Fluorine Levels in Plants of the Warrenton Area, 1968-1970:

Cultivated and Native Woody and Herbaceous Plants Prior to Aluminum Factory Operations

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Contents

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Summary

A plant analysis survey for leaf fluorine 1/ concentrations was made in 1968-1970 in anticipation of the construction of an aluminum reduction factory near Warrenton, Oregon. Cultivated and native plants mostly within six miles of the factory site were sampled. Forages were collected eight times and all other plant materials from one to four times.

Pasture herbages contained an average of 0.8 to 3.2 ppm fluorine with only 11 percent of the 457 samples exceeding 3.4 ppm. The fluorine content of each of the other six species averaged 2.9 ppm, with the exception of 4.2 ppm found in 2-year-old Sitka spruce needles during 1968. Five improved strains of pasture grasses maintained in pure stands were consistently and uniformly low in fluorine content.

Within the area sampled, differences in terrain (tideland versus upland), river valley, or distance and direction from the factory site produced no trends in the fluorine contents of pasture herbage.

Introduction

This report presents the fluorine contents of foliage samples from native and cultivated plants collected during 1968-1970 in the Warrenton-Astoria area of Oregon in anticipation of the construction of an aluminum reduction factory near Warrenton.

Plants normally absorb variable amounts of fluorine from the soil through their roots and accumulate it in leaves, stems, and fruits. The concentration of soil-derived fluorine is generally less than 10 ppm

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1/ The term "fluorine" in this report refers to the total amount of this element detected by the method of analysis. It is not implied that fluorine occurred as the free element. In all the materials analyzed the fluorine (F) was in the combined or fluoride form.

(5, 7, 8, 16, 19)[2] but may exceed several hundred ppm in certain species.[3] Plants are also able to absorb fluorine from the air through their leaves, and fluorine from gaseous hydrogen fluoride (22) emitted by industry may be accumulated in amounts sufficient to produce injury on foliage or fruits of sensitive species grown nearby (1, 2, 7, 8, 19, 26).

Symptoms of foliar injury resembling those caused by elevated fluoride levels may also be produced by other causes such as high chloride content of the soil, drought, insect attacks, and mineral deficiencies (29, 30). Often the only way to identify foliar injury by fluoride is by chemical analysis (10). It is therefore important to determine the soil-derived plant fluorine levels prior to nearby industrial discharges into the air so that contributions by industry may be assessed.

In 1968 the Northwest Aluminum Company asked the Oregon Agricultural Experiment Station to conduct a survey of livestock and of crop and forest plants in the vicinity of their proposed aluminum reduction factory which was to be constructed about two miles south of Warrenton and three and a half miles southwest of Astoria, Oregon. The purpose of the survey was to determine 1) the health and condition of livestock and crops including forest trees raised in the area; 2) the fluorine levels in livestock, in forages grown or used in the area, and in foliage of native forest trees, fruit trees, berry crops, vegetables, and ornamentals including shore pine planted in the dunes area to the west of the factory site. The survey was to be conducted for two years prior to and for at least three years after the start of factory operations scheduled for 1971.

Methods

Forage sampling sites were selected at approximately one-mile intervals in the Warrenton area and along the Lewis and Clark and Youngs Rivers as shown on the map (Figure 1). Sixty-seven fields or pastures from the 35 sites or farms were sampled. Eight of these were dairy farms, 20 beef operations, three bent grass seed fields grazed part of the year, and four miscellaneous grass fields or plots. Two of the dairy farms were within three miles of the factory site. The sampling units are named and described in Table 1 and their locations are shown on the map, Figure 1.

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[2] Numbers in parentheses refer to Literature Cited, pages 10 and 11.

[3] Two samples of camellia leaves (*Camellia japonica*) collected in June 1970 at Corvallis, Oregon, contained 1,404 and 1,743 ppm F for Pink Perfection and an unknown variety, respectively. Foliage of eight other species of plants growing nearby contained 1-11 ppm F.

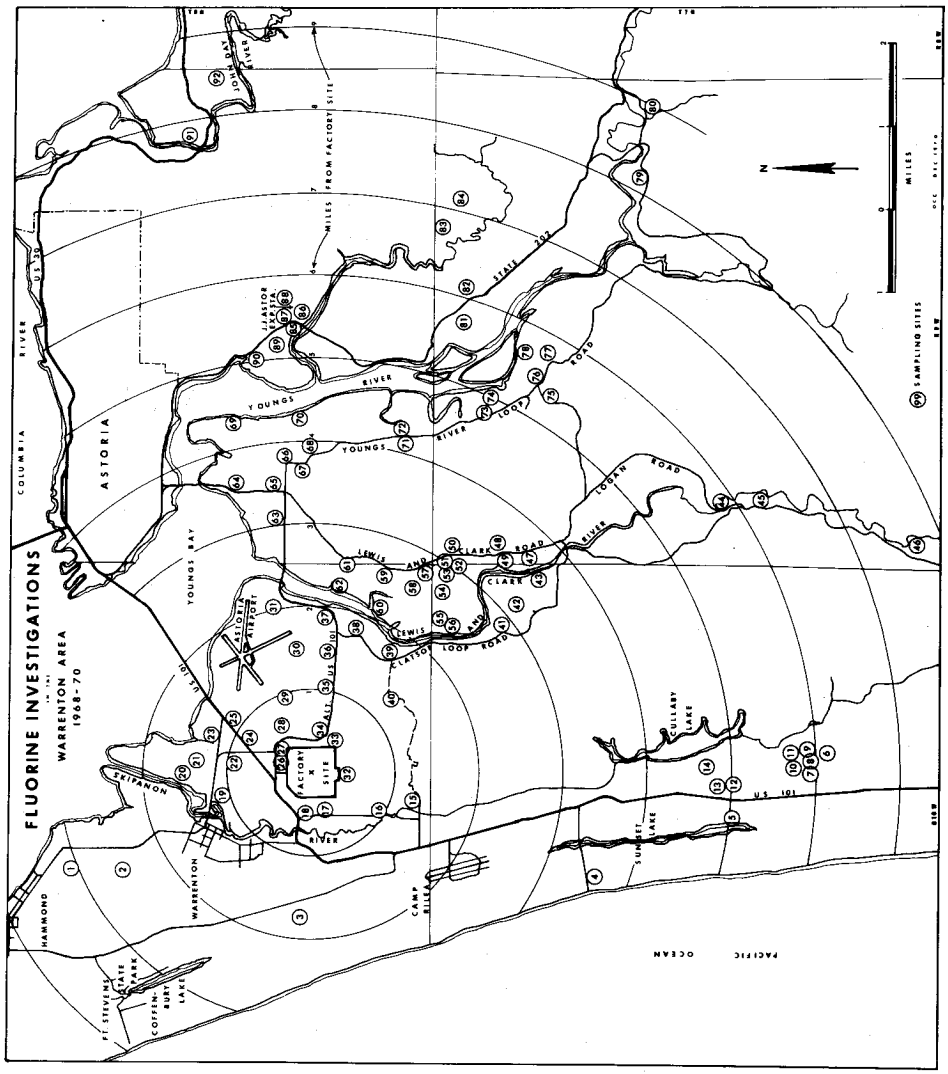

Figure 1. Geographical distribution of forage and foliage sampling locations. Site descriptions are given in Table 1.

Forage samples were obtained from one to seven fields at each site, depending upon grazing rotation, elevation, soil differences, and dominant grass species. Herbage was collected over a 2-3 acre area selected at random from each large field, while the whole pasture constituted the sampling unit in the small fields. The herbage was clipped within 2-3 inches of the soil surface from 10-20 points selected at random (up to 50 points when herbage was scarce) in each sampling unit and combined into one large sample of 300-400 grams.

Fifteen sampling sites for holly, blueberry, Sitka spruce, and western hemlock and 10 sites for cranberries were selected (see Table 1 and Figure 1).

Holly and blueberry leaves were collected from the middle third of the current season's growth of 5 to 15 holly trees and 15-20 blueberry plants. There were only two holly trees per variety at Sampling Site 88. Spruce or hemlock shoots and branches were collected from 5-10 trees at each site and combined into one sample per site. Pole pruners were used on the taller trees; otherwise, branches from 4 to 7 feet above ground were taken. Cranberry bogs were sampled by clipping 10-20 shoots from each of 10-20 places selected at random and combining these shoots into one sample, which supplied both leaves and fruits.

Pasture samples were collected once in 1968, three times in 1969, and five times in 1970. Holly, blueberry, cranberry, and forest tree samples were collected once or several times a season as indicated in the tables.

The pasture grass species plots maintained at the J. J. Astor Experiment Station were sampled twice in 1969 - on May 21 just prior to cutting for silage and on September 19 after seasonal regrowth.

During the summer all samples were iced when collected.

All leaf samples, except pasture herbage or hay, were washed in a solution containing 0.05 percent disodium (Ethylenedinitrilo)tetraacetate and 0.05 percent Alconox detergent (17, 25) and rinsed immediately in three changes of distilled water to remove surface contaminants. The washed samples were blotted or placed in a fan stream to remove free water. Pasture herbages collected when wet were treated similarly. After the samples were chopped into approximately one-inch lengths and mixed, 100 gram portions were frozen in cellophane bags containing 1.5 grams of low fluorine lime. The samples were prepared for analysis by the sodium hydroxide fusion technique developed by Remmert and Parks (21) and were analyzed for fluorine content by the semi-automated methods of Weinstein et al. (31,32) as modified by Jacobson (13, 14). Analytical results are reported as ppm fluorine on a dry weight basis.

Results

Fluorine content of 1968 samples

The fluorine contents of all samples collected in 1968 are presented in Table 2. The 33 pasture herbage samples collected between October 3 and November 1 averaged 2.4 ppm fluorine while the range was 1.1 to 7.8 ppm. Ninety-one percent of them were below 4 ppm.

Cranberry foliage and fruit did not exceed 3.5 ppm fluorine except for one sample of leaves taken October 8 which contained 9.2 ppm. The averages for leaves and fruits were 2.9 and 2.2 ppm, respectively.

Holly, hemlock, and spruce foliage contained from 0.2 to 7.4 ppm fluorine. Holly leaves averaged 2.2 ppm and two-year-old spruce needles, 4.2 ppm.

Fluorine content of 1969 samples

The fluorine contents of the pasture herbage samples taken in 1969 are reported in Table 3. The 37 samples taken in mid-May contained an average of 2.1 ppm, while those collected June 25-July 3 and September 8-10 contained averages of 1.8 and 2.5 ppm, respectively. Only 13 percent of all pasture herbages taken in 1969 contained more than 3.4 ppm fluorine. The range of all 121 samples was 0.5 to 13.1 ppm.

The fluorine contents of foliage samples of cranberry, holly, hemlock, spruce, trailing blackberry, and bracken fern are presented in Table 4. None of these samples exceeded 4.2 ppm fluorine, while the average for each species or time of sampling varied from 0.8 ppm in cranberry to 2.5 ppm in trailing blackberry.

The fluorine contents of the five pasture grass species are reported in Table 5. In May each species averaged about 1 ppm fluorine and from 1.4 to 3.2 ppm in September. At the first sampling there was remarkably little variation between species and among the samples of a species, the range being from 0.6 to 1.7 ppm F. At the September sampling differences between species were greater, but they were not statistically significant.

Fluorine content of 1970 samples

Pasture herbage samples were collected five times at approximately monthly intervals from late April to September (Table 6). The average for all samples collected in April and May was 2 to 3.2 times as high as for the other samplings, probably because of the considerably longer growth period and greater opportunity for contamination by soil residues. The average was 3.2 ppm F at the first sampling and 1.0, 1.2, 0.8, and 1.5 ppm for the June,

July, August, and September collections, respectively. Over 73 percent of all pasture herbages sampled in 1970 contained 2.0 ppm fluorine or less, while only 9 percent contained more than 3.5 ppm.

Table 7 gives the fluorine contents of leaf and fruit samples from the cranberry bogs in the Cullaby Lake area on August 12-13. The fluorine contents ranged from 0.1 to 2.3 in leaves, averaging 1.1 ppm, and from 0.2 to 7.9 in fruits, averaging 2.6 ppm. Although fruits contained slightly more fluorine than the leaves, the differences were small.

The average fluorine contents of the 1970 pasture herbage samples have been summarized according to terrain, distance from factory site, river valley, and by sector (Table 8). All pastures protected from incoming tides by dikes were classified as tidelands, while all others were listed as uplands regardless of elevation. Similarly, all pastures in the two drainage systems were listed according to their river valley, the Lewis and Clark or Youngs. Distance from the factory site was in increments of two miles. Because of the small number of fields in certain directions, the sectors to the N and NE were enlarged as shown in Table 8. The E and ESE sectors contained the largest number of fields. There appears to be no trend in fluorine contents in any of these categories; for instance, tidelands averaged 1.5 ppm and uplands, 1.4 ppm; Lewis and Clark River valley, 1.5 ppm, and Youngs River valley, 1.4 ppm. The distribution of levels of fluorine in pasture herbage seemed to be entirely at random in each category.

The fluorine contents of the pasture herbages obtained since October 1968 are summarized by range, average, and frequency class in Table 9. In October 1968 almost half of the 33 samples fell in the 1.4-2.0 ppm F class. There were none in some frequency classes and only two in the last class - 6.5 ppm from the Don Tagg field and 7.8 ppm from the Astor Experiment Station Pasture 1. Data are presented in Table 2. All other samples for each time of collection were classified similarly. Nearly all values for the entire sampling period are very low, with only a few that may be called moderate.

Discussion

In the absence of airborne fluorides, most plants accumulate only small amounts of soil-derived fluorine in their foliage. (See footnote 3, page 2 for examples of exceptions.) The form of fluoride in most soils according to MacIntire et al. (15) is the relatively insoluble calcium fluoride (solubility 16 ppm @ 18°C). Fluorides deposited from fertilizers, sprays, industrial effluents, and rain are converted to calcium fluoride (15). Forage plants accumulated only small amounts of fluorine from soils treated experimentally with calcium fluoride, and germination and growth

were not affected. Tomato plants dusted with powdered calcium fluoride or cryolite showed no adverse effects and leaf fluorine levels were not increased appreciably (17).

The forage samples collected in the Warrenton area were not washed, and their fluorine contents included internal and external fluoride derived from the soil. This fluorine, as noted above, has little or no effect on plants or on animals consuming it. As cattle normally consume unwashed vegetation, pasture herbages routinely are not washed for fluorine analysis and an occasional above-average fluorine value may be found (23).

In the Warrenton area, there were only two herbage samples out of the 457 that contained more than 10 ppm fluorine - 13.1 ppm from No. 37 in May 1969 and 12.0 ppm from No. 29 in July 1970. These low soil-derived fluorine levels would have no effect on plants or animals (1, 23, 24).

The relationship between the fluoride content of the diet and the effects on dairy cattle has been reported by Shupe (23) and Suttie (24). Shupe found no adverse effects at 15-30 ppm fluorine in the total diet but rated the chronic fluorosis borderline at 30-40 ppm. Suttie's conclusions were similar. He proposed an air quality standard for the protection of dairy cattle, the farm animal rated the most sensitive to injury by fluoride (20). The proposed standard would limit forage fluoride to a yearly average of 40 ppm determined by monthly samplings, with limits of 60 ppm for not over two consecutive months and 80 ppm for one month. This proposed standard is consistent with the safe level of 30 ppm in the total ration of dairy cattle as stipulated by the National Research Council (20). Grain and silage in the usual ration are low in fluorine and would dilute any higher fluorine levels in forages.

The average fluorine contents of the Warrenton area pasture samples were slightly lower than those of similar samples taken in 1952-1954 from the control pastures in the Willamette Valley (5, 6) and are less than half as great as those for alfalfa herbage taken in The Dalles area in 1957-1958 prior to aluminum factory operations (8).

In the Warrenton area, although pastures did vary in species composition as observed when samples were collected, the fluorine contents of these unwashed herbages varied in a random manner. There appeared to be no trend by terrain, river valley, or distance and direction from the factory site. Factors affecting the absorption of the small amounts of fluorine found in these herbages appear to have a similar effect throughout the area. MacLean et al. (16) reported that a timothy-red clover sward in New York contained 2-3 ppm fluorine prior to controlled hydrogen fluoride fumigation, almost the same value as those obtained in the Warrenton area and in the Willamette Valley (5, 6).

The amounts of fluorine found in the five common pasture grasses from the plots at the J. J. Astor Experiment Station were remarkably

similar throughout. All grasses accumulated only nominal amounts of fluorine from the soil. Orchard grass from Sampling Site 27 in 1969-1970 contained almost identical amounts of fluorine as the two varieties at the Experiment Station five miles to the east. These were all unwashed samples as were those analyzed by MacLean et al. (16).

It is evident from the data presented in Tables 2 through 7 that the seven plant materials analyzed in 1968-1970 contained similar low amounts of fluorine. The average fluorine contents varied from 0.8 to 3.2 ppm with the exception of 4.2 ppm in two-year-old Sitka spruce needles collected in 1968. In contrast, the average fluorine contents of the foliage of seven crops collected four times prior to aluminum factory operations in The Dalles area ranged from 4.0 to 14.9 ppm fluorine (8). Soils, crops, and climate differ considerably between the Warrenton and The Dalles areas.

Treshow (28, 29) has emphasized the importance of determining beforehand the health and vigor of plants growing in a potential air pollution area. Of equal importance is a knowledge of foliar fluoride levels. In The Dalles area fluoride levels were determined according to distance and direction from the factory for seven crops, including alfalfa, before and after factory operations (8). These data showed the changing fluoride levels in the area before and after the operation of the aluminum factory. Similar data for the Warrenton area should prove equally valuable.

Plants readily injured by an air pollutant and referred to as "indicators" have been used effectively as a visual expression of air pollution. Cole (4) found many native plants useful for showing the presence of sulfur dioxide, among them blackberry, oak, ash, and various weeds. Adams et al. (2) used ponderosa pine seedlings and gladiolus as indicators to delineate areas of high atmospheric fluoride pollution. Middleton and Paulus (18) conducted a statewide air pollution survey in which field crops, fruits, flowers, vegetables, and weeds were observed for symptoms of injury by various air pollutants. Darley (11) has reviewed the reports on use of plants as air pollution monitors. Compton and Remmert (7) used visual symptoms of injury and fluorine content of gladiolus leaves to pinpoint areas of greatest fluoride concentration and leaf injury around an aluminum reduction factory.

In the absence of visible injury to foliage, chemical analysis of leaves for fluorine content has been relied upon to determine levels of pollution. Compton, Remmert, and Spencer (5, 6) used the fluorine contents of pasture herbages and other livestock feeds to assess a potential hazard to dairy cattle in northwestern Oregon. As noted above, Suttie (24) proposed air quality standards for the protection of livestock based on the fluorine content of forages.

Only a few species of plants are readily injured by airborne fluorides (3, 26, 27, 29) and most of these are cultivated kinds. In the

absence of native plants readily injured by fluoride, Compton and Remmert (5) used the fluorine contents of the foliage of potted buckwheat plants to determine air fluoride pollution in the Sauvie Island area. The fluorine contents of sweet cherry foliage were used similarly in The Dalles area (9).

Native plants that can be used as indicators of airborne fluorine in the Warrenton area have been sought. The trailing evergreen blackberry (Rubus ursinus) and bracken fern (Pteridium aquilinum) were examined for their suitability. Both are widely distributed throughout the area and have a long growing season. The blackberry is browsed by the local elk herds during the winter (12). Because of its upright growth habit and frond formation, bracken is more readily sampled than blackberry, but it dies down in winter. The evergreen blackberry would, however, provide samples throughout the year. Foliage of both plants contained only nominal amounts of fluorine. Their capacity for absorption through the leaves has not been determined.

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Table 1. Location and description of sites from which samples of cultivated and native plants of the Warrenton area were obtained for fluorine analysis

Station No.	Sample site name	Township, range, section and quarter	Plant cover	Terrain	Distance and direction from factory site	
					Miles	Direction
1	Tagg, 13th Ave. fields	8N-10W-9-SW	Pasture	Tideland	3.1	NNW
2	" Home pastures	8N-10W-16-NW	"	"	2.5	NNW
3	Kunkler, Beef and Sheep field	8N-10W-29-NE	"	Sand dune	1.6	W
4	Sunset Lake Dunes	7N-10W-9-SW	Pine	" "	3.6	SSW
5	Holmes-Seppa, Beef pasture	7N-10W-21-SE	Pasture	" "	5.0	S
6	Kaino, Bump bog	7N-10W-27-SE	Blueberry, cranberry	Bog	6.1	S
7	Anderson, South bog	7N-10W-27-SE	Cranberry	"	5.9	S
8	Kaino-Dellinger, West bog	7N-10W-27-NE	"	"	5.9	S
9	" " Main bog	7N-10W-27-NE	"	"	5.9	S
10	Kaino, West bog	7N-10W-27-NE	"	"	5.8	S
11	" East bog	7N-10W-27-NE	Blueberry, cranberry	"	5.8	S
12	Anderson, Howell bog	7N-10W-22-SW	Cranberry	"	5.0	S
13	" Searles bog	7N-10W-22-NW	"	"	4.9	S
14	" Main bog	7N-10W-22-NW-NE	"	"	4.8	S
15	Ballman, Pasture & Hay field	8N-10W-34-SW	Pasture, hay	Upland	1.2	SSW
16	Old Anderson, Dolphin Ave. bog	8N-10W-34-NW	Cranberry	Bog	0.9	SSW
17	Aluminum Co., west	8N-10W-27-SW	Forest	Upland	0.5	WSW
18	Adams, K., Dolphin Ave.	8N-10W-28-NE	Holly	"	0.6	WNW
19	Willener, Heron St.	8N-10W-22-SW	Pasture	Tideland	1.1	NNW
20	" King St. at Youngs Bay	8N-10W-22-NW	"	"	1.5	N
21	" King St. Barn field	8N-10W-22-NE	"	"	1.4	N
22	" Big Barn field	8N-10W-22-SE	"	"	0.9	N
23	" RR and Holbrook Slough	8N-10W-22-NE	"	"	1.3	NNE
24	Reed, US 101 at Holbrook Slough	8N-10W-22-SE	"	"	0.9	NNE
25	" US 101 at Youngs Bay	8N-10W-23-SW	"	"	1.1	NNE
26	Aluminum Co., north	8N-10W-27-NE	Forest	Upland	0.3	NNE

Table 1. (Continued)

Station No.	Sample site name	Township, range, section and quarter	Plant cover	Terrain	Distance and direction from factory site: Miles	Direction
27	Aluminum Co., NE, Old Orchard	8N-10W-27-NE	Grass	Upland	0.4	NE
28	Moore, Slough field	8N-10W-26-NW	Pasture	Tideland	0.7	NE
29	" Truck Route field	8N-10W-26-NW	"	"	1.0	ENE
30	Airport Rd. Corner	8N-10W-26-NE	"	"	1.5	E
31	Morrell, Alt. US 101 at Lewis & Clark R.	8N-10W-25-NE	"	"	2.1	ENE
32	Aluminum Co., south	8N-10W-27-SW	Forest	Upland	0.3	S
33	" " SE, Power line	8N-10W-27-SE	Grass	"	0.4	SE
34	Oregon Forestry Dept., Adair Creek	8N-10W-27-SE	Forest	"	0.5	ESE
35	" " " Experimental Plot	8N-10W-26-SE	"	"	1.1	E
36	" " " Clatsop Loop Rd.	8N-10W-26-SE	"	"	1.5	E
37	Morrell, Horse & Beef field	8N-10W-25-SW	Pasture	Tideland	1.9	E
38	Everson, Wm.	8N-10W-36-NW	"	"	1.8	ESE
39	Ft. Clatsop National Memorial	8N-10W-35-SE	Forest, grass	Upland	1.7	ESE
40	Crown, Station 13 on Perkins Rd.	8N-10W-35-SW	Forest	"	1.3	SE
41	Reith, J. Jr., 12 Acre pasture	7N-10W-1-SW	Pasture	Tideland	2.9	SE
42	Kamera Bros., Astoria Bent grass	7N-10W-12-NW	Grass seed	"	3.1	SE
43	Hannu, Astoria Bent grass	7N-10W-12-NE	" "	"	3.6	SE
44	Burkhart, Bridge field	7N-9W-19-NE	Pasture	River valley	5.8	SE
45	" N Dairy field	7N-9W-19-SE	"	" "	6.3	SSE
46	Hartill, Home, East field	7N-9W-31-SW	"	" "	7.7	S
47	Reith, John, Peterson Slough	7N-9W-7-NW	"	Tideland	3.7	SE
48	" " Hill field	7N-9W-6-SW	Pasture, hay	Upland	3.4	SE
49	" " Home, Tidelands field	7N-9W-6-SW	Pasture	Tideland	3.4	SE
50	Seppa, Elk Hay field	7N-9W-6-NW	Hay	Upland	3.2	ESE
51	" Spruce Tree field	7N-9W-6-NW	Pasture	"	3.1	ESE
52	" Church field	7N-10W-1-NE	"	"	3.0	SE
53	" Hill field	7N-10W-1-NE	"	"	2.9	ESE
54	" Barn field	7N-10W-1-NE	"	Tideland	2.8	SE
55	" 15 Acre field	7N-10W-1-NW	"	"	2.4	SE

Table 1. (Continued)

Station No.	Sample site name	Township range, section and quarter	Plant cover	Terrain	Distance and direction from factory site	
					Miles	Direction
56	Seppa, 40 Acre field	7N-10W-1-NW	Pasture	Tideland	2.4	SE
57	Hartill-Nelson, 1st Bench field	8N-10W-36-SE	"	Upland	2.8	ESE
58	" " Tidelands East field	8N-10W-36-SE	"	Tideland	2.6	ESE
59	Kaakenin, Bent grass, East field	8N-10W-36-NE	Grass seed	"	2.5	ESE
60	" Bent grass, West field	8N-10W-36-NW	Grass seed, hay	"	2.1	ESE
61	Olson, R., Red Barn field	8N-9W-30-SW	Pasture	"	2.6	E
62	" Jeffries Slough	8N-10W-25-SE	"	"	2.1	E
63	Leino, Richfield Station	8N-9W-30-NE	"	"	3.1	E
64	Reikkola, Home Place, north	8N-9W-19-SE	"	"	3.6	ENE
65	" Home Place, south	8N-9W-30-NE	"	"	3.5	E
66	Hartill, Cooks Slough east	8N-9W-29-NW	"	"	3.8	E
67	" Cooks Slough west	8N-9W-29-NW	"	"	3.7	E
68	Reikkola, Wireless Rd.	8N-9W-29-SW	"	"	3.9	E
69	Kraft-Hess, Russian Pt. field	8N-9W-20-SE	"	"	4.4	ENE
70	" " Towers field	8N-9W-29-NE	"	"	4.3	E
71	Anderson, Home, Improved field	8N-9W-32-SW	"	Upland	4.2	ESE
72	" East field at Slough	8N-9W-32-SE	"	Tideland	4.3	ESE
73	Kraft, Gate field	7N-9W-5-SE	"	"	4.7	ESE
74	" Spruce Tree field	7N-9W-5-SE	"	"	4.9	ESE
75	Johnson, 12 Acre field at Tucker Slough	7N-9W-9-NW	"	"	5.4	ESE
76	" Tucker Slough field	7N-9W-9-NW	"	"	5.4	ESE
77	" South Levee field	7N-9W-9-NE	"	"	5.8	ESE
78	" North Barn field	7N-9W-9-NE	"	"	5.7	ESE
79	Colvin, East field	7N-9W-14-NE	"	Upland	8.2	ESE
80	Gindroz, Half Mile field	7N-9W-13-SE	"	"	8.9	ESE
81	Henningson, Slough field	7N-9W-4-NE	"	Tideland	5.8	ESE
82	" Hay field	7N-9W-3-NW	Hay	Upland	6.1	ESE
83	Kuppenbender	7N-9W-2-NW	Holly	"	6.8	ESE
84	Carlson, Wallace	7N-9W-2-NW	"	"	7.1	ESE

Table 1. (Continued)

Station No.	Sample site name	Township, range, section and quarter	Plant cover	Terrain	Distance and direction from factory site	
					Miles	Direction
85	JJ Astor Exp. Sta., Machine Shed field	8N-9W-28-NE	Pasture	Tideland	5.4	E
86	" " " " Tideland Pastures 1-6	8N-9W-28-NE & -27-NW	"	"	5.6	E
87	" " " " Farm Home fields	8N-9W-28-NE & -27-NW	Hay, grass	Upland	5.5	E
88	" " " " East fields	8N-9W-27-NW	Holly, etc.	"	5.7	E
89	Lee, Hill field	8N-9W-28-NE	Hay	"	5.3	E
90	" Gravel Dump field	8N-9W-21-SE	Pasture	Tideland	5.1	E
91	Carlson, Victor	8N-9W-24-NW	Holly	Upland	7.9	E
92	Timmerman Orchards	8N-9W-24-NE	"	"	8.5	E

Table 2. Fluorine content of samples of pasture herbage, cranberry leaves and fruit, and foliage of holly, hemlock and spruce, Warrenton area, 1968

Station No.	Sample site name	Fluorine content, dry weight basis (ppm)	Distance and direction from factory site	
			Miles	Direction
October 3-November 1 -- Pasture Herbage				
1	Tagg, 13th Ave.	5.3	3.1	NNW
2	" Home fields	6.5	2.5	NNW
3	Kunkler	1.7	1.6	W
5	Holmes-Seppa	1.8	5.0	S
19	Willener, Heron St.	3.2	1.1	NNW
22	" Big Barn	3.1	0.9	N
24	Reed, US 101 at Holbrook Slough	1.3	0.9	NNE
28	Moore, Slough field	1.6	0.7	NE
29	" Truck Route	2.3	1.0	ENE
37	Morrell, Horse & Beef	1.2	1.9	E
38	Everson	1.1	1.8	ESE
45	Burkhart, N Dairy field	3.2	6.3	SSE
46	Hartill, Home, East field	1.5	7.7	S
47	Reith, Peterson Slough	1.4	3.7	SE
53	Seppa, Hill field	1.5	2.9	ESE
55	" 15 Acre field	2.6	2.4	SE
61	Olson, Red Barn	3.2	2.6	E
63	Leino, Richfield Station	1.8	3.1	E
64	Reikkola, Home, north	3.7	3.6	ENE
68	" Wireless Rd.	1.7	3.9	E
71	Anderson, Home, Improved	1.8	4.2	ESE
73	Kraft, Gate field	1.9	4.7	ESE
76	Johnson, Tucker Slough	2.8	5.4	ESE
79	Colvin, East field	1.2	8.2	ESE
80	Gindroz, Half Mile field	1.6	8.9	ESE
81	Henningson, Slough field	3.3	5.8	ESE
82	" Hay field	1.7	6.1	ESE
86	Astor Exp. Sta. Tideland Pasture 1	7.8	5.6	E
86	" " " " " 2	1.2		
86	" " " " " 3	1.4		
86	" " " " " 4	1.8		
86	" " " " " 5	2.2		
86	" " " " " 6	2.0		

October 8-27 -- Cranberry		Foliage	Fruit		
7	Anderson, South bog	2.5	1.9	5.9	S
12	" Howell bog	2.2	2.1	5.0	S
13	" Searles bog	2.5	3.5	4.9	S
		9.2	1.5		

Table 2. (Continued)

Station No.	Sample site name		Fluorine content, dry weight basis (ppm)		Distance and direction from factory site	
					Miles	Direction
October 8-27 -- Cranberry			Foliage	Fruit		
14	Anderson, Main bog		3.5	1.9	4.8	S
8	Kaino-Dellinger, West bog		1.7	2.0	5.9	S
9	" " Main bog		2.0	2.0	5.9	S
10	Kaino, West bog		1.9	2.5	5.8	S
11	" East bog		1.7	2.6	5.8	S
16	Old Anderson, Dolphin Ave. bog		1.9	2.0	0.9	SSW
November 1-15 -- Holly			Foliage			
18	Adams, K.		2.6		0.6	WNW
83	Kuppenbender, Eng.-French		2.4		6.8	ESE
83	" Variegated		1.9			
84	Carlson, W., Eng.-French		1.3		7.1	ESE
84	" Variegated		2.3			
88	Astor Exp. Sta., Ore. Select		2.0		5.7	E
88	" " " Mrs. Pilkington		0.2			
88	" " " Rederly		2.3			
88	" " " Silvary		3.6			
91	Carlson, V.		3.1		7.9	E
92	Timmerman		2.6		8.5	E
December 12-13 -- Forest trees			Hemlock	Spruce		
17	Aluminum Co., west	1 yr. (1968)	2.6	2.6	0.5	WSW
		2 yr. (1967)	2.0	4.5		
27	Aluminum Co., Old Orchard	1 yr.	2.3	2.0	0.4	NE
		2 yr.	4.5	2.7		
30	Airport Rd. Corner	1 yr.	---	4.2	1.5	E
		2 yr.	---	5.5		
32	Aluminum Co., south	1 yr.	2.2	2.7	0.3	S
		2 yr.	3.3	2.4		
34	Ore. Forestry Dept., Adair Creek	1 yr.	2.7	2.0	0.5	ESE
		2 yr.	3.2	2.1		
35	Ore. Forestry Dept., Experimental Plot	1 yr.	2.5	3.2	1.1	E
		2 yr.	3.2	4.1		
36	Ore. Forestry Dept., Clatsop Loop Rd.	1 yr.	2.9	1.5	1.5	E
		2 yr.	1.3	7.4		
40	Crown, Station 13	1 yr.	2.1	2.0	1.3	SE
		2 yr.	2.5	4.8		

Table 2. (Continued)

Summary

	Pasture herbage	Cranberry Foliage	Cranberry Fruit	Holly	Hemlock 1 yr.	Hemlock 2 yr.	Spruce 1 yr.	Spruce 2 yr.
No. samples	33	10	10	11	7	7	8	8
Range, ppm	1.1-7.8	1.7-9.2	1.5-3.5	0.2-3.6	2.1-2.9	1.3-4.5	1.5-4.2	2.1-7.4
Avg., ppm	2.4	2.9	2.2	2.2	2.5	2.9	2.5	4.2

Table 3. Fluorine content of samples of pasture herbage, Warrenton area, 1969

Station No.	Sample site name	Fluorine content, dry weight basis			Distance and direction from factory site	
		May 15-23	June 25-July 3	Sep. 8-10	Miles	Direction
		ppm	ppm	ppm		
1	Tagg, 13th Ave.	2.9	2.9	0.7	3.1	NNW
2	" Home fields	4.3	1.7	1.8	2.5	NNW
3	Kunkler	8.8	2.3	0.9	1.6	W
4	Sunset Lake	2.0	1.1	2.5	3.6	SSW
5	Holmes-Seppa	0.5	0.7	2.0	5.0	S
19	Willener, Heron St.	1.8	1.4	2.2	1.1	NNW
22	" Big Barn	5.2	0.7	1.5	0.9	N
24	Reed, US 101 at Holbrook Slough	1.8	0.7	1.4	0.9	NNE
27	Aluminum Co., NE, Old Orchard	1.0	1.9	1.5	0.4	NE
28	Moore, Slough field	5.3	3.9	1.4	0.7	NE
29	" Truck Route field	2.2	2.4	2.7	1.0	ENE
33	Aluminum Co., SE, Power Line	1.7	1.1	3.8	0.4	SE
37	Morrell, Horse & Beef	13.1	2.6	3.4	1.9	E
38	Everson	2.3	2.0	3.0	1.8	ESE
39	Ft. Clatsop National Memorial	0.7	0.5	1.5	1.7	ESE
45	Burkhart, N Dairy field	0.7	1.6	1.9	6.3	SSE
46	Hartill, Home, East field	1.2	2.2	3.6	7.7	S
47	Reith, Peterson Slough	0.6	0.9	5.2	3.7	SE
50	Seppa, Elk Hay field	0.6	3.2	3.0	3.2	ESE
51	" Spruce Tree field	0.5	1.6	1.8	3.1	ESE
52	" Church field	0.6	2.1	2.3	3.0	SE
53	" Hill field	0.7	2.6	3.2	2.9	ESE
54	" Barn field		3.7	2.6	2.8	SE
55	" 15 Acre field	0.6	2.0	1.8	2.4	SE
56	" 40 Acre field	0.9	2.5	2.6	2.4	SE
61	Olson, Red Barn	0.8	1.2	3.8	2.6	E
63	Leino, Richfield Station	0.9	1.4	1.8	3.1	E
64	Reikkola, Home, north	2.0	0.6	2.5	3.6	ENE
68	" Wireless Rd.	0.7	0.5	3.5	3.9	E

Table 3. (Continued)

Station No.	Sample site name	Fluorine content, dry weight basis: May 15-23	June 25-July 3	Sep. 8-10	Distance and direction from factory site: Miles	Direction
		ppm	ppm	ppm		
71	Anderson, Home, Improved field	0.7	0.7	2.8	4.2	ESE
73	Kraft, Gate field	2.9	1.9	3.0	4.7	ESE
76	Johnson, Tucker Slough	1.3	1.1	4.4	5.4	ESE
77	" S. Levee field		0.9	1.6	5.8	ESE
78	" N. Barn field			2.1	5.7	ESE
79	Colvin, East field	0.6	1.3	3.2	8.2	ESE
80	Gindroz, Half Mile field	3.0	4.8	3.8	8.9	ESE
81	Henningson, Slough field	3.6	1.5	---	5.8	ESE
82	" Hay field		2.0	1.9	6.1	ESE
86	Astor Exp. Sta. Tideland Pasture 1			1.7	5.6	E
86	" " " " " 2		2.0	3.0	5.6	E
86	" " " " " 3			2.9	5.6	E
86	" " " " " 4	0.9	0.8	2.6	5.6	E
86	" " " " " 5			2.8	5.6	E
86	" " " " " 6	0.7		2.9	5.6	E
89	Lee, Hill field	1.0	1.7	2.5	5.3	E
Summary						
Number of samples		37	40	44		
Range, ppm		0.5-13.1	0.5-4.8	0.7-5.2		
Average, ppm		2.1	1.8	2.5		

Table 4. Fluorine content of samples of foliage of cranberry, holly, hemlock, spruce, wild blackberry and bracken, Warrenton area, 1969

Station No.	Sample site name	Fluorine content, dry weight basis (ppm)		Distance and direction from factory site	
		July 3	Oct. 23-24	Miles	Direction
Cranberry					
6	Kaino, Bump bog	---	1.0	6.1	S
7	Anderson, South bog	1.8	0.6	5.9	S
8	Kaino-Dellinger, West bog	---	0.7	5.9	S
9	" " Main bog	3.0	0.6	5.9	S
10	Kaino, West bog	1.6	1.4	5.8	S
11	" East bog	1.0	---	5.8	S
12	Anderson, Howell bog	1.3	0.5	5.0	S
13	" Searles bog	1.0	0.7	4.9	S
14	" Main bog, Section 1	---	1.5	4.8	S
14	" " " " 3	1.1	0.6		
14	" " " " 5	---	1.3		
14	" " " " 7	---	0.5		
14	" " " " 8	1.5	---		
14	" " " " 9	---	0.5		
Holly -- September 25-26					
18	Adams, English	1.3		0.6	WNW
83	Kuppenbender, Eng.-French	0.7		6.8	ESE
	" Variegated	0.6			
84	Carlson, W., Eng.-French	1.9		7.1	ESE
	" Variegated	0.7			
88	Astor Exp. Sta., Ore. Select	0.7		5.7	E
	" " " Mrs. Pilkington	0.6			
	" " " Rederly	1.4			
	" " " Silvary	1.9			

Table 4. (Continued)

Station No.	Sample site name	Fluorine content, dry weight basis (ppm)				Distance and direction from factory site	
						Miles	Direction
Holly -- September 25-26							
91	Carlson, V., Variegated	1.7				7.9	E
92	Timmerman, Bailey's Pride	0.6				8.5	E
	" Variegated	0.5					
Hemlock, Spruce, Blackberry, Bracken -- September 25-October 24		Hemlock[1/]	Spruce[1/]	Blackberry	Bracken		
17	Aluminum Co., west	1.3	1.1	2.7	---	0.5	WSW
18	Adams, K., Dolphin Ave.	1.2	1.2	2.3	0.6	0.6	WNW
32	Aluminum Co., south	1.8	1.6	4.0	---	0.3	S
33	" " SE	1.2	1.0	4.2	---	0.4	SE
35	Ore. Forestry Dept. Exp. Plot	0.8	0.7	1.7	---	1.1	E
39	Ft. Clatsop National Memorial	1.2	1.1	2.0	2.1	1.7	ESE
40	Crown, Station 13, Perkins Rd.	0.5	0.3	2.9	2.1	1.3	SE
83	Kuppenbender	2.0	1.3	2.2	1.4	6.8	ESE
88	Astor Exp. Sta.	1.6	0.8	2.4	1.7	5.7	E
91	Carlson, V.	---	---	2.2	0.4	7.9	E
92	Timmerman	1.3	1.3	1.0	0.6	8.5	E

Summary	Cranberry		Holly	Hemlock	Spruce	Blackberry	Bracken
	July 3	Oct. 23-24					
Number of samples	8	12	12	10	10	11	7
Range, ppm	1.0-3.0	0.5-1.5	0.5-1.9	0.5-2.0	0.3-1.6	1.0-4.2	0.4-2.1
Average, ppm	1.5	0.8	1.1	1.3	1.0	2.5	1.3

[1/] 1969 needles.

Table 5. Fluorine content of samples of pasture grass species, J. J. Astor Experiment Station, 1969

Replication and sampling date	Alta fescue	New Zealand H-1 annual rye grass	Pennlake orchard grass	S-143 orchard grass	Teptoe Reville perennial rye grass
	Fluorine content, dry weight basis				
	ppm	ppm	ppm	ppm	ppm
May 21					
1	1.4	1.1	1.7	1.1	1.1
2	0.8	1.0	0.9	1.2	0.7
3	0.6	1.0	1.1	0.7	0.6
4	1.0	0.9	1.5	1.0	1.0
Average	1.0	1.0	1.3	1.0	0.9
September 9					
1	2.9	0.7	2.5	2.5	4.1
2	0.7	2.9	1.5	1.8	3.0
3	0.5	0.6	0.5	1.3	1.8
4	1.3	1.5	2.3	1.7	3.7
Average	1.4	1.4	1.7	1.8	3.2

Table 6. Fluorine content of samples of pasture herbage, Warrenton area, 1970

Station No.	Sample site name	Fluorine content, dry weight basis					Distance and direction from factory site	
		Apr. 23-May 13	June 9-15	July 15-24	Aug. 11-21	Sep. 22-Oct. 8	Miles	Direction
		ppm	ppm	ppm	ppm	ppm		
1	Tagg, 13th Ave.	5.7	0.4	1.3	0.2	0.2	3.1	NNW
2	" Home pastures	2.5	0.4	1.6	0.2	1.4	2.5	NNW
3	Kunkler	5.7	0.4	---	---	---	1.6	W
5	Holmes-Seppa	4.4	1.1	---	---	---	5.0	S
15	Ballman				0.2	1.4	1.1	SSW
19	Willener, Heron St.	2.1	1.1	1.4	0.2	1.6	1.1	NNW
20	" King St. at Youngs Bay		1.4	2.8	5.4	0.2	1.5	N
21	" King St. Barn			1.7	1.6	1.6	1.4	N
22	" Big Barn	1.3	0.2	1.3	0.2	7.9	0.9	N
23	" Holbrook Slough			0.1	0.2	5.1	1.3	NNE
24	Reed, US 101 at Holbrook Slough	2.2	0.1	0.1	0.1	---	0.9	NNE
25	" US 101 at Youngs Bay					2.1	1.1	NNE
27	Aluminum Co., NE, Old Orchard	1.5	0.7	0.2	0.2	1.8	0.4	NE
28	Moore, Slough field	3.2	0.4	1.2	0.1	0.2	0.7	NE
29	" Truck Route field	2.5	1.4	12.0	0.2	1.9	1.0	ENE
31	Morrell, Alt. 101 at L.&C. River	3.9	0.1	0.1	0.1	0.2	2.1	ENE
33	Aluminum Co., SE, Power Line	2.4	0.1	0.2	0.1	1.6	0.4	SE
37	Morrell, Horse & Beef field	7.5	0.8	0.2	0.2	2.5	1.9	E
38	Everson, Wm.	7.2	0.2	1.0	0.2	2.5	1.8	ESE
39	Ft. Clatsop National Memorial	2.6	1.5	1.3	0.1	0.9	1.7	ESE
41	Reith, John Jr.			0.8	0.2	0.2	2.9	SE
42	Kamera Bros.			0.1	0.2	0.2	3.1	SE
43	Hannu			0.1	0.1	1.5	3.6	SE
44	Burkhart, Bridge field					2.7	5.8	SE
45	" N Dairy field	4.1	0.2	1.6	0.2	7.8	6.3	SSE
46	Hartill, Home, East field	0.7	1.4	0.2	0.2	1.1	7.7	S
47	Reith, J., Peterson Slough	2.6	0.2	0.2	0.2	2.3	3.7	SE
48	" Hill field	1.4	0.1	4.1	---	1.9	3.4	SE
49	" Home, Tidelands field				0.2	1.6	3.4	SE

Table 6. (Continued)

Station No.	Sample site name	Fluorine content, dry weight basis					Distance and direction from factory site	
		Apr. 23-May 13	June 9-15	July 15-24	Aug. 11-21	Sep. 22-Oct. 8	Miles	Direction
		ppm	ppm	ppm	ppm	ppm		
50	Seppa, Elk Hay field	3.1	0.1	0.9	0.2	2.5	3.2	ESE
51	" Spruce Tree field	3.3	0.1	0.1	0.2	3.2	3.1	ESE
52	" Church field	3.0	0.1	1.3	0.1	4.3	3.0	SE
53	" Hill field	4.0	0.1	2.9	0.1	7.4	2.9	ESE
54	" Barn field	3.7	0.2	0.9	0.2	5.7	2.8	SE
55	" 15 Acre field	4.8	0.1	0.1	0.2	0.2	2.4	SE
56	" 40 Acre field	3.5	0.1	0.3	0.2	1.8	2.4	SE
57	Hartill-Nelson, 1st Bench field	3.0	0.1	1.5	0.1	1.0	2.8	ESE
58	" " Tidelands East	6.0	1.3	1.7	0.2	1.5	2.6	ESE
59	Kaakenin, East field				0.2	0.2	2.5	ESE
60	" West field			2.6	0.2	0.2	2.1	ESE
61	Olson, R., Red Barn field	5.5	0.3	1.8	0.2	2.3	2.6	E
62	" Jeffries Slough field	4.0	1.9	1.6	0.2	1.6	2.3	E
63	Leino, Richfield Station	3.9	2.0	0.2	0.2	2.2	3.1	E
64	Reikkola, Home Place, north			0.2	0.1	1.6	3.6	ENE
65	" Home Place, south	3.0	0.7	0.1	0.2	6.5	3.5	E
66	Hartill, Cooks Slough east	4.2	2.8	0.2	2.4	0.2	3.8	E
67	" Cooks Slough west				0.2	0.2	3.7	E
68	Reikkola, Wireless Rd. field	4.4	2.0	0.1	2.1	0.2	3.9	E
69	Kraft-Hess, Russian Pt. field	3.4	1.3	0.1	0.2	0.2	4.4	ENE
70	" " Towers field	1.3	0.9	0.1	0.6	0.2	4.3	E
71	Anderson, Home field	1.8	0.6	0.9	0.3	0.2	4.2	ESE
72	" East field			0.1	1.1	0.2	4.3	ESE
73	Kraft, Gate field	3.5	3.4	1.1	4.2	0.2	4.7	ESE
74	" Spruce field			1.9	1.5	0.2	4.9	ESE
75	Johnson, 12 Acre field			1.0	---	0.2	5.4	ESE
76	" Tucker Slough field	1.8	1.4	3.5	0.7	0.2	5.4	ESE
77	" South Levee field	1.2	1.5	1.6	1.1	0.2	5.8	ESE
78	" North Barn field	1.5	1.5	2.1	2.1	0.2	5.7	ESE

Table 6. (Continued)

Station No.	Sample site name	Fluorine content, dry weight basis					Distance and direction from factory site	
		Apr. 23-May 13	June 9-15	July 15-24	Aug. 11-21	Sep. 22-Oct. 8	Miles	Direction
		ppm	ppm	ppm	ppm	ppm		
79	Colvin, East field	2.5	1.4	0.1	0.2	0.2	8.2	ESE
80	Gindroz, Half Mile field	1.8	2.4	1.5	1.8	0.2	8.9	ESE
82	Henningson, Hay field	1.8	1.6	3.1	1.1	0.1	6.1	ESE
85	Astor Exp. Sta. Machine Shed field	2.0	1.3	0.2	1.9	1.4	5.4	E
86	" " " Tidelands Past. 1	6.2	1.5	1.9	1.9	0.2	5.6	E
	" " " " " 2	2.2	2.1	0.4	2.7	0.2	5.6	E
	" " " " " 3	2.6	2.1	1.7	1.8	0.2	5.6	E
	" " " " " 4	3.3	1.9	0.2	1.5	0.2	5.6	E
	" " " " " 5	3.2	1.5	1.0	2.9	1.4	5.6	E
	" " " " " 6	2.3	2.6	1.1	2.5	1.7	5.6	E
	" " " " " 7	2.2	1.2	0.7	---	---	5.6	E
89	Lee, Hill field	1.5	0.1	1.2	0.2	0.2	5.3	E
90	" Tidelands Gravel Dump field	2.5	1.5	3.0	0.2	0.2	5.1	E

Summary

Number of samples	54	55	63	64	67
Range, ppm	0.7-7.5	0.1-3.4	0.1-12.0	0.1-5.4	0.1-7.9
Average of all samples	3.2	1.0	1.2	0.8	1.5
Average - 49 fields sampled 5 times	3.2	1.1	1.3	0.8	1.7

Table 7. Fluorine content of samples of cranberry foliage and fruit, August 12-13, 1970

Station No.	Sample site name	Fluorine content, dry weight basis		Distance and direction from factory site	
		Foliage	Fruit	Miles	Direction
		ppm	ppm		
6	Kaino, Bump bog	---	---	6.1	S
	Section 3	1.1	7.9		
	" 8	1.3	1.3		
7	Anderson, South bog	---	---	5.9	S
	Section 2	1.3	0.2		
8	Kaino-Dellinger, West bog	---	---	5.9	S
	Section 1	1.4	2.4		
	" 3	0.9	0.5		
9	Kaino-Dellinger, Main or East bog	---	---	5.9	S
	Section 2	1.6	3.1		
	" 3	2.2	2.4		
10	Kaino, West bog	---	---	5.8	S
	Section 1	0.1	4.7		
	" 4	0.1	3.5		
11	Kaino, East bog	---	---	5.8	S
	Section 1	2.3	2.1		
	" 4	0.6	2.8		
12	Anderson, Howell bog	---	---	5.0	S
	North section	1.2	3.0		
13	Anderson, Searles bog	---	---	4.9	S
	South section	0.9	3.8		
14	Anderson, Main bog			4.8	S
	Section 1	0.1	1.6		
	" 3	0.9	0.2		
	" 5	1.3	1.0		
	" 7	1.0	2.1		
	" 9	1.2	4.3		
Summary					
Number of samples		18	18		
Range, ppm		0.1-2.3	0.2-7.9		
Average F content		1.1	2.6		

Table 8. Average fluorine content of pasture herbage from fields in different geographical portions of the Warrenton area, 1970

Classification	Number of samples	Fluorine content, dry weight basis				
		Apr. 23-May 13	June 9-15	July 15-24	Aug. 11-21	Sep. 22-Oct. 8
		ppm	ppm	ppm	ppm	ppm
Terrain						
Tidelands	36-49	3.4	1.2	1.2	0.9	1.3
Uplands	16-18	2.5	0.7	1.3	0.3	2.1
Distance from factory site						
0-2 miles	11-14	3.5	0.7	1.8	0.6	2.2
2.1-4 "	20-28	3.8	0.7	1.0	0.3	1.9
4.1-6 "	18-20	2.6	1.5	1.2	1.5	0.5
6.1-8.9 "	5	2.2	1.4	1.3	0.7	1.9
River valley						
Lewis and Clark	20-27	3.9	0.5	1.1	0.2	2.2
Youngs	23-27	2.6	1.6	1.1	1.4	0.6
Section						
NNW-N-NNE	5-8	2.8	0.6	1.3	1.0	2.5
NE-ENE	5-6	2.9	0.8	2.3	0.2	1.0
E	17-18	3.5	1.5	0.9	1.2	1.2
ESE	15-20	3.0	1.1	1.5	0.8	1.1
SE	7-12	3.1	0.1	0.8	0.2	2.0

Table 9. The range, average, and frequency distribution of the fluorine contents of pasture herbage, Warrenton area, 1968-1970

	1968		1969				1970									
	Oct. 3-Nov. 1		May 15-23		June 25-July 3		Sep. 8-10		Apr. 23-May 13		June 9-15		July 15-24		Aug. 11-21		Sep. 22-Oct. 8	
Range, ppm	1.1-7.8		0.5-13.1		0.5-4.8		0.7-5.2		0.7-7.5		0.1-3.4		0.1-12.0		0.1-5.4		0.1-7.9	
Average, ppm	2.4		2.1		1.8		2.5		3.2		1.0		1.2		0.8		1.5	
No. of samples	33		37		40		44		54		55		63		64		67	
Frequency classes	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-0.6 ppm F	0		7	19.0	3	7.5	0		0		23	41.8	25	39.7	45	70.3	31	46.2
0.7-1.3 " "	5	15.2	14	37.8	12	30.0	2	4.5	4	7.4	10	18.2	16	25.4	4	6.3	3	4.5
1.4-2.0 " "	15	45.4	5	13.5	13	32.5	14	31.8	9	16.7	16	29.1	13	20.6	7	10.9	17	25.4
2.1-2.7 " "	3	9.1	2	5.4	7	17.5	10	22.7	13	24.1	4	7.3	2	3.2	5	7.8	8	11.9
2.8-3.4 " "	6	18.2	3	8.1	2	5.0	11	25.0	9	16.7	2	3.6	4	6.3	1	1.5	1	1.5
3.5-4.1 " "	1	3.0	1	2.7	2	5.0	5	11.4	8	14.8	0		2	3.2	0		0	
4.2-4.8 " "	0		1	2.7	1	2.5	1	2.3	4	7.4	0		0		1	1.6	1	1.5
4.9-5.5 " "	1	3.0	2	5.4	0		1	2.3	1	1.8	0		0		1	1.6	1	1.5
5.6-6.2 " "	0		0		0		0		4	7.4	0		0		0		1	1.5
6.3+ " "	2	6.1	2	5.4	0		0		2	3.7	0		1	1.6	0		4	6.0
Totals	33	100.0	37	100.0	40	100.0	44	100.0	54	100.0	55	100.0	63	100.0	64	100.0	67	100.0