

Evolution of phosphine from aluminium phosphide formulations at various temperatures and humidities

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Abstract

The rates of evolution of phosphine from aluminium phosphide tablets and sachets (produced in China, Shenyang Pesticide Factory) were determined in the laboratory in an air stream under controlled temperatures and humidities. Results showed that the maximum rate of evolution of phosphine was linearly related to the absolute humidity of the air. With absolute humidity moisture contents of air from 4.7 g/m³ to 35.5 g/m³ decomposition times ranged from 36 to 204 hours. The decomposition rate of the tablets was slightly faster than the sachets.

Introduction

Phosphine is an important fumigant for controlling insect pests of stored grain in China. Almost 85% of grain in state warehouses is fumigated with phosphine generated from aluminium phosphide every year. In actual practice, it was observed that aluminium phosphide tablets sometimes had not completely decomposed by the end of fumigation. Incomplete decomposition was noticed especially in short fumigations of 3–5 days exposure time and in dry grain.

Meuser et al. (1977) studied hydrolysis rates of aluminium phosphide in desiccators at two temperature and humidity combinations.

In this study, the decomposition rates of aluminium phosphide tablets and sachets were determined in the laboratory in an air stream under four temperature and humidity combinations, to provide basic data relevant to use of aluminium phosphide in fumigation practice.

Materials and Methods

Materials

The aluminium phosphide formulations used were produced at the Shenyang Pesticide Factory in China and

contained 55% aluminium phosphide. Each tablet weighed 3.3 g and each sachet 33 g.

Methods

A special apparatus (Fig. 1) was assembled with the aim of passing air of constant humidity ($\pm 5\%$) over the exposed tablets or sachets held at constant temperatures ($\pm 0.5^\circ\text{C}$). Dry air was produced by passing an airstream through calcium chloride tubes, and moist air by passing a second airstream through wash bottles filled with water. The flow rates were controlled by valves, and air of the desired humidity was obtained by varying the relative flow rates. The airstream of known constant humidity then passed through a flow meter and a wet and dry bulb hygrometer before it passed through the decomposition chamber. Every determination involved either 10 tablets or 1 sachet of the aluminium phosphide formulation. The air flow rate was 30 L/minute and this flow rate was calculated to provide sufficient moisture for complete reaction. The effluent gas was sampled using an automatic gas sampler. The phosphine concentration was determined using a colorimetric method in which the phosphine was absorbed in potassium permanganate solution and reacted with molybdenum blue (Boltz 1958). Formulations were considered to have decomposed completely when phosphine was no longer detected in the air stream.

Results and Discussion

The times for complete decomposition of both the tablet and sachet formulations under various temperatures and humidities are given in Table 1. The longest time was 204 hours for an air moisture content of 4.7 g/m³ and the shortest was 36 hours for a moisture content of 35.5 g/m³ and decomposition of tablets was slightly faster than for sachets. The formulation differences are unlikely to be significant in commercial fumigation practice.

The rates of evolution of phosphine at various times throughout the reaction are shown in Figure 2. Tablets reached the maximum rate slightly more rapidly than did sachets, and the maximum rates of evolution were slightly higher.

The maximum rates of evolution of phosphine for each temperature and relative humidity combination are listed in Table 2. Linear regression of these maximum rates with absolute humidities gave a correlation of coefficient $r = 0.963$, indicating a direct relationship between rate of evolution and absolute humidity. The data are consistent with those of Mori and Kawamoto (1977).

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Table 1. Times for the complete decomposition of aluminum phosphide at various temperatures and relative humidities.

Temperature (°C)	Formulation	Relative humidity (%)							
		90		70		50		30	
		Decomposition time (hours)	Moisture content of air (g/m ³)	Decomposition time (hours)	Moisture content of air (g/m ³)	Decomposition time (hours)	Moisture content of air (g/m ³)	Decomposition time (hours)	Moisture content of air (g/m ³)
10	Tablet	102	8.5	143	6.6	198	4.7	—	—
	Sachet	106	—	138	—	204	—	—	—
20	Tablet	48	15.5	78	12	98	8.6	—	—
	Sachet	58	—	84	—	108	—	—	—
30	Tablet	35	27.9	40	21.7	72	15.5	108	9.3
	Sachet	42	—	48	—	78	—	120	—
40	Tablet	—	—	38	35.5	—	—	—	—
	Sachet	—	—	42	—	—	—	—	—

Table 2. Maximum rates of evolution of phosphine (g/hour) from 10 tablets or one sachet of aluminium phosphide at various combinations of temperature and relative humidity.

Temperature (°C)	Formulation	Relative humidity			
		90%	70%	50%	30%
10	Tablet	0.190	0.130	0.110	—
	Sachet	0.188	0.132	0.088	—
20	Tablet	0.346	0.268	0.190	—
	Sachet	0.350	0.270	0.172	—
30	Tablet	0.550	0.446	0.308	0.176
	Sachet	0.470	0.424	0.284	0.162
40	Tablet	—	0.736	—	—
	Sachet	—	0.552	—	—

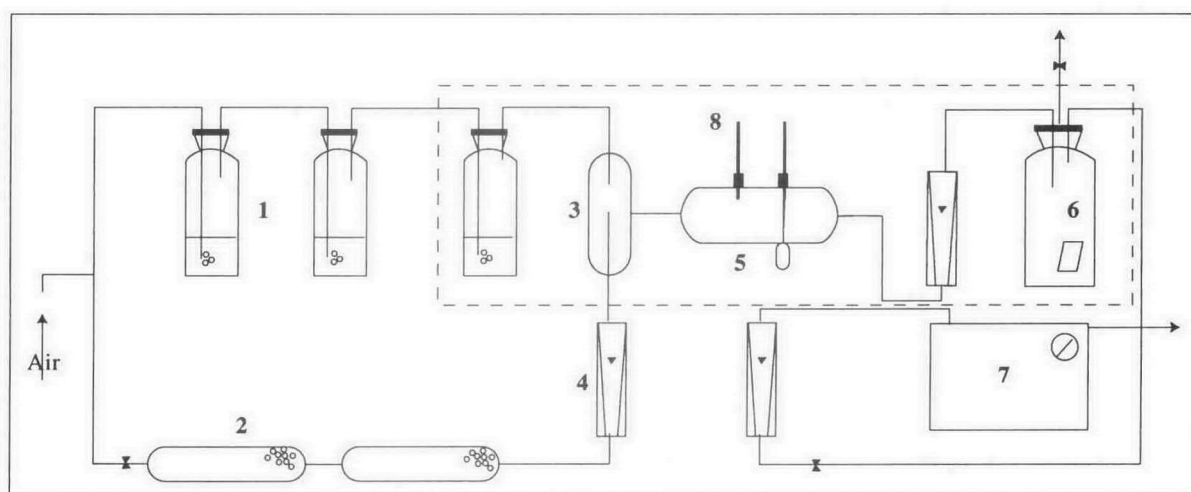


Fig. 1. Apparatus for determination of the evolution rate of phosphine from aluminium phosphide. (1) wash bottle, (2) calcium chloride tube, (3) gas mixer, (4) rotameter, (5) wet and dry bulb hygrometer, (6) reaction vessel, (7) automatic gas sampler and (8) controlled temperature cabinet.

Conclusion

The rate of evolution of phosphine by aluminium phosphide is directly influenced by absolute humidity and was not directly influenced by temperature.

References

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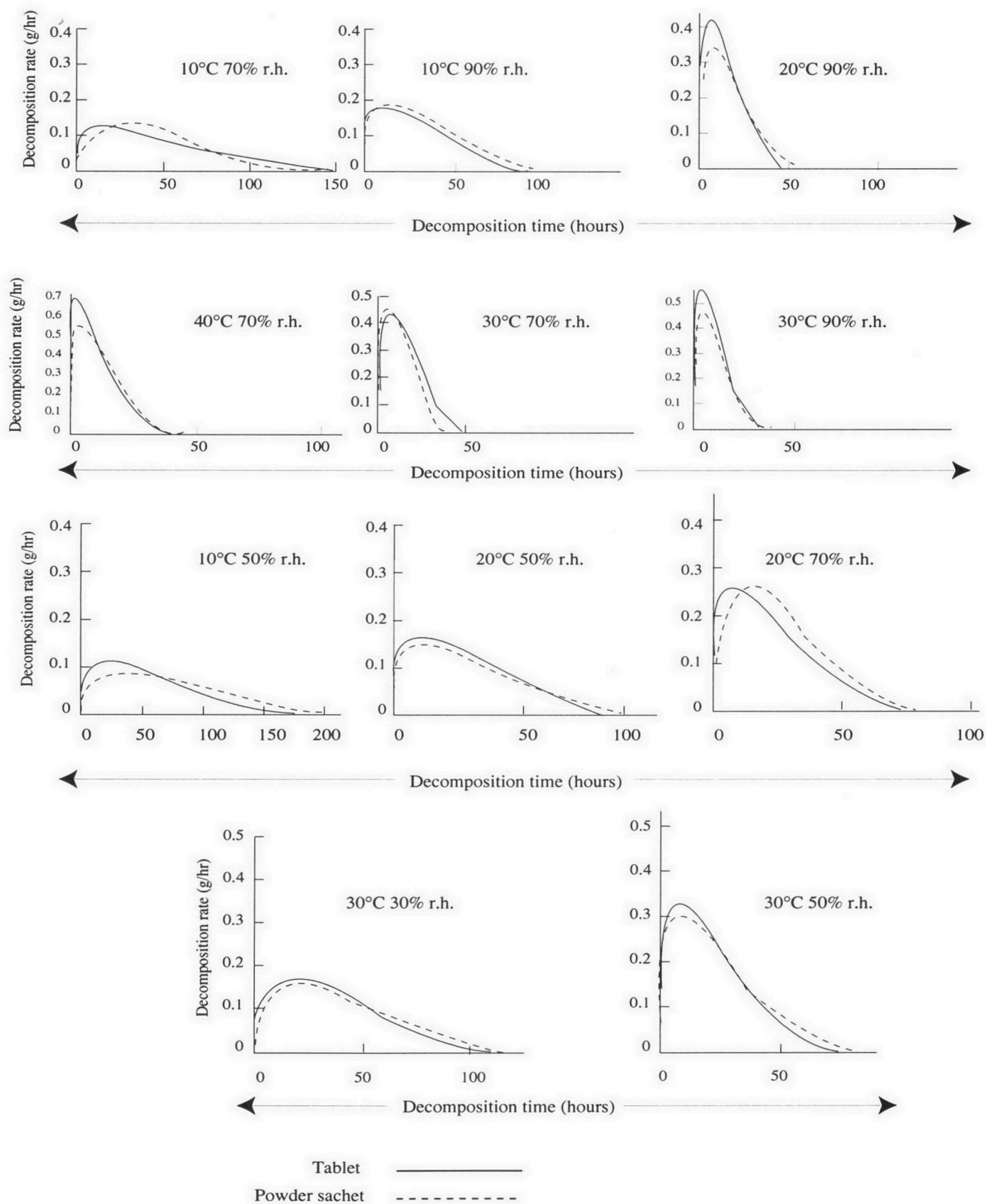


Fig. 2. Rate of evolution of phosphine from aluminium phosphide formulations at various temperatures and relative humidities.