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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_2) were then quantitatively analyzed by gas chromatography.

RESULTS

The experimental results are presented in Tables 1A and 1B. The data for CO and CO_2 are expressed in weight per weight of sample.

DISCUSSION

Toxicity hazard due to the products CO and CO_2 was calculated by a method proposed by the present authors[1]. 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 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 ppm for CO[2] and 70,000 to 100,000 ppm for 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 CO and 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_2 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

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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_2	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_2	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