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The Removal of Arsenical Residue from Apples

BY

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SUMMARY

The use of one-third of one per cent hydrochloric acid in the wash solution is sufficient to remove the arsenical residue to the world tolerance from apples not oil-sprayed at the beginning of the season.

Two-thirds of one per cent or even one or one and one-third of one per cent hydrochloric acid may be used when oil or wax accumulations cause more difficult removal.

Concentrations of acid above two per cent are not advisable as injury to the fruit may result.

The use of oil sprays by the grower has seriously complicated the problem of residue removal. Oils with a higher viscosity than 65 to 75 cause considerable difficulty in the removal of the arsenical residue.

Oils of even lower viscosity cause more difficult removal if used more than twice in the spray program or if placed on the apple after July 25. The removal of arsenical residue becomes very difficult when the apples are placed in common storage or when they are allowed to stand for some time before washing.

Apples placed at once in cold storage are almost as easily washed as those treated immediately after picking.

Sodium chloride additions to the acid wash solutions are erratic in their behavior, sometimes aiding in arsenical removal and at other times being of no value.

Kerosene emulsion is very useful in dissolving wax and oil accumulations when used with hot hydrochloric acid solutions. It is not beneficial in cold solutions.

Where arsenical residue removal is difficult, heating the solution to a temperature of 95° F. to 105° F. has brought about much more efficient removal than increasing the strength of the acid solution.

The Removal of Arsenical Residue from Apples

BY
ROBERT S. SNYDER and H. P. MAGNUSON§

THE use of oil sprays in codling moth control and the lowering of the domestic tolerance to approximately .01 grain of arsenical residue per pound of apples has brought about the need for greater care in the washing program. Two avenues of approach are open in solving this problem. One is that of using efficient wash solutions, better controlled operation and improved equipment. The other is the careful consideration of the spray program as it affects the difficulty of removal of arsenical residue from apples.

Washing Methods

Commercial machines which are highly efficient in removing arsenical residue and which do not injure the fruit have been developed for washing apples. Of the types in common use, the flood wash and diffused spray type are most satisfactory. In these the fruit is agitated so that all parts of the apple come in contact with the wash solution without deep submergence. With all of these machines, however, careful attention must be given to the washing solution used, the temperature of the bath, the rinsing and handling of the fruit.

The success of the washing solution depends on the use of a solvent for arsenic that satisfactorily removes the residue but does not injure the apples. A number of solvents have been tried, and since arsenic is soluble in either acids or alkalis, weak solutions of these materials are the basis of washing operations.

Table No. 1 shows that alkali solutions are nearly as effective as hydrochloric acid (HCl) in the removal of the arsenical residue but require a longer time. Solutions of four per cent washing soda (Na_2CO_3), two per cent washing soda, and the same concentrations of washing soda to which was added four per cent of common salt (NaCl) were used. These solutions were slightly better in their efficiency in cleaning the fruit than one-third of one per

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cent hydrochloric acid but not as effective as the two-thirds of one per cent acid whether oil was used in the spray applications or not. The apples were kept in the alkali solution for two minutes and in the acid bath only one minute.

TABLE I

Comparative Efficiency of Alkali and Acid Wash Solutions

Arsenic reported as arsenous oxide (As_2O_3)

Arsenical Residues after Washing Grains of As_2O_3 per pound of apples

Spray Materials	60°F.					100°F.			
	Load	4% Alkali	2% Alkali	1/3% Acid	2/3% Acid	4% Alkali	2% Alkali	1/3% Acid	2/3% Acid
Lead Arsenate	0416	0068	0087	0087		0053	0031	0050	
Lead Arsenate Oil	0355	0150	0160	0150	0175	0130	0195	0177	0127

Time Required for Washing

The removal of arsenical residue is improved by leaving the apples in the wash solution for a longer time. Increasing the strength or raising the temperature of the washing solution is more economical than lengthening the washing period.

Table II shows that at ordinary temperatures the most efficient removal occurs after six minutes in alkalis and after four minutes in acids, which is an excessive time for practical purposes.

TABLE II

Effect of Time on Cleaning Efficiency of Various Solutions

Arsenical Residue after Washing Grains As_2O_3 per pound of Apples

Chemicals tested for residue removal	Washing periods in minutes						
	Load	2	4	6	8	10	12
4%NaCl & 4%Na_2CO_3	0335	0085	0087	0029	0035	0030	0030
2%NaCl & 4%Na_2CO_3		0115	0075	0085	0040	0040	0040
4%Na_2CO_3		0095	0075	0060	0070	0050	0040
2%Na_2CO_3		0090	0090	0030	0030	0050	0040
2/3%HCl		0095	0025	0045	0030	0025	0025

Most machines are rated to carry the apples through in less than one minute, so that for all later work reported in these investigations one minute has been considered as a practical time to use. Increased efficiencies have been secured by varying the strength or composition of the solution used and by increasing the temperature.

Hydrochloric acid solution is the one commonly used in apple washing. It is used in strengths of from one-third of one per cent to one and one-third of one per cent or even two per cent. A concentration of two-thirds of one per cent acid is usual for the early part of the season with increasing strengths as the removal of the arsenical residue becomes more difficult later in the season. **Table III** shows the relative efficiency of one-third of one per cent, two-thirds of one per cent, one per cent, one and two-thirds of one per cent, and two per cent acid. The removal of the residue with two per cent is not economical, since the amount of residue removed is not commensurate with the increase in acid.

Efficiency of Various Wash Solutions

The use of one-third of one per cent hydrochloric acid is sufficient to remove the arsenical residue below the world tolerance figure from non-oil-sprayed apples if washed immediately following picking. The removal of arsenical residue is more difficult on apples that have been oil-sprayed. In **Tables III and V** it is clearly shown that at least two-thirds of one per cent hydrochloric acid solutions must be used in order to remove the residue from oil-sprayed apples when washed at once. When heavy oil is used in the spray program or when the apples are sprayed with oil after July 25, higher strengths of acid are required in the wash solution in order to clean the apples properly.

The influence of cold and common storage upon the removal of the arsenical residue is shown in **Table IV.** It is evident that in order to remove the arsenical residue, apples placed in cold storage may be treated in about the same manner as those washed at once. A slight increase in the strength of the acid solution was considered advisable in this experiment in order to be certain the apples

TABLE III

The efficiency of various acid concentrations and supplements on efficiency of the washing process. All apples washed for one minute, and carefully rinsed.

Arsenical Residue after washing. Grains of As_2O_3 per pound of apples.

Manner of Spraying and handling fruit	Tem-pera-ture	Load	1/3% HCl	2/3%HCl	1%HCl	1 1/3% HCl	2% HCl	1% HCl 1% NaCl	1% HCl 1¼%Ker. A	1% HCl 1½%Ker.B
Oil Sprayed Apples	†Cold	0285	0137	0121	0081		0082			
Stored 3 months	Hot		0083	0063	0070		0052			
Oil Sprayed Apples	Cold	0271	0120	0096	0076					
Rome Beauty	Hot		0089	0061	0059					
Oil Sprayed Apples	Cold	0379	0139	0103	0067					
Winesaps	Hot		0098	0071	0052					
Rome Beauty Apples Not oil sprayed										
Common storage	Cold	0355		0121	0085	0078				
2 weeks	Hot			0059	0084	0062				
Common Storage	Cold	0355			0158	0131		0127	0141	
10 weeks	Hot				0122	0081		0083	0094	
Cold Storage 10 wks	Cold	0355			0073	0089		0110	0106	0125
	Hot				0047	0049		0053	0060	0045
Rome Beauty Apples Oil Sprayed In common storage										
2 weeks	Cold	0506		0185	0179	0145				
	Hot			0124	0105	0108				
Common Storage										
10 weeks	Cold	0506			0257	0235		0250	0287	
	Hot				0192	0160		0156	0136	
Cold Storage 10 wks	Cold	0506			0162	0129		0156	0189	0166
	Hot				0099	0096		0098	0105	0075

†Cold refers to the ordinary temperature of the wash solution. Hot refers to temperature of 95° F. to 105° F.

were properly cleaned.

The wax secretion on apples held in common storage causes great difficulty in the removal of the residue. Strengths of one or even one and two-thirds of one per cent hydrochloric acid are not sufficient for efficient removal, especially on those apples that have been oil-sprayed.

Effect of Supplements

Various supplements were added to the hydrochloric acid solutions to determine whether they would aid in the removal of the residue. One per cent sodium chloride additions to the acid solutions gave such erratic results that no definite conclusions could be drawn. Apparently it aided in the removal at times and at others did not. In averaging the series of samples washed by this method, it was found that the general effect of the sodium chloride additions was to cause a slight improvement in the removal of the arsenical residue.

Two types of kerosene emulsion were used in this experiment, designated in **Tables III and IV** as A and B. Neither emulsion increased the efficiency of the wash solution when used with cold one per cent hydrochloric acid. Both emulsions greatly aided in the removal of the residue when the solutions were heated. The B emulsion with heat showed the best cleansing effect, this being the only wash solution tested that would remove the arsenical residue below the world tolerance figure from the apples held in common storage.

Kerosene emulsion is recommended only for heavily waxed apples or for apples that have been heavily oil-sprayed because it often imparts a disagreeable odor to the fruit. It should be used only with heated solutions. Care should be taken that the temperature of the bath does not rise above 105° F. due to the disagreeable odor of kerosene which is given off at high temperatures. The emulsions used should be stable in the acid solution and should be made up from the odorless fraction of the kerosene.

The emulsion should not be used except in machines having a high degree of agitation to keep the emulsion from breaking. If the emulsion is broken down, the apples will carry some odor of kerosene which is undesirable. Apples washed in a broken down emulsion have shown a

TABLE IV

Arsenical residue on apples held in various kinds of storage, showing Arsenical Residue after Washing

Spray Treatment	Temperature	Load	Washed at once 2/3% HCl	Common Storage 2 weeks 2/3% HCl	Common Storage 2 weeks 1% HCl	Common Storage 2 weeks 2/3% HCl 1% NaCl	Cold 1%HCl
Delicious, not Oil sprayed	Cold	.0383	.0080	.0120	.0082	.0158	.0070
	Hot		.0042	.0075	.0010	.0080	.0060
Delicious Oil sprayed	Cold	.0569	.0103	.0235	.0215	.0188	.0131
	Hot		.0102	.0157	.0135	.0162	.0107
Rome Beauty Not oil sprayed	Cold	.0323	.0062	.0145	.0095	.0132	.0062
	Hot		.0062	.0040	.0062	.0100	.0020
Rome Beauty Oil sprayed	Cold	.0439	.0084	.0159	.0164	.0116	.0120
	Hot		.0099	.0100	.0074	.0081	.0078
Winesap, not Oil sprayed	Cold	.0324	.0097	.0097	.0077	.0085	.0087
	Hot		.0062	.0062	.0080	.0062	.0060
Winesap Oil sprayed	Cold	.0516	.0154	.0154	.0156	.0149	.0235
	Hot		.0113	.0113	.0105	.0104	.0112
All Varieties Not oil sprayed	Cold	.0335	.0080	.0121	.0085	.0128	.0076
	Hot		.0055	.0059	.0084	.0062	.0047
All Varieties Oil sprayed	Cold	.0506	.0115	.0185	.0177	.0151	.0162
	Hot		.0105	.0124	.0105	.0115	.0099

distinct odor of kerosene even after one month in storage.

Effect of Temperature

There is always danger of piling up a heavy load of arsenic that cannot be easily removed if the apples are sprayed with oil and arsenic combinations late in the season or have been treated with oils of high viscosity. There is also greater difficulty in removal of the arsenical residue if wax accumulations take place due to late picking, not washing immediately or to placing in storage. When oil and wax are both present the difficulty of removal becomes still greater. These facts are well shown in **Tables III, IV and V.** Under such conditions the increase in efficiency of removal by raising the temperature becomes so great that it is the most practical and economical of any single modification of the methods of washing in use at the present time.

Temperatures of 95° F. to 105° F. were found very satisfactory and not harmful to the keeping quality of the fruit. Tests made by the United States Department of Agriculture show that injury to the apples sometimes occurs with temperatures above 120° F. Maintaining tem-

TABLE IV

Effect of storage on removal by a number of different solutions.

Grains of As_2O_3 per pound of apples

Storage 10 weeks		Common Storage 10 weeks			Cold Storage 10 weeks Common Storage 14 weeks		
1% HCl 1% NaCl	1% HCl 1½% Ker.A	1% HCl	1% HCl 1% NaCl	1% HCl 1½% Ker.A	1% HCl	1% HCl 1% NaCl	1% HCl 1½% Ker.B
.0077	.0087	.0190	.0150	.0170			
.0053	.0085	.0165	.0102	.0150			
.0120	.0147	.0251	.0264	.0328			
.0092	.0107	.0209	.0154	.0131			
.0078	.0067	.0140	.0107	.0090	.0095	.0070	.0112
.0042	.0032	.0085	.0067	.0085	.0067	.0082	.0025
.0120	.0181	.0215		.0251	.0165	.0178	.0162
.0082	.0077	.0159	.0138	.0141	.0119	.0087	.0066
.0175	.0165	.0145	.0125	.0162	.0146	.0113	.0137
.0065	.0062	.0115	.0087	.0080	.0130	.0134	.0065
.0229	.0237	.0305	.0271	.0281	.0229	.0195	.0169
.0120	.0130	.0209	.0171	.0136	.0135	.0178	.0084
.0110	.0106	.0158	.0127	.0141	.0120	.0092	.0125
.0053	.0060	.0122	.0083	.0094	.0099	.0108	.0045
.0156	.0189	.0257	.0250	.0287	.0197	.0187	.0166
.0098	.0105	.0192	.0156	.0136	.0127	.0132	.0075

peratures below 105° F. should leave a sufficient margin of safety.

Most machines are so constructed that the washing solution can be heated either by steam pipes passing through the solution, by introduction of live steam into the bath or by the use of electrical heating units. The washing solution should be tested as to the concentration of the acid at frequent intervals throughout the day, particularly when live steam is run into the bath. Heating the solution is much more effective in removing the arsenical residue than increasing the concentration of acid and results in a reduction in costs, because less acid is required to satisfactorily clean particular lots of fruit.

Handling of Fruit Before Washing

Most of the data presented in this bulletin are on stored and oil-sprayed apples, since these are the types of apples that present the chief difficulty in removal of arsenical residue. Lower concentrations of acids usually suffice for apples that are sprayed with lead arsenate alone, picked at the proper time, and cleaned immediately. These experiments are concerned chiefly with the more difficult res-

idue removal problems. An examination of the results presented shows that even with the best methods of washing, apples are not always cleaned to meet the world tolerance. Attention, therefore, must be given to improved methods of cleaning the fruit.

Effect of Oil in Combination With Lead Arsenate in the Spray

Three types of oil were used in the spray program, designated by numbers having the following specifications:

	Unsulfonable Residue	Viscosity at 100° F.
No. 4	90	50
No. 6	90	70-75
No. 106	85	53-55

Viscosity is the factor in the oil which has the greatest influence on arsenical removal when used in combinations with lead sprays. This is the measure of the heaviness of the oil. A heavy accumulation of oil can occur on the apple regardless of the oil used if several applications are made but the difficulty of removal of the arsenical residue is always materially increased by a heavier oil. The heavier oil is a better insecticide and holds more arsenic on the apple, but, since it is harder to remove, a compromise is necessary between the entomologist and the chemist in making practical recommendation to the grower. An oil with a viscosity ranging from 65 to 75 has been agreed upon.

Table V shows the effect on arsenical removal of various oils used in different concentrations and at different times in combination with lead arsenate in the spray program. Mineral oils No. 4 and No. 6 were used in these sprays. As the specifications show, No. 4 is a lighter oil than No. 6. Comparing the residues in Plot 1 with those in Plot 3, in which the light and heavy oil and lead arsenate were applied in combination in all cover sprays, we note a better removal of arsenic in Plot 1 than in Plot 3 at each stage in storage. Plots 4 and 6 are the same oils respectively, but in higher concentration. The effect of viscosity is still noticeable at the higher concentrations.

The same oil was used in the spray on Plots 3 and 9, but on plot 9 it was applied only at the third and fifth cover sprays. Plot 9 shows much less arsenical residue after washing than Plot 3, even though there was not much difference in the original load carried by the apples. Plot 18

TABLE V

The effect of Various oils on Arsenic Removal

No. Plot	Time of Washing	Load	Arsenical residues after washing — Grains of As_2O_3 per pound of apples: Cold 1/3% HCl	Cold 2/3% HCl	Cold 1% HCl	Hot 1/3% HCl	Hot 2/3% HCl	Hot 1% HCl	Combinations in the Spray Program
1A	Immediate	.0250	.0063	.0034	.0030	.0034	.0035	.0038	Lead Arsenate all
	2 weeks		.0086	.0041	.0042	.0064	.0035	.0033	sprays
	5 weeks		.0095	.0088	.0075	.0066	.0055	.0044	#4 oil—3/4%
	11 weeks		.0123	.0091	.0101	.0070	.0050	.0089	all cover sprays
	Average		.0092	.0064	.0062	.0059	.0044	.0049	
3A	Immediate	.0294	.0187	.0082	.0068	.0138	.0076	.0055	Lead Arsenate all
	2 weeks		.0128	.0092	.0082	.0111	.0082	.0061	sprays
	5 weeks		.0182	.0153	.0084	.0126	.0077	.0070	#6 oil—3/4%
	11 weeks		.0234	.0153	.0081	.0121	.0086	.0080	all cover sprays
	Average		.0183	.0120	.0079	.0124	.0080	.0066	
4A	Immediate	.0297	.0143	.0084	.0096	.0105	.0060	.0058	Lead Arsenate all
	2 weeks		.0131	.0131	.0105	.0157	.0050	.0075	sprays
	5 weeks		.0174	.0121	.0133	.0124	.0064	.0072	#4 oil—1½%
	11 weeks		.0210	.0174	.0174	.0133	.0082	.0126	all cover sprays
	Average		.0166	.0128	.0127	.0130	.0064	.0083	
6A	Immediate	.0289	.0187	.0104	.0085	.0100	.0056	.0079	Lead Arsenate all
	2 weeks		.0167	.0142	.0133	.0139	.0076	.0081	sprays
	5 weeks		.0122	.0143	.0132	.0123	.0116	.0074	#6 oil—1½%
	11 weeks		.0102	.0106	.0141	.0137	.0090	.0081	all cover sprays
	Average		.0145	.0124	.0121	.0125	.0084	.0079	
9A	Immediate	.0260	.0074	.0040	.0039	.0046	.0025	.0024	Lead Arsenate all
	2 weeks		.0112	.0090	.0088	.0125	.0081	.0066	sprays
	5 weeks		.0112	.0115	.0053	.0091	.0078	.0051	#6 oil—3/4%
	11 weeks		.0140	.0109	.0067	.0087	.0047	.0060	2 peak sprays
	Average		.0110	.0089	.0062	.0090	.0058	.0050	3rd and 5th covers

TABLE V (Cont.)

Arsenical Residue after Washing — Grains of As_2O_3 per pound of apples

Plot No.	Time of Washing	Load	Cold			Hot			Combinations in the Spray Program
			1/3% HCl	2/3% HCl	1% HCl	1/3% HCl	2/3% HCl	1% HCl	
12	Immediate	.0262	.0060	.0040	.0040	.0045	.0030	.0026	Lead Arsenate
	2 weeks		.0049	.0050	.0055	.0041	.0033	.0035	2-100 calyx and
	5 weeks		.0057	.0069	.0056	.0043	.0026	.0032	all covers
	11 weeks		.0103	.0068	.0055	.0072	.0040	.0032	
	Average		.0067	.0054	.0051	.0050	.0032	.0032	
18	Immediate	.0291	.0065	.0050	.0032	.0057	.0038	.0090	Lead Arsenate in
	2 weeks		.0140	.0084	.0085	.0068	.0060	.0038	all sprays #6
	5 weeks		.0170	.0129	.0054	.0073	.0089	.0056	oil in first peak
	11 weeks		.0121	.0093	.0060	.0065	.0072	.0050	This is third cover
	Average		.0124	.0089	.0058	.0071	.0065	.0061	
7A	Immediate	.0430	.0110	.0060	.0050	.0040	.0026	.0031	Lead Arsenate—
	2 weeks		.0132	.0085	.0046	.0146	.0068	.0036	all sprays—oil
	5 weeks		.0172	.0180	.0113	.0145	.0107	.0094	on calyx only
	11 weeks		.0104	0078	.0065	.0104	.0050	.0040	
	Average		.0130	.0102	.0065	.0104	.0063	.0050	
7E	Immediate	.0475	.0111	.0060	.0054	.0091	.0051	.0046	Lead Arsenate—
	2 weeks		.0264	.0157	.0097	.0136	.0105	.0099	all sprays—oil
	5 weeks		.0305	.0260	.0154	.0160	.0117	.0078	on calyx and 1st
	11 weeks		.0086	.0104	.0082	.0087	.0070	.0074	4 covers
	Average		.0192	.0143	.0097	.0118	.0086	.0074	
8E	Immediate	.0232	.0067	.0047	.0022	.0051	.0050	.0022	Lead Arsenate—
	2 weeks		.0134	.0095	.0050	.0095	.0095	.0043	all sprays—oil
	5 weeks		.0151	.0106	.0062	.0087	.0058	.0039	on 5th cover
	11 weeks		.0139	.0101	.0073	.0136	.0103	.0068	
	Average		.0123	.0087	.0052	.0093	.0076	.0043	

received only one application at the peak of the egg-laying period of the first brood of codling moth in the third cover spray. There is little difference in Plots 9 and 18 with any type of washing. Good removal was obtained in all stages of storage on Plot 12 which received no oil-spray, and carried a low load. Plots 7A and 7E were Winesap apples and carried a heavier load than the Rome Beauty apples used for the former plots. Removal was more difficult in Plot 7E, where oil was applied in four cover sprays. A fairly good removal was obtained on Plot 8E when oil was applied in the fifth cover only, although the original load was not as heavy as on the other two.

Table VI shows the percentage of removal when apples were washed immediately after picking. There is great

TABLE VI

Percentage of Removal on Apples Washed at Once After Picking.

			1/3% HCl		2/3% HCl		1% HCl	
Plot No.	Tem-pera-ture	Load, grains As_2O_3 Per Pound	Residue Grains As_2O_3 per Pound	Per Cent Re-moval	Residue Grains As_2O_3 per Pound	Per Cent Re-moval	Residue Grains As_2O_3 per Pound	Per Cent Re-moval
12	Cold	.0262	.0060	77.1	.0040	84.7	.0040	84.7
	Hot		.0045	82.8	.0030	88.6	.0026	90.1
1A	Cold	.0251	.0063	74.8	.0034	86.4	.0030	88.0
	Hot		.0034	86.9	.0035	86.0	.0033	86.8
3A	Cold	.0294	.0187	36.4	.0082	72.2	.0068	76.9
	Hot		.0138	53.1	.0086	74.2	.0055	81.3
4A	Cold	.0297	.0143	51.8	.0084	71.8	.0096	67.4
	Hot		.0105	64.4	.0060	79.8	.0058	80.5
6A	Cold	.0289	.0187	35.3	.0104	64.1	.0085	70.6
	Hot		.0100	65.4	.0055	81.0	.0079	72.7
9A	Cold	.0262	.0074	71.8	.0040	84.9	.0039	85.1
	Hot		.0046	82.4	.0025	90.5	.0024	90.8
18	Cold	.0291	.0065	77.7	.0050	82.8	.0032	89.0
	Hot		.0057	80.4	.0038	86.9	.0090	69.1
7A	Cold	.0430	.0110	74.4	.0065	84.9	.0050	88.4
	Hot		.0040	70.7	.0026	93.6	.0031	92.8
7E	Cold	.0475	.0111	76.6	.0060	87.4	.0054	88.6
	Hot		.0091	80.9	.0051	89.3	.0046	90.3
8E	Cold	.0232	.0067	71.1	.0047	79.8	.0022	90.5
	Hot		.0051	78.0	.0050	76.5	.0022	90.5

variation in the percentage of removal depending on the original load carried. There is a persistently better removal with the non-oil-sprayed apples than with those receiving oil applications. Higher percentage of removal was obtained on Rome Beauty than on Winesap apples.

A careful record of the spray materials used and the time applied is a very important aid to the washing process. Where oil is necessary for satisfactory codling moth control, provisions can thus be made to clean these apples properly by using more drastic methods.

Table VII gives removal data for 1930 for three kinds of oil. The load is considerably higher than in former trials, and the removal less satisfactory. When the removal percentage is considered, however, results are quite comparable to those of former years as expressed in **Table VI.** Any influence that increases the load of arsenic on the apples, increases the difficulty of removal.

Effect on Wax

Wax develops very rapidly on apples that have been picked. It accumulates slowly even before picking, especially after the apples reach the firm stage. This wax is insoluble in water and acids, hence protects the arsenic on the apple from attack by acid in the wash solution. The grower should pick the apples as soon as they are ready and have them washed immediately. Higher temperatures permit greater wax accumulation. Common storage in the autumn is therefore not advisable for temperatures are still quite high. **Table V** shows that at the end of 14 days in such storage, the difficulty of cleaning had greatly increased. These apples were continued in storage and washed after 35 days and after 80 days. At each stage, the difficulty of removal increased. In **Table VII** a similar comparison was made on apples that were washed immediately after picking, on apples stored in common storage, and on apples placed in cold storage the same day they were picked. The stored apples were washed 10 weeks after picking. Apples left in cold storage for this length of time were almost as easy to wash as apples washed immediately, and easier cleaned than those left in common storage for two weeks. The cold storage apples were placed in common storage after the samples were washed at the 10-week period, and held for 14 weeks longer. This being

TABLE VII

The Effect of Various Oils on Arsenic Removal under different Storage conditions.

Arsenical Residues after washing — Grains of arsenic per pound of apples

Plot No.	Time of Treatment	Load	Cold 2/3% HCl	Cold 1% HCl	Hot 2/3% HCl	Hot 1% HCl	Combinations in the Spray Program
1C	Immediate	.0358	.0097		.0062		Lead arsenate all sprays
	2 weeks common			.0077		.0080	
	10 weeks common			.0145		.0115	
	10 weeks cold			.0087		.0060	
	10 weeks cold & 14 weeks common			.0146		.0130	
4C	Immediate	.0588	.0160		.0115		Lead arsenate all sprays # 4 oil— 3rd and 6th cover
	2 weeks common			.0165		.0112	
	10 weeks common			.0260		.0235	
	10 weeks cold			.0160		.0112	
	10 weeks cold & 14 weeks common			.0210		.0180	
5C	Immediate	.0523	.0205		.0117		Lead arsenate all sprays # 6 oil— 3rd and 6th cover
	2 weeks common			.0210		.0122	
	10 weeks common			.0461		.0172	
	10 weeks cold			.0410		.0107	
	10 weeks cold & 14 weeks common			.0265		.0077	
6C	Immediate	.0426	.0155		.0105		Lead arsenate all sprays # 106 oil— 3rd and 6th cover
	2 weeks common			.0140		.0110	
	10 weeks common			.0285		.0240	
	10 weeks cold			.0175		.0110	
	10 weeks cold & 14 weeks common			.0210		.0140	
9A	Immediate	.0498	.0115		.0117		Lead arsenate all sprays # 106 oil— 3rd and 6th cover
	2 weeks common			.0110		.0075	
	10 weeks common			.0215		.0190	
	10 weeks cold			.0195		.0120	
	10 weeks cold & 14 weeks common			.0230		.0145	

in late December, the common storage was very good. Even after this second period in storage, they were not as hard to clean as those held in common storage and washed two weeks after picking.

Delicious, Rome Beauty, and Winesap varieties were used in the storage trials. Oil-sprayed and non-oil-sprayed specimens of each were included. The data show oil and wax combined complicate the washing process consider-

ably. The arsenical load carried on apples treated in 1930 was heavier than the load carried in 1929 and the difficulty of removal was materially greater. This can be partially explained by the fact that the final oil spray was applied later in the season in 1930 than in 1929. No oil spray should be applied after July 25. These data show that the difficulty of washing persists in these varieties at each stage of the cleaning process. Rome Beauty apples clean most easily, while the Delicious and Winesaps are more difficult.

Keeping Quality

No injury to the fruit or deterioration in the keeping quality that can be attributed to the washing has resulted from solutions that have been used in these experiments. Decay is usually associated with some form of injury so that special care should be taken in handling the fruit to prevent bruising. Injury produced by careless handling may cause more decay than the washing process. Acid or arsenic "burning" of the apples causes injury where decay may enter. The removal of decayed fruit before washing cuts down the contamination of the washing solution and does not spread the spores to other fruit.

Rinsing

An abundant quantity of fresh running water should be used for rinsing. This is very important in removing the arsenical residue. The most satisfactory method is to add the fresh water to the bath as a spray playing on the apples as they leave the rinse bath. The rinsing is one of the most important parts of the whole process and should be given the attention it deserves. Where an ample supply of water is not available the rinse water may be treated with slacked lime at the rate of two pounds to 50 gallons of water to neutralize any acid that might be carried over from the wash solution. Too much emphasis cannot be placed on careful rinsing in all cases, as this is often the process which determines the success or failure of the washing operation.

Testing the Acid

Where hydrochloric acid is used as the cleaning solution it should be checked frequently. This can be done by the operator by a very simple chemical test. The following equipment is neccessary:

1 10 C C bulb pipette
1 10 C C measuring pipette graduated to .1 C C
1 glass bottle or tumbler
Standard bicarbonate solution, made by dissolving 23 grams of sodium bicarbonate in 1000 C C of distilled water, and adding enough Methyl Orange to give it a yellow color.

To make the test, rinse the bulb pipette with the washing solution after it is thoroughly mixed by running the machines for some time. Fill the bulb pipette with the solution to the mark and then run the 10 C C of solution into the glass bottle. Then fill the measuring pipette to the zero mark with the standard sodium bicarbonate solution, and let it flow slowly into the bottle containing the acid. Shake the bottle constantly and continue adding the bicarbonate solution until the acid solution changes from red color to yellowish, and record the amount of standard bicarbonate solution used. This will give the reading direct in per cent by dividing by 10. For instance, if it requires 6.6 C C of standard bicarbonate solution to neutralize the 10 C C of acid solution, the acid has a strength of 0.66 per cent or is a 2/3 of one per cent solution.

Care of Acid

Hydrochloric acid is very corrosive and must be handled with great care. Any acid coming in contact with any part of the body or clothing should be immediately washed off with a copious supply of water. Even with diluted solutions, the water may evaporate thus concentrating the acid to the point where it is harmful. Hydrochloric acid reacts quickly with common baking soda to form sodium chloride or common table salt. For this reason boxes of baking soda should be kept at convenient places in the washing shed, which can be used to neutralize any acid that may come in contact with the body. A solution of baking soda should be kept on hand to wash the affected parts, especially if acids should splash on the face of the operator.

The most convenient method to procure the acid is in the form of concentrated commercial acid of 20 degrees Baume strength with a specific gravity of 1.18. This is approximately 33 per cent strength, so that one gallon of the concentrated acid to 100 gallons of water gives a solu-

tion of approximately one-third of one per cent strength. This acid is usually available in large glass carboys containing 10 to 12 gallons. Acid attacks practically all metals, so it is imperative to handle it in glass, stoneware or wooden vessels. A one-gallon glass pitcher is very convenient for rough measuring. If acid is inadvertantly spilled on floors or about the packinghouse, it can be neutralized by soda, or more economically where large quantities are concerned by finely ground limestone. It is quite important that even diluted acid spilled about the plant be neutralized for the water will evaporate, leaving the concentrated acid which gives off undesirable fumes and attacks the materials with which it comes in contact. The old solution is also objectionable, so it should be disposed of where it does not accumulate near growing vegetation or where animals can get it.

Preparation of Kerosene Emulsion

Commercial emulsions can be obtained on the market which are suitable for use as an addition to the wash solution. Care should be taken, however, to ascertain whether these emulsions are stable in hydrochloric acid. They should be made from the odorless fraction of kerosene.

Diehl and Fahey of the United States Department of Agriculture give the following formula for the preparation of a kerosene emulsion that has proven satisfactory in their work.

Materials:

a. Kaolin, 1 1/3 pounds, of a quality similar to that supplied as No. 1 Kaolin.
b. Kerosene, 1 gallon. Perferably odorless such as can be supplied by any oil company.
c. Irrigation or tap water, 1/2 gallon.

Procedure:

The water and kaolin are mixed in a crock or similar container and allowed to stand until the mixture can be stirred to a thin paste without forming a gummy mass at the end of the mixer. Agitate the mixture for one minute in an emulsifier with a propeller type mixer and then add one-half gallon of kerosene. After the second portion is added, run the agitator for ten minutes.

The ordinary agitator of the washing tank or spray

tank will not properly emulsify the kerosene for this purpose.

One and one-half gallons of this emulsion is used with 100 gallons of water. The washing bath should be kept agitated as the emulsion may break down, leaving kerosene on the surface of the solution in the tank. It is better to add the emulsion to the acid solution after it is warmed so that it can be kept agitated continuously.

The Idaho Agricultural Experiment Station recommends the following procedure for apple washing:

1. The removal of the arsenical residue should be considered by the grower at the very beginning of his spray schedule. Keep accurate records of all sprays used and number of applications made. Use the following precautions when oil is necessary for proper insect control:
   a. Do not use oil with a viscosity of above 65 to 75.
   b. Do not make more than two oil applications during the season.
   c. Do not apply oil after July 25.
2. Pick the apples as soon as they are ready and wash immediately. If immediate washing is impossible, place the fruit in cold storage at once and hold until washing can be done. Fruit held in common storage or fruit left standing at ordinary temperatures for a period of time develops a coating of wax that makes residue removal difficult.
3. Use one-third of one per cent of hydrochloric acid (one gallon of acid to 100 gallons of water) in washing non-oil-sprayed apples at the beginning of the season. Two-thirds of one per cent or even one or one and one-third of one per cent may be used when the oil or wax accumulations cause more difficult removal. Concentrations above two per cent are not advisable as injury to the fruit may result.
4. Heat wash solutions to a temperature of 95° F. to 105° F. under the following conditions:
   a. When apples have received several oil sprays.
   b. When apples are heavily waxed.
   c. When apples have stood for some time before washing.
   d. When apples have been held in common storage.
   e. When apples have been left on the tree later

than the proper picking date.

5. Use kerosene emulsion with heavily oiled or waxed apples when the removal of the arsenical residue is impossible without it. It is effective only in heated solutions. It cannot be used except in machines having a high degree of agitation as the emulsion must not break down in the wash solution.

6. Rinsing is one of the most important processes in the washing of apples and should be done very carefully. Use a large quantity of running water. A final rinsing of the apples should be made with a diffused spray of water as they are leaving the bath. It is very important that all acid or dissolved arsenic be removed from the apples before storage in order to prevent acid injury or arsenic burn on the fruit. If an ample supply of water is not available, use two pounds of lime to every fifty gallons of water.

7. Remove all decayed or injured fruit before the apples are washed. This eliminates all unnecessary contamination in the wash tank or rinse solution. Care must be exercised in the handling of the fruit. Bruises or injury offer opportunity for decay to enter.

8. Use utmost care in the handling of hydrochloric acid as it is very harmful to metals, clothes or body. Check the strength of the wash solution frequently and make up a new solution every day or after washing 1000 boxes. This removes excess arsenic and decay organisms. Alkali solutions need to be changed for the same reasons.

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