

## NRC Publications Archive Archives des publications du CNRC

### Toxic combustion products of wood and polystyrene Tsuchiya, Y.; Sumi, K.

This publication could be one of several versions: author's original, accepted manuscript or the publisher's version. / La version de cette publication peut être l'une des suivantes : la version prépublication de l'auteur, la version acceptée du manuscrit ou la version de l'éditeur.

For the publisher's version, please access the DOI link below. / Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

#### **Publisher's version / Version de l'éditeur:**

<https://doi.org/10.4224/40000629>

*Building Research Note, 1971-09*

#### **NRC Publications Archive Record / Notice des Archives des publications du CNRC :**

<https://nrc-publications.canada.ca/eng/view/object/?id=e37ffa5c-779e-4c80-83de-39c5bc73d161>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=e37ffa5c-779e-4c80-83de-39c5bc73d161>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

**Questions?** Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

**Vous avez des questions?** Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

Ser  
TH1  
B92  
no. 76  
c. 2

BLDG

# BUILDING RESEARCH NOTE

ANALYZED

TOXIC COMBUSTION PRODUCTS OF WOOD AND POLYSTYRENE

by

Kikuo Sumi and Yoshio Tsuchiya

Division of Building Research  
National Research Council of Canada

Ottawa, September 1971

3345992

# TOXIC COMBUSTION PRODUCTS OF WOOD AND POLYSTYRENE

by

Kikuo Sumi and Yoshio Tsuchiya

Toxic gases and vapours produced at fires are responsible for the majority of deaths at building fires. Information on the gases causing these deaths is scarce because of lack of detailed pathological examination of victims. It is generally assumed that carbon monoxide (CO) is the most important toxic gas produced at fires because it is one of the main combustion products from cellulosic materials that are consumed in quantity at most building fires. The increasing use of new materials, such as polystyrene, raises the possibility that when involved in fire they may increase the toxic gases produced at fires.

The purpose of this Note is to provide data on the toxic gases produced from the combustion of white pine and untreated polystyrene, and evaluate the toxic hazard that is created by the combustion products.

## EXPERIMENTAL

Specimens were made in the form of pellets from white pine sawdust and untreated expanded polystyrene, and burned at 800°C in a 5-litre flask containing air. The sample weight was varied so that the range of weights would cover the condition for producing the maximum amount of CO per gram of sample.

The gaseous combustion products were cooled and collected in an evacuated bottle. The amounts of carbon monoxide and carbon dioxide (CO<sub>2</sub>) were then quantitatively analyzed by gas chromatography.

## RESULTS

The experimental results are presented in Tables 1A and 1B. The data for CO and CO<sub>2</sub> are expressed in weight per weight of sample.

## DISCUSSION

Toxicity hazard due to the products CO and CO<sub>2</sub> was calculated by a method proposed by the present authors<sup>(1)</sup>. Briefly, the method

of evaluation is as follows:

Toxicity,  $t$ , due to a gaseous or volatile product is assumed to be proportional to its concentration,  $c$ , and to its relative toxicity,  $t_r$ . Relative toxicity is defined as

$$t_r = \frac{1}{c_f}$$

where  $c_f$  is the concentration of the gaseous product that is fatal to man in a short exposure of about 30 minutes. The toxicity of a product based on both the nature of the material and the quantity evolved, then becomes

$$t = \frac{c}{c_f}$$

In order to present data on toxicity in a consistent manner, the authors suggest using the equation

$$T = \frac{c_e}{c_f}$$

where  $T$  is the toxicity index of a gaseous product, and  $c_e$  is the concentration of the product evolved when one gram of material is decomposed, and the products are diffused in a volume of  $1 \text{ m}^3$ . Concentrations,  $c_e$  and  $c_f$ , are expressed in ppm. The toxicity index of the material is obtained from the sum of the toxicity indices of the products.

The toxicity indices obtained from the results of the present experiments using  $c_f = 4000 \text{ ppm}$  for  $\text{CO}^{(2)}$  and 70,000 to 100,000 ppm for  $\text{CO}_2^{(3)}$  are presented in Tables 2A and 2B.

When wood is decomposed by heat, a large variety of combustible gases and vapours are produced. Some of these products act as mild irritants to the eyes and respiratory tract. When wood is burned, a large proportion of these vapours are consumed by the fire. The maximum toxicity index for wood, based on the present experiments was 0.09. The toxicity due to  $\text{CO}$  and  $\text{CO}_2$  only were considered in Table 1A because the amounts of other thermal decomposition products found in the present experiments were so much less than these two gases.

In order to discuss the contribution of styrene to the toxicity of the atmosphere following combustion of polystyrene, the lethal concentration,  $c_f$ , of styrene is required. This information could not be found in the literature, and an estimate had to be made. It was assumed that the lethal concentration of styrene is similar to those of benzene, toluene and xylene. The maximum concentration of these three compounds that can be inhaled for one hour without serious disturbance is reported as 3130 to 4700 ppm, and the concentration that is fatal for even a short exposure as 19,000 ppm (1.9 per cent). The lethal concentration for a 30-minute exposure is probably somewhere between these figures, and for the present discussion, is estimated to be 1 per cent or 10,000 ppm for benzene, toluene, xylene and styrene.

If polystyrene is completely decomposed to styrene monomer in the absence of air, the calculated toxicity index for styrene is 0.02. This theoretical value is much less than the toxicity index from CO obtained from experimental results. The toxicity index for CO ranged from 0.065 to 0.092, as presented in Table 2B. The maximum toxicity index for polystyrene obtained from CO and CO<sub>2</sub> data of the present study was 0.10. Even if the remaining carbon atoms of the sample were all converted to styrene (which is not possible in practice) the toxicity index for styrene would only be 0.005. Thus, CO is the main toxic product formed from the combustion of polystyrene.

The maximum toxicity index obtained from the combustion of polystyrene was of the same order as that from wood. Thus, on a weight basis, the potential hazard due to toxic combustion products from polystyrene is about the same as that from wood.

#### REFERENCES

1. Tsuchiya, Y. and K. Sumi. Thermal Decomposition Products of Polyvinyl Chloride. J. Applied Chem. Vol. 17, p. 364 (1967).
2. Henderson, Y. and H. W. Haggard. Noxious Gases and the Principles of Respiration Influencing their Action. 212 p. (1927)
3. Documentation of Threshold Limit Values. American Conference of Governmental Industrial Hygienists. 223 p. (1966)

Table 1A

## Combustion Products of White Pine

Sample Weight (mg)	Carbon Monoxide (g/g)	Carbon Dioxide (g/g)	Residue (g/g)
800	0.24	0.86	0.13
799	0.25	0.84	0.13
1007	0.35	0.90	0.13
999	0.36	0.92	0.14
1194	0.45	0.55	0.13
1197	0.44	0.57	0.14
1606	0.41	0.54	0.14
1600	0.43	0.53	0.14

Table 1B

## Combustion Products of Polystyrene

Sample Weight (mg)	Carbon Monoxide (g/g)	Carbon Dioxide (g/g)	Residue (g/g)
298	0.36	2.36	0
296	0.27	2.94	0
350	0.44	1.94	0.01
351	0.45	1.93	0.01
400	0.46	1.54	0.01
406	0.41	1.49	0.01
498	0.39	1.21	0.01
497	0.40	1.16	0.01
599	0.35	1.09	0.02
604	0.32	1.03	0.02



Table 2A

Toxicity due to Combustion Products  
of White Pine

Sample Weight (mg)	Toxicity Index		
	CO	CO <sub>2</sub>	SUM
800	0.048	0.005	0.05
799	0.051	0.005	0.06
1007	0.071	0.005	0.08
999	0.072	0.005	0.08
1194	0.090	0.003	0.09
1197	0.089	0.003	0.09
1606	0.082	0.003	0.08
1600	0.086	0.003	0.09

Table 2B

Toxicity due to Combustion Products  
of Polystyrene

Sample Weight (mg)	Toxicity Index		
	CO	CO <sub>2</sub>	SUM
298	0.072	0.014	0.09
296	0.055	0.017	0.07
350	0.088	0.012	0.10
351	0.090	0.012	0.10
400	0.092	0.009	0.10
406	0.081	0.009	0.09
498	0.077	0.007	0.08
497	0.079	0.007	0.09
599	0.069	0.007	0.08
604	0.065	0.006	0.07