDIX D

Chlorinated Dioxins and Furans in the Environment

PRT → TREVOR

Chlorinated dioxins and furans in the environment

Their sources, fate and transport, health effects, and relative toxicity are being studied intensively, but the exact mechanisms of their formation are not yet fully understood

No community enjoys having national attention focused on it because of a contamination episode. But that is what happened in January to Times Beach, Mo., situated on the Meramec River, about 30 miles southwest of St. Louis. Electronic and print media carried the news—complete with photographs of "space-suited" technicians taking soil and water samples, while unprotected citizens looked on—that the environmental contaminant commonly known as dioxin might be present in the area. Reportedly, the largest concentration was found in roadway soil; it was well in excess of the one part per billion (ppb) "hazardous dose" level set by the national Centers for Disease Control.

According to EPA, soil samples taken before the area was flooded in early January "indicated the presence of dioxin in roadway soil." Whatever dioxin may have been found is believed to have been contained in herbicides mixed with waste oil sprayed on the community's unpaved roads during the early 1970s. However, after the flood, Rita Lavelle, EPA assistant administrator for Solid Waste and Emergency Response, said that samples taken "from at least 20 surfaces in the garbage and debris showed no detectable dioxin." It is very likely that not everyone will agree with this assessment, and the Times Beach controversy will continue for some time to come.

The chemical to which the media and EPA were referring is actually 2,3,7,8 - tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Fears about this compound are understandable when one considers that its LD$_{50}$—the dosage at which 50% of test animals die—can range as low as 0.6-2.0 μg/kg of body weight for guinea pigs. To be sure, the sensitivity of laboratory animals to 2,3,7,8-TCDD is not uniform. The LD$_{50}$ is given in the literature as 22-45 μg/kg for rats and as about 280 μg/kg for mice. Fred Hileman of Monsanto Research Corporation (Dayton, Ohio) points out that these sensitivities "have not necessarily been reflected in humans."

The purported presence of 2,3,7,8-TCDD in 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) is one reason why EPA has moved toward canceling registration of the herbicide. The presence of 2,3,7,8-TCDD also accounts for the raging controversy and litigation surrounding the defoliant "Agent Orange." The latter is an equal-parts mixture of the butyl esters of 2,4,5-T and 2,4-dichlorophenoxyacetic acid (2,4-D). Gangadhar Choudhary of the National Institute for Occupational Safety and Health (NIOSH, Cincinnati, Ohio) notes that 2,3,7,8-TCDD is retained as a trace contaminant during the manufacture of these herbicides and in the final product (except in 2,4-D). He says that this TCDD isomer is found in other products, such as wood preservatives, for which trichlorophenol (TCP) is a feedstock.

2,3,7,8-TCDD and other compounds in the polychlorinated dibenzo-*p*-dioxin (PCDD) and structurally similar planar polychlorinated dibenzofuran (PCDF) classes may be formed during the uncontrolled burning of halogenated organic chemicals, such as chlorophenols, pesticides, and polychlorinated biphenyls (PCBs). John Todhunter, assistant administrator for Pesticides and Toxic Substances at EPA, points out that PCDDs and PCDFs also may be formed when nonchlorinated organics are burned in the presence of chlorine-containing compounds.

Rappe:
keep TCDD in perspective

But questions remain as to the precise mechanism of their formation and their fate and transport. Moreover, the confirmed identification and quantification of many congeners have been hampered by a lack of valid analytical standards for many of them, although some scientists say that this situation is improving.

Conservative assumptions

2,3,7,8-TCDD receives the most attention because of its extreme toxicity to specific laboratory animals. However, at least nine other congeners of the PCDD/PCDF family have been found to be very toxic. Examples are 1,2,3,7,8 - pentachlorodibenzo-*p*-dioxin (LD$_{50}$ = 3.1 μg/kg in guinea pigs; 337.5 μg/kg in mice) and 2,3,7,8-tetrachlorodibenzofuran (TCDF, LD$_{50}$ = 5-10 μg/kg in guinea pigs; 6000 μg/kg in mice). On the other hand, 1,2,3,8-TCDD has a considerably lower toxicity for guinea pigs, about 10^6 μg/kg of body weight.

The 75 PCDD and 135 PCDF congeners were subjects of a special Symposium on Chlorinated Dioxins and Dibenzofurans in the Total Environment, which was a part of the 184th ACS National Meeting held in Kansas City, Mo., in September. EPA's Todhunter reminded the symposium that for TCDDs and TCDFs, the numbers of isomers are 22 and 38, respectively.

"These compounds are a messy area," said Todhunter, adding that EPA's assumptions concerning them, particularly for regulatory purposes,

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added. For instance, octaCDDs may be associated with pentachlorophenol, while both PCDDs and PCDFs could arise from trichlorophenols, the latter used in the compounding of phenoxy herbicides.

As for PCDD/PCDF formation through uncontrolled burning, some scientists have suggested a few general rules of thumb. For example, PCDDs seem to form from trichlorophenols and lower chlorinated benzenes. On the other hand, PCBs, when burned, transform to PCDFs, with essentially no PCDD generation.

Rappe cited several cases of chloracne that occurred in Czechoslovakia about 10 years ago. These cases appeared at a plant at which pentachlorophenol had been used for herbicide manufacturing. But when the facility changed over to 2,4,5-trichlorophenol as a feedstock for preparing 2,4,5-T, a "dramatic" chloracne increase followed. The increase could be ascribed to the presence of PCDDs, including traces of 2,3,7,8-TCDD. On the other hand, Rappe said that he knows of no data showing linkages between pentachlorophenol and 2,3,7,8-TCDD.

"Distinguish myths from realities"

A more recent look at occupational exposure was the focus of a discussion by Choudhary. He listed chlorophenol and pesticide/herbicide plants, and facilities involved with cooling towers, pulp/paper, transformers, capacitors, adhesives, incinerators, and disposal as potential exposure areas.

Choudhary noted that workers handling chlorophenol, or working with chlorinated diphenyl ethers at 600 °C, for example, are at risk of PCDD/PCDF exposure. Chlorobenzenes, which workers could also come into contact with, might form PCDDs, while the ethers may form various dioxin precursors. On the other hand, aromatics with the trichlorophenate structure could form 2,3,7,8-TCDD plus some PCDFs, he said, also observing that with heat and air, some PCBs re-form into PCDFs.

But suppose workers are exposed to various PCDD/PCDF congeners. "The myths of exposure must be distinguished from the realities of exposure. We need a clearer understanding of chemical, biological, toxicological, and other properties of congeners before health assessments can be made," Choudhary said. He expressed optimism that progress will be made in these fields, but "we are far away from perfect sampling and analysis, and toxicological data are much more limited than analytical data. Isomer-specific analyses must be conducted for any measurement of an analyte," he added.

As the most toxic PCDD/PCDF compounds a worker at risk could face, Choudhary listed 2,3,7,8-TCDD and -TCDF, 1,2,3,7,8-pentaCDD and -pentaCDF, and 1,2,3,4,7,8-hexaCDF. Can workplaces harboring these compounds be decontaminated? Some possible measures he supports are exposing contaminated materials or areas to ultraviolet (UV) light in the presence of hydrogen donors; incinerating contaminated materials at temperatures above 800 °C; or degrading the chemicals to hydroxyl compounds, perhaps by microbiological or electrochemical approaches.

Commercial fish

TCDDs and TCDFs, in trace amounts, perhaps originally formed in the manufacture of certain pesticides, can find their way into commercial lake fish, J. Ryan of the Food Division, Health Protection Branch (Ottawa, Canada) warned. He and his colleagues looked at rock bass, sunfish, white sucker, white and yellow perch, brown bullhead, crappies, catfish, eel, and smelt. They took 62 samples during 1980 and early 1981, of which 56 were from eastern Lake Ontario, four from Lake Erie, and two from the Welland Canal that links the two lakes. Each type of fish was made into samples of 2-3 kg of muscle fillet from which 10-g aliquots were taken. The analyte of interest was 2,3,7,8-TCDD.

Sample extraction was carried out with chloroform and methanol. The next steps consisted of the exchange of solvent to hexane and lipid degradation with sulfuric acid. Florisil column chromatography separated dioxins from PCBs; reversed-phase high-performance liquid chromatography (HPLC) separated 2,3,7,8-TCDD from other dioxin congeners. Determinations were conducted by gas chromatography/mass spectrometry (GC/MS).

Levels of 2,3,7,8-TCDD in those fish testing positively ranged from 2 to 39 parts per trillion (ppt or pg/g). Rock bass analysis showed no detectable 2,3,7,8-TCDD, while concentrations in eel ranged from 6 to 39 ppt. Smelt and catfish had the next highest concentrations, in general. Eel, catfish, and smelt are relatively high in fat content (about 37%, 13%, and 3.5%, respectively), which could explain the higher 2,3,7,8-TCDD levels found in them. These species also showed levels of PCBs ranging from 0.95 to 8.78 ppm and of the pesticide Mirex ranging from not detected (ND) to 0.29 ppm.

Disposal sites

The much-publicized Times Beach site is by no means unique. Indeed, Missouri officials now fear that there are perhaps 100 dioxin-contaminated sites in that state.

Louis Thibodeaux of the University of Arkansas spoke of a roughly one-square-mile hazardous waste disposal site near Jacksonville, Ark., at which 2,3,7,8-TCDD and other isomers have been detected. One plant made 2,4-D and 2,4,5-T there since 1949, and another produced the same herbicides since 1958. Those plants no longer function. However, approximately 3000 barrels of wastes were stored at the site, and some were in poor shape and leaking. One portion of the manufacturing area, where accidental reactor "blowouts" had occurred, was found to contain 2,3,7,8-TCDD concentrations in excess of 1 ppb.

After TCDD was detected in 1979, federal, state, and industry representatives took about 1000 samples. It then became necessary to develop and employ transport models, in order to estimate quantities of TCDD leaving the site. Aims of the study were

- to use simple transport models for estimating rates of emission of TCDD from various points of origin on the site;

Concentration of TCDD in various media, parts per trillion [a]

Medium	Sample size	Average	Range
Air, particulate	2	1 100	±350
Water (includes off-site)	23	14	ND[b] to 47
Soil	5	1 300	ND to 2900
Sediment (creek)	5	770	ND to 1800
Sediment (pond)	3	22 100	±2100

[a] At disposal facility near Jacksonville, Ark. [b] ND = not detected

Source: Presentation by Louis Thibodeaux of the University of Arkansas (Fayetteville)

- to identify major sources and *mechanisms for off-site transport;* and
- to enumerate measurements that needed to be made for better quantification of off-site transport rates.

Among probable mechanisms of off-site transport, Thibodeaux listed particulate matter carried by streams in the vicinity; vaporization from burial areas; resuspension of dust in the air; and volatilization from the pond water surface, the source being, perhaps, contaminated cooling water and sediment. Movement of particulate matter containing adsorbed chlorinated organics is considered by many scientists to be a much more important removal mechanism than leachate, because of the low solubility of these compounds in water.

High-temperature effects

When materials such as PCBs, tri- and pentachlorophenol, certain pesticides, and some other chlorinated organic species are burned, PCDDs and PCDFs are often found in the gaseous and particulate matter emissions, especially in the case of accidental fires. H.-R. Buser of the Swiss Federal Research Station (Wädenswil, Switzerland), Rappe, and their colleagues found as many as 30 PCDD and 60 PCDF congeners in samples taken from incinerators in West Germany, Holland, Switzerland, Sweden, the U.S., and Canada.

Rappe has used the following protocol to test for PCDDs and PCDFs: Extract soot samples with toluene in a Soxhlet extractor for 36–48 h. Purify extracts or condensates in a multistep "cleanup" process that includes an alumina column. Analyze by GC/MS. Identify, quantify, and confirm by comparison with valid standards.

With this protocol, Rappe and his associates at the University of Umeå tested samples from a Norwegian rotatory cement kiln in which a test burn of PCBs was conducted. PCDDs and PCDFs were not detected. However, Rappe also tested bottom and baghouse ash from an industrial boiler in the U.S., at which pentachlorophenol was known to have been burned. He found about 5 ppm PCDDs and 2.5 ppm PCDFs, with 2,3,7,8-TCDD "only a very minor peak, and more than 90% of the PCDDs were lower-chlorinated congeners than octaCDD, the 'expected' dimerization product."

These incinerations involved controlled situations. What about accidental fires, such as a PCB fire in Stockholm, Sweden, which broke out when a series of PCB-containing capacitors was ignited, perhaps because of an electrical failure? No PCDDs were identified. However, there were TCDFs and pentaCDFs, among which 2,3,7,8-TCDF and 2,3,4,7,8-pentaCDF were tentatively identified as being present. But major peaks showed Cl_{2-5} polychlorinated biphenylenes or the less probable isomeric polychloroacenaphthalenes; polychloropyrenes were also observed, Rappe noted.

Rappe described a transformer fire in Binghamton, N.Y., that involved a dielectric fluid consisting of 65% of the PCB Aroclor 1254 and 35% chlorobenzenes. Soot analysis revealed that PCDFs predominated, with penta- (including 2,3,4,7,8-) and hexaCDFs (including 1,2,3,4,7,8-) as the major components. However, the toxic 2,3,7,8-TCDF was tentatively identified as being present, along with several PCDDs. Among the PCDDs, the dominating congeners were the highly toxic 2,3,7,8-TCDD and 1,2,3,7,8-pentaCDD.

M. Taylor of Wright State University (Dayton, Ohio) said that "while several reports have appeared in the literature, which implicate certain incineration processes as sources of chlorinated hydrocarbons, no definitive studies which establish the mechanism(s) of their generation have been accomplished to date." He observed that suggested mechanisms entail PCDD/PCDF formation from precursors present in the material being burned or, alternatively, *de novo* formation in the flame by thermal synthesis from carbonaceous fuels and endogenous chlorine. Yet another possibility, according to Taylor, is that PCDDs/PCDFs are actually present in incineration feedstocks and fuels and may survive incineration "because of their exceptional resistance to thermal oxidation." Using a Method V sampling train, he studied stack emissions from a municipal incinerator fitted with a heat recovery system.

Yusho PCB analysis for PCDFs

Y. Masuda and H. Kuroki of the Daiichi College of Pharmaceutical Sciences (Fukuoka, Japan) analyzed PCBs, involved in the Yusho episode, for PCDFs. They studied PCBs marketed under the names Kanechlor KC-300, KC-400, KC-500, and KC-600, all made in Japan. PCDF content was found to be 1, 18, 4, and 5 ppm, respectively. KC-400, which has the highest PCDF content, was the contaminant found in the Yusho rice oil; 5 ppm of PCDFs were detected in the rice oil. Masuda and Kuroki explain that there were about 1000 ppm of PCBs in the rice oil; thus, the PCDF content of the rice oil should have been 0.018 ppm. Thus, the PCDF concentration of 5 ppm was about 280 times the amount expected. Masuda and Kuroki believe that the PCB KC-400 had been strongly heated, thereby increasing the PCDF content. They also suggest that the PCDF concentration was further increased during the rice oil's deodorization process.

Monsanto's Hileman added the caveat that PCDFs can be formed from PCBs only in a narrow temperature range. At too low a temperature, they are not formed. At too high temperatures, they are decomposed.

Synthesis and identification

In the municipal samples, Taylor found a number of congeners of PCDDs and PCDFs. He cautioned, however, that the presence of some had to be inferred from comparison with data for closely related isomers, because their standards were not available.

That may be one reason why Hileman and his colleagues at Monsanto Research were motivated to carry out the difficult task of synthesizing and then identifying all 38 TCDF isomers. They prepared the isomers using several procedures, including the carefully controlled oxidative pyrolysis of selected PCBs (generally more than 97% pure); the UV photolysis of pentaCDFs; and the electrophilic chlorination of specific triCDF isomers. For instance, to prepare 1,2,6,7-TCDF, Hileman's group started by pyrolyzing 2,3,3′,4′-tetrachlorobiphenyl, which gave both 1,2,6,7-, and 1,2,7,8-TCDF. The identity of the 1,2,6,7-TCDF was confirmed by pyrolyzing 2,2′,3,3′,4,4′-hexachlorobiphenyl to form 1,2,3,6,7-pentaCDF, which was then UV-photolyzed to 1,2,6,7-TCDF.

Hileman said that it became possible to identify the 38 TCDF isomers by distinguishable "relative retention times" (RRTs) on both glass-coated SP-2330 and fused-silica SE-54 capillary columns. With the SP-2330 column (60 m × 0.25 mm i.d.), conditions were 200 °C, 1 min isothermal, then 8 °C/min to 250 °C, and isothermal at 250 °C for the rest of the run time. The hydrogen carrier gas was at 15 psi to give a linear flow velocity of 40 cm/s.

All RRTs are based on those of

isotopically labeled 2,3,7,8-TCDF, whose four chlorine atoms consist of ^{37}Cl and whose RRT is defined as 1.000. Using two different capillary columns, Hileman and his associates showed that the 2,3,4,8-TCDF had comparable retention characteristics on both columns, as did the 2,3,7,8-TCDF. Thus, 2,3,4,8-TCDF could be a serious interferant in the analysis of 2,3,7,8-TCDF. Hileman urged that studies such as these be carried out for all PCDDs and PCDFs to permit a proper interpretation of the analytical data being generated.

Immunodepressive effects

When one works with PCDDs and PCDFs, meticulous observance of all safe chemical handling and disposal procedures cannot be overemphasized. One good reason is a finding, presented by Annunziata Vecchi of the Istituto di Ricerche Farmacologiche "Mario Negri" (Milan, Italy) that even single, very low doses of 2,3,7,8-TCDF caused immunodepression (impairment of immune system functioning) in mice; TCDD had been known to have this effect. It took much less TCDD (6 μg/kg of body weight) than TCDF (180 μg/kg for an "equiactive" dose), but the outcome was parallel.

Work in immunodepressivity and additional health effects, fate and transport, analysis, formation, and other aspects of PCDD/PCDF biology and chemistry continues. Further advances in the field will be discussed at a second symposium wholly devoted to this subject, which will be a part of the 186th National Meeting of the American Chemical Society, to be held in Washington, D.C., this coming September.

This symposium, like the first, is being organized by Lawrence Keith of Radian Corporation (Austin, Tex.), Gangadhar Choudhary, and Christoffer Rappe for the ACS Division of Environmental Chemistry. The proceedings of both symposia will be published in a two-volume series; the first volume will be available this summer from Ann Arbor Science Publishers Inc. (Ann Arbor, Mich.).

—Julian Josephson

Additional reading

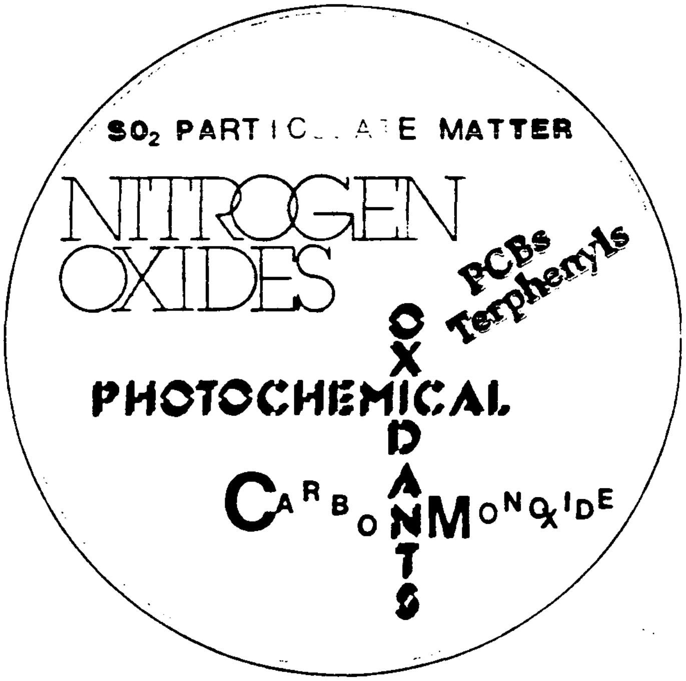
(1) "Chlorinated Dioxins and Related Compounds: Impact on the Environment"; O. Hutzinger et al., Eds.; Pergamon Press Inc.: Elmsford, N.Y., 1982.

(2) Mazer, Thomas; Hileman, Fred D. "The Ultraviolet Photolysis of Tetrachlorodibenzofurans," *Chemosphere* **1982,** *11* (7), 651-61.

(3) Hay, Alastair. "The Chemical Scythe: Lessons of 2,4,5-T and Dioxin"; Plenum Press: New York, N.Y., 1982.

Reviewing health effects of pollutants

Issued by the World Health Organization in conjunction with the United Nations Environment Programme, the Environmental Health Criteria documents assess the health effects of pollutants



Ten years ago, the World Health Organization (WHO) initiated an Environmental Health Criteria Programme to assess the health effects of pollution. In 1980, this program was incorporated into a more comprehensive International Program on Chemical Safety (IPCS). Sponsored by the WHO, the United Nations Environment Programme (UNEP), and the International Labour Organization, this program's major objectives are:

- to assess existing information on the relationship between exposure to environmental pollutants (or other physical and chemical factors) and human health, and
- to provide guidelines for setting exposure limits consistent with the protection of public health.

At the end of 1982, a number of new executive summaries on these criteria were published. The following comments were gleaned from those summaries.

PCBs and terphenyls

Polychlorinated biphenyls (PCBs) and polychlorinated terphenyls (PCTs) are manufactured and used in the form of mixtures rather than as individual compounds. PCBs have been found in the ambient air, water, soil and sediments, and in human and animal tissue in almost all parts of the world. Such are the comments from the summary on Criteria 2, an 85-page document issued by the WHO in 1976. According to the summary, the average human daily intake of PCBs from the air and from drinking water has been estimated to be less than 1 μg

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from each of these sources. In the industrialized countries, the average daily intake from food, including fish, is rarely <5.0 μg or >100.0 μg (approximately 1 μg/kg body weight)/d.

PCBs accumulate in human tissue as they do in animal tissue. Measurements of human fatty tissue have shown that most samples contain levels of PCBs on the order of 1 mg/kg, that is, roughly 1000 times the average daily intake level. This marked contrast is due to their prolonged retention in fat deposits. According to the summary document, national surveys have revealed PCB blood levels of 0.3-1.2 μg/100 mL in persons not subjected to occupational exposure, compared with levels as high as 190 μg/100 mL in occupationally exposed workers. Similarly, PCB levels as high as 700 mg/kg have been found in the fatty tissue of occupationally exposed workers, compared with a typical level of 1 mg/kg in the general population.

It is apparent from these exposures that PCBs are not acute poisons, but produce their effects through gradual accumulation in the body. But there is no known treatment that increases the rate of removal of the PCBs from the body.

Toxic effects of PCBs have been observed in humans at an estimated average daily intake of 0.07 mg/kg body weight over an exposure period of approximately 120 d. This was the Yusho case, which occurred in Japan in 1968. The effects of this exposure level were influenced by the intake of impurities more toxic than PCBs (*ES&T*, Vol. 17, No. 1, 1983, p. 11A).

Oxides of nitrogen

The two most important oxides of nitrogen are nitric oxide (NO) and nitrogen dioxide (NO_2). Of these two, NO_2 has been shown to produce adverse effects on human health when it is inhaled at concentrations not very different from those found in urban air. On the other hand, NO plays an important role in photochemical reactions that lead to the formation of several reaction products, including NO_2. In fact, in the atmosphere nitrogen dioxide is formed largely by reactions involving nitric oxide.

Effects of NO_2 on humans have been studied in experiments on both healthy volunteers and volunteers with preexisting respiratory illness. These studies show that the human respiratory system is affected by exposure to NO_2. When healthy volunteers were exposed to 1300-3800 μg/m^3 of NO_2 for 10 min, changes that caused difficulty in breathing were observed in the air passages. As NO_2 levels were increased further, the effects became more severe. Criteria 4, for these pollutants, is a 79-page document issued by the WHO in 1977.

Though it is difficult to generalize, annual mean nitrogen dioxide concentrations in urban areas throughout the world are typically in the range of 20-90 μg/m^3. The highest daily means are in the range of 130-400 μg/m^3, and the highest hourly mean values are 240-850 μg/m^3. For nitric oxide (NO), the annual average concentration ranges from 49-95 μg/m^3.

According to this summary document, a nitrogen dioxide concentration of 940 μg/m^3 (0.5 ppm) was selected as an estimate of the lowest level at which adverse health effects due to short-term exposure to nitrogen dioxide could be expected to occur. By adopting a minimum safety factor of 3-5, a task group agreed that a maximum 1-h exposure of 190-320 μg/m^3 (0.10-0.17 ppm) should be consistent with the protection of public health and that this exposure should not be exceeded more than once per month. Because of the lack of information on the effects of long-term exposure to nitrogen dioxide in humans, only a short-term limit was suggested.

Photochemical oxidants

Criteria 7, a 110-page document published by the WHO in 1979, notes that photochemical oxidants include ozone, nitrogen dioxide, and peroxyacetyl nitrates. More than 90% of the total oxidants is in the form of ozone. In fact, the results of ambient air monitoring are normally expressed as concentrations of ozone.

In large urban areas, maximum 1-h ozone, or total oxidant levels, can range from 300-800 μg/m^3 (0.15-0.40 ppm) or more. Ozone is the strongest of the photochemically formed oxidants that is stable enough to be identified and measured. Evidence from one controlled human exposure study indicates that exposure to an ozone level of 200 μg/m^3 (0.1 ppm) for 2 h can cause some obstruction in healthy human subjects.

It was recommended that 1-h levels of ozone of 100-200 μg/m^3 (0.1-0.25 ppm), measured by the chemiluminescence method, should be used as a guideline for the protection of public health. It was also agreed that a 1-h oxidant concentration of 120 μg/m^3 (0.06 ppm) would be the best single value estimate of the exposure limit for oxidants in the ambient air. As this level is approximately equal to the highest natural background level of oxidants, attainment of this concentration could prove extremely difficult, particularly near large urban areas.

Blood analysis. *Analyst is preparing a sample for screening of industrial workers.*

SO_2 and particulate matter

The health effects of mixtures of sulfur dioxide and particulate matter are studied usually because there is general agreement that a synergistic (potentiating) effect occurs when both forms of pollution are present in air. In fact, in epidemiological studies it has not generally been possible to identify the individual effects of either of these forms of air pollution, according to Criteria 8, a 108-page document issued by WHO in 1979.

In 1965, an estimated 146 million tons of sulfur dioxide were produced globally by man-made sources. Although concentrations in different cities vary considerably, the annual mean sulfur dioxide concentrations are generally in the range of 100-200 μg/m^3 (0.035-0.070 ppm); the highest daily means may be three or four times higher.

Clinical studies have shown that sulfur dioxide alone can produce slight effects on respiratory function in healthy subjects exposed under controlled conditions for 30 min to a concentration of 2100 μg/m^3 (0.75 ppm) but not to 1100 μg/m^3 (0.37 ppm). Studies confirmed that mortality increases when 24-h average concentrations of combined sulfur dioxide and smoke exceed 2000 $\mu g/m^3$. Combined exposure to concentrations of sulfur dioxide below 500 $\mu g/m^3$ and smoke at 250 $\mu g/m^3$ (24-h means) did not induce any long-term effects.

According to this document, most studies on the long-term effects of exposure to SO_2 and suspended particulate matter in adults have been based on the prevalence of respiratory symptoms. The results of this work indicate that more subjects living in communities with high concentrations of sulfur dioxide (annual average 125-200 $\mu g/m^3$) and suspended particulate matter (annual average 150-225 $\mu g/m^3$) show a higher incidence of respiratory symptoms than do those in communities with low levels of sulfur dioxide (annual average, 45-60 $\mu g/m^3$) and suspended particulate matter (annual average of less than 100 $\mu g/m^3$).

Criteria 8 noted that it has been suggested that air pollution may be a cause of lung cancer. The evidence for this is threefold: an urban/rural gradient for the disease, the presence of known cancer-producing agents (such as benzo[*a*]pyrene in suspended particulate matter), and a temporal relationship between rising lung cancer and increasing air pollution. Studies of indigenous and migrant populations suggest, however, that if air pollution is a factor, it is very small compared with cigarette smoking. Guidelines for exposure limits consistent with protection of human health are: a 24-h mean for SO_2 of 100-150 $\mu g/m^3$ and for smoke of 100-150 $\mu g/m^3$, and an annual arithmetic mean for SO_2 of 40-60 $\mu g/m^3$ and for smoke of 40-60 $\mu g/m^3$.

Carbon monoxide

The most important biological characteristic of CO is its affinity for hemoglobin, the oxygen-carrying pigment of red blood cells. This results in the formation of carboxyhemoglobin (HbCO), which is over 200 times more stable than oxyhemoglobin (HbO_2).

Occupational exposure to CO can be considerable. Levels of CO in garages have been shown to reach as high as 600 mg/m^3, and workers in such places may exhibit HbCO levels up to five times higher than normal. During a day's work, highway inspectors have been shown to exhibit HbCO concentrations from 4-7.6% (smokers) and from 1.4-3.8% (nonsmokers). By contrast, HbCO levels in the general population rarely exceed 1%, although a study of 18 urban areas in North America showed that 45% of nonsmokers exposed to ambient CO had HbCO levels exceeding 1.5%. Humans themselves produce CO during normal metabolic processes. Such endogenous production probably accounts for about 0.1-1.0% of the total HbCO in blood.

The effects of CO in humans depend on the preexisting state of health. For example, some fat people seem capable of tolerating HbCO levels as high as 40% for short periods, but persons with heart or lung diseases may succumb to HbCO levels of 5-10%. The performance of vigilance tasks—those involving the ability of an individual to detect small changes in his environment taking place at unpredictable times and demanding continuous attention—may be impaired by HbCO levels below 10%, and even as low as 5%. (This is roughly equivalent to CO levels in air of 80 and 35 mg/m^3, respectively.)

A task group convened by the WHO was concerned about the lack of corroborative data on low-level, long-term exposure to CO and about the conflicting data on behavioral effects at such low levels. Behavioral disorders probably occur at HbCO levels below 20%, but a no-observed-adverse-effects level has not been established. Work capacity is affected by CO exposure, and limitations probably start at HbCO levels of 4%. Although maximal work effort is not diminished at 2.5-4.0%, the length of time that such effort can be maintained is shortened.

Because smoking is a major contributor to the HbCO levels of smokers, recommendations for exposure limits are designed to protect nonsmokers. An HbCO level of 2.5-3.0% is the tentative maximum suggested by the task group for the protection of the general public, including those with impaired health. For occupationally exposed groups, the HbCO level should not exceed 5%.

Monitoring stations

There has always been the question of whether fixed outdoor monitoring stations can provide a fair estimate of what people breathe and to what they are exposed. As part of the Global Environmental Monitoring System (GEMS), the Gage Research Institute and the Institute for Environmental Studies, both of which are part of the University of Toronto, conducted a program that correlated indoor air pollution, using a personal sampler, with outdoor ambient pollution. Measurements were made at indoor sites and immediately adjacent outdoor sites. Scientists measured human exposure to SO_2, NO_2, and suspended particulate matter and concluded that quantification of a person's exposure to pollutants can be obtained with a personal sampler. But the statistical correlations found in the Toronto area were not sufficiently high to make general predictions of human exposures from measurements made at an ambient air quality monitoring station or, for that matter, from measurements made with an indoor sampler, even for homes free of major sources of pollution. Such are the findings of WHO Internal Report ERP/82.38.

There is also a report on human exposure to carbon monoxide and total suspended particulates (TSP) in Zagreb, Yugoslavia—WHO Internal Report ERP/82.33. Measurements with personal samplers and outdoor ambient monitoring stations were correlated. The weighted-average personal exposure (WAE) was compared to the average of simultaneously measured concentrations of TSP and their respirable fraction (RP) at the nearest outdoor network station; to the concentration to which the subject was exposed at home; to the indoor-outdoor concentration ratio; and to the background concentration levels. For the subjects of this study (all of the employees of the Institute for Medical Research and Occupational Health in Zagreb commuting to and from work from different parts of town and moving around), WAE for both CO and RP was correlated best with exposure at home, where they spent about 65% of their time. A most important factor in CO exposure was the presence of indoor emission sources at home such as smoking, gas heating, and cooking. For respirable particulate matter, WAE was in fair correlation with outdoor concentrations in winter but not in summer when outdoor concentrations were much lower than WAE. This shows that a considerable part of personal exposure comes from other sources.

Availability

Each criteria document comprises an extensive scientific review concerning a specific environmental pollutant or group of pollutants. Information ranges from sources and exposure levels to a detailed account of the available information concerning effects on health. For more information write: Division of Environmental Health, World Health Organization, 1211 Geneva 27, Switzerland.

—Stanton Miller