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NEW HAMPSHIRE AGRICULTURAL
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ARSENICAL RESIDUES AFTER SPRAYING

I. RESIDUES OF LEAD ARSENATE ON FRUIT AND VEGETABLES.

II. TOXIC PROPERTIES OF LEAD ARSENATE, AND SOLUBILITY IN HUMAN GASTRIC JUICE.

III. EXPERIMENTS WITH CALVES, SHEEP AND POULTRY.

By W. C. O'KANE
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OF
AGRICULTURE AND THE MECHANIC ARTS
DURHAM, N. H.

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SUMMARY.

INTRODUCTION.

ARSENICAL RESIDUES AFTER SPRAYING.

W. C. O'Kane, C. H. Hadley, Jr., and W. A. Osgood.

(A list of references will be found at the end of this bulletin. The numbers in parentheses in the text refer to these citations.)

INTRODUCTION.

The experiments described in this bulletin have been in progress during the last five years, beginning with the year 1912. They were undertaken with the intention of discovering the possibility of danger resulting from residues of arsenate of lead remaining on fruit or foliage after spraying with that material.

The immediate circumstance leading to the investigation was the invasion of the browntail moth in New Hampshire apple orchards. Altho many orchard owners adopted the practice of cutting off the winter nests of this pest, the fact remained that this treatment, while effective in avoiding injury the next spring, resulted in more or less unfavorable trimming of the trees. It was found that a poison spray applied to the foliage about the first week in August killed the young caterpillars when they first hatched from the egg and before they had opportunity to make up the winter nest. This spraying in August was, therefore, recommended.

Immediately, the question arose as to the possible danger that might result to persons eating fruit from trees sprayed at this time in the growing season, especially in the case of early fruit, which would be nearly or quite ripe at the time such spray was applied. Along with this arose the question of possible poisoning of live stock allowed to graze beneath trees so sprayed, or fed on hay cut from beneath such trees.

The investigation at first contemplated only experimental spraying, and analyses of the residues on fruit from such trees. At the close of the season it appeared wise to expand the inquiries, in order properly to interpret the results of the analyses. Sufficiently detailed or accurate data as to the poisonous properties of arsenate of lead did not appear to be in existence.

The study was, therefore, widened to include experiments

that would throw light on the toxic properties of lead arsenate, both by means of experimental feeding of guinea pigs and by determinations of the solubility of lead arsenate in normal human gastric juice. Other inquiries were begun, to determine the facts about the danger to live stock. Finally, the study was made to include determinations of the residues found on small fruits and vegetables. The work was brot to a close at the end of the summer of 1916.

ACKNOWLEDGEMENT.

The authors are indebted to Mr. B. E. Curry, head of the department of chemistry of this station, for analyses of residues on apples and forage.

Acknowledgement is offered also for assistance rendered by Mr. C. R. Cleveland and Mr. C. A. Weigel.

MATERIAL USED.

The arsenate of lead used in all of the experiments that follow was from one lot of "electro" dry lead arsenate. A sample was submitted to analysis November 12, 1912, and was found by the station chemist to contain moisture 0.18 per cent, arsenic oxid, AS_2O_5, 33.4 per cent.

RESIDUES ON FRUITS AND VEGETABLES.

APPLES.

In July 1912, 10 trees were selected on or near the station farm, representing 6 varieties of apples. These trees were of varying size. All were in fruit.

Arsenate of lead was prepared at the equivalent of 3 lbs. of arsenate of lead paste to 50 gallons of water. This spray was applied to one tree, a Porter, No. 8, July 29, this tree being of medium size. Twelve quarts of spray material was used. The spraying was done thoroly.

Nine other trees were sprayed four days later, August 2, with arsenate of lead at the equivalent of 3 lbs. of the paste to 50 gallons of water. Two of these trees were Tolman Sweets, two Early Harvest, two Astrachans, one Benoni, one Porter and one Fameuse. The amount of spray material applied per tree varied from 3 to 12 quarts. A record of the amount will be found in Table No. 1.

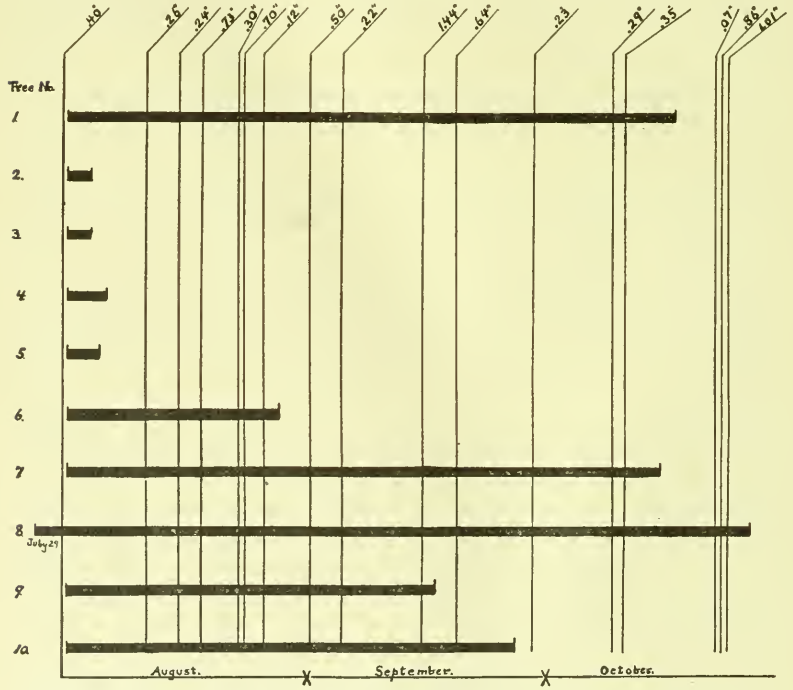
Table No. 1. Summary of Residues on Apples (I).

Record of Trees Sprayed with Arsenate of Lead at Rate of 3 Pounds of Paste to 50 Gallons of Water.

Tree No.	Variety.	Size of tree.	Condition of foliage.	Amount spray used.	Date sprayed.	Date picked.	Time elapsed.
1	Tolman	Small	Thick	7 qts.	Aug. 2	Oct. 18	76 days
2	Early Harvest	Small	Thick	5 qts.	Aug. 2	Aug. 5	3 days
3	Early Harvest	Small	Thick	3½ qts.	Aug. 2	Aug. 5	3 days
4	Astrachan	Small	Thick	3 qts.	Aug. 2	Aug. 7	5 days
5	Astrachan	Small	Thick	4½ qts.	Aug. 2	Aug. 6	4 days
6	Benoni	Small	Thin	4 qts.	Aug. 2	Aug. 29	27 days
7	Tolman	Small	Thick	6 qts.	Aug. 2	Oct. 17	75 days
8	Porter	Large	Ragged	12 qts.	July 29	Oct. 28	91 days
9	Porter	Medium	Ragged	12 qts.	Aug. 2	Sept. 18	47 days
10	Fameuse	Large	Leafy	15 qts.	Aug. 2	Sept. 28	57 days

Table No. 2. Summary of Residues on Apples (II).

Record of Rainfall During Period While Apples Remained on Trees.



Horizontal line opposite each tree indicates period during which apples remained on tree. Vertical lines indicate rainfall.

TABLE NO. 3. SUMMARY OF RESIDUES ON APPLES (III).

Results of Analyses of Fruit from Trees Shown in Tables Nos. 1 and 2.

Tree No.	Amount fruit.	No. of apples.	Total residue AS_2O_3	Residue per apple (AS_2O_3).
		Fruit Picked Carefully.		
1	1 bu.	195	.0027 gms.	.11 mgms.
2	$\frac{7}{8}$ bu.	161	.0598 gms.	.37 mgms.
4	Special*	25	.0192 gms.	.77 mgms.
7	1 bu.	180	.0148 gms.	.08 mgms.
		Fruit Picked in Ordinary Manner.		
1	1 bu.	190	.0336 gms.	.18 mgms.
2	1 bu.	203	.1023 gms.	.5 mgms.
6	$\frac{7}{8}$ bu.	264	.0392 gms.	.15 mgms.
7	1 bu.	188	.0049 gms.	.02 mgms.
8	$\frac{7}{8}$ bu.	132	.0262 gms.	.2 mgms.
10	$\frac{7}{8}$ bu.	175	.0581 gms.	.33 mgms.
		Fruit Handled with Cotton Gloves.		
1	1 bu.	204	.0197 gms.	.10 mgms.
5	1 bu.	209	.0452 gms.	.21 mgms.
7	1 bu.	188	.0279 gms.	.14 mgms.
9	$\frac{7}{8}$ bu.	155	.0232 gms.	.15 mgms.
10	$\frac{7}{8}$ bu.	165	.0241 gms.	.15 mgms.
		Fruit Handled with Cotton Gloves and Wiped.		
1	1 bu.	190	.0153 gms.	.08 mgms.
4	$\frac{7}{8}$ bu.	229	.0425 gms.	.18 mgms.

* These 25 apples were selected as showing maximum residue adhering.

Picking of fruit from early varieties began August 5, with the Early Harvest, 3 days after these trees had been sprayed. No rain had intervened. Other lots of fruit were picked from sprayed trees at various times up to October 28, 90 days after the spray had been applied.

RAINFALL.

The amount and time of rainfall during the period while fruit remained on the tree is shown in the diagram in Table No. 2. The horizontal lines indicate the period during which the fruit of each tree remained hanging. Each vertical line indicates a fall of rain of an amount designated at the top of the vertical line. It will be observed that in the case of four trees the fruit was picked before any rain fell. In the case of the fruit that remained on the tree longest, rain fell at 16 different times and in varying amounts.

METHOD OF PICKING.

The fruit from the sprayed trees was picked in four different ways, as follows:

First, certain lots were picked very carefully, handling the apple by the stem only, with the idea of not disturbing any drops of poison that might be adhering to the surface of the fruit. The lots of fruit picked in this fashion, with the results of analyses, will be found at the beginning of Table No. 3, under the heading, "Fruit Picked Carefully."

Other lots from the sprayed trees were picked in the ordinary manner, without taking care not to remove the poison and without wiping the fruit any more than would be done in the ordinary process of picking. These lots are described, with the resulting analyses, in Table No. 3, under the heading "Fruit Picked in Ordinary Manner."

In other lots the picker wore common cotton gloves, which would tend to remove part of the residues on fruit, altho none of the fruit was wiped. The results in these lots will be found in Table No. 3, under the heading "Fruit Handled with Cotton Gloves."

Finally, other lots were handled with cotton gloves and, in addition, each fruit was given a twist within the gloved hand as it was picked, with the intention of removing such of the residues as would be wiped off by that manner of picking. The results of these lots are given in Table No. 3, under the heading "Fruit Handled with Cotton Gloves and Wiped."

DISCUSSION OF RESULTS.

In Table No. 3 the results of analyses are first shown as the total amount of arsenious oxid, AS_2O_3, recovered for the entire number of apples in the lot analyzed. Following this, in the same line, will be found the amount of arsenic per apple, expressed in milligrams of AS_2O_3.

It will be noted that the amounts are computed per apple, rather than at the usual proportion by weight. This is deemed desirable for the following reason:

The arsenic that any fruit may carry is naturally all on the surface of the fruit. This is quite different from the case of other food substances, such as candy, where the poison may be found permeating the material. With the latter, as with liquids, the amount per unit of weight is the natural index. With apples the amount per fruit may be considered the natural index and is somewhat more useful, as well as more graphic.

Examining the results of analysis as given in Table No. 3, we find that where fruit was picked carefully, handling it by the stem only in order not to remove poison from the surface of it, the amount of arsenic per apple varied from .08 milligram to .77 milligram. The latter is from a special lot of 25 apples picked 5 days after the tree was sprayed, without intervening rain, and individually chosen because they appeared to exhibit the largest amount of spray material. Reduced to other terms these several lots of apples disclosed residues of such amount that from 3 to 25 apples would be required to equal a medicinal dose of arsenic (2 to 5 milligrams) and from 80 to 700 to equal a so-called dangerous dose (60 milligrams).

In the case of fruit picked in the ordinary manner the average residues per apple in the several lots varied from .02 milligram to .5 milligram. This is the equivalent of 4 to 100 apples as representing a medicinal dose of arsenic and 120 to 3,000 apples as representing a dangerous dose.

Where the fruit was handled with cotton gloves in the process of picking the residues ranged from .10 milligram per apple to .21 milligram per apple, or the equivalent of 10 to 20 apples to equal a medicinal dose, or 300 to 600 to equal a dangerous dose.

Where the fruit was wiped with cotton gloves in the process of picking, the residues ranged from .08 to .18 milligram per apple,

or the equivalent of 11 to 25 apples to equal a medicinal dose, or 330 to 750 to equal a dangerous dose.

Examining into the effects of rain and weather, as reducing the amount of poisonous residues, we find the following:

Where fruit was picked in the ordinary fashion, the average of several lots picked within 3 to 5 days of spraying, and before a rain, showed .5 milligram per apple. Where 27 to 57 days had elapsed the average was .24 milligram per apple. And where 75 to 91 days had elapsed, the average was .13 milligram per apple. This is a reduction in arsenical residues for the whole period of approximately 75 per cent, due, apparently, to the effects of rain and weather.

Looking at it from another angle and considering the apparent effect of handling the fruit with gloves, or wiping it, we find the following:

Where no rain had fallen and the fruit was picked within 3 to 5 days after spraying, the average picked in ordinary fashion is .5 milligram per apple, that picked with cotton gloves is .21 milligram per apple and that picked with cotton gloves and wiped in picking is .18 milligram per apple. This indicates a reduction of half in the amount of residue as the result of use of the cotton gloves. This it will be remembered is fruit that has not been subject to rain.

In the case of fruit that had remained 27 to 57 days on the trees, and had been subject to rain, the average picked in ordinary fashion is .24 milligram per apple and that picked with gloves, .15 milligram. Here we have a reduction of approximately 40 per cent.

Where the fruit was allowed to remain for 75 to 91 days on the tree after spraying, the average of that picked in ordinary fashion was .13 milligram per apple, that picked with gloves, .12 milligram per apple and that picked with gloves and wiped, .8 milligram per apple. Here it will be observed that the reduction, due to the method of picking, is comparatively slight.

The results obtained in the supplementary experiments in 1916, as summarized in Table No. 4, are for fruit picked in ordinary manner, two lots before a rain, and two lots immediately after a sharp shower of 10 minutes' duration. They are intended to serve as a check on the previous experiments. It will be

TABLE NO. 4. SUPPLEMENTARY RECORD—RESIDUES ON APPLES.

Trees Sprayed in 1916, with Arsenate of Lead, at the Rate of 3 Pounds of Paste to 50 Gallons of Water.

Tree No.	Variety.	Size.	Amount spray used.	Sprayed.	Picked.	Rain.	Amount fruit picked.	No. of apples.	Total residue (AS_2O_3).	Residue (AS_2O_3) per apple.
11		Medium	$12\frac{1}{4}$ qts.	Aug. 29	Aug. 30	None	$\frac{3}{4}$ bu.	141	.0425 gms.	.30 mg.
					Aug. 30	None	$\frac{3}{4}$ bu.	147	.0079 gms.	.05 mg.
					Sept. 2	Heavy 10 min.	$\frac{3}{4}$ bu.	180	.0463 gms.	.25 mg.
					Sept. 2	Heavy 10 min.	$\frac{3}{4}$ bu.	169	.0458 gms.	.27 mg.

noted that the amounts of arsenic recovered varied from .05 to .30 milligram per apple, and that these figures substantiate the previous records.

In experiments at the Maine Station, reported by Woods (14), winter apples were sprayed the first week in August. Sample lots were carefully picked at harvest and submitted to analysis. Arsenious oxid was found ranging from .034 milligram to .1 milligram per fruit. The concentration of material used, and the amount of rain that intervened, are not stated.

It should be pointed out that the results here discussed are based on the residues remaining on the surface of the fruit. That occasionally there may be absorption of some arsenic by the skin of the fruit has been noted by O'Gara (12). This, it appears, results from the use of lead arsenate in which the arsenic and the lead are not properly combined. In such cases the skin is apt to develop red or black spots.

SPRAY APPLIED DIRECTLY TO APPLES.

The purpose of the experiments described below was to determine the maximum amount of spray material that could be induced to cling to the surface of apples.

In the studies so far described various lots of apples were picked from trees to which arsenate of lead spray had been applied. In all of these cases the amount of spray material recovered on the apples represented that proportion which happened to strike the apple and to stick to it. It has been shown that in these cases analyses disclosed the maximum amounts of .3 to .8 milligram AS_2O_3 per apple. As noted beyond, this is to be compared with the ordinary medicinal dose of 1 to 5 milligrams and the dangerous dose of 60 to 120 milligrams.

It is conceivable that an occasional apple might be eaten carrying much more than the average maximum. Such an occurrence is unlikely for the reason that an apple exhibiting such excessive amounts of arsenate of lead would immediately excite suspicion. Furthermore, in ordinary handling, much of the material would likely be rubbed off, as is shown in records quoted earlier in this bulletin. However, the subject was given further study.

By preliminary trials it was found that dipping the fruit in

Fig. 1. SPRAY APPLIED DIRECTLY TO FRUIT
Baldwin apples showing maximum amount of arsenate of lead that could be induced to cling to fruit.

spray material did not result in as large an amount of spray adhering to the surface of the apple as could be secured by applying a mist-like spray to the surface. When the apple was dipped there was more tendency for the material to run off. When a fine spray was applied to the surface and the application was stopped before the drops coalesced, a maximum coating was secured. It should be noted that the stem end of the apple was not filled up with poison. The spray material was used in a concentration equivalent to 6 lbs. of arsenate of lead paste to 50 gallons of water.

The first lot was Baldwins, picked in the fall and treated in December. The test showed 665 apples required to use up one gallon of spray material. Translated into other figures this means 9.6 grams of white arsenic to 665 apples, or 4 milligrams per apple. Thus it will be seen that each of these apples carried five to eight times the amount found as the maximum in the case of fruit picked from sprayed trees. On the other hand the apples were so obviously coated with spray material that one could not be unaware of their condition (see photograph). Again, the spray here was used at the rate of 6 lbs. to 50 gallons, whereas recommendations for spraying trees in fruit seldom specify more than 3 lbs. to 50 gallons. The latter strength would result in practically half the arsenical residue per apple, since all our experiments have shown that with any ordinary concentrations of lead arsenate, after the maximum amount of spray has been applied that will cling to the surface, the residues that will remain are governed by the concentration of material used, not by the application of larger quantities of spray.

It seemed possible that the apples used in the above test in December might not fairly represent those on a tree in the fall, through variation in the ability of the skin to retain spray. For this reason another lot was similarly treated in October of the following year. The results were practically identical: 656 apples to a gallon of spray, as compared with 665.

Again it was possible that a variety with a rougher skin might retain more. Therefore, the test was repeated, using Russets. The results with these were nearly the same: 648 apples to the gallon.

SUMMARY AND DISCUSSION.

The conclusion to be drawn from the above experiment would seem to be that a single apple might, under extraordinary conditions, retain the equivalent of 4 milligrams of white arsenic AS_2O_3. At the same time, it is not believed that such an occurrence would be likely, because of the obvious condition of the apple and because any handling would be certain to remove an appreciable part of the residue. The results, therefore, are taken to reinforce the experiments described earlier.

SMALL FRUITS.

In the summer of 1916 it was arranged to spray certain small fruits with arsenate of lead and to carry out analyses of the arsenical residues remaining, as had been done with apples. The fruits used were strawberries, currants and blackberries. It was anticipated that analysis might show a larger amount of residue adhering to strawberries and blackberries than had been found in the case of apples, because of the rough surface of the former.

The spray material was prepared as before, using dry powdered arsenate of lead, at the rate of 1 oz. to 2 gallons of water or the equivalent of 3 lbs. of arsenate of lead paste to 50 gallons of water. All the spraying was done thoroly, probably more so than would be the case in commercial work. In other words, the plants were drenched with the material, and care was taken to spray all parts directly.

The plan of the experiment included 4 plots of each of the 3 varieties of fruit. From two of these plots the fruit was to be picked within a day or two after spraying and before any rain had fallen. From the other two the fruit was to be picked after rain had fallen. This plan was carried out as indicated.

Each plot of strawberries included 15 feet of row. These 4 plots were sprayed July 15, using $1\frac{1}{2}$ quarts of spray material to each plot. Two plots were picked July 17, before any rain had fallen. The other two plots were picked July 21, after a heavy rain of July 20.

Each plot of currants consisted of 3 bushes. The fruit was of average size and abundance and the foliage medium in amount and thickness. Each of these plots was sprayed July 15, using $1\frac{1}{4}$ quarts of spray material to each plot. The fruit was picked

TABLE NO. 5. SUMMARY OF RESIDUES ON SMALL FRUITS.

Sprayed with Arsenate of Lead at the Rate of 3 Pounds of Paste to 50 Gallons of Water.

Lot No.	Kind.	Number plants sprayed.	Amount spray applied.	Date sprayed.	Date picked.	Rain-fall.	Amount fruit picked.	Total residue found (AS_2O_3).	Residue per unit (AS_2O_3).
1	Strawberry	15 ft. row	1½ qts.	July 15	July 17	None	147 berries, 1 qt.	0.0115 gms.	11.5 mg. berry
2	Strawberry	15 ft. row	1½ qts.	July 15	July 17	None	164 berries, 1 qt.	0.0093 gms.	9.3 mg. qt.
3	Strawberry	15 ft. row	1½ qts.	July 15	July 21	.50 in.	63¾ qts.	0.0114 gms.	34.2 mg. qt.
4	Strawberry	11 ft. row	1½ qts.	July 15	July 21	.50 in.	95½ qts.	0.0043 gms.	8.6 mg. qt.
5	Currants	3 bushes	1¼ qts.	July 15	July 18	None	3 qts.	0.0243 gms.	8.1 mg. qt.
6	Currants	3 bushes	1¼ qts.	July 15	July 18	None	2½ qts.	0.0254 gms.	10.2 mg. qt.
7	Currants	3 bushes	1¼ qts.	July 15	July 21	.50 in.	2½ qts.	0.0170 gms.	6.8 mg. qt.
8	Currants	3 bushes	1¼ qts.	July 15	July 23	.04 in.	3½ qts.	0.0275 gms.	7.8 mg. qt.
9	Blackberries	2 bushes	1½ qts.	Aug. 18	Aug. 18	None	1½ qts.	0.0148 gms.	9.9 mg. qt.
10	Blackberries	2 bushes	1½ qts.	Aug. 18	Aug. 18	None	1½ qts.	0.0168 gms.	11.2 mg. qt.
11	Blackberries	2 bushes	1½ qts.	Aug. 24	Aug. 24	.59 in.	2 qts.	0.0075 gms.	3.8 mg. qt.
12	Blackberries	2 bushes	1½ qts.	Aug. 24	Aug. 24	.59 in.	1 qt.	0.0046 gms.	4.6 mg. qt.

from two of the plots July 18, before any rain had fallen and from the other two July 21, after a heavy rain of July 20.

In the case of the blackberries each plot included 2 bushes. The foliage was large and heavy, the fruit abundant and part of the berries were ripe. The bushes were sprayed August 18, using $1\frac{1}{2}$ quarts of spray material to each plot. The spraying was done in the morning. In the afternoon the fruit was picked from two of the plots. The fruit was picked from the other two plots August 24, after a hard rain of August 23.

Summary of these plots, together with the results of analyses, is given in Table No. 5. Opposite each plot will be found the amount of fruit picked from that plot, the total residue found as expressed in AS_2O_3, and the residue per quart of fruit.

It will be noted that with the strawberries the residue AS_2O_3 per quart ranges from 8.6 milligrams to 34.2 milligrams. As was anticipated, these fruits showed a larger residue per unit than would the currants or the blackberries. If we were to assume that 1 quart of strawberries will provide a reasonable portion for 4 persons, we should have residues per portion ranging from 2 to 8 milligrams of AS_2O_3.

The residues found on currants ranged from 6.8 milligrams to 10.2 milligrams per quart. It seems rather evident that the spray material did not collect in as large amounts on the currants as on the strawberries, quite possibly due to the difference in the surface of the fruit.

With the blackberries, residues ranged from 3.8 to 11.2 milligrams per quart. If 1 quart is sufficient to make 4 portions for an adult person, this is the equivalent of .9 to 2.8 milligrams AS_2O_3 per portion.

VEGETABLES.

Two kinds of vegetables, including 4 plots each, were sprayed with arsenate of lead in the summer of 1916 and the residues of arsenic determined by analysis. The spray material was made up at the rate of 1 oz. of dry arsenate of lead to 2 gallons of water or the equivalent of 3 lbs. of arsenate of lead paste to 50 gallons of water. The vegetables were sprayed directly and thoroly.

Four plots of cabbages were sprayed, each plot including 3 cabbages. The spray was applied August 1. The cabbages from two of the plots were removed August 3 and submitted to analy-

TABLE NO. 6. SUMMARY OF RESIDUES ON VEGETABLES.

Sprayed with Arsenate of Lead at the Rate of 3 Pounds of Paste to 50 Gallons of Water.

Lot No.	Kind.	No. plants sprayed.	Amount spray applied.	Date sprayed.	Date picked.	Rainfall.	Amount fruit picked.	Total residue found (AS_2O_3).	Residue per unit (AS_2O_3).
1	Cabbage	3 heads	2½ pts.	Aug. 1	Aug. 3	None	3 heads	0.1306 gms.	43.5 mg. head
2	Cabbage	3 heads	2½ pts.	Aug. 1	Aug. 3	None	3 heads	0.1308 gms.	43.6 mg. head
3	Cabbage	3 heads	2½ pts.	Aug. 1	Aug. 9	.10 in.	3 heads	0.1460 gms.	48.6 mg. head
4	Cabbage	3 heads	2½ pts.	Aug. 1	Aug. 9	.10 in.	3 heads	0.1543 gms.	51.4 mg. head
5	Lettuce	10 heads	2½ pts.	Aug. 2	Aug. 3	None	10 heads	0.0633 gms.	6.3 mg. head
6	Lettuce	10 heads	1 qt.	Aug. 2	Aug. 3	None	10 heads	0.0116 gms.	1.6 mg. head
7	Lettuce	10 heads	1 qt.	Aug. 2	Aug. 8	.10 in.	10 heads	0.0725 gms.	7.2 mg. head
8	Lettuce	10 heads	1 qt.	Aug. 2	Aug. 8	.10 in.	10 heads	0.1059 gms.	10.6 mg. head

sis. No rain had fallen. The cabbages from the remaining two plots were removed August 9, after a very light rain the night of August 3 and a moderately heavy rain the afternoon and night of August 8.

Four plots of lettuce were sprayed, each plot including 10 heads. The spray was applied August 2. The heads from plots 1 and 2 were removed August 3, before any rain had fallen. Those from plots 3 and 4 were removed August 8, having received a light shower the night of August 3 and a heavy rain the afternoon and evening of August 8.

The results of analyses are given in Table No. 6.

It was expected that the cabbage might show relatively large amounts of residues because of the spray material collecting in the base of the leaves. In lesser degree this was anticipated in the case of lettuce. The results bore out the expectations. As will be noted, the cabbages showed 43.5 to 51.4 milligrams AS_2O_3 per head; the lettuce 1.6 to 10.6 milligrams AS_2O_3 per head. There is no indication of reduced amount because of rain. This is not surprising, if we assume that most of the poison had collected in the base of the leaves. Rain would not be likely to remove it from such a position.

If the outer leaves had been broken off and discarded before making the analysis, the result would, no doubt, have been quite different. Probably in ordinary commercial practice the outer leaves would have been removed. However, the idea in these experiments was to determine the maximum that could be found. The writers would assume that in the ordinary course of events, even if cabbages or lettuce had been directly sprayed as thoroly as was done in this experiment, the amount of arsenic that would eventually find its way to the table would be only a small fraction of the amount indicated in the analytical result, allowing for the intervening operations of removing the outer leaves, washing and preparing for human consumption.

In experiments at the Kentucky Station, described by Garman (6), one lot of cabbage was sprayed four times with arsenate of lead at the rate of 2 lbs. to 100 gallons of water. Later, one of these heads, with the outer leaves removed, was submitted for analysis. The amount of arsenious oxid found was 5.2 milligrams. Another head, from a row sprayed twice, gave 7.8 milligrams AS_2O_3.

POSSIBLE DANGER OF HUMAN POISONING.

TOXIC STANDARDS.

In standard works on toxicology will be found the approximate amount of arsenic considered to be dangerous as well as the amount commonly prescribed as a medicinal dose. The medicinal dose, expressed as arsenious oxid, AS_2O_3, is 2 milligrams, with a maximum of 5 milligrams. The dangerous dose is commonly quoted as 60 milligrams and the minimum recorded fatal dose is given as 130 milligrams.

The amount that may be administered in medicine is, of course, fixed by long years of practice. As regards the danger of fatal doses, however, some comments may be proposed. The amounts quoted as dangerous or fatal are naturally based on many records, partly from the annals of criminology. In these sundry cases the form in which the arsenic has been ingested has varied. In some instances it has been taken in a soluble form as in Fowler's solution. In others it has been in the form of common white arsenic or arsenious oxid AS_2O_3. In this form its solubility varies, influenced in part by its physical condition. One part may dissolve in 30 to 80 parts of water or may require as much as 400 parts of water.

If now, we attempt to draw a comparison between the possible toxic properties of the arsenic in arsenate of lead and those of arsenic as quoted in the literature of toxicology, we find ourselves dealing with some unknown factors. Remembering that the poisonous properties of a substance, aside from its corrosive qualities, are dependent on the extent to which it is dissolved after being ingested, we should need to know something of the solubility of arsenate of lead in human gastric juice, in order to appraise its possible danger. This solubility, as noted further, was determined for us by the Hull Physiological Laboratory of Chicago University.

In general, we may propose that the arsenic in arsenate of lead is not going to prove more toxic than that in common white arsenic, AS_2O_3. This is for the reason that arsenate of lead is specifically devised to present arsenic in a form largely insoluble, in order to avoid burning the foliage of plants that are sprayed; and it accomplishes this purpose. Common white arsenic on

the other hand, if mixed with water to form a spray material, is apt to burn the foliage of plants severely.

It will be noted that this does not take into account possible poisoning by lead. We are here concerned with the arsenic rather than the lead, because the latter can hardly be present in sufficient quantities to cause acute poisoning from a single or a few doses if the arsenic is not present in sufficient quantity.

SOLUBILITY OF LEAD ARSENATE IN HUMAN GASTRIC JUICE.

Thru the kindness of Dr. A. J. Carlson and Dr. A. Woelfel, of the Hull Physiological Laboratory, Chicago University, experiments were carried out to provide data relative to the solubility of arsenate of lead in normal human gastric juice.

The report of these investigators is here quoted verbatim:

THE SOLUBILITY OF LEAD ARSENATE IN HUMAN GASTRIC JUICE.

A. J. Carlson and A. Woelfel.

(From the Hull Physiological Laboratory of the University of Chicago.)

The following tests were made at the request of Prof. W. C. O'Kane of the New Hampshire Agricultural Experiment Station. Lead arsenate is used as an insecticide in the spraying of fruit trees, and is therefore liable to be ingested with such fruit as is not peeled before being eaten. The lead arsenate used in these tests was sent us by Professor O'Kane.

In the present series of tests we followed the procedure of our previous investigations of the solubility of other lead compounds in human gastric juice.* The gastric juice was obtained from Mr. V., our man with permanent gastric fistula.† The free acidity of the gastric juice varied from 0.42 per cent to 0.47 per cent.

Series I.

0.5 gr. lead arsenate
25 cc. human gastric juice } at 38° C. for 12 hours
25 cc. distilled water

In Solution.

Lead, determined as $PbSO_4$.	Arsenic, determined as $Mg_2As_2O_7$.
1. 0.0163 gr.	1. 0.0104 gr.
2. 0.0154 gr.	2. 0.0115 gr.
3. 0.0160 gr.	3. 0.0103 gr.

* Carlson and Woelfel, Am. Jour. of Publ. Health, 1913, p. 755; Bull. U. S. Bureau of Labor Statistics, 1914, No. 141, p. 82.

† Carlson, Am. Jour. of Physiol., 1912, XXXI, p. 151.

Series II.

0.5 gr. lead arsenate
25 cc. human gastric juice
25 cc. distilled water
25 gr. apple pulp
} at 38° C. for 12 hours

In Solution.

Lead, determined as $PbSO_4$.	Arsenic, determined as $Mg_2As_2O_7$.
1. 0.015 gr.	1. 0.020 gr.
2. 0.018 gr.	2. 0.012 gr.
3. 0.018 gr.	3. 0.019 gr.
4. 0.014 gr.	4. 0.013 gr.
5. 0.015 gr.	5. 0.015 gr..

Series III.

0.2 gr. lead arsenate
25 cc. human gastric juice
25 cc. milk
} at 38° C. for 12 hours

In Solution.

Lead, determined as $PbSO_4$.	Arsenic, determined as $Mg_2As_2O_7$.
1. Trace ?	1. Trace ?
2. Trace	2. Trace ?
3. Trace ?	3. Trace.

The arsenate of lead, especially as prepared for commercial use as an insecticide, is probably not a definite compound.* According to the analysis furnished us by Professor O'Kane, the lead arsenate used by us contained 0.18 per cent moisture, and yielded 33.4 AS_2O_5. We ran two analyses of the lead arsenate itself with the following results:

1. 0.25 gr. lead arsenate, yielded { $PbSO_4 = 0.1794$ gr. / $Mg_2As_2O_7 = 0.1006$ gr.
2. 0.25 gr. lead arsenate, yielded { $PbSO_4 = 0.1843$ gr. / $Mg_2As_2O_7 = 0.1010$ gr.

On the basis of these figures it is clear that about 5 per cent of the arsenates of lead are dissolved in human gastric juice when mixed in the proportion of 0.5 gr. lead arsenate to 25 cc. of the juice. It is probable that the essential solvent in the gastric juice is the free hydrochloric acid, so that by increasing the quantity of the gastric juice, or reducing the quantity of the lead arsenate, the percentage of the arsenate dissolved in the gastric juice is correspondingly increased.

* Tartar and Robinson, Jr. Am. Ch. Soc., 1914, XXXVI, p. 1843.

Summary.

1. Lead arsenate, used as an insecticide or spray on fruit trees, is sufficiently soluble in human gastric juice to cause lead and arsenic poisoning. Measures must, therefore, be taken to remove this spray from the fruit.

2. The presence of apple pulp appears to slightly increase the solubility of the lead arsenate in the human gastric juice, probably owing to the organic acids in the pulp.

3. Milk mixed with the gastric juice in the proportion of 1–1 practically prevents solution of the lead arsenate, probably by neutralization and fixation of the free hydrochloric acid.

DISCUSSION.

The conclusion offered in the second sentence of the first paragraph of the summary just quoted should be understood as that of Drs. Carlson and Woelfel and not that of the writers of this bulletin. Our own conclusions, as will be noted elsewhere, may be somewhat differently expressed.

Unfortunately, there are, apparently, no records showing the solubility of ordinary white arsenic AS_2O_3 in gastric juice. Commenting on this point in a letter to the writer, December 1, 1914, Dr. A. J. Carlson says:

"I do not know of any actual determination of the solubility of white arsenic (AS_2O_3) in gastric juice. It is quite soluble in cold water (1 part in 30 to 80), more soluble in hot water, and still more soluble in hydrochloric acid. It is clear from the above that in the following mixture: 0.5 grams AS_2O_3 plus 25 cc. gastric juice, plus 25 cc. water, at 38° C. for 10 hours, all of the arsenic would go in solution. You ought to find that lead arsenate is less toxic than white arsenic (AS_2O_3)."

In another letter, dated November 20, 1914, Dr. Carlson writes:

"Since lead arsenate is not, to my knowledge, used in therapeutics, there is probably no figure available in the matter of exact toxic dose. Could you not determine it approximately on rabbits or dogs, by running parallel series with arsenic and lead arsenate? You can then compute the doses of lead arsenate for man on the AS_2O_3 basis.

"Speaking as a physiologist interested in public health I should say the question is not how much of the poison may be ingested without producing acute or obvious chronic symptoms, but how completely can man be safeguarded against even traces of the poison. There is no question in my mind that even in less

than so-called toxic doses lead and arsenic have deleterious effects on cell protoplasm, effects that are expressed in lowered resistance to disease, lessened efficiency, and shortening of life."

RESULTS OF FEEDING LEAD ARSENATE AND WHITE ARSENIC TO GUINEA PIGS.

It has been shown that the maximum amounts of arsenic found by analysis are: for apples .3 to .8 milligram per fruit; for small fruits 2 to 8 milligrams per portion of one-fourth quart; for cabbage 45 milligrams per head; and for lettuce 6 to 10 milligrams per head. These we are to interpret in their relation to the ordinary standards which cite 1 to 5 milligrams as a medicinal dose of white arsenic, AS_2O_3, and 60 to 120 milligrams as a dangerous dose. It has been shown, also, by the results of the determinations made at the Hull Physiological Laboratory in behalf of this investigation, that the arsenic in arsenate of lead is not in a highly soluble form in human gastric juice but probably in that medium is less soluble than is arsenic in the form of white arsenic.

To help in arriving at a correct interpretation it was now proposed:

(1) To feed to small mammals daily doses of arsenate of lead equal to the average maximum found on sprayed apples, increasing the amount from time to time up to the point of fatal poisoning.

(2) To feed to parallel lots of small mammals equal amounts of lead arsenate and of white arsenic, in order to establish some basis of comparison between the toxic properties of these two substances.

With this double object in view, experiments were begun in feeding, directly, known amounts of lead arsenate and white arsenic to guinea pigs.

Pens were constructed in the open air insectary belonging to the department. This is a building in which a fairly constant temperature is maintained thruout the year. In summer the sides are of gauze wire. In winter, glass sash are substituted for the gauze wire, and steam heat, under thermostat control, maintains a temperature reasonably constant.

The guinea pigs secured were of apparently uniform good health and varied in weight from 16 to 23 ounces. They were

fed on grain, hay and fresh vegetables, such as carrots and cabbage. At one time there was an epidemic of intestinal disorder among some of the pigs; but on the whole they remained in good condition, as shown by the record of the check pigs.

The arsenate of lead used was from the same lot as that employed in the spraying experiments already recorded. The amount constituting a dose was weighed out on chemists' balances and was fed directly to the pig by the attendant. Usually the poison was inserted in a piece of carrot or other vegetable, or was spread on a thin slice which was then folded over. The piece of vegetable containing the poison was placed within the pig's mouth and the attendant held him until he had chewed it up and swallowed his portion. After a few experiences the pigs usually accepted this treatment without special objection.

THE UNIT DOSE CHOSEN.

The amount of arsenate of lead selected as a unit of dose was the average maximum per apple found in the analyses of sprayed apples picked in ordinary manner before any intervening rain as recorded earlier in this bulletin (see Table No. 3). This average, if expressed as dry powdered lead arsenate analyzing 33.4 per cent AS_2O_5, was 1.7 milligrams. This amount of dry lead arsenate, therefore, constituted the unit. All feeding was of this unit or multiples thereof.

In the series of pigs that were fed white arsenic, AS_2O_3, instead of lead arsenate, an amount was used equivalent in arsenic content to the unit of lead arsenate and the multiples thereof.

In the three tables summarizing the results (see Tables Nos. 7, 8 and 9), each horizontal line represents the feeding of one guinea pig. The solid portions of the line indicate by their thickness the relative amount of the poison fed to the pig. Thus, the thinnest line indicates one unit daily. Progressively, the heavier lines indicate 2, 3, 4, 7 units, and so on. The number of units fed is shown by the figures at the end of each segment of a line. The length of the solid portions of a line represents the length of period thru which the pig received his daily dose of the unit in question. The scale is stated at the top of each table. The dotted portion of a line indicates a resting period, during which the pig received no poison. The length of this dotted portion of the line is drawn to the same scale.

TABLE NO. 7. ARSENATE OF LEAD FED TO GUINEA PIGS IN PROGRESSIVE DOSES.

Horizontal lines indicate periods during which the poison was administered. 1 centimeter equals 13 days. Figure at the right end of each solid horizontal line indicates number of "units" fed daily. A "unit" is the average maximum residue found per apple in analyses. Dotted lines indicate rest period during which pig received no poison. A cross at the extreme right hand end of line indicates death of pig.

RESULTS AND DISCUSSION.

In Table No. 7 are set forth the results of feeding lead arsenate beginning with relatively small doses, continuing such doses daily, for 30 days or sometimes less; then permitting a resting period; then again resuming the poison, but with a heavier dosage; then, again, a resting period; again resuming the poison, with a still heavier dosage; and continuing this, up to serious illness or death of the pig. A cross at the end of a line indicates the death of the pig.

It will be observed, at once, that pigs receiving 1 unit, 2 units or 3 units daily, for a period of 30 days showed no evidence of fatal poisoning. When such pigs were placed on a daily dosage of 4 units, 5 units and 6 units daily, they still showed no fatal poisoning; when the dosage was increased to 7 units the pigs still survived.

The first case of fatal poisoning occurred when 8 units were fed. From that point on up to 13 units, fatal poisoning occurred.

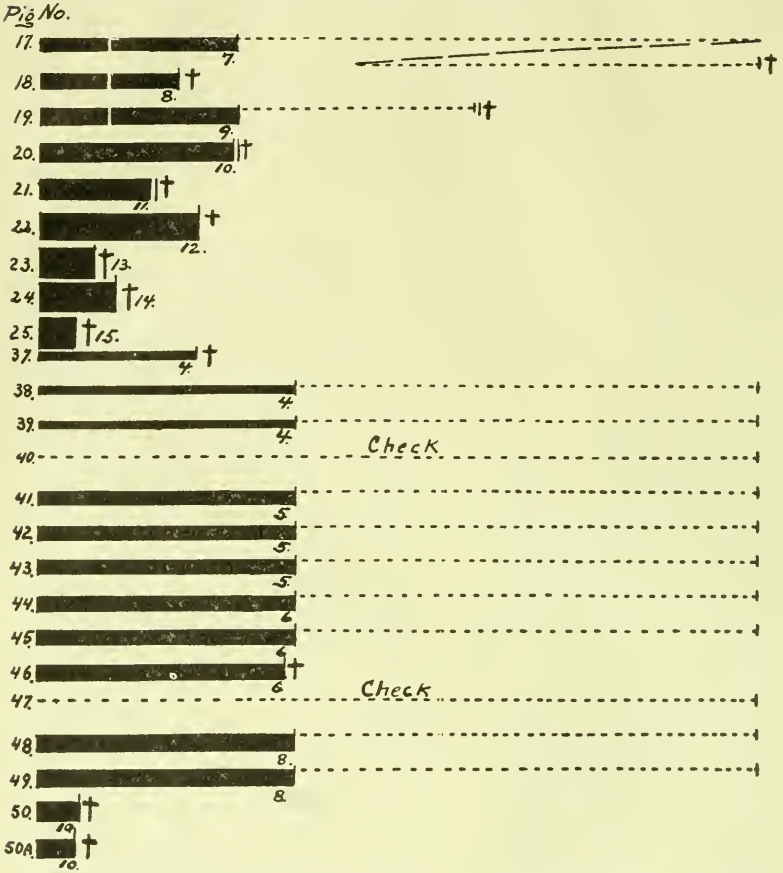
In Table No. 8 are shown the effects beginning with a heavy dosage in the daily feeding, without any preliminary period of lighter dosage. This series of experiments was undertaken in view of the possibility that the pigs recorded in Table No. 7 might have reached safely a dosage of 8 units daily because of acquired tolerance, resulting from earlier feeding with lighter doses.

In this table it will be observed that in one case, No. 18, the administration of 8 units daily for a period of 22 days was followed by the death of the pig. With pig No. 46, the administration of 6 units daily for a period of 38 days was followed by the death of the pig. Doses of less amount than these did not result fatally, except with pig No. 37, who received 4 units daily for a period of 25 days and died.

On the whole, the dosage point at which fatal poisoning is apt to occur appears to be similar to that found with pigs that had first received lighter doses thru considerable periods. In other words, there is no marked evidence of acquired tolerance.

In Table No. 9 are set forth the results where equivalent units are fed in the form of white arsenic AS_2O_3, instead of lead arsenate. In this case, fatal results began with a dosage of 4 units, administered thru 14, 15 and 20 days, respectively, as shown by the

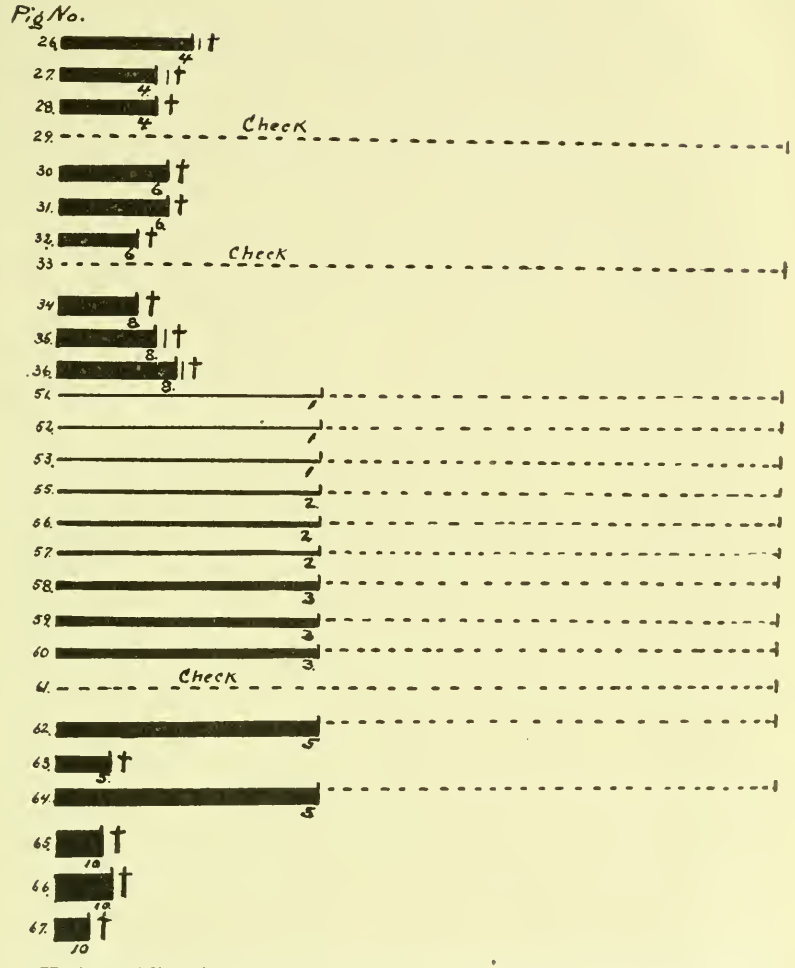
TABLE NO. 8. RESULTS OF FEEDING ARSENATE OF LEAD TO GUINEA PIGS WITHOUT PRELIMINARY SMALL DOSES.



Horizontal lines indicate periods during which the poison was administered. 1 centimeter equals 11 days. Number at the right end of each solid horizontal line indicates number of "units" fed daily. A "unit" is the average maximum residue found per apple in analyses. Dotted lines indicate rest period during which pig received no poison. A cross at the extreme right hand end of line indicates death of pig.

records of pig Nos. 27, 28 and 26. There is again rather prompt evidence of serious poisoning with doses of 6 units continued thru 12 to 17 days, as shown by pigs Nos. 30, 31 and 32; and fatal results from a dose of 5 units continued thru 8 days, as shown by pig No. 63.

TABLE NO. 9. RESULT OF FEEDING WHITE ARSENIC AS_2O_3 TO GUINEA PIGS.



Horizontal lines indicate periods during which the poison was administered. 1 centimeter equals 11 days. Number at the right end of each solid horizontal line indicates number of "units" fed daily. A "unit" is the average maximum residue found per apple in analyses. Dotted lines indicate rest period during which pig received no poison. A cross at the extreme right hand end of line indicates death of pig.

On the other hand, the records of pigs Nos. 55 to 60 show no fatal effects with doses of 2 and 3 units, continued thru 40 days. Pig No. 62 and pig No. 64 succeeded in withstanding 5 units continued thru a period of 40 days.

On the whole, this table, as compared with the preceding two, rather clearly indicates that with guinea pigs the administration of arsenic in the form of white arsenic, AS_2O_3, will cause fatal poisoning at about 1/2 or 2/3 the dosage necessary for fatal results when the arsenic is administered in the form of lead arsenate.

Summarizing, it would appear that the two propositions offered at the beginning of this set of experiments may be answered as follows:

(1) So far as our experiments with guinea pigs may be relied on, the results indicate that five or even ten times the average maximum per apple found in our analyses could not be expected to constitute a dangerous single dose for a human being. It is quite true that a guinea pig may be less susceptible to this poison than is a human being. But the weight of a guinea pig is only about 1/100 of that of an adult human being. Even if the guinea pig is less susceptible, we should not expect any such ratio as 1 to 100. Therefore, since guinea pigs can ingest daily, without serious poisoning, amounts of arsenate of lead equal to the average maximum found on 6 apples, we should not expect serious or fatal results to follow the daily ingestion of an equal amount by an adult person.

(2) So far as the guinea pigs fed in these experiments are concerned, it is evident that arsenic administered in the form of white arsenic will cause fatal poisoning in about one-half or two-thirds the dosage required with arsenic administered in the form of lead arsenate. If this is true, as would seem definitely indicated, then the standards quoted in authorities for computing dangerous or fatal doses of arsenic, being based on administration of the poison in the form of white arsenic or Fowler's solution, may be assumed as quite safe in estimating the danger or safety of arsenic in residues of arsenate of lead.

SUMMARY AND CONCLUSIONS.

Considering the various experiments so far described in this bulletin, the writers propose the following conclusions as to the danger of poisoning human beings thru residues of arsenic remaining on fruits or vegetables following spraying with arsenate of lead.

In the case of apples, the maximum amount of the poison in terms of AS_2O_3 that may be expected to occur on apples in the ordinary course of events would not exceed .5 milligram per fruit. It is true that the surface of an apple may contain more than this, even as much as 5 milligrams, as made clear by experiments already described in direct spraying of poison on the surface of the fruit. But as pointed out in that place, such fruit would certainly attract attention and in picking and handling would certainly lose a material part of this residue, even if no rains intervened. It is believed, therefore, that under ordinary conditions no apples will reach the consumer carrying such amounts of arsenate of lead per fruit that a healthy human adult can eat enough at one time to cause fatal poisoning. In offering this conclusion the writers are taking into account the result obtained in feeding equivalent amounts of the poison to guinea pigs and other data already mentioned, which have a bearing on the toxic properties of arsenate of lead.

The possibilities in the case of strawberries appear a little different. The surface of this fruit is of such nature that larger amounts of the poison may be retained and quite possibly may escape notice. These residues also would be much less likely to be rubbed off in handling and probably would wash off less readily. One portion of strawberries, consisting of one-fourth quart of the berries, may carry as much as 8 milligrams AS_2O_3. This would probably seldom or never constitute a dangerous dose for an adult person in good health, but it might for a child or for an adult in weakened condition. The writers believe, therefore, that strawberries that are fully formed or nearly so, should not be directly sprayed with arsenate of lead, unless they are to be thoroly scrubbed before using.

In the case of blackberries and currants there is the possibility that a portion of these fruits suitable for an adult might carry a questionable amount of the poison. The possibility appears

rather remote. It would seem more serious in the case of blackberries, because of the nature of the surface of the fruit. The writers believe that blackberries should not be directly sprayed with arsenate of lead after the berries are formed. They believe that currants, if so sprayed, should be well washed. This is because there might be residues of questionable amount for a child or an adult in poor health.

With cabbage and lettuce it is evident, from the analyses, that a whole head directly sprayed and without removal of outer leaves may carry a relatively large amount of the poison. The writers believe that arsenate of lead should not be applied except lightly and sparingly to cabbage or to lettuce that is ready for market. If these vegetables are sprayed the outer leaves should be removed and the heads should then be washed. If this is done, it is believed that there is no danger that these vegetables will carry to the table an amount of arsenic involving a dangerous dose for a human being.

As to the possible injurious effects from long continued, daily consumption of fruits or vegetables carrying a relatively small amount of arsenate of lead, the case is not clear. Indeed, it is complicated by the literature of the subject. The records in standard references offer strange inconsistencies. Thus, Blyth (2) records what would appear to be serious poisoning resulting from the prolonged daily ingestion of one-sixth of a milligram of arsenic oxid, the poison being present in beer. This is a very small amount and is less than the equivalent often found per apple in the fruit from trees sprayed in our experiments. One is inclined to suspect that other causes played a part in these cases. As against this record may be set down the fact that there are at least two areas in the world where many of the inhabitants follow the practice of eating arsenic; namely, among the mountaineers of a region adjacent to Hungary and among peoples in certain sections of India. The practice is followed because these people consider that the drug gives them greater vigor and enables them to carry out difficult physical labor with less fatigue. It is the habit of these arsenic eaters to begin with a small dose daily and after a time gradually to increase the amount. Eventually, an individual may consume relatively large doses, even amounting to 300 milligrams daily. The records appear to show that these people live to old age.

In the face of the above record the writers feel that the subject is one requiring much care in drawing conclusions. Considering all of the data already cited in this bulletin, including the feeding experiments, it is believed that the use of apples from trees sprayed with arsenate of lead at the rate of 3 lbs. of the paste to 50 gallons of water offers very slight danger, even if the fruit from such trees is consumed frequently, provided rains have intervened after spraying. An occasional fruit might show as much as .5 milligram or even 1 milligram AS_2O_3, but this would not be common. Most of the fruit in the ordinary process of handling, and subject to average weather conditions, would be likely to exhibit only a small fraction of the above amounts per fruit. If one is dealing with winter fruit which has been sprayed two months or more prior to harvest, the residues would appear negligible. In the case of early fruit, sprayed just before harvesting, the fruit should be wiped.

EXPERIMENTS WITH LIVE STOCK.

DRIP FROM TREES.

The amount of spray material that may be expected to lodge on the ground beneath a sprayed tree naturally varies with several factors. It will be less if the operator is careful and greater if he is careless. It will likely increase as the total amount of material applied to a tree is increased. It may be more when a coarse nozzle is used than when a mist nozzle is employed.

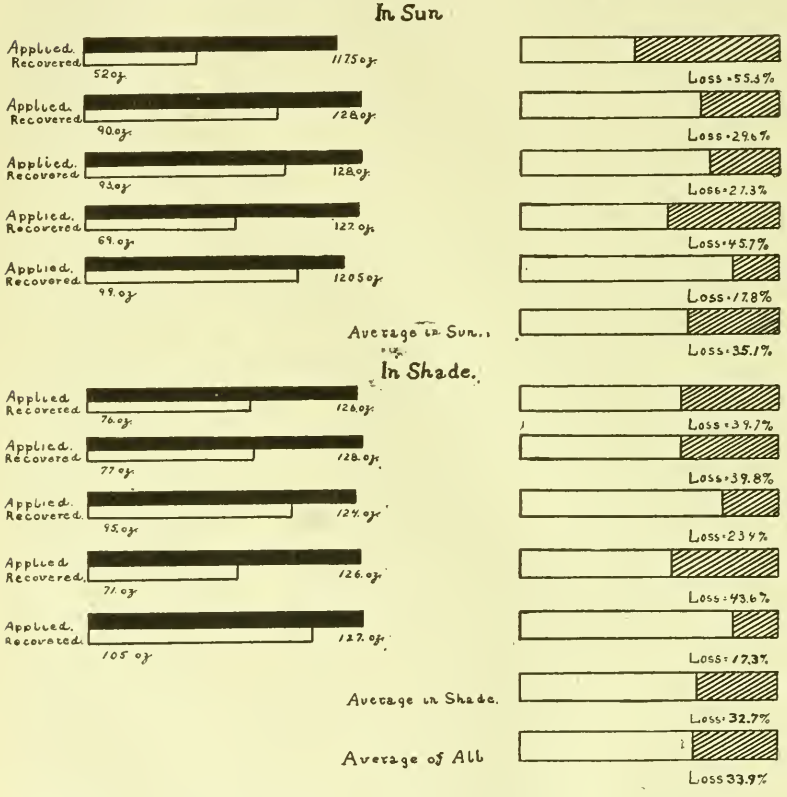
These factors concern the amount of liquid material. Another and an important factor which will greatly influence the amount of arsenic recoverable beneath the tree is the concentration of spray material employed. If 10 gallons of spray material is applied to a tree and if 2 gallons of this finds its way to the ground, that which falls on the ground will carry increasing amounts of arsenic as the concentration of the spray material is increased. We should expect and shall find double the amount of arsenic on the ground if the concentration of the spray material is the equivalent of 6 lbs. of arsenate of lead paste to 50 gallons of water than we shall find if the concentration is only 3 lbs. Neither of these concentrations, nor any other in common use, alters the physical character of the spray material in sufficient degree to cause it to drip less readily.

The following experiments were undertaken in order to arrive at some notion of the proportion of spray material that will fail to lodge on the tree.

The plan of the experiment involved using large squares of cloth beneath trees to catch the drip, weighing these squares before and after spraying. It was necessary, therefore, first to determine the amount of evaporation that would take place from the cloth during the time that the tree was dripping.

Preliminary tests showed that 5 minutes covered the time that

TABLE NO. 10. RESULT OF EVAPORATION TESTS.



Left-hand column shows amounts applied to ground cloths (in black) with amounts recovered by weight at the end of five minutes (in white). Right-hand column shows the same reduced to a percentage basis, the white indicating percentage recovered on cloth and the diagonal shading indicating percentage lost by evaporation.

drip continued to fall from a sprayed tree. Squares of heavy muslin, measuring 25 feet each way, were now laid out on the ground and to these squares spray was applied directly. The square was weighed before being sprayed. The weight of spray material applied to it was recorded. At the end of 5 minutes the square was again weighed. Five such squares were so tested lying in the sun, and five squares lying in the shade. The results of the tests, together with the average of each lot and the final average, are shown in Table No. 10.

It will be observed that in the case of squares of cloth lying in the sun the percentage of loss due to evaporation varied from 17.8 per cent to 55.3 per cent, with an average of 35.1 per cent. In the case of the squares of cloth lying in the shade the evaporation ranged from 17.3 per cent to 43.6 per cent, with an average of 32.7 per cent. Since the cloths to be used beneath the trees would lie partly in sun and partly in shade, it was deemed fair to take an average of the above two lots, which is 33.9 per cent, as representing the allowance that should be made for evaporation in computing the drip from sprayed trees.

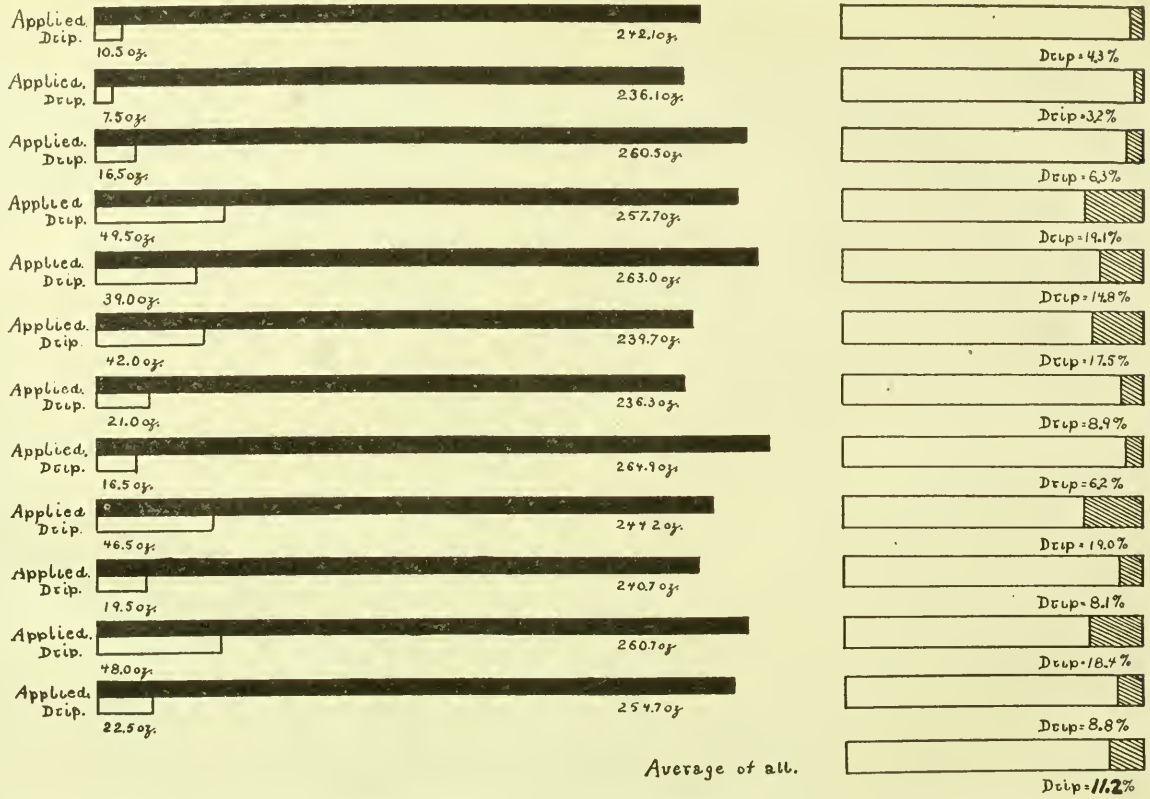
Similar squares were now placed beneath trees of various size. These trees were sprayed and a record was kept of the weight of material applied. The cloth was weighed just before spraying, and at the end of 5 minutes the cloth was again weighed. The results are shown in Table No. 11.

In setting down in Table No. 11 the difference in weights of the cloths allowance was made for evaporation in accordance with the data described above in Table No. 10. In other words, to the difference in weight in each case was added one half to account for evaporation.

It will be noted that the results show, in the first column of the chart, actual total amounts of spray applied to the tree ranging from 236.3 oz. to 264.9 oz. The amounts recovered on the cloth, allowing for evaporation, range from 7.5 oz. to 49.5 oz. Reducing these amounts to percentages, we find that the drip from these sprayed trees ranged from 3.2 per cent to 19.1 per cent.

The average of 12 trees was 11.2 per cent. This amount is assumed to represent a fair percentage of drip from a sprayed tree where the material is applied with reasonable care.

Table No. 11. Drip from Sprayed Trees.



Column at the left shows total amount applied to tree (in black) and amount of drip recovered on cloth (in white). Column at the right shows the same reduced to percentage basis, the white showing percentage remaining on tree and the shaded portion the percentage of drip.

CALVES.

In the experiments just noted it was found that the amount of material dripping from trees that had been sprayed with reasonable care averaged 11 per cent of the total amount applied to the tree. Taking for granted that spraying is often carelessly done it is assumed that we may properly allow double the percentage of drip found in the experiments, namely 20 per cent of the total amount applied to the trees.

Assuming further that in the case of large trees 10 gallons of spray material may be applied per tree, we may expect to find a probable maximum of 2 gallons of this spray material on the grass beneath such a tree. Probably this drip would be distributed over a rather large area, especially if any wind were blowing. But as a basis for maximum concentration of the drip it is now assumed that in the case of such a tree all of the 2 gallons of drip would be found on an area 25 feet square beneath the tree.

Preliminary tests were now made, applying a spray to such an area of grass. These tests were carried out in an orchard in which the growth of grass was of moderate thickness and 10″–14″ high. It was found by these tests that 2 gallons of spray material applied directly to an area 25 feet square represented approximately what the grass would hold readily. Apparently if more was applied some of it would run off onto the ground. Therefore, in the experiments now to be described, the unit area selected was a plot 25 feet square, including 625 square feet, and to each such plot 2 gallons of spray material was applied directly on the grass by means of an ordinary bucket pump.

Three concentrations of arsenate of lead were chosen: first, a mixture made up at the rate of 3 lbs. of arsenate of lead paste to 50 gallons of water; second, 6 lbs. of arsenate of lead paste to 50 gallons of water; and third, 10 lbs. of arsenate of lead paste to 50 gallons of water.

In the orchard above mentioned 3 pens were placed, each pen including an area 25 feet square, or 625 square feet to each pen. The pens were so arranged as to include grass of approximately uniform stand. In plot I, the grass was sprayed with 2 gallons of material made up of 1 oz. of dry arsenate of lead to 2 gallons of water. This concentration, it will be observed, represents the approximate equivalent of 3 lbs. of arsenate of lead paste to

50 gallons of water. The second pen was sprayed with 2 gallons of material containing 2 oz. of dry arsenate of lead. The third was sprayed with 2 gallons of material containing $3\frac{1}{3}$ oz. of dry arsenate of lead.

Since the dry arsenate of lead used was shown by analysis to contain 33.4 per cent of arsenic oxid AS_2O_5, it will be noted that the material applied to the grass in the first plot contained the equivalent of 9.4 grams of arsenic oxid; that applied to the second plot contained the equivalent of 18.8 grams of arsenic oxid and that applied to the third plot, the equivalent of 31.5 grams of arsenic oxid.

Two calves were turned into each plot. These calves were about eight months old and of reasonably uniform size. All were apparently in fairly good condition. Fresh water was kept continually before the calves in each plot. A grain ration was fed daily. The calves had access to no other grass than that within the enclosure.

In each plot, when the calves had eaten all of the grass a new plot was prepared, exactly as before, and the calves were transferred to it.

This schedule was maintained to the end of the experiment. Thus, it will be noted that none of the calves in the experiment was permitted, at any time, to exercise a choice as to the grass on which it should feed, as would, of course, be the case with live stock pastured in an orchard or meadow. In other words, the conditions represented maximum severity.

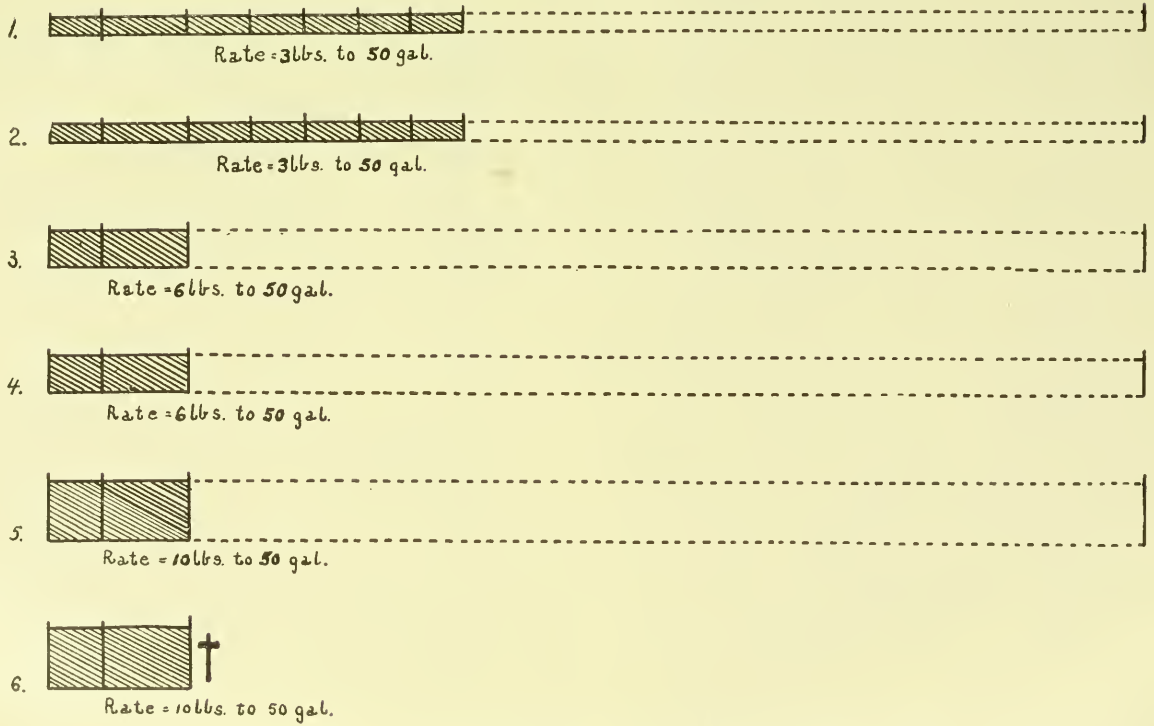
The results of the experiment are shown graphically in Table No. 12. The results in detail are as follows:

Plot I.—Arsenate of lead at the rate of 3 lbs. to 50 gallons of water.

The calves in this plot ate freely when first put into the pen. The first day following they did not seem quite as lively as at the beginning, but this may have been due to the unusual surroundings. By the second day they apparently had regained normal condition and at the close of the third day all of the grass in the pen had been cropped close.

On the fourth day the calves were transferred to a new plot prepared as before. There was a heavy, cold rain on the sixth day and perhaps for this reason the calves appeared to be in less favorable condition and were removed temporarily to a barn.

TABLE NO. 12. CALVES PASTURED ON SPRAYED PLOTS.



Horizontal shaded block indicates period during which calves were pastured on sprayed grass. Vertical divisions show change of calf to new plot, sprayed as before. Dotted lines indicate recovery period. Depth of shaded block indicates concentration of spray material used.

But on the seventh day they were in the plot again and appeared to be practically normal.

By the ninth day the second lot of grass was gone and on the tenth day the third plot was prepared and the calves placed in it. They appeared to show no further marked effects at this time, altho they did not seem to be quite as heavy or well rounded out as they should. At the end of sixteen days they were transferred to a fourth plot.

At the end of the twenty days the calves were transferred to a fifth plot. They still showed no definite symptoms of poisoning or other marked ill effects, except some failure to gain weight. At the end of twenty-four days they were transferred to a sixth plot; at the end of twenty-eight days to a seventh. They were still in approximately the same condition.

At the end of thirty-one days the experiment was discontinued. Seemingly the only results were a failure to gain weight properly, together with occasional dullness or listlessness, but without symptoms of acute poisoning.

Plot II.—Arsenate of lead at the rate of 6 lbs. to 50 gallons of water.

After two days' feeding the two calves in this plot apparently had no appetite and were not inclined to drink water, but showed no symptoms of acute poisoning. On the third day they appeared listless; their grain ration was untouched. By the fourth day they had eaten about all of the grass in the pen but had not eaten it as closely as the calves in plot I.

A new plot was now prepared and the calves were transferred to it. At the end of the fifth day it was necessary to remove the calves from the pen and place them in a barn temporarily, because of cold rains. The next day they were again placed in the pen but they still appeared to be in rather poor condition. On the eighth day they were eating very little and lay down most of the time. Their movements were stiff and they seemed weak. Apparently, they showed definite effects of the poison.

On the eleventh day the two calves were removed to a large plot of fresh grass to which no spray material had been applied and were allowed to graze there until the close of the experiment. This was done in order to observe rapidity of recovery. Within a short time, both calves showed marked improvement. Their weight increased, they looked brighter

Fig. 2. Calves in normal condition at beginning of experiments.

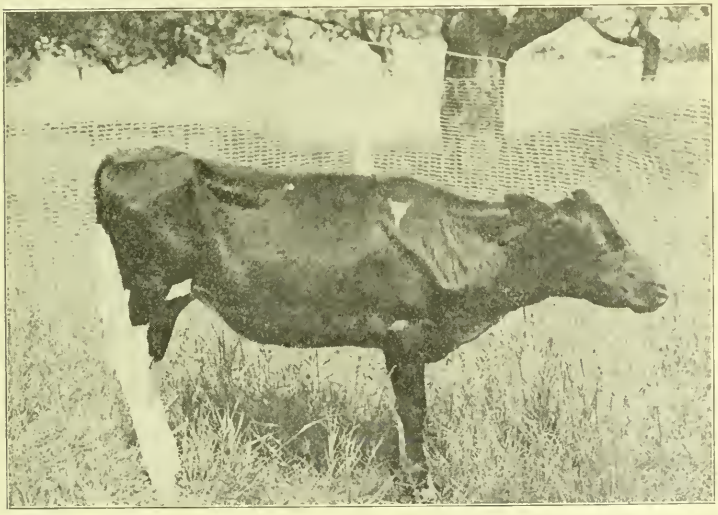


Fig. 3. Calf showing effect of poisoning by arsenate of lead.

and their appetite was much better. In two or three days more they drank water freely, ate their grain ration heartily and began to look well rounded out. This improvement continued until the end of the experiment.

When the experiment was discontinued at the end of three weeks of recovery treatment the calves appeared to show no ill effects, except that their weight was probably less than it would have been had they not been fed for a time on grass containing the spray material. In other words, they appeared to have been set back three or four weeks in their growth.

Plot III.—Arsenate of lead at the rate of 10 lbs. to 50 gallons of water.

The two calves placed in this pen at once began to eat the grass readily and at the close of the first day showed no ill effects. By the end of the second day, however, they looked languid, moved around very little and refused their grain ration. They had now eaten about one-third of the grass in the pen. They continued to eat sparingly of the grass and by the end of the fourth day had consumed most of the grass in the pen. They were now moved to a new plot sprayed as before. One of the calves now showed stiffness or weakness of muscles and this condition still prevailed on the fifth day. On the sixth day the calves were removed to a barn, temporarily, because of rain.

They were replaced in the pen on the seventh day. The calves still showed ill effects and were unsteady. On the eighth day one of the calves lay down most of the time. Both calves were weak and staggered when they walked. On the ninth day both calves were breathing hard. One of them, a Guernsey, appeared to be the worse off of the two. The other, a black and white grade, showed marked effects.

On the next day, the tenth, both calves appeared better and were able to get up. Both drank some water, but the Guernsey had little appetite. Seemingly, on the following day, both calves were better and were able to walk about without the marked effects noted on the two or three days prior. They were still weak, however. On the morning of the twelfth day the Guernsey was again down and breathing hard. Her legs were rigid and her eyes staring. Shortly afterward this calf died. The remaining calf in the pen was now turned out in a large enclosure on grass that had not been sprayed. Immediately

Fig. 4. Grass showing spray applied directly in plot experiments.

this calf began to show marked improvement and at the end of the experiment, three weeks later, appeared to be in good condition. It now exhibited no apparent effects of the ordeal, except that it had been set back in weight and growth.

Post mortem examination of the calf that died showed few marked symptoms that could be ascribed definitely to poisoning by the spray material. There was some emaciation and some extravasation of blood into the walls of the small intestine. Part of the small intestine showed a bluish green discoloration.

SUMMARY AND DISCUSSION.

It should be noted clearly that not all of the spray material applied to the grass in the pens could have reached the stomachs of the calves. It is true that in applying the spray care was taken to direct it carefully on the grass within the plot. Nevertheless, a considerable part of the spray material must have failed to lodge on the grass and have made its way to the ground beneath. Second, there was interference from rain. Third, altho in most cases the grass was eaten pretty closely in the pens, it is impossible that the calves could have got all of it. Furthermore, with the more concentrated doses the appetite of the calves was so much impaired that part of the grass remained uneaten. Fourth, the trampling of the grass by the calves must have dislodged part of the spray material after it had dried.

How much this loss may have amounted to it is impossible to say. It may easily have been 50 per cent. The points to be noted are, first, that there must have been a distinct loss, and second, that this would be the case in ordinary field conditions where calves or other live stock were pastured on grass beneath sprayed trees.

Examining now the amount of arsenic actually applied to the grass in these several plots, we find the following:

Where the material was used at the rate of 3 lbs. of paste to 50 gallons of water, the calves consumed the grass on 7 different plots within a period of thirty-one days. To these 6 plots was applied arsenate of lead, representing 65.8 grams of arsenic oxid, AS_2O_5. This is the equivalent of 32.9 grams for each of the two calves or 1.06 grams per calf per day. This amount represents 3.18 grams of dry arsenate of lead or 6.36 grams of arsenate of

lead paste containing 50 per cent water per calf per day, so far as the amount of material applied to the grass is concerned.

Where the material was used at the rate of 6 lbs. of arsenate of lead paste to 50 gallons of water, the calves consumed most of the grass in the two plots within a period of 10 days. To this grass was applied arsenate of lead, representing 37.8 grams of arsenic oxid AS_2O_5 or 18.9 grams for each calf or 1.9 grams per calf per day. This is approximately 5.7 grams of dry arsenate of lead or 11.4 grams of arsenate of lead paste, containing 50 per cent water per calf per day, so far as the material applied to the grass is concerned.

Where the material was applied at the rate of 10 lbs. of arsenate of lead paste to 50 gallons of water the two calves did most of their feeding in the first 4 days. To this grass was applied arsenate of lead representing 31.5 grams of arsenic oxid AS_2O_5 or 15.7 grams per calf or 3.9 grams per calf per day. This is the equivalent of 11.7 grams of dry arsenate of lead or 23.4 grams of arsenate of lead paste per calf per day so far as the material applied to the grass is concerned.

Comparing now the results recorded by Paige (13) in experiments conducted at the Massachusetts Agricultural Experiment Station in 1907. In these experiments 5 cows condemned as tubercular were used. To these cows arsenate of lead was administered with their food, in varying amounts and with varying results. Twenty-nine consecutive doses of 1 gram of arsenate of lead paste per day administered to cow No. 1 was followed by the death of the cow on the forty-first day. An autopsy disclosed extensive tubercular lesions. To another cow .5 grams of arsenate of lead paste was administered for 33 consecutive days and the animal was killed at the end of 37 days. Again an autopsy showed serious tubercular lesions. The question arises whether the symptoms of poisoning observed in these cows may not have been accelerated by their physical condition. To 3 other cows varying amounts of arsenate of lead paste were administered, ranging from 2 grams to 56.7 grams. In some instances the smaller doses resulted in symptoms of poisoning but in another case after administration of varying doses a single dose of 50.4 grams was administered to a cow without fatal effects.

It is interesting in comparison to note the results found by

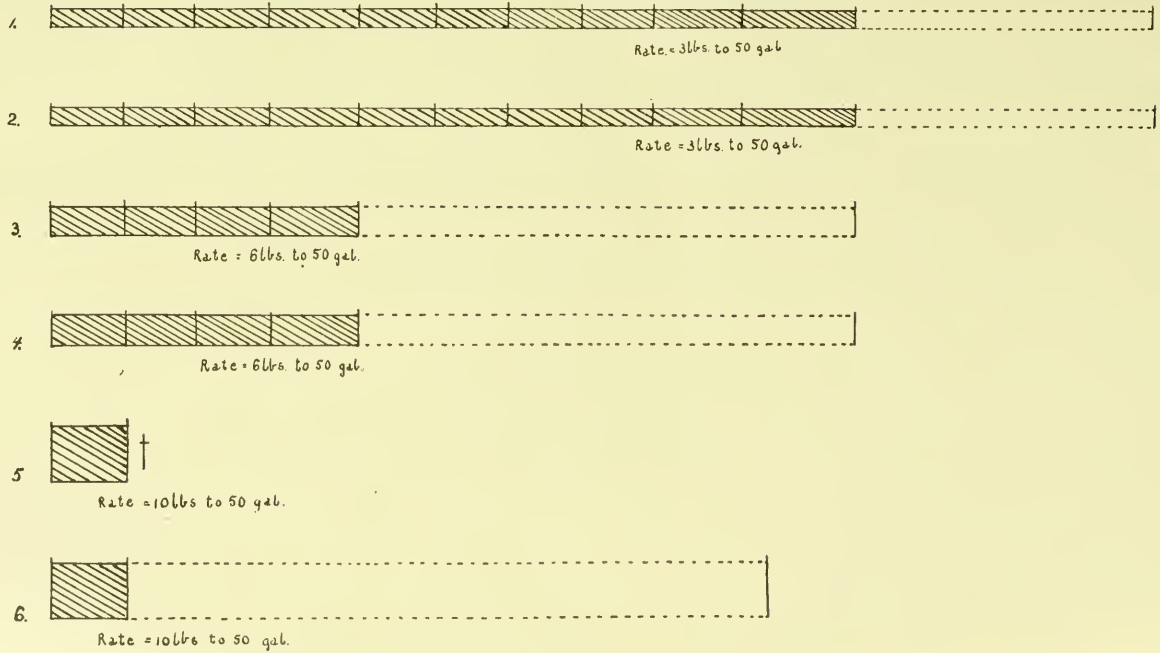
Haywood (10) in studies of the arsenic content of forage at Anaconda, Montana, near a smelter giving off daily large amounts of volatile arsenic. Analyses showed water-soluble arsenious oxid ranging from 0.16 grams to 0.94 grams per 25 pounds of dried forage. Similarly, Harkins (Formad 5) in the same locality found arsenic present in amounts ranging from 0.1 to 8.0 grams per 25 pounds of forage. Live stock had suffered severely in the neighborhood. It should be observed, however, that the effects may quite probably have been due in part to volatile arsenic entering the lungs. In fact this is indicated by the findings of Formad (5) whose post-mortems of animals from the region showed usually congested lungs and trachea as well as ulcerated nostrils.

So far as our own experiments are concerned, they appear to indicate that healthy calves may be pastured for a period on grass carrying considerable spray when the strength of solution used is 3 lbs. of arsenate of lead paste to 50 gallons of water. When the concentration of spray material is increased to 6 lbs. of arsenate of lead paste to 50 gallons of water continued feeding on such grass may result in definite and serious symptoms of poisoning. With the concentration at 10 lbs. of arsenate of lead paste to 50 gallons of water, serious or fatal poisoning is likely to result.

SHEEP.

The first set of experiments with sheep followed the plan of those carried out with calves and described above. Movable pens were used, each enclosing a space measuring 25 feet each way, or 625 square feet. These pens were set up in an orchard in which there was a fairly uniform growth of grass 6 to 8 inches high. The sheep were grade ewes of practically uniform weight, condition and health. When a pen was set up the grass within it was sprayed with 2 gallons of spray material. This amount of material was used because, as noted above, it appeared to be the maximum that would cling to the grass in the area indicated, this area representing the space beneath a large tree. Sprays of three different concentrations were used; namely, the equivalents of 3 lbs. of arsenate of lead paste to 50 gallons of water, 6 lbs. to 50 gallons and 10 lbs. to 50 gallons. As soon as the sheep had eaten all of the grass within a pen, sheep and pen were moved to a new plot prepared as before.

TABLE NO. 13. SHEEP PASTURED ON SPRAYED PLOTS.



Horizontal shaded block indicates period during which sheep were pastured on sprayed grass. Vertical divisions show change of sheep to new plot, sprayed as before. Dotted lines indicate recovery period. Depth of shaded block indicates concentration of spray material used.

The results are summarized in Table No. 13. A detailed discussion follows:

In plot No. 1 the grass was sprayed with 2 gallons of spray material containing 1 oz. of dry arsenate of lead or approximately material made up at the rate of 3 lbs. of arsenate of lead paste to 50 gallons of water. Two sheep were placed in this plot. They were maintained on this diet for 45 days. In this time they consumed the grass in 10 sprayed plots. Usually they required about 4 days to eat up the grass in a plot.

The symptoms exhibited by the sheep were comparatively slight. In the beginning they would drink but little water. This characteristic prevailed more or less thruout the test. Their bodies were a little lank, and once, about the middle of the test, their heads drooped and for a day or two they seemed sluggish. By the last two weeks of the test even these slight symptoms were lacking. The animals ate well and otherwise appeared normal. At no time did they exhibit symptoms indicating acute poisoning.

After the last plot these sheep were removed to a stock pen, where no spray material had been applied and were kept under observation for 17 days longer. Their condition remained normal.

In the second lot the grass was sprayed with 2 gallons of water containing 2 oz. of dry arsenate of lead or the equivalent of material at the rate of 6 lbs. of arsenate of lead paste to 50 gallons.

The two sheep placed in this plot showed definite symptoms. Beginning with the second day evidence of poisoning occurred. At the end of 4 days they had consumed all the grass in this plot and were transferred, on the fifth day, to a new plot that had been sprayed as before. Here they apparently recovered from the early symptoms and by the time they had eaten all of the grass in the second plot they seemed normal. Again they were moved to a new sprayed plot. On the third day after being moved they again developed symptoms and one of them gave evidence of slight paralysis of a hind leg. However, they ate up the grass in the third plot and were then transferred to a fourth. Very soon both showed some evidence of paralysis in the hind quarters and other symptoms of poisoning. After 3 days in this plot, one of the sheep was decidedly sick, had clearly marked

paralysis and its breathing was spasmodic. Neither sheep would eat. On the fifth day the conditions were similar, but a little worse.

Both sheep were now moved to a stock pen free from spray material, in order to observe recovery. The first day both were a little improved. The second day they began to eat and in 3 days more the symptoms of poisoning had disappeared, appetite had returned and both sheep appeared normal.

In the third lot 2 gallons of spray material was applied containing $3\frac{1}{3}$ oz. of dry arsenate of lead, or at the rate of 10 lbs. of arsenate of lead paste to 50 gallons of water.

Each of the two sheep placed in this pen showed prompt and definite symptoms of poisoning. By the end of the first day both were languid and would eat but little. They drank no water. One of them stood with drooping head. On the second day both were definitely sick. Paralysis began to appear.

Another 24 hours found one of the sheep in a bad way. It was unable to stand. Its breathing was spasmodic. The other sheep was somewhat better off. On the fourth day one of the sheep died, exhibiting definite symptoms of poisoning. The other sheep was now removed to the stock pen free from sprayed grass. Within a day it showed considerable improvement. It began to eat and could walk without staggering. This improvement continued steadily, with the result that in 4 days more this sheep appeared quite normal. It was maintained under observation for 3 weeks longer and showed no further symptoms of poisoning.

To get at the subject from another angle. Arrangements were made to pasture sheep beneath the trees that had been sprayed with definite amounts of arsenate of lead. The results are shown in Table No. 14. A discussion of the results in detail follows:

A pen was set up up beneath an apple tree which was then sprayed with arsenate of lead, at the rate of 6 lbs. of the paste to 50 gallons of water. The tree was of medium size and was sprayed carefully with the purpose of avoiding unnecessary drip. The amount of spray material used was $1\frac{1}{4}$ gallons. One sheep was placed in the pen. This animal had been pastured on sprayed grass earlier in the season, but for 36 days had had no access to

TABLE NO. 14. SHEEP PASTURED BENEATH SPRAYED TREES.

Column at the left indicates amount of material applied and rate of concentration. Column at the right indicates period during which sheep were pastured on sprayed grass (shaded portion) and recovery period (dotted portion). Vertical depths of blocks indicate concentration of spray material used.

material carrying arsenic and for 31 days had been in apparently normal condition.

In 9 days the sheep consumed all the grass beneath the sprayed tree. It was then moved to a stock pen. It exhibited no symptoms of poisoning.

A pen was now set up beneath another tree of medium size and this tree was sprayed with arsenate of lead, at the rate of 6 lbs. of the paste to 50 gallons of water. The material here was applied in excessive amounts, so that there was a good deal of drip.

Two sheep were placed in the pen. These sheep had been pastured on sprayed grass earlier in the season, but had not had access to material carrying arsenic for 29 days and for 24 days had apparently been in normal condition. Two days after the experiment was started there was a heavy rain. Therefore, another tree was sprayed as before and the sheep were removed to the grass beneath it. On the second day in the new plot one of the sheep exhibited slight symptoms, but in another two days these symptoms had disappeared and both sheep seemed quite normal. At the end of 5 days they had eaten all of the grass in the plot and were now moved to the stock pen, free from spray material. Here they were kept under observation, but developed no further symptoms.

Another pen was set up beneath a tree, which was then sprayed, using a coarse nozzle and applying 12 gallons of material, at the strength of 3 lbs. of arsenate of lead paste to 50 gallons.

Two sheep were pastured in this pen. In 7 days they had eaten all of the grass in the plot. During this time they showed no symptoms of poisoning and to the end of the period they seemed entirely normal.

Another pen was set up and the tree within it was heavily sprayed with a coarse nozzle, using arsenate of lead at the rate of 6 lbs. of the paste to 50 gallons of water. Twelve gallons of material were applied. Two sheep were placed in this pen. On the first day there were slight symptoms of poisoning and this became somewhat more pronounced on the second day. But on the third day the symptoms had largely abated, appetite had come back and at the end of the fifth day the sheep appeared normal.

In a final lot the tree was sprayed heavily with a coarse nozzle,

using arsenate of lead, at the rate of 10 lbs. of the paste to 50 gallons of water and applying 12 gallons of spray material. Two sheep were pastured within a pen beneath this tree.

In this case, definite symptoms appeared, altho the sheep survived. At the end of the first day there was evidence of poisoning. At the end of the second day both sheep were sluggish and one of them wanted to lie down. In 3 days more, however, the symptoms gradually abated and at the end of the eighth day the sheep were moved to the stock pen. They had not yet recovered their appetite and there were still some evidences of poisoning, altho these evidences were hardly acute. As soon as the sheep were moved to the stock pen, free from sprayed material, they at once began to eat and in 9 days more they seemed to have fully recovered.

SUMMARY AND DISCUSSION.

The remarks that have been made in discussing the results with calves, concerning the amounts of poison actually ingested in these experiments, apply to the results noted with sheep. Clearly, they did not get all of the poison that was applied to the grass. Just as clearly, however, the conditions under which they were pastured represent probably as severe circumstances as would be found under field conditions where anything like ordinary care was observed in the application of spray material.

Certainly, so far as these experiments are concerned there was no acute poisoning of sheep confined to the grass beneath sprayed trees, so long as the material was applied in concentration of 3 lbs. of arsenate of lead paste to 50 gallons of water. There was very little poisoning where the concentration was increased to 6 lbs. Even with the spray material applied at the rate of 10 lbs. of arsenate of lead paste to 50 gallons of water, with the sheep confined exclusively to sprayed grass and with excessive amounts of material applied to trees, resulting in heavy drip, the sheep survived.

SYMPTOMS OF POISONING.

The symptoms of poisoning observed in these experiments have been similar thruout in calves, sheep and guinea pigs.

Usually, loss of appetite and refusal to drink water are ob-

served early. If an animal can gain access to food to which no arsenate of lead has been applied it is apt to hunt it up and let the sprayed forage alone. A lankness or gauntness of body becomes evident. Diarrhea soon begins and as the poisoning progresses this symptom grows pronounced. The animal becomes languid or listless. There is rarely any tendency toward excitation or nervousness. Rather the senses seem to be dulled with the possible exception of a tendency in some individuals to avoid light.

As acute poisoning approaches there is more or less paralysis of the legs, especially of the hind extremities. The animal staggers on trying to walk. The paralysis soon grows more pronounced, and ability to stand is lost. Respiration becomes more rapid. There is frothing at the mouth. The muscles twitch. The body is apt to bloat. There are convulsive tremors, and sometimes genuine convulsions. With the approach of death breathing becomes spasmodic. Frothing and bloating are evident. The animal usually dies with the hind legs drawn backward and the muscles tense.

The symptoms of chronic and of acute poisoning are well stated by Paige (13), from whom the following is quoted:

"*Chronic Poisoning.*—Loss of appetite, refusal of water, purgation, with feces liquid and nearly black in color, containing an abundance of mucus and blood, the latter either disintegrated or in clots, suppression of urine, progressive paraplegia, emaciation, with hair harsh and rough. There appears to be but little disturbance of the temperature functions, the maximum reading obtained being only 103.2°F. The pulse becomes somewhat accelerated and of a thready character, but is not sufficiently altered to constitute an important sympton. There is dullness of the eye and general indications of depression when the symptoms enumerated above are most in evidence, but with the elimination of the poison from the system there is a gradual return of the normal body functions, as indicated by a cessation of purgation and a return of the appetite.

"*Acute Poisoning.*—Attack sudden, characterized by shivering, refusal of food and water, back arched, skin dry and harsh, hair erect, abdominal pain, slight elevation of temperature, pulse thready and increased to 55 to 60 beats per minute, respiration accelerated and difficult. Following these symptoms in

quick succession is purgation, with feces abundant, watery, dark in color and bloody. The urine is scanty and passed only at long intervals. Paresis develops early, with the other symptoms, and is progressive, affecting the posterior portions of the body most. At this stage of development of the symptoms the head is moved about nervously, the eyeballs are retracted and glassy, there is more or less champing of the jaws, and at irregular intervals the animal suffers from convulsions, from which it falls and struggles violently. In fatal cases purgation continues, the pain becomes intense, the expression of the face more anxious, pulse faster and weaker, paralysis more marked and the convulsions more frequent and severe. Partial coma precedes death. In this stage the symptoms are less urgent, and there may be involuntary passage of urine and regurgitation of material from the stomach."

POULTRY.

Experiments with poultry were so planned as to confine both mature hens and young chicks to enclosures in which grass had been sprayed with arsenate of lead. The amount of spray material applied to the grass within each enclosure was proportioned to the amount applied to the large pens in which calves and sheep were pastured, as described above, but the pens used for poultry were smaller and the actual amount of spray material applied was, therefore, less.

Three concentrations of material were used, as with the calves and sheep; namely, the equivalent of 3 lbs. of arsenate of lead paste to 50 gallons of water, 6 lbs. to 50 gallons, and 10 lbs. to 50 gallons.

Three pens contained one hen each and 3 pens contained one chick each. As soon as the hen or the chick had eaten all of the grass within its pen, the pen was moved to a new plot prepared as before. The hens and chicks had grain before them continually and fresh water daily. The experiment continued for 56 days. In this time all of the hens and chicks were moved 10 times and consumed the sprayed grass in their pens each time. They showed no symptoms of acute arsenical poisoning. They appeared not to gain in weight as they should, and the chicks seemed to show this symptom more than the hens. Otherwise the results were the same. All survived in fairly good shape.

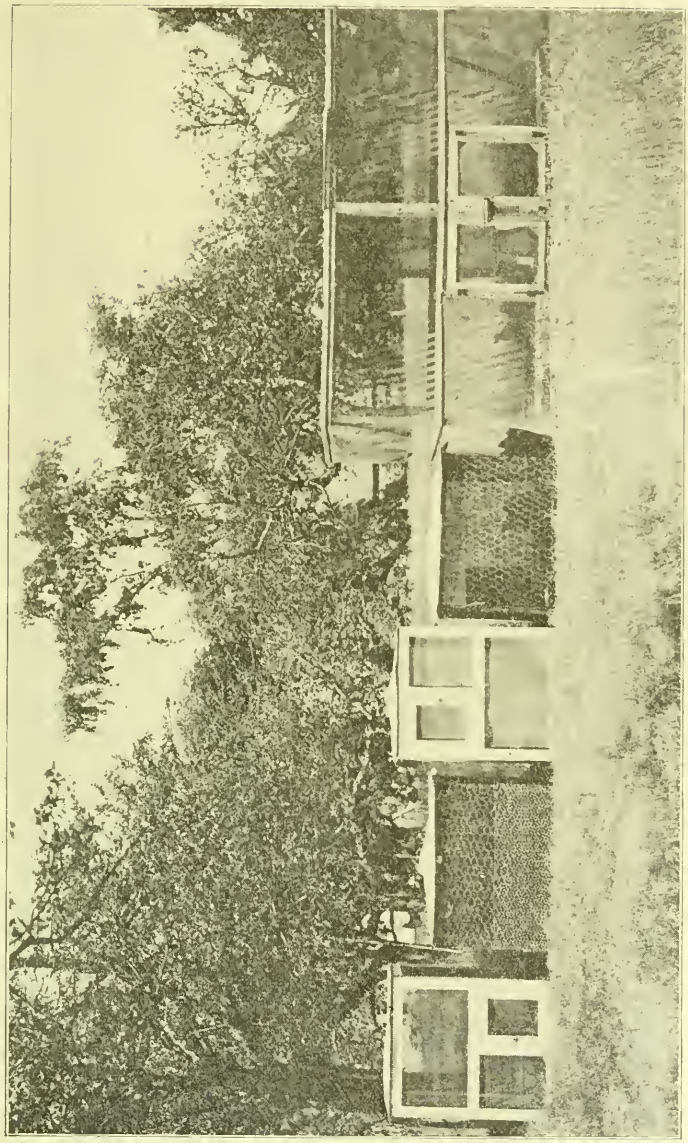


Fig. 5. Pens in which hens and chicks were confined on sprayed grass.

SUMMARY AND DISCUSSION.

The results of experiments seem to indicate clearly that there is exceedingly slight danger of poisoning when either chicks or hens are allowed to eat grass on which arsenate of lead spray has dropped. This is true even if the spray material is used at a concentration as high as 10 lbs. of arsenate of lead paste to 50 gallons of water, and even if large amounts of it fall on the grass. Apparently, chickens are not especially susceptible to poisoning by arsenate of lead.

HAY.

Frequently requests arise for information as to the possible danger that may lie in feeding live stock hay cut beneath trees that have been sprayed. A similar question arises where grass has been directly sprayed, as in the control of such insects as grasshoppers.

To get at this, 3 plots were staked out, each measuring $12\frac{1}{2}$ x 25 feet. The grass was of practically uniform stand and was from 12 to 15 inches high. One gallon of spray material was applied directly to each plot. This amount was chosen because, as noted above, prior experiments had shown that a space 25 feet square might reasonably be considered an area on which spray falling from a tree would lodge. On such a space 2 gallons of spray material might lodge, as a probable maximum, where 10 gallons was applied to the trees,—such an amount being a heavy application. Also, it had been found that 2 gallons of spray material applied to a plot of grass 25 feet square represented about all that the grass would reasonably hold.

To the first plot 1 gallon of water, containing $\frac{1}{2}$ oz. of dry arsenate of lead was applied, this rate representing the equivalent of 3 lbs. of arsenate of lead paste to 50 gallons of water. The rate for plot II was the equivalent of 6 lbs. to 50 gallons and the rate for plot III 10 lbs. to 50 gallons. The spraying was done July 14, 1914. The grass was cut by hand the next day and dried in the ordinary way and the hay was stored July 17. During this period there was no rain. The hay was stored in bags, under cover. Several months later it was sampled and analyzed. The chemists found only a trace of arsenic in each sample.

Assuming that in most cases there is apt to be rainfall between the time of spray and that of haymaking, 3 more plots were pre-

pared. These were of the same size as those just described and were sprayed in the same manner, using 3 concentrations of spray material, just described.

Sixteen days elapsed between the time when the spray was applied and the time when the grass was cut and made into hay. In this period there were heavy rains.

Samples were submitted for analysis 3 months later. Two samples showed no recoverable amount of the spray material. The third sample showed a trace only. This sample was from the plot which had received spray material made up at the rate of 10 lbs. of arsenate of lead paste to 50 gallons of water.

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