TITLE:	Toxic Emissions from Fire Department Training
PROJECT MANAGER:	Kirby E. Kiefer
ORGANIZATION:	FIRE/EMS/Safety Center Minnesota State Colleges & Universities
ADDRESS:	1450 Energy Park Drive, Suite 100-B St. Paul, MN 55108-5218
LEGAL CITATION:	ML97, Chap. 216, Sec. 15, Subd. 8 (a)
APPROPRIATION AMOUNT:	$ 65, 000

Statement of Objectives:

Identify the scope of fire service training in acquired structures in Minnesota

Identify the toxic substances released during the burning of the structure

Estimate the quantities of toxics released to the environment

Estimate the dollar-costs of these toxics

Identify the costs of alternative training strategies

Overall Project Results

292 structural fire service training exercises were permitted by the Department of Natural Resources in 1997, we estimate that 90 exercises were conducted without DNR permits. Emissions from the wood burned approximate those released annually by a wood cabinet factory.

Substances released by a fire are variable and dependent on factors such as oxygen availability, moisture content of the wood and other fuel substances (paint, furnishings, insulation, etc.) We estimated the quantities of major substances released annually by fire service training to be:

Carbon Dioxide	7,875,000 pounds	Carbon Monoxide	262,500 pounds
Water	3,937,500 pounds	Hydrocarbons	105,000 pounds
Particulates	262,500 pounds	Nitrogen Oxides	15,700 pounds

Unforeseen complexities prevented attaching dollar costs to the pollutants released by fire service training exercises; the weighing of alternative strategies was, therefore, impossible.

At three fire service structural fire training exercises, Hazardous Materials Response Teams conducted ground-level air monitoring. Samples were taken approximately 75 feet from the burning building during the periods of worst smoke obscuration. Subsequent analysis disclosed that all target substances were below acceptable atmospheric thresholds. Undesirable substances were certainly in the smoke cloud, but concentrations were surprisingly low.

Project Results Use and Dissemination

We learned two lessons with long-term environmental benefits: First, the practice of restricting an incipient fire's growth (so students can watch the dynamics of developing fires) will be changed to encourage more rapid initial heat production. More complete combustion from hotter fires yields less visible smoke and other pollutants. The more vigorous thermal column carries combustion by-products aloft where they are dispersed more quickly. This may not reduce the total emissions, but it does reduce more objectionable substances, especially at ground level.

Second, we learned that most of a building's mercury can be found in electrical switches and thermostats. Removing these items before the structure is ignited eliminates a pollution source without any negative impact on the educational experience.

The results of this study will be disseminated to the Minnesota Fire Service Community through the Minnesota Smokeater monthly newsletter and the bi-monthly Minnesota Fire Chief magazine.

Date of Report: July 1, 1999

LCMR Final Work Program Update Report

Date of Workprogram Approval: June 25, 1997

Project Completion Date: June 30, 1999

LCMR Work Program 1997-D-1 ML97, Chap. 216, Sec. 15, Subd. 8 (a)

PROJECT TITLE: Toxic Emissions from Fire Department Training
Project Manager: Kirby E. Kiefer
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Total Biennial Project Budget:

$ LCMR:	65, 000	**$ Match:** (in-kind)	27, 600
-$ LCMR Amount Spent:	5, 511.48	**-$Match Amount Spent:**	9, 419.24
= $ LCMR Balance:	59, 488.52	**= $ Match Balance:**	18, 180.76

A. Legal Citation: ML 1997, [Chap. 216], Sec. [15], Subd.8 (a).
Appropriation Language:

TOXIC EMISSIONS FROM FIRE DEPARTMENT TRAINING $65,000

This appropriation is from the future resources fund to the FIRE/EMS Center at Metropolitan State University to identify and quantify toxic emissions from live burn training in acquired structures to evaluate and propose alternatives. This appropriation is available until June 30, 2000, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

B. Status of Match Requirement: No Match Required

Several Technical College Administrators proviced access to live burn training exercises. The costs of the structure, fire suppression equipment, staff time and safety monitoring were all considered "match" and were borne by the institutions.

The fire service training simulator industry did not contribute to this project.

Metropolitan State University (MnSCU) agreed to assign the Project Manager at an estimated value of $12,660.

This project required access to live structural fire service training exercises, and technical college administrators provided access to them. The cost of instruction for such a session was approximately $500; the owner of the property was generally given a receipt for a tax write-off of $1,000.

II. PROJECT SUMMARY AND RESULTS:

This project identified and quantified airborne emissions from fire department structural fire training exercises. First, we determined (as closely as possible) exactly how many fire department live structural fire training exercises actually take place.

Next, we measured the emissions from several structural fire training exercises conducted by various technical colleges. The measurement was conducted by a the North Metro Chemical Assessment Team which measured for Carbon Monoxide, Nitrogen Dioxide, Lead, Sulphur Dioxide, Volatile and Organic Compounds. These materials were selected because they were part of the "big seven" criterion pollutants designated by the Environmental Protection Agency in 1970.

Data was compiled and the gross annual release was compared to other sources of pollution to evaluate the relative seriousness of the problem.

II. PROGRESS SUMMARY:

January, 1998

The Department of Natural Resources provided documentation of 292 exercises for which appropriate 1997 burn permits have been issued. Estimates of non-permitted fire service training exercises range from a low of 10% (30 burns) to a high of 30% (90 burns). A significant problem in gathering statistical data aroise because many local fire officials appeared to be of the opinion that they may issue permits to incinerate structures (and, therefore, do not obtain the required DNR permit).

Architects and the University of Minnesota Extension Service shared data which estimated that an average 4-bedroom house comprised slightly less than 20 tons of wood (18,000 board feet per house @ 2.21 pounds per board foot). For this and all associated calculations, I assumed the worst possible case and rounded upwards. If, indeed, Minnesota's fire service conducts 350 live-burn training sessions in acquired structures, the approximate quantities of the major constituents of smoke are probably less than:

Carbon Dioxide	28,000,000	pounds
Water	14,000,000	pounds
Particulates	1,400,000	pounds
Carbon Monoxide	1,050,000	pounds
Hydrocarbons	280,000	pounds
Nitrogen Oxides	42,000	pounds

The reader will note that the weights listed above far exceed the raw weight of the wood in the structures. In large part, this is because atmospheric oxygen is consumed in the combustion process. The reader should also note that the figures above are preliminary calculations based on a review of the available literature.

Discussions with Minnesota Pollution Control Agency personnel revealed that the minute amounts of mercury found in thermostats and silent light switches are responsible for much of the heavy-metal pollution which appear in smoke. We have taken steps to have these appliances removed from buildings before a training fire is ignited.

May, 1998

Since the last progress report, the FIRE/EMS Center has been administratively reassigned to the central office of the Minnesota State Colleges and Universities. This relocation has caused some significant disruption and reassignment of staff activities.

The literature research continued. Using LCMR funds, the FIRE/EMS Center Library has acquired:

Griffiths, J.F. & Barnard J.A. (1995) Flame and Combustion (3rd ed) $48.96

Glassman, I (1996) Combustion (3rd ed) $62.96

ASTM Standard Method for E1678-96 - Measuring Smoke Toxicity for Use in Fire Hazard Analysis $22.50

Cox, G. (1995) Combustion: Fundamentals of Fire $128.30

The estimates listed in the January, 1998 report appeared to be higher than my experience would suggest, especially when compared with other pollutants as reported by the Minnesota Pollution Control Agency. Based on observations by instructors who regularly conduct live fire training, the building used in the January, 1998 calculations was much larger than the average house donated for fire service training.

Using figures for a smaller, 2-story house with 30' x 30' dimensions, I calculated that there were about 6,379 board-feet of wood which weighed about 7.5 tons (6,379 x 2.21 pounds per board foot = 14,097 pounds). Again assuming 350 house-burns per year, the estimated releases are:

Carbon Dioxide	7,875,000	pounds
Water	3,937,500	pounds
Particulates	262,500	pounds
Carbon Monoxide	262,500	pounds
Hydrocarbons	105,000	pounds
Nitrogen Oxides	15,750	pounds

At this point, Results # 1 and # 2 had been accomplished as well as is

reasonably possible. The major pollutants have been identified, and their quantities estimated. Numerous other compounds are produced by the burning of abandoned houses, but these compounds are quite erratic in their presence and may appear in quantities too small to measure (within the scope of this study).

I compared the Ryan data with a similar table from Quintiere (1998) and learned that ventilation conditions (the availability of air to the combustion process) have a profound impact on the nature and amounts of emissions from fires. While the majority of a building's demolition takes place in hot, free-burning combustion, it may be impossible to predict (or measure) precisely what pollutants are produced.

Because of this fact, I proposed that the direction of this research shift from measuring total pollutants from a structural fire training session. Instead, I proposed that we measure the air quality in the area immediately surrounding the structure used for fire service training, and compare it with the standards as recommended by OSHA and other agencies.

January, 1999

Since the last report, in cooperation with the North Metro Chemical Assessment Team, ground-level air monitoring was conducted at three fire training exercises. Samples were drawn at "nose-level" 75 feet downwind from the fire building. The samples were taken during the worst concentration of smoke at that level. Using equipment and instruments available to the Chemical Assessment Teams, no pollutants were at threshold concentrations. While this is good news from a neighborhood-safety standpoint, it is clear that there is, indeed, smoke at that level-the instruments were simply not sensitive enough to measure it.

Two more books were purchased for the FIRE/EMS/Safety Center Library.

Sax (1997) Dangerous Properties of Industrial Materials (10^{th} Ed) 500.00

Hawley (1998) Condensed Chemical Dictionary (13^{th} Ed) 125.00

IV. OUTLINE OF PROJECT RESULTS:

Fires in structures emit hundreds of toxic substances. Buildings acquired for fire service training release toxic substances when they are burned. With the exception of asbestos and certain petroleum products, these substances and their environmental impacts are unknown. Several high-technology alternatives are becoming available, but their cost-effectiveness has never been evaluated from an environmental perspective. This project's final report will:

Result 1. Identify the scope of fire service training in acquired structures in Minnesota.

This result will be accomplished through a combination of review of Department of Natural Resources records and then comparison with returns from a statewide anonymous survey. The statistical difference should give an accurate count of the actual total number of live burn training sessions conducted.

Budget	$ 1, 000	
	- (22.26	Local Mileage & Supplies)
	977.74	(Returned to LCMR)
Match	$ 2, 110	Metropolitan State University Staff
	- (1, 949. 60	- 2 Weeks Staff Time)
	$ 160. 40	
Match $	1, 000	Metropolitan State University Project
Match $	TBA	Minnesota Fire Chiefs' Association

Result 2. Identify the toxic substances released during the burning of the structure.

The initial phase of this effort will be a review of the literature on combustion by-products. The FIRE/EMS Center Library should be adequate to provide an extensive list of the chemicals found in the smoke of confined fires.

The second phase of this segment will be accomplished through sampling at live fire training exercises.

Budget	$ 22, 200	
	- (887.72	Books)
	$ 21, 312.28	(Returned to LCMR)
Match	$ 3, 165	Metropolitan State University Staff
	- (1, 949.60	- 2 Weeks Staff Time)
	$ 1, 215.40	
Match	$ 7, 500	Technical Colleges/Communities

Result 3. Estimate the quantities of toxics released to the environment.

A literature review in the FIRE/EMS Center Library can give some information on the quantities of various by-products based on the types and quantities of building materials and contents.

Measurements of ground-level atmospheres will be compared with accepted OSHA and other standards.

Budget	$ 24, 630	
	- (4, 601.50	- Assessment Team & Expendables)
	$ 20, 028.50	(Returned to LCMR)
Match	$ 3, 165	Metropolitan State University Staff
	- (45.24	Travel Expenses)
	- (974.80	- 1 Week Staff Time)
	$ 2, 144.96	
Match	$ 7, 500	Technical Colleges/Communities
	- (4, 500	- Acquired Structures)
	$ 3, 000	

Result 4. Estimate the dollar-cost of these toxics.

The environmental impact literature carries many indices of costs-per-unit of various pollutants. By multiplying the unit costs by the estimated number of units released, a dollar-value impact can be calculated. BECAUSE OF UNFORESEEN COMPLICATIONS, THIS OBJECTIVE WAS NOT MET.

Budget	$ 15, 000	(Returned to LCMR)
Match	$ 2, 110	Metropolitan State University Staff
Match	$ TBA	Pollution Control Agency Staff

Result 5. Identify the costs of alternative training strategies.

Personnel, travel, equipment depreciation and capital investment expenses can be obtained from local municipalities. The costs of alternative building disposal can be obtained from contractors, landfill operators and pollution control officials. Prices for emerging simulator equipment can be obtained from the manufacturers. BECAUSE RESULT #4 COULD NOT BE ACCOMPLISHED, THIS OBJECTIVE WENT UNMET.

Budget	$ 2, 170	(Returned to LCMR)
Match	$ 2, 110	Metropolitan State University Staff
Match	$?	Industry Match

V. Dissemination:

Because of the public policy implications of the findings, I expect to publish an article in Fire Chief magazine, an international fire service administration monthly.

Since the results of the study could have impacts on Minnesota's fire service community, I have published an article in the "Minnesota Smokeater" monthly newsletter and will publish in the bi-monthly "Minnesota Fire Chief" magazine.

VI. CONTEXT:

A. Significance:

For more than fifty years, fire departments have conducted "live-burn" structural fire training in buildings donated for that purpose. The buildings have generally been abandoned houses, but larger commercial and industrial buildings have also been demolished in fire fighter training exercises. It is generally agreed that live-fire training in acquired structures is the most realistic training available.

Live-fire training is not without its risks. Nationally, on average, 7.8 fire fighters die every year when some element of the exercise goes awry. Sometimes, poorly planned drills result in the fire burning in unexpected directions, involving unintended properties. Occasionally, there are serious complaints from neighbors or others directly affected by the exercise.

In recent years, we have come to recognize the environmental impact of burning structures. We know that carcinogens and other poisons are in the smoke which is released to the atmosphere. We know that the runoff water also carries toxic substances; often directly into surface streams. We do not know, however, the quantity or impact of these substances which are released to the environment.

In response to the known pollution risks, regulations have been implemented to at least identify the asbestos which may become airborne during the fire service training evolutions. Standards and rules also regulate what building materials are allowed to be consumed; enforcement of these standards and rules is variable.

Several different high-tech solutions have reached the market. They include computer-controlled simulators which burn relatively clean-burning gasses. These simulators are very costly and still create some (albeit lower-grade) undesirable emissions. The market has also seen virtual-reality simulators which emit no toxics at all. The virtual reality simulators are also expensive and do not approach the realism achieved in other simulators or acquired structures.

At the moment, live-fire training in acquired structures is the only economically feasible alternative for most small, rural community fire departments.

B. Time: This project can be completed within two years.

C. Budget Context:

In 1989, the Metropolitan Airport Commission approached the FIRE/EMS Center for alternatives for training its airport crash fire fighters. Burning jet fuel (often hundreds of gallons at a time) in required training exercises was becoming environmentally unacceptable. The Federal Aviation Administration recognized that this was a problem nationwide and supported our efforts to produce a model Aircraft Rescue & Fire Fighting Training Center in Duluth. In 1994, Lake Superior College opened the doors to the world's most sophisticated live fire training simulator. The budget for that project was approximately $14 million.

The percentage of that money directed explicitly to pollution control was never identified. Some of the technological achievements of that project could serve as the basis from which we could explore similar problems in live-burn structural fire training. The scale is smaller and the issues different, but we believe that significant economies can be achieved through technology-transfer and collaborations.

	July 1995-June 1997	July 1997-June 1999	July 1999-June 2001
	Prior expenditures	**Proposed expenditures**	**Anticipated future expenditures**
	on this project	**on this project**	**on this project**
1. LCMR	$ 0	$ 65,000	$ 0
2. Other State	$ 0	$ 12,660 (Project Manager x 12 weeks)	$ 0
3. Non-State	$ 0	$ 15,000 (Structures, Exercise & Access)	$ 0

BUDGET:

Personnel:	$ 32, 000	Hazardous Materials Response Teams to conduct monitoring and sampling ($400/hour x 8 hrs x 10 exercises)
Equipment:	$ 6, 500	Expendable colormetric sampling tubes, sample bags, respirators, videocamera, tapes and incidentals
Acquisition:	0	
Development:	0	
Other:		
Travel	$ 2, 650	Lodging, mileage, meals to ten exercises plus other incidental travel
Books	$ 2, 200	1998 edition of Sax/Lewis Manuals (to supplement FIRE/EMS Center collection)
Survey	$ 2, 267	Postage, printing, statistical analysis (to be leveraged with funds from Fire Chiefs Association)
Lab Work	$ 19, 383	
Total:	$ 65, 000	

	July 1995-June 1997	July 1997-June 1999	July 1999-June 2001
	Prior expenditures on this project	**Actual expenditures on this project**	**Anticipated future expenditures on this project**
1. LCMR	$ 0	$ 5, 511.48	$ 0
2. Other State	$ 0	$ 4, 874 (Project Manager x 5 weeks) $ 45.24 (Mileage to three exercises)	$ 0
3. Non-State	$ 0	$ 4, 500 (Structures, Exercise & Access)	$ 0

BUDGET:

Personnel:	$3,036.60	Hazardous Materials Response Teams to conduct monitoring and sampling at three exercises
Equipment:	$ 1, 564.90	Expendable colormetric sampling tubes, sample bags, film and incidentals
Acquisition:	0	
Development:	0	
Other:		
	$ 887.72	Books as listed above to supplement FIRE/EMS Center collection
	$ 22.26	Local Mileage & Office Supplies
Survey	$ - 0 -	Postage, printing, statistical analysis (to be leveraged with Fire Chiefs Association fund)
Lab Work	$ - 0 -	
Total:	$ 5, 511.48	

VII. COOPERATION:

Minnesota State Fire Chiefs Association - may help fund survey

Minnesota State Fire Department Association

Minnesota Department of Natural Resources - will supply data

contact: S. Olin Phillips
MN Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155
(State Employee at no cost to this project)

Minnesota Pollution Control Agency - perhaps may do lab work & sampling

contact: Steve Lee
MN Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155-4194
(State Employee at no cost to this project)

Minnesota Department of Public Safety - perhaps may do sampling

contact: Robert Dahm
MN Department of Public Safety
444 Cedar Street, Suite 100 M
St. Paul, MN 55101-2156
(State Employee at no cost to this project)

VIII. LOCATION: Statewide

IX. Reporting Requirements:

Periodic workprogram progress reports will be submitted not later than December 30, 1998. A final workprogram report will be submitted by June 30, 1999 or by the completion date as set in the appropriation.

X. Research Projects:

Not applicable