Station Bulletin 317 September 1933

The Removal of Lead and Arsenic Spray Residues from Apples and Pears

Agricultural Experiment Station
Oregon State Agricultural College
CORVALLIS

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SUMMARY

1. Both lead and arsenic may be removed effectively below the established tolerances by washing either in a solution of hydrochloric acid or sodium silicate. The concentration, temperature, and time in either of these solvents must be regulated depending upon the amount of oil or wax present on the fruit that makes cleaning especially difficult.

2. Most varieties of apples and pears harvested at the proper time of maturity and washed immediately after picking and before excess wax forms, may be effectively cleaned without the aid of heat. providing no late oil sprays have been applied.

3. When excessive accumulations of wax are present or late oil sprays have been applied, it may require unusual washing treatment, such as the double process wash, the use of degumming agents, etc., together with especially adapted machinery, to clean the lead effectively below the tolerance.

4. All lots of fruit tested, including very waxy, heavily sprayed samples, were cleaned well below both the lead and the arsenic tolerances by cleaning with a double process. This consisted of passing the fruit first through a washing unit containing sodium silicate and then through a hydrochloric acid wash. Temperature, concentration, and time in each solvent must be regulated according to the condition of the fruit.

5. For fruit difficult to clean, underneath brushes revolving at the rate of 125 r.p.m. were found superior to the overhead flood type machine. Oscillation of part of the underneath brushes increased the cleaning somewhat. Rubber brushes having projected fingers that protruded into the stem-end cavity and around the calyx showed promise of a high degree of effectiveness.

6. Degumming or wetting agents used in combination with hydrochloric acid aid materially in cleaning heavily sprayed, waxy fruit. Effective cleaning of very waxy fruit was obtained by the use of a degumming agent, vatsol, with hydrochloric acid both in flotation tests and in commercial washers. On account of excessive foaming, degumming agents cannot be used in commercial washers until a satisfactory anti-foaming compound is found.

7. Experimental tests indicate that the following treatments and the following modifications may improve the cleaning action:

a. Sawdust used in either the hydrochloric acid solution or the sodium silicate solvent produces a slight cleaning effect.

b. Either sodium chloride or sodium nitrate used at the rate of 16 pounds to the hundred has been found beneficial as a supplement to hydrochloric acid heated to 90° F. or above.

c. Cold, waxy fruit, chilled by standing in the orchard or warehouse or removed from cold storage, may be more easily cleaned if warmed by floating in a predip maintained at 110° F. before passing into the solvent.

8. Until storage tests have been carried on to observe conditions in which burning or other injury may occur to recently harvested fruit, great care must be exercised in the application of any of the suggestions embodying the double processes, the use of degumming agents, and exposure of the fruit to solvents at elevated temperatures for abnormal lengths of time. Especial care must be exercised in washing of susceptible varieties and fruit unprotected by natural wax.

The Removal of Lead and Arsenic Spray Residues from Apples and Pears

By

R. H. Robinson and M. B. Hatch

INTRODUCTION

THE establishment of a tolerance for lead on fruits and vegetables in addition to the arsenic tolerance that has prevailed during the past few years has reopened many problems that pertain to the removal of spray residues. Chemical analyses of certain lots of washed fruits have shown that the arsenic may be removed well below the .01 grain tolerance, yet excessive amounts of lead still remain. The purpose of the investigations reported herein was to learn what complications prevent the removal of lead residues and what solvents and washing processes will enable the fruit industry to meet the new regulations.

While the arsenic tolerance continues at .01 grains per pound, the lead tolerance has been set temporarily at .02 grains per pound for the 1933 season. Furthermore, the industry has been notified that, in the event no satisfactory substitute for lead arsenate can be found during the coming season, a proposed tolerance of .014 grain lead per pound would prevail for the 1934 season. It was necessary, therefore, that throughout these investigations every effort be made to develop methods for cleaning the fruit not only below the .02 grain tolerance, but also to reduce it well below the proposed .014 tolerance. With this purpose in mind, the problem was approached from several angles: (1) to find a solvent or a combination of solvents that would remove both lead and arsenic effectively or that might be selective in dissolving the lead residue and yet remove the arsenic well below the established tolerance; (2) to learn what complicating factors prevented the removal of lead residue even though the arsenic was reduced effectively; (3) to compare the efficacy of various types of fruit washers and to test out new mechanical improvements.

LABORATORY STUDIES FOR SPECIAL LEAD SOLVENTS

Preliminary chemical analyses of some lots of washed apples disclosed the ratio of lead to arsenic to be several times higher than the ratio, i.e., approximately 2.15 of lead (Pb) to 1.0 of arsenic (As_2O_3) that exists either in lead arsenate itself or in the lead arsenate residue on freshly sprayed fruit. Furthermore, exposure to the elements of the lead arsenate deposits on the fruit throughout the growing season may increase the ratio[1] of lead to arsenic, especially when rains occur frequently and under conditions of high humidity and heavy dew. Under these conditions it is probable that part of the lead arsenate may change to the normal or basic lead carbonate, or a mixture of both forms, with attending loss of arsenic in a water-soluble form through the run-off action of rains and dew. The importance of discovering a solvent or a combination of solvents that is more selective in action upon lead than any now in use is obvious. Accordingly, laboratory studies were conducted during the limited period of time permitted for this phase of the work in the hope of finding a promising solvent.

In the laboratory studies, the selective solvent action of various chemicals for lead was ascertained in the following manner: Samples of lead arsenate (Standard $PbHAsO_4$) were introduced into each of several bottles containing the solvent to be tested. These were then shaken in a mechanical shaking machine for two minutes, the solution clarified by centrifuging, and then the lead and arsenic determined in the clear supernatent liquid. The ratio of lead to arsenic indicated whether the solvent was selective in its action on lead. Table I reports the results obtained with some of the commonly used solvents together with a few new combination solvents.

TABLE I. SOLUBILITY OF LEAD AND ARSENIC OF LEAD ARSENATE IN SOLVENTS

Solvent		Time of reaction	Temperature	Arsenic (As_2O_3) per 100 milliliters	Lead (Pb) per 100 milliliters	Ratio $\frac{Pb}{As_2O_3}$
	%	*Minutes*	*Degrees F.*	*Milligrams*	*Milligrams*	
Hydrochloric acid	.5	2	70	78.5	164.0	2.09
Hydrochloric acid and Acetic acid	.5 / 1.0	2	70	81.0	165.0	2.04
Hydrochloric acid and Nitrate of soda	.5 / 2.0	2	70	94.1	190.0	2.02
Hydrochloric acid and Ferric nitrate	.5 / 2.0	2	70	192.0	402.0	2.08
Hydrochloric acid and Ferric citrate	.5 / 2.0	2	70	4.7	6.1	1.30
Nitric acid	.5	2	70	32.1	69.0	2.15
Nitric acid and Acetic acid	.5 / 1.0	2	70	32.8	69.8	2.13
Nitric acid and Nitrate of soda	.5 / 2.0	2	70	45.2	94.0	2.08
Nitric acid and Ferric nitrate	.5 / 2.0	2	70	132.0	275.0	2.05
Sodium silicate	6.0	2	70	2.8	4.8	1.71
Theoretical for the lead arsenate used	....	..	....	....	....	2.15

The ratio of lead (Pb) to arsenic (As_2O_3) in the commercial lead arsenate used was found to be 2.15 to 1.0. For most of the solvents, the lead and arsenic dissolved in the theoretical proportion. Among those tested, none showed a selective solvent action on lead. One of these, the hydrochloric acid and ferric citrate combination depressed the solubility of the lead arsenate materially. Obviously this would be impracticable as a solvent for removing lead arsenate from fruits since the residue probably would not be dissolved. Both ferric nitrate and nitrate of soda increased appreciably the solubility of the lead and arsenic. The combinations that showed most promise were tested in a commercial fruit washer and will be commented upon later.

Since most of the solvents and combination solvents dissolved the lead and arsenic of commercial lead arsenate in theoretical proportions, it is very apparent that some complicating factors depress the solubility of lead as it occurs on the fruit. A limited number of analyses of acid-washed pears and apples, having very little wax formation, showed that the small amount of residual lead and arsenic remained in approximately the same proportion as was found on the unwashed fruit. On the other hand, analyses of washed apples, waxy and very difficult to clean, showed a high, varying ratio of lead to arsenic—in one case 8 to 1. It may be concluded from these observations that, during the washing process, wax or oil on the fruit retards the solubility of lead much more than arsenic. This may be explained chemically as follows: When certain acids or alkaline solvents react with lead arsenate residue that is partly or wholly protected by wax or oil, the arsenic is changed to a form that is very soluble and is thus removed. The lead, however, may be reprecipitated as the insoluble chloride, hydroxide, phosphate or other form, depending upon the solvent used and, owing to wax complications, may not redissolve during the short time in the solvent. In order to clean both lead and arsenic effectively from waxy fruit, therefore, part of the protective waxy coating must be removed either before or during the washing process or other washing conditions such as temperature, concentration, and time in solvent must be regulated in order to redissolve the precipitated lead. If, however, fruit is washed before excessive amounts of wax form and coat the lead arsenate particles, both lead and arsenic can be easily removed by hydrochloric acid or certain alkaline solvents.

EXPERIMENTAL WASHING TESTS IN COMMERCIAL FRUIT WASHERS

While every effort should be made to harvest fruit at the proper time and to wash immediately after picking, yet it must be admitted that the present system of washing and packing fruit in central packing houses makes this difficult if not impossible. Moreover, certain varieties of apples, such as Arkansas Black and Spitzenburg, develop comparatively large amounts of wax before the optimum time of harvest. Furthermore, according to the observations of Overly et al.,[2] fruit grown under adverse or abnormal conditions such as insufficient water, low fertility of the soil, insect infestation, etc., has been found difficult to clean, mainly because of abnormal skin conditions and excessive wax formation. Also Markley and Sando[3] report that applications of the various sprays, such as lead arsenate, nicotine, and especially oil sprays, increase the wax coating by physiological stimulation. Consequently, no matter how much care is exercised, the washing problem is complicated by the formation of excessive wax exudations. Washing tests, therefore were carried on in commercial fruit washers and modifications thereof, using very waxy fruit and such solvents as limited time permitted.

In order that fruit difficult to clean might be used in all the experimental washing tests, several unwashed lots were obtained. These consisted of Winesap apples that had received five to eight cover sprays of lead arsenate during the 1932 season. The apples had been kept in cold storage for more than six months during which time heavy wax deposits had accumulated. The lead and arsenic present on these lots of apples were as follows:

Lot	Arsenic (As_2O_3) per pound	Lead (Pb) per pound
	Grains	*Grains*
1	.061	.138
2	.093	.210
3	.129	.270

Lot 2 was used in most of the tests except where otherwise specified. In all of the tables, averages of tests are given, taken from more than 600 chemical analyses.

The relative effectiveness of various solvents for removal of lead. In previous spray-residue investigations the effectiveness of various solvents has been based on the amount of arsenic remaining on washed fruit. The establishment of a lead tolerance makes it necessary to learn the effectiveness of these solvents for the removal of lead as well as arsenic from fruit, especially when complicated by wax or oil deposits. The solvents tested included those in practical use during the past few years and the combination solvents that showed promise in laboratory studies. In all, eighteen different solvents or combinations of solvents were used. The results obtained from a part of these washing tests are reported in Table II. The results are the averages of numerous analyses of washed apples taken from

TABLE II. RELATIVE EFFECTIVENESS OF DIFFERENT SOLVENTS

Solvent		Time in solvent	Temperature		Arsenic (As_2O_3) per pound	Lead (Pb) per pound
			Fruit	Solvent		
	%	*Seconds*	*Degrees F.*	*Degrees F.*	*Grains*	*Grains*
Unwashed	----	----	----	------	.0930	.210
Sodium silicate	6.0	32	50	110	.0081	.023
Sodium silicate	9.0	32	50	110	.0053	.019
Hydrochloric acid	1.0	32	50	110	.0057	.018
Hydrochloric acid plus Sodium chloride	1.0 / 2.0	32	50	110	.0054	.017
Hydrochloric acid plus Sodium nitrate	1.0 / 2.0	32	50	110	.0055	.015
Hydrochloric acid plus Ferric nitrate	1.0 / 1.0	32	50	110	.0097	.017
Nitric acid	1.0	32	50	110	.0086	.019
Nitric acid plus Sodium chloride	1.0 / 2.0	32	50	110	.0070	.016
Sodium silicate	9.0	32	73	110	.0067	.016
Sodium silicate	9.0	60	73	120	.0058	.013
Hydrochloric acid	1.5	32	73	110	.0051	.012

Lot 2, each solvent being tested in one to six different types of fruit washers.

None of the washing solutions tested showed an outstanding solvent action on lead. Instead, the ratio of lead to arsenic was abnormally high, i.e., approxamitely 3 to 1, indicating that more arsenic than lead was removed by the different solvents. Furthermore, the washing-machine tests did not confirm the laboratory observations where, for example, a combination of hydrochloric acid and ferric nitrate was especially effective in its solvent action. On the contrary, the presence of the iron salt seemed to depress solubility of both lead and arsenic.

Hydrochloric acid was most effective and at relatively low concentrations and at 100° to 110° F. Sodium silicate was equally effective when concentration, temperature, and time in solvent were maintained at higher levels. It may be observed at this point that hydrochloric acid is a very rapid solvent for lead arsenate in contrast to sodium silicate or other alkaline solvents that require much higher concentrations and higher temperatures to dissolve equivalent amounts in the same length of time.

When hydrochloric or nitric acid was supplemented by either sodium chloride (table salt), as previously observed,[4] or sodium nitrate a slightly beneficial action was obtained.

It will be observed that when the temperature of the apples before washing was about 50° F., the lead was not reduced below the proposed tolerance of .014 grain per pound, although the arsenic was removed effectively. When these same apples were warmed to a temperature of about 73° F. before washing and with slight adjustments in the concentration and temperature of the solvent, however, the lead was brought below the .014 tolerance.

The foregoing comments apply to fruit carrying lead and arsenic loads indicated for the unwashed samples of Lot 2. When apples such as in Lot 3, carrying higher residue deposits, are washed under similar conditions, effective removal of the lead may not always be obtained. The spray residue load, however, present on Oregon-grown fruit at harvest time rarely exceeds the amount found on the apples of Lot 2.

It may be concluded from these comparative tests of solvents that either hydrochloric acid or sodium silicate may best be used for the removal of lead as well as arsenic residue from waxy fruit and that effective results may be obtained within certain limits of the residue load and wax or oil complications. Each lot of fruit, difficult to clean, will require adjustments of the temperature and concentration of the washing solution and time in solvent sufficient to meet the particular exigency. Sodium silicate is a slower acting solvent than hydrochloric acid and must be used at higher concentrations, longer periods of time in the solvent, and at higher temperatures (110° to 120° F.) to obtain equivalent results. It functions somewhat as a degumming agent, however, and may be more effective than hydrochloric acid for cleaning very waxy fruit without causing injury. The effectiveness of hydrochloric acid for cleaning lead from waxy fruit depends upon the application of heat whereby the wax is softened and the chemical action is accelerated. Time in the solvent and temperatures must be carefully controlled to prevent fruit injury. Temperatures as high as 100° to 110° F. should be used only for very waxy fruit.

The cleaning efficiency of various types of fruit washing-machines. Since the inception of the spray residue problem, mechanical improvements in the commercial fruit washers have enabled the industry to produce cleaner fruit with each succeeding year. In a consideration, therefore, of means to aid removal of the lead residue, tests were made in machines so constructed that maximum abraisive effects were produced on the fruits during the period of exposure to the solvents. The following modifications of various washing-machines were used in the tests: the overhead flood type; the impeller wash; the overhead flood with underneath tampico brushes; the same as the latter with the brushes oscillating; the overhead flood with underneath velour-covered rolls (that act as brushes); the same as the latter with oscillating rolls; and the overhead flood with underneath oscillating rubber brushes. The brushes were rotated at the rate of 125 r.p.m. and oscillation was produced by a lateral motion of half or each alternate brush.

It is difficult if not impossible to compare these different variations of washing-machines unless very great care is taken to adjust the temperature of the washing solution, the length of time in the solvent, and the concentration of the solvent exactly the same for each machine. Although great care was taken to make similar adjustments, variations necessarily occurred. The results of analyses taken for fruit washed in each machine using three different solvents; namely, sodium silicate, hydrochloric acid, and nitric acid, were calculated to a mean. These averages, obtained on two different lots of fruit, are reported in Table III.

TABLE III. THE RELATIVE EFFECTIVENESS OF VARIOUS TYPES OF FRUIT WASHES

Type of washer	Apples at 50° F.				Apples at 73° F.		
	Time in solvent	Temperature of solvent	Arsenic (As_2O_3) per pound	Lead (Pb) per pound	Time in solvent	Arsenic (As_2O_3) per pound	Lead (Pb) per pound
	Seconds	*Degrees F.*	*Grains*	*Grains*	*Seconds*	*Grains*	*Grains*
Overhead flood	25	110	.0067	.023	32, 41, 60	.0070	.021
Impeller wash	25	110	.0082	.021	32, 41, 60	.0078	.023
Underneath tampico brushes	25	110	.0058	.015	....	....	......
Same with brushes oscillating	25	110	.0056	.015	32, 41, 60	.0059	.012
Underneath velour-covered rollers	....	......	.0052	.016	....	....	......
Same with rollers oscillating	25	110	.0049	.012	....	....	......
Underneath oscillating rubber brushes	25	......	....	......	32, 41, 60	.0056	.013

It is very evident that any system of underneath brushes, whether tampico, velour, or rubber, aids the cleaning process by their abraisive action. Both the lead and arsenic were removed more effectively whenever any under brushes were used. The velour-covered rollers seemed more effective than the tampico brush, but probably would be impracticable, since the cotton velour disintegrated rapidly under the action of the chemicals. Oscillation of part of the brushes also produced a slightly increased cleaning action.

The experimental tests of the underneath oscillating rubber brushes were limited, since the idea occurred too late to carry on a sufficiently elaborate series of observations. The mechanical arrangement, however, of the rubber fingers on the brush whereby an abraisive action is obtained by penetration of these fingers into the stem cavity and around the calyx lobes as the brushes revolve, seems very promising. Since excessive amounts of the residue often accumulate in the stem-end cavity, around the calyx, and in rougher portions of the fruit, this improvement should produce more effective cleaning.

Sawdust as a supplemental cleaning agent. Sawdust was suggested as a supplemental cleaning agent since an abraisive action might be produced on parts of the fruit inaccessible to rotating brushes. Accordingly, unsifted fir sawdust was added to several solvents, using it at the rate of either 10 or 20 gallons of the sawdust to 100 gallons of the solvent. The results reported in Table IV are the averages of analyses of apples washed under the conditions cited.

TABLE IV. THE INFLUENCE OF SAWDUST AS A SUPPLEMENTAL CLEANING AGENT TO SODIUM SILICATE AND HYDROCHLORIC ACID

Type of washer	Solvent		Sawdust (per 100 gallons)	Temperature	Arsenic (As_2O_3) per pound	Lead (Pb) per pound
		%	*Gallons*	*Degrees F.*	*Grains*	*Grains*
Overhead flood	Sodium silicate	6.0	None	110	.0075	.020
Overhead flood	Sodium silicate	6.0	10	110	.0064	.020
Overhead flood	Sodium silicate	6.0	20	110	.0062	.022
Overhead flood	Sodium silicate	9.0	10	110	.0052	.022
Overhead flood	Sodium silicate	9.0	20	110	.0064	.020
Overhead flood	Hydrochloric acid	1.0	None	110	.0081	.028
Overhead flood	Hydrochloric acid	1.0	10	110	.0080	.024
Overhead flood	Hydrochloric acid	1.0	20	110	.0064	.023
Underneath tampico brushes	Sodium silicate	9.0	None	110	.0040	.014
Underneath tampico brushes	Sodium silicate	9.0	20	110	.0044	.011
Underneath tampico brushes	Hydrochloric acid	1.0	None	110	.0039	.016
Underneath tampico brushes	Hydrochloric acid	1.0	20	110	.0038	.011
Impeller wash	Hydrochloric acid	1.0	None	110	.0110	.029
Impeller wash	Hydrochloric acid	1.0	10	110	.0060	.016
Impeller wash	Hydrochloric acid	1.0	20	110	.0058	.017

These results show that under the conditions of the tests, no outstanding, beneficial results were obtained when the sawdust was used in the amounts specified above. An average of 40 tests, however, showed a definite increased cleaning action, but not enough to warrant recommending sawdust for general practical use. Occasionally a group of analyses showed excellent reductions of both lead and arsenic and then again a lot showed only a slight improvement.

Degumming or wetting agents in combination with hydrochloric acid for cleaning waxy fruit. For several years McLean and Weber[5] of the New

Jersey Agricultural Experiment Station have been studying the use of degumming or wetting agents for the removal of spray residue from apples difficult to clean. These compounds may be used in acid solution and promote contact between the acid and the lead arsenate particles by more thorough wetting. Apparently some of the more effective wetting agents act also as degumming compounds and may remove part of the wax or oil coating. Recently Weber and McLean[6] have recommended one of these degumming compounds, known by the trade as vatsol, in combination with hydrochloric acid for cleaning both lead and arsenic from very waxy or oil-covered apples. They report excellent results from laboratory tests and by the use of a flotation-type washer. In order to learn whether these results could be confirmed using waxy, Northwest apples, laboratory flotation tests were carried out. Three different lots of fruits were used in the test, all of which were very waxy but varied in the amount of spray residue present. The vatsol was added to 1.5 per cent hydrochloric acid and the fruit was exposed to this combination solvent for varying periods of time and temperature. Table V reports averages of the washing tests obtained in laboratory flotation experiments.

TABLE V. LABORATORY FLOTATION TESTS FOR LEAD AND ARSENIC REMOVAL BY MEANS OF HYDROCHLORIC ACID AND A DEGUMMING AGENT

Solvent					
Kind	Percentage used	Temperature	Time	Arsenic (As_2O_3) per pound	Lead (Pb) per pound
	%	*Degrees F.*	*Minutes*	*Grains*	*Grains*
Unwashed	....	....	....	.0610	.138
Hydrochloric acid Vatsol	1.5 1.0	70	2.5	.0038	.011
Unwashed	....	....	....	.0920	.188
Hydrochloric acid Vatsol	1.5 1.0	70	2.5	.0042	.013
Unwashed	....	....	....	.1290	.270
Hydrochloric acid	1.5	70	2.5	.0358	.087
Hydrochloric acid Vatsol	1.5 1.0	70	2.5	.0094	.024
Hydrochloric acid Vatsol	1.5 1.0	100	2.5	.0114	.023
Hydrochloric acid Vatsol	1.5 1.0	70	5.0	.0056	.016

The foregoing results indicate that the degumming agent, vatsol, aids the hydrochloric acid materially in lowering further both the lead and the arsenic residues of heavily sprayed, waxy fruit. Although the most heavily sprayed lots were not cleaned below the .02 grain tolerance for lead during 2.5 minutes exposure, yet when this was lengthened to 5 minutes, very satisfactory results were obtained.

It appears from these results that with adjustments of temperature and time in the combination solvent, depending upon the amount of spray residue and complications with wax and oil, effective cleaning of the worst fruit might be accomplished.

Washing tests using the degumming agent, vatsol, in combination with hydrochloric acid in a commercial fruit washer. In order to learn whether the combination of vatsol and hydrochloric acid would be effective when used in a commercial fruit washer, a series of tests were carried on using an underneath-brush type machine. The time, temperature, and concentration of the solvent mixture were varied to learn what conditions would produce most effective results. The degumming compound caused excessive foaming of the mixture and in order to overcome this condition an anti-foam reagent was added. Table VI reports a few of the results indicative of the general effectiveness of this mixture.

TABLE VI. THE EFFECTIVENESS OF A DEGUMMING AGENT AS A SUPPLEMENT TO HYDROCHLORIC ACID WHEN USED IN AN UNDERNEATH BRUSH FRUIT WASHER

Solvent	Time	Temperature	Arsenic (As_2O_3) per pound	Lead (Pb) per pound
% %	*Seconds*	*Degrees F.*	*Grains*	*Grains*
Unwashed	....	....	.0930	.210
Hydrochloric acid 1.5	45	100	.0056	.014
Hydrochloric acid 1.5 + vatsol .5	45	70	.0054	.016
Hydrochloric acid 1.5 + vatsol .5	45	100	.0052	.008
Hydrochloric acid 1.5 + vatsol 1.0	30	70	.0072	.021
Hydrochloric acid 1.5 + vatsol 1.0	30	100	.0033	.008
Hydrochloric acid 1.5 + vatsol 1.0	45	100	.0038	.007

It is evident that the hydrochloric acid and vatsol mixture may produce excellent results in a commercial type washer. A temperature of approximately 100° F. is necessary, however, in order to reduce the lead below the proposed .014 tolerance during the short time the fruit is allowed in the solvent. Even higher temperatures or a longer period in the solvent may be necessary for fruit more difficult to clean.

Another conditional factor in these tests was the possible additive cleaning effect produced by the anti-foam compound. This was used in the vatsol and hydrochloric acid mixture at the rate of 1 gallon to 150 gallons and, being a wax solvent, it may act similarly to kerosene as a supplemental cleaning agent. In this manner it may have aided the combination.

While vatsol and other wetting or degumming compounds in combination with hydrochloric acid may show every promise of being a very effective solvent for both lead and arsenic, definite recommendations for their use cannot be given at this time: because (1) their effect on newly harvested fruit, washed in either the flotation type or commercial machine, must be determined; (2) the anti-foam used in these experimental tests controlled foaming for a short time only, and a more practical, odorless substitute must be found; (3) packing-house operations must be observed to learn the limitation under which the combination solvent will function. This information will be available from the Agricultural Experiment Station as soon as investigations of these phases can be completed.

The effectiveness of a double or tandem washing process. Previous experimental work emphasizes the need of removing a part of the waxy covering that protects the lead arsenate particles from the action of the solvent if effective removal of the lead residue from very waxy or oil-covered fruit is to be accomplished. Degumming compounds act in that manner. An examination of apples washed in a sodium silicate solution also shows evidence that part of the wax had been removed. It was thought, therefore, that if sodium silicate removed part of the wax by a detergent action, an additional short-time wash in an acid wash might clean the lead effectively below the tolerance. Hence, very waxy Winesap apples were washed in a double machine set-up wherby the fruit was first put through one unit containing sodium silicate and then through an acid wash in another machine. The time of exposure of the fruit to the solvents in each unit or machine was varied in order to learn the lowest limit of exposure that would remove the residue adequately. Table VII shows the results of a few of the tests.

TABLE VII. THE REMOVAL OF LEAD AND ARSENIC RESIDUES BY THE DOUBLE OR TANDEM PROCESS

Type of washer	Solvent		Time in solvent	Temperature	Arsenic (As_2O_3) per pound	Lead (Pb) per pound
		%	*Seconds*	*Degrees F.*	*Grains*	*Grains*
Overhead flood then impeller	Sodium silicate then Hydrochloric acid	6.0 1.0	32 21	110 53	.0059	.013
Overhead flood then Tampico brush	Sodium silicate then Hydrochloric acid	6.0 1.0	41 25	110 100	.0016	.005
Tampico brush then Tampico brush	Sodium silicate then Hydrochloric acid	9.0 1.5	30 15	110 100	.0047	.007
Rubber brush then rubber brush	Sodium silicate then Hydrochloric acid	9.0 1.5	30 15	110 97	.0050	.010
Tampico and rubber brush then tampico and rubber brush	Sodium silicate then Hydrochloric acid	9.0 1.5	30 30	110 98	.0047	.008

As reported in Table VII, this double process removed the lead well below the proposed .014 tolerance when time in each solvent and temperatures were properly regulated. Without exception, no matter how long a time in the solvent or whether the acid was used at low temperatures, cleaning of the lead below the 1933 tolerance was obtained. This confirms the observation that sodium silicate functions somewhat as a detergent or degumming agent, with the result that a short exposure to the hydrochloric acid, even at comparatively low temperatures, cleaned the fruit effectively.

While no tests were made here whereby the acid was used in the first unit of the double washing process, yet the Washington Experiment Station workers[4] report excellent results when that procedure is followed. Perhaps the longer time necessarily taken in the double or tandem process may be the principal reason for obtaining such effective results.

Obviously, in order to make a double process practicable for packing-house conditions, manufacturers of commercial washing-machines must perfect a washer whereby thorough rinsing from the fruit of the solvent used in the first unit is accomplished before it passes into the final wash of the second unit. Meanwhile, very waxy apples that are too difficult to clean in a single process fruit washer may be cleaned satisfactorily by a tandem set-up of two different machines. Fruit packers who may find it necessary to wash some lots of apples by this procedure are warned to pay particular attention to avoid injury of the fruit by overexposure to solvents maintained at elevated temperatures. The concentration of the solvent in each machine and the temperatures should be regulated to the point where satisfactory cleaning will be obtained and yet injury to the fruit will be avoided.

STORAGE TESTS

Necessarily, in order to learn under what conditions very waxy or oily fruit could be satisfactorily cleaned, storage apples judged most difficult to wash were selected for the purpose. Since the waxy coating of the apple aids in preventing injury by the washing treatment, storage tests of washed fruit must be made using recently harvested fruit, especially of those varieties susceptible to injury, that have been cleaned by the new processes. Until results from experimental storage tests are available, every precaution should be taken by the orchardist or fruit packer to guard against injury from overheating, too long a time in the solvent, or faulty rinsing of the fruit as it leaves the machine no matter what washing process is used.

ACKNOWLEDGMENTS

The authors express appreciation to the Cutler Manufacturing Company, Portland, Oregon, for their valuable cooperation in permitting the use of the facilities and fruit washers available at their plant.

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