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HYDROCYANIC-ACID GAS AGAINST HOUSEHOLD INSECTS.

By L. O. HOWARD.

Hydrocyanic-acid gas is one of the most effective remedies known against various classes of insects. For more than twenty years it has been the principal means of controlling scale insects on citrus trees in California and is now in general use for the disinfection of all deciduous nursery stock and other plant material for shipment, and is also one of the most effective methods of ridding greenhouses and cold frames of plant-lice, thrips, white fly, and various scale pests which infest plants grown under glass.²

It has been fully demonstrated that this gas, which is very deadly to all forms of animal life, is, under proper precautions, an excellent remedy for household insects. Probably its first use for this purpose was in June of 1898 by Mr. Marlatt, of this office, against book-lice in the residence of an employee of the Department of Agriculture, using the cyanide first at the ordinary strength employed on fruit trees, then double, and finally quadruple the strength. The book-lice came from recently introduced leather-covered furniture, the covering of which was so tightly fastened as to be almost, if not quite, impervious to the gas, and the treatment was only partially successful. Another early use of this gas for household insects was in 1899 in San Francisco by Mr. Alexander Craw, Chief Quarantine Officer of the Board of Horticulture. In this case it was used against bedbugs and in very small proportions. Two and one-half fluid ounces of commercial sulphuric acid and 2½ ounces 98 per cent cyanide of potassium were used in a house of several rooms, each containing about 2,250 cubic feet of space. The rooms were closed for two hours, then entirely aired. The operation was apparently successful.

Perfectly successful experiments were made during the summer of 1901 by Mr. W. R. Beattie, of the Department of Agriculture, and by Mr. A. H. Kirkland, of Boston, Mass., formerly Secretary of the Association of Economic Entomologists. Mr. Beattie's experiments were against cockroaches and Mr. Kirkland's in one case against fleas and in the other against clothes moths.

¹ Revised by C. L. Marlatt, Entomologist and Acting Chief in Absence of Chief.

² Refer to Circulars 37, 42, and 57, and Farmers' Bulletin 172.

Entomologists have long noticed that insects vary greatly in their susceptibility to cyanide fumes. The ordinary killing bottle used in making collections contains cyanide of potassium covered with plaster of Paris, which the fumes of the cyanide penetrate. Certain weevils, and especially such weevils as *Lixus* and *Sphenophorus* and other hard-bodied forms, will frequently be left overnight in a cyanide bottle and recover after being removed. It has been noticed also that in greenhouses certain insects recover. The experience gained, however, indicates that the use of hydrocyanic-acid gas in houses is successful against cockroaches, bedbugs, fleas, clothes moths, ants, white ants, house flies, and other soft-bodied insects; and as these constitute the majority of the household pests, the use of the gas must now be considered a standard remedy. Moreover, rats and mice are also killed by its use, and it fortunately has the effect of first causing these animals to rush out from their holes into the open, so that the subsequent annoyance of dead mice in walls and under floorings is not experienced.

Since the initial experiment against household pests in 1898 a great deal of experience has been gained in practical work by this Bureau. Many residences and public buildings and offices of this Department, stores, and schools have been fumigated, especially since 1901. This work has been conducted chiefly under the direction of Mr. Marlatt by Messrs. Busck, Pratt, Kotinsky, J. H. Beattie, and other members of the office force, and has given practically uniform success. Most of this work was done subsequent to the publication of Circular 46, second series, and is the basis for the present revision of that circular, which, however, has not been changed in essential details.

Some entomologists recommend as a substitute for hydrocyanic-acid gas a substance which has been more or less effectively used, viz, carbon bisulphid. The great danger in the use of this latter substance, however, from its extreme inflammability and the explosiveness of its vapor when confined, renders it perhaps less available and more than counteracts the danger to human beings from the use of the hydrocyanic-acid gas.¹

¹To determine the availability of hydrocyanic-acid gas against the insect enemies of stored products or in granaries, some experiments were made during 1898 and the spring of 1899 by Messrs. Marlatt and Chittenden, of this office, in the presence of Mr. D. G. Fairchild and others, against certain grain weevils and the Angoumois grain moth, but with imperfect success, although the proportions used were much greater than in Mr. Craw's experiment. In his recent book on fumigation methods, Prof. W. G. Johnson states that he used the hydrocyanic-acid gas in a granary and storehouse in June, 1899, using it at the rate of 0.1 gram of cyanide per cubic foot of space. The granary was affected by weevils, and, from the report of the owner, it appears that most of the latter were destroyed, though many escaped. During the same month in an Ohio mill another experiment of this kind was carried on under Professor Johnson's instructions. The owner considered the experiment to be "a most grand success." The Mediterranean flour moth and certain granary beetles were destroyed. There is still some doubt, however, as to its efficiency under granary and mill conditions, and further experimentation is needed.

DIRECTIONS FOR USE.

Much experience indicates that in order to destroy the household insects mentioned, 1 fluid ounce of commercial sulphuric acid (about 1.84 Baumé) diluted with 2 fluid ounces of water, to increase the bulk of the liquid and insure complete chemical action, and 1 ounce of high-grade (98 per cent) cyanide of potassium, must be used for every 100 cubic feet of space. The formula per hundred cubic feet, therefore, is as follows:

Potassium cyanide (98 per cent)-----	avoirdupois ounce--	1
Commercial sulphuric acid-----	fluid ounce--	1
Water-----	fluid ounces--	2

For loosely constructed frame houses the above amounts may be doubled per hundred cubic feet. The cyanide costs about 40 cents a pound and the sulphuric acid (thick or more sirupy commercial brand) about 4 cents a pound.

Before performing the operation the house must be vacated. It is not necessary to remove any of the furniture or household belongings unless of polished nickel or brass, which may tarnish a little. Liquid or moist foods, as milk, meats, or other larder supplies that are not dry and might absorb the gas, should be removed from the house. All fires should be put out; for while the gas will not burn under ordinary conditions, it is as well to take no risks.

The cubic contents of each room on each floor should be carefully computed and a tabular statement, such as that given below, prepared, designating for each floor and the different rooms the capacity and the amount of water, acid, and cyanide needed.

Table designating rooms, capacity, and amounts of chemicals.

Floor.	Room.	Cubic feet.	Water.	Acid.	Cyanide.
			<i>Fl. oz.</i>	<i>Fl. oz.</i>	<i>Avd. oz.</i>
Fourth-----	Garret-----	^a 7,000	140	70	70
Third-----	Front-----	2,800	56	28	28
	Middle-----	1,400	28	14	14
	Back-----	2,200	44	22	22
Second-----	Front-----	^a 5,500	110	55	55
	Middle-----	2,200	44	22	22
	Back-----	2,000	40	20	20
First-----	Parlor-----	^a 4,400	88	44	44
	Middle-----	2,400	48	24	24
	Dining-----	2,900	58	29	29
Basement-----	Servant's-----	1,200	24	12	12
	Hall-----	2,000	40	20	20
	Kitchen-----	1,800	36	18	18
Total-----	-----	37,800	756	378	378

^a The charges for these rooms should be halved and set off in two vessels.

The house is prepared for treatment by seeing that all the windows are closed, and calked, if necessary, with moist paper or rags, and that

the doors and windows are left unlocked or unfastened, so that they may be opened from without. The fireplace flues in the different rooms should be stuffed with paper and the registers closed. Carpets and rugs, where possible, should be cleared away from the floor to prevent their being burned should the acid spatter or boil over. As generators, porcelain basins or preferably jars of a capacity of at least 2 gallons should be placed in each room; and if the rooms are large ones, two or more such vessels should be provided. One vessel will suffice for each 2,000 or 3,000 cubic feet, preferably the former amount. Under each of these vessels a rather thick carpeting of old newspapers should be placed, or a larger vessel, and care must be exercised to see that none of the vessels are cracked, on account of the danger of breakage from the heat generated by the process. Deep vessels are more satisfactory for the experiment than the wash basins often used, but the latter are always available and will serve the purpose. Deeper vessels give greater depth to the water and acid and accelerate the chemical action, and there is less danger of spattering. Whenever the room is of such size that much more than 2 pounds of cyanide must be employed for it, it is perhaps better to make two charges of half size for such room.

The cyanide should be broken up into lumps not exceeding twice the size of a walnut, the powdered and smaller fragments serving equally well, and put in paper bags in pound or one-half-pound lots. The bags should be of very thin paper. If they are of thick, heavy paper, the action of the acid is delayed and sometimes prevented completely. If there is any danger of this, make two or three slits in the bottom of each bag to facilitate the entrance of the acid.

After the house has been put in a state of readiness for the experiment, and the vessels for the charges have all been placed in their proper locations, the requisite amount of water indicated by the table already prepared should be poured into each of the different vessels. Following this the proportionate amount of acid (half that of the water) should be added slowly to the vessels now containing the water; never in the reverse order. Considerable heat will be developed by the addition of the acid, and some acid fumes may come off, but these are harmless. The cyanide, previously weighed out, should be distributed through all the different rooms in the proper amounts, placing the bags alongside of, not in, the generating vessels.

The house is now in readiness to be fumigated. Coats and hats and everything needed outside must be removed, and preferably two persons should then go to the top of the house, taking different rooms on the same floor to expedite the process, and place the bags containing the cyanide gently into the vessels to receive them. The chemical action will begin at once, but the gas will not rise to any extent for a few seconds or a quarter of a minute, and there is ample time to leave the room quickly without any danger of breathing any of the gas. Having

finished the garret or top floor, the operators should pass rapidly to the next, and so on to the basement, making their exit through the lower door to the street.

Hydrocyanic-acid gas is lighter than air, and consequently rises; therefore the operation must be begun at the top of the house.

The house should be locked up from the outside and, if necessary, a warning sign put up to caution against entrance.

The preparation of the different rooms, getting their cubic contents, fixing the vessels, and preparing the charges, in a house of the size indicated in the table given above, will take from two to three hours, and this much time must be allowed for. The house should remain closed for the gas to become fully generated and do its work for four to six hours—preferably, however, and to get the greatest efficiency, overnight.

At the close of the operation, or the following morning, the doors may be opened and the windows lowered or opened from the outside, and after an hour's airing the house may be entered if no strong odor of gas is detected, and opened up even more thoroughly, if possible, to allow a complete airing for several hours. The house should not be reinhabited until all traces of the odor of the gas has disappeared. This odor resembles that of peach kernels.

The contents of the generating jars should be poured into the sewer trap or disposed of in some place where they will not be a source of danger, and the jars thoroughly cleaned.

THE CYANIDE AND GAS A DEADLY POISON.

In the use of this gas for household fumigation it must not be lost sight of for a single instant that one is dealing with one of the most poisonous substances known, and that the accidental eating of a small portion of cyanide will necessarily be fatal, and that the inhalation of a few breaths of the gas will asphyxiate, and, if rescue be not prompt, also have a fatal termination. It is much better, therefore, if fumigation be contemplated, to put the work in the hands of someone who has had experience, if such a person be available; if not, to carefully consider all the recommendations and precautions in this circular and become thoroughly familiarized with them before undertaking the experiment.

While the writer thus strongly emphasizes the dangerous and even fatal qualities of this gas when breathed by human beings, it is worthy of remark that in the thousands of operations which have been carried on with this gas in specially constructed houses for fumigation of nursery stock in different parts of the world, no case of fatal accident to a human being has ever been recorded. Furthermore, the abundant experience which has been gained by the different members of the force of this office and many others in the fumigation of dwelling houses has

demonstrated that all danger is easily overcome by care in conducting the operation, and in all the house-fumigation work which has been done during the last five years no accident has occurred, except in one or two instances the burning of rugs in attempting to set off charges in too small vessels and a case of headache where a few whiffs of much diluted gas had been accidentally breathed.

It follows, from what we have just said, that there may be danger from fumigating one house in a row of houses separated only by party walls, the other house being inhabited. Unnoticed cracks in a wall would admit the poisonous gas to the neighboring houses. In such a case a householder must consult his neighbors. In isolated houses, however, with the precautions indicated, the operation will be a safe one. The fact that Mr. Kirkland observed that English sparrows resting on the ridge of one of his houses were killed by the ascending fumes indicates also that where the house to be operated upon immediately adjoins a higher structure to which the gas may possibly gain entrance there may be some danger to the occupants of the higher structure.

It is undesirable to fumigate single apartments or rooms in buildings, and this should only be attempted when the whole building can be vacated during the operation. In case of contiguous houses of loose construction an arrangement should be made so that the adjoining houses also may be vacated during fumigation.

In handling the acid great care should be used in pouring it from the bottle and in putting it into the vessels to avoid spattering on the hands or face, since it will burn rapidly through the skin, and should it spatter into the eyes would cause serious inflammation, or if on the clothing it would burn a hole in the garment. Should a drop fly to the hands or face, bathe the part promptly and freely in water, and the same also for garments or the carpet. It is further desirable to have at hand a bottle of ammonia water to neutralize the acid should it spatter on clothing.

The handling of the dry cyanide is not accompanied by any danger if there be no open wound on the hand, but it is advisable to wear an old pair of gloves in breaking up the cyanide and putting it in the sacks, these gloves to be afterwards burned. The fact that the cyanide has a superficial resemblance to sugar adds to the danger of keeping it about the premises, and it is much better to at once deeply bury or throw down the sewer trap any left-over cyanide.

SUMMARY OF METHOD.

The general directions for treatment may be briefly summarized as follows:

- (1) Prepare tabular statement designating room capacity and amount of chemicals for each compartment, and secure the chemicals and vessels for generating the gas.

(2) Arrange for the opening of doors and windows from the outside at the conclusion of the fumigation, and close all registers, fireplaces, and other openings. Do necessary calking and remove carpets and rugs and moist food material and any metallic objects which are likely to be tarnished.

(3) Place the generating vessels in each room with a thick carpeting of old newspapers under each.

(4) Break up the cyanide out of doors and place it in thin paper sacks containing a pound or a half pound each, suited to the amounts to be used in the different rooms.

(5) Measure into each of the generating jars the proper amount of water, and afterwards add the acid slowly in the proper amount to each of the jars.

(6) Take the cyanide in bags in a basket and place the bags to the proper amount alongside of the generating jars in each room.

(7) Start at the top of the house and place the cyanide gently, so as not to spatter, into each jar, and quickly leave the room. As soon as the upper floor is finished go to the next lower, and pass in this manner from floor to floor until the basement is reached and exit is made through the lower door. If two persons work together in this operation, they should both be on the same floor together, taking different rooms.

(8) The following day, or after the completion of the fumigation, open the windows and doors from the outside, and let the house ventilate for an hour before entering it.

(9) After the house is thoroughly ventilated and the odor of the gas has disappeared, the jars should be emptied in a safe place, preferably through the sewer trap, and thoroughly and repeatedly washed before being used for any household purpose.

Approved:

JAMES WILSON,

Secretary of Agriculture.

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