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## Comparing Application of Slow-releasing Fumigation in Large Warehouse

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**Abstract:** Recirculation fumigation, slow-releasing fumigation and recirculation, plus slow-releasing fumigation under film were compared in large warehouses with 6m deep grain bulk, the concentration change of PH<sub>3</sub> and killing effect were determined. The results showed that these three methods all can distribute PH<sub>3</sub> well. *Sitophilus oryzae* Motschulsky was killed in 5 days, while *Cryptolestes ferrugineus* (Stephens) was killed in 35 – 40 days.

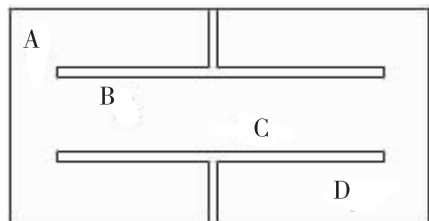
**Key words:** large warehouse, recirculation, slow-releasing, fumigation

Slow-releasing fumigation has the advantages of operating simply, keeping insecticide effect long and killing insects completely, so it was widely used in small grain bulks against insects, but use in large warehouses (the depth of the bulk is greater than 6m) was seldom reported. The effective period of PH<sub>3</sub> distribution was compared among recirculation fumigation, slow-releasing fumigation and recirculation, plus slow-releasing fumigation in our test, and the insect killing effect was also observed.

### 1 Materials and Methods

#### 1.1 Materials

1.1.1 Tested warehouse A1 – 1, A3 – 2 and A4 – 1 warehouses were chosen in Maoming Grain Depot for the test. They were all brick-concrete structure; length: 48m, width: 30m, grain bulk depth: 6m, wall thickness: 0.37m, bulk volume: 8640m<sup>3</sup>; main air-ducts each with 3 branches (Fig. 1) and 6 air intakes installed in the warehouse which could realize aeration at two sides; fixed recirculation fumigation system in which fan power was 0.75kW, the fumigation-ducts under disposable film was expressed in Fig 1, air return tubes: PVC tube, φ160mm with flat holes.



**Fig. 1** The fumigation-ducts under disposable film layout floor plan (ichnography) of warehouses

1.1.2 Tested grain The tested warehouses all contained stored bulk corn from Liaoning Province. Near the surface of grain bulk, the air outlet and near the door were found *Sitophilus oryzae* Motschulsky and *Cryptolestes ferrugineus* (Stephens) before test, where the population density was 2 – 4 insects per kg. The basic grain conditions are expressed in Table 1

1.1.3 Test instruments Sampling device of deep grain layer (made in Chengdu); PH<sub>3</sub> concentration determine tube (made in Guangzhou); PH<sub>3</sub> gas detector (made in Beijing); PVC plastic film (0.08mm, bought in the market); cloth bag (25cm × 40cm); U type manometer (made in Guangzhou); stopwatch.

**Table 1.** The basic grain condition in warehouse

	A1 – 1	A3 – 1	A4 – 1
Quantity (t)	6033	5892	5987
Bulk density (g/L)	705	695	690
Moisture content (%)	13.1	13.2	12.7
Surface grain temperature (°C)	23.2	23.7	22.9
Highest grain temperature (°C)	24.7	25.5	24.9
Lowest grain temperature (°C)	15.5	15.0	16.1
Average grain temperature (°C)	18.2	17.5	18.7
Insect population density (heads/kg)	4	2	3
Storage style	bulk	bulk	bulk

#### 1.2 Methods

1.2.1 Sealing method: Grain surface was

sealed by 0.14mm PVC film with sealed slot alongside the outside wall. Doors and Windows were sealed by 0.14mm PVC film too. The air outlet was a self-sealed type air outlet.

1.2.2 Test of air tightness: Air tightness was tested by negative pressure in reference warehouse after sealed. The pressure half-life of the A1-1, A3-2 and A4-1 warehouse was 41s, 42s, 45s separately. Testing was performed in accordance with the specifications of "Technical standards for PH<sub>3</sub> recirculation fumigation".

1.2.3 Location of gas detecting sites: There were 4 detecting points (A, B, C, D) positioned in the 4 corners at a distance of 0.5m to the end and side walls of the warehouse. Each testing point had sample tubes with inlets at upper, middle and bottom layers which were respectively at 0.5m, 3.0m and 5.5m below the grain surface. E detecting point was set on the film. These 5 sites with 13 gas detecting points were fitted with plastic pipes which were brought out through the door.

1.2.4 PH<sub>3</sub> concentration determination: AHL-210 type PH<sub>3</sub> gas detector (made in Beijing) was used for regular sampling the concentration of PH<sub>3</sub> after application. The detector was corrected by PH<sub>3</sub> concentration determine tube (made in Guangzhou) before used.

1.2.5 Insects inspection method: Sieve and visual inspection method were used for inspecting insects. The insects death condition was inspected by insect cage during fumigation, and inspecting the death condition of *Cryptolestes ferrugineus* (Stephens) on the footpath board by eyesight (visual). Insect cage making method was as follows: Select robust insects putting into nylon bag, filled with broken wheat and corn. In each warehouse were set 10 insect cages. In each cage were put 60 insects (50 of them were *Cryptolestes ferrugineus* (Stephens), 10 of them were *Sitophilus oryzae* Motschulsky), then we sealed and buried the cages (with a retrieval rope attached). 0.5m and 3m below grain surface and near the inspecting door respectively. The insects death condition in the cages was inspected after fumigant application and the warehouse was unsealed.

1.2.6 Application method: Recirculation fumigation under film was carried out in the A1-1 warehouse. Fumigant dosage was 2g/m<sup>3</sup>, 18kg AIP was applied for 50 intakes which were under the film, each cloth bag contained 60 tablets AIP. The rest of the AIP was put into 6 air outlets, each outlet bag contained 1.5 kg.

Slow-releasing fumigation was carried out in the A3-1 warehouse. Fumigant dosage was 2g/m<sup>3</sup>, sealed into 200 PVC bags, each bag contained 30 tablets. 139 bags were applied on the surface; 50 bags were put into 1.5m length, 120mm diameter PVC tubes, probed into the bulk, then the tube was taken out of the bulk, thus AIP was buried about 1m below the surface of the bulk. The remaining 11 bags were put in the air outlet and door respectively.

Recirculation + slow-releasing fumigation was carried out in the A4-1 warehouse. Fumigant dosage was 2g/m<sup>3</sup>. Every 30 tablets was put into a PVC bag, 100 PVC bags were put on the grain surface altogether. The rest of the AIP had been put into cloth bags in 6 air outlets, each air outlet contained 1.5 kg AIP.

Continuous recirculation was carried out for 48h after the fumigant was applied, then the fan was operated 2~3h each day for 7 days in A1-1 and A4-1 warehouse. There was no recirculation in A3-1 warehouse.

## 2 Results

### 2.1 Change of PH<sub>3</sub> Concentration

The determination of results of PH<sub>3</sub> concentrations in tested warehouses during fumigation was listed in Table 2. The results from Table 2 showed that: gas release speed of PH<sub>3</sub> was slowest using slow-releasing fumigation; PH<sub>3</sub> distributed well in all three tested warehouses; PH<sub>3</sub> distribution was bad in the corner of the A1-1 and A4-1 warehouse in the horizontal direction. This was maybe because of the location of the air return tube. PH<sub>3</sub> distribution was bad in vertical direction in A3-1 warehouse. The concentration was low in bottom layer, that was because the natural vapor pressure diffusing ability of PH<sub>3</sub> was limited; the gas concentration retention time of PH<sub>3</sub> was longest in A3-1 warehouse. The tests showed while recirculation fumigation improved the diffusing speed of PH<sub>3</sub>, at the same time, recirculation caused leakage of PH<sub>3</sub>. So recirculation + slow-releasing fumigation could receive best effect considering PH<sub>3</sub> distribution and duration of concentration.

### 2.2 Results of Killing Insects

Insect survival condition of the tested warehouse was expressed in Table 2. The insects in the surface of grain was inspected by eyes, observe if there had any live insects on the footpath board. The results from Table 2 sh

**Table 2. PH<sub>3</sub> concentration determine and insect killing condition**

T, d days	PH <sub>3</sub> concentration (mL/m <sup>3</sup> )										Mortality (%)								
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	IYM	IXB	IIM	IIXB	surface	
	1	75	63	92	104	93	72	73	93	86	97	68	107	25	30	0	30	32	Yes
	3	298	276	322	262	220	271	278	265	216	273	232	318	15	100	32	100	40	Yes
	5	426	350	366	411	392	355	415	395	428	396	322	411	19	100	50	100	60	Yes
	7	457	447	402	435	489	426	452	455	495	465	409	491	15	100	66	100	74	Yes
	10	423	321	361	365	378	388	402	401	459	356	423	478	25	100	78	100	88	Yes
A1 - 1	15	333	268	305	254	313	371	376	355	386	350	358	382	15	100	90	100	90	Yes
	20	241	201	213	227	244	297	289	324	321	267	321	323	19	100	100	100	100	Yes
	25	213	165	176	175	196	169	225	256	320	190	253	281	12	100	100	100	100	Yes
	30	160	102	121	132	144	135	189	191	279	175	189	243	11	100	100	100	100	No
	35	124	104	105	97	119	99	114	145	161	135	158	192	15	100	100	100	100	No
	40	52	64	74	61	72	86	64	71	84	80	89	90	15	-	-	-	-	No
	1	48	55	12	97	85	6	121	61	17	70	49	24	18	20	20	10	10	Yes
	3	155	131	35	157	163	71	147	114	62	179	182	69	15	100	36	90	20	Yes
	5	222	165	56	223	221	102	213	289	89	224	209	107	10	100	50	100	20	Yes
	7	289	225	98	267	273	116	231	298	98	298	264	152	12	100	60	100	50	Yes
	10	324	301	123	303	369	142	362	365	107	358	293	165	16	100	72	100	60	Yes
A3 - 1	15	426	386	164	346	411	153	402	316	122	401	360	184	5	100	84	100	72	Yes
	20	338	374	189	406	401	105	387	285	185	396	335	203	10	100	90	100	80	Yes
	25	270	309	205	355	305	161	321	246	186	302	284	179	9	100	100	100	98	Yes
	30	215	251	197	298	257	203	274	202	144	279	186	165	5	100	100	100	100	Yes
	35	146	206	177	243	199	166	222	261	123	264	142	156	7	100	100	100	100	No
	40	108	142	110	130	166	123	153	165	106	110	121	131	10	-	-	-	-	No
	1	102	78	115	99	85	76	67	77	87	73	88	94	23	20	40	20	10	Yes
	3	235	232	206	257	201	281	224	246	250	277	264	287	18	100	42	100	40	Yes
	5	324	306	315	266	221	256	313	289	298	307	291	375	10	100	64	100	52	Yes
	7	389	366	398	361	288	345	355	398	371	417	362	415	12	100	84	100	74	Yes
	10	425	405	485	453	402	442	419	469	427	489	396	459	15	100	86	100	98	Yes
A4 - 1	15	398	416	364	344	411	350	382	351	366	374	412	355	11	100	90	100	100	Yes
	20	385	354	355	313	392	321	358	279	342	268	387	263	16	100	100	100	100	Yes
	25	299	211	290	230	355	332	341	255	232	220	314	217	8	100	100	100	100	Yes
	30	176	172	208	174	216	245	274	204	209	199	265	185	5	100	100	100	100	No
	35	145	126	177	135	153	167	192	152	165	132	142	124	5	100	100	100	100	No
	40	99	105	89	103	105	106	103	113	120	111	121	101	5	-	-	-	-	No

owed that PH<sub>3</sub> enduring ability of different insects was not the same, *Sitophilus oryzae* Motschulsky was easier killed than *Cryptolestes ferrugineus* (Stephens) at the same fumigation condition, *Sitophilus oryzae* Motschulsky was all killed after 5 days fumigation, while *Cryptolestes ferrugineus* (Stephens) was still active in the earlier stage of fumigation, live insects could be found after 25 days fumigation, the mortality was 100% after 30 - 35 days. The results also showed that live insects could still found on the grain surface when the insects in the cage had all been killed, so the cage can only be a reference for inspecting fumigation results. In practice, when the insects in the cage all died, fumi-

gation should be continuing for a period to strengthen the killing effect on those insects near the boundaries and surfaces of the storage bulk.

Sampling device of deep grain layer was used for inspecting upper, middle and bottom layer, especially sample the corner and impurity area after degassed, and no live insects were found. There was also no live insects found after continuous observing 2 months after the fumigation (the grain in A4 - 1 warehouse rotated after degassed 25 days).

### 3 Discussion

3.1 The practice showed that whether

recirculation fumigation, slow-releasing fumigation or recirculation + slow-releasing fumigation are used, all three methods can provide good effect on killing insect. Slow-releasing fumigation can be used in large grain bulk such as large warehouse for controlling insects, it was because: (1) grain temperature in large grain bulk had the advantages of outside surfaces were hot and the center was cool, thus, the cool center let  $\text{PH}_3$  diffused deeply into the grain bulk; (2) insects in large grain bulk almost distribute at corner, near the door and air outlet, under 1m of the grain surface,  $\text{PH}_3$  can naturally diffuse satisfactorily to these areas.

3.2 Recirculation + slow-releasing fumigation method was suggested to kill the insects in large grain bulk, considering the factors of slow-releasing fumigation can maintain long time effect, and recirculation fumigation can distribute  $\text{PH}_3$  well, and this method or operation was simple.

3.3 According to many years practice, the keys of using slow-releasing fumigation method in large grain bulk we considered were as follow:

3.3.1 Under film fumigation should be used if possible, in order to enhance grain bulk airtightness, ensure fumigation effect.

3.3.2 High resistance insects should be killed as early as possible. The insects we observed by visual inspection were almost all adults, so when we find the insect damage seriously, it had many eggs and larva etc, these insect stage was lower susceptibility (higher resistance) against  $\text{PH}_3$  than adults, so it was more difficult to control.

3.3.3 Different application method should be chosen against different insects. When the density of insects was large, recirculation + slow-releasing fumigation or regular + slow-releasing

should be used; when the bulk had resistance insect, slow-releasing + interval fumigation should be used. Effective fumigation time should be prolonged as long as possible with whatever method you chose to insure all the insects are killed.

3.3.4 The dead corner such as impurity area and four corner of the bulk etc should receive pre-bury tube to strengthen killing effect.

3.3.5 DDVP can be sprayed to control insects around the warehouse.

3.4 Safety measures must be adopted before enter the warehouse when using slow-releasing fumigation method to kill insect. Start axial-flow ventilation fan first and operate for several hours, then determine  $\text{PH}_3$  and oxygen concentration in the space to be safe, then enter the warehouse.

3.5 The dead bodies of *Cryptolestes ferrugineus* (Stephens) gathered concentrated at the area where  $\text{PH}_3$  application dust residue was disposed, while no dead *Sitophilus oryzae* Motschulsky were found. The reason should be further researched.

## References

- [1] Wang Dianxuan. The technical expectation on phosphine recirculation fumigation. Grain Storage, 2003(2)29-32
- [2] Cui Jinbo, Deng Yongxue, Wang Jinjun et al. Community comparison and structure analysis of stored grain insects in large warehouse. Grain Storage, 2005(6)10-12
- [3] Shi Guangping et al. Comprehensive application of slow-releasing fumigation and interval fumigation in large warehouse. Journal of Scientific Technology of Grain and Oils, 2004(3)31-32
- [4] Jiang Hanzhong, Miu Qingchao et al. Test of slow-releasing recirculation fumigation under film. Journal of Scientific Technology of Grain and Oils, 2002(6)30-31