6.2.3.2 Emissions Estimation

Creosote and creosote solution emissions in California during 1977 are from two sources. The first source is the emissions associated with the treatment processes and the second is from the evaporative losses that occur when the treated products are in storage or in place.

There were four wood preservation plants that treated with creosote in California during 1977. Emissions data associated with creosote treatment for two of the plants were obtained from local APCD engineering estimates contained in their files. One plant had emissions equivalent to 0.2 percent of their annual poundage of creosote used. The other plant had emissions equivalent to 0.3 percent of their annual consumption before a barometric condenser was installed in the treatment tank vacuum system and a negligible amount of emissions after the installation of the condenser.[54] Stationary source emissions could not be obtained for two of the treatment plants. Therefore, it was assumed that there were no barometric condensers installed, and the average value of 0.25 percent was used for calculating the stationary source emissions associated with creosote treatment at those two plants.

The monthly emissions from each of the treatment plants were derived from the monthly use pattern provided by one of the creosote treatment plants that responded to the questionnaire survey. It is assumed that the monthly creosote use distribution is the same in other treatment plants in California.

The second source of emissions is from the evaporative losses that occur from wood products treated with creosote. As was discussed earlier, a conservative value of 10 percent was arrived at for the first year evaporative losses from wood products treated with creosote and creosote solution. Because the railroads are the primary consumers of creosoted wood products in California, the NSHC wood preservatives consumption for each county is assumed to be proportional to the total miles of railroad track located in each county. It is further assumed that the monthly emission rates are the same.

Table 6-3 summarizes the estimated hydrocarbon emissions associated with creosote treatment and use during 1977 based on the survey reported use pattern.

6.3 Emission Inventory

As may be expected, the temporal and spatial patterns of emissions resulting from pesticide oil applications are quite similar to the patterns of the oil applications themselves. Figure 6-3 shows the monthly emissions of total organic gas (TOG) from formulation 10 pesticide oil use in California in 1977. This figure is very similar to Figure 5-3. Distinct but steadily declining peaks are noticeable in April, June, August, and November. Table 6-4 more clearly enumerates the monthly TOG emissions from pesticide oil applications.

As was mentioned previously, the summer and fall months (June through October, especially) is the time when most ozone

TABLE 6-3

Estimated Hydrocarbon Emissions Associated with Creosote and Creosote Petroleum Treatment and Use in California During 1977

	Treatment plant emissions (tons)	First year evaporative losses (tons)	Total (tons)
Wood preserving plants and treated products	11	638	649
Railroad	--	641	641
Wholesale distributors	--	48	48
TOTAL	11	1,327	1,338

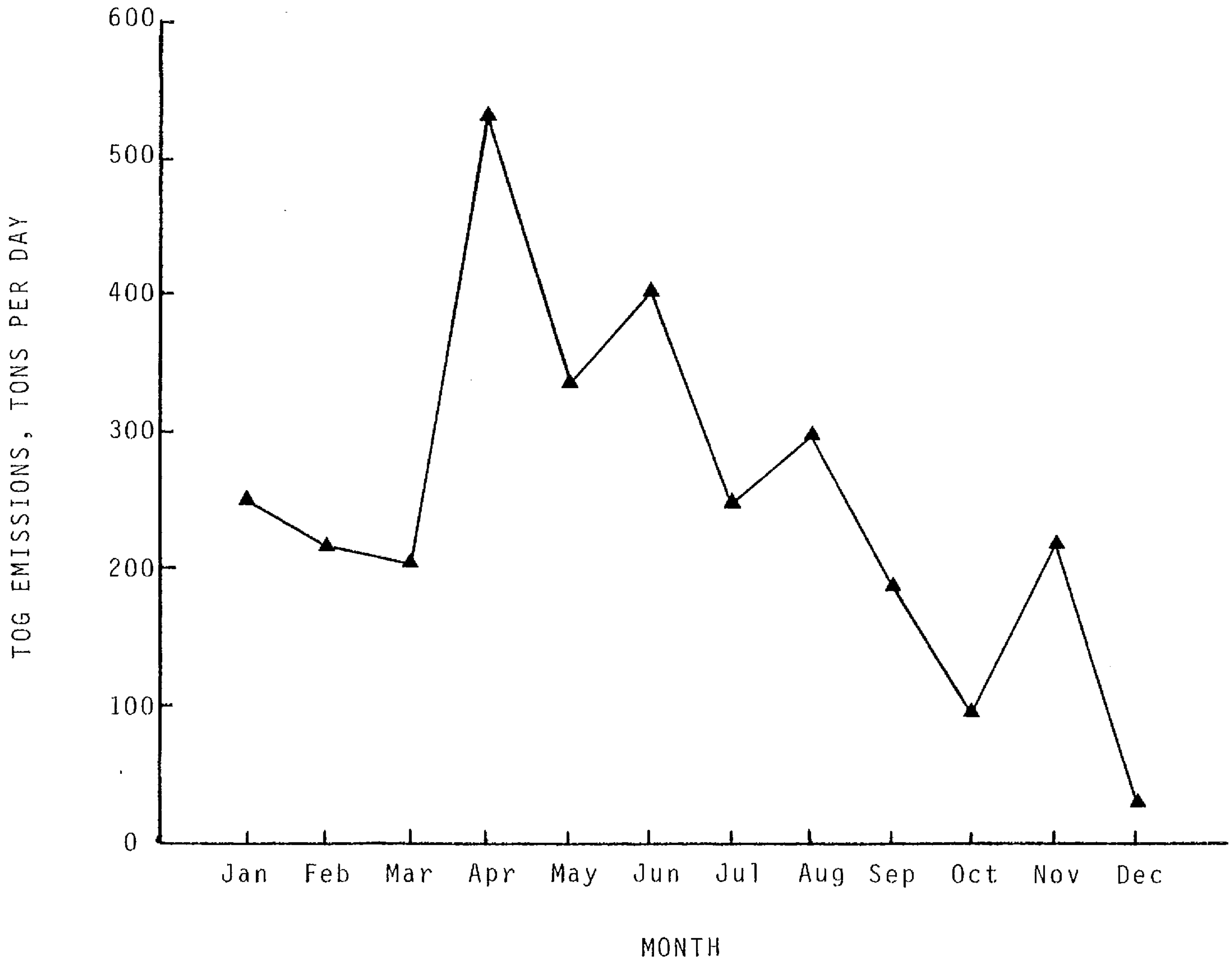

Figure 6-3. Emissions of Total Organic Gas (TOG) Resulting from Formulation 10 Oil Pesticide Use in California in 1977

TABLE 6-4

1977 Monthly Total Organic Gas (TOG) Emissions
from Formulation 10 Oil Pesticide Applications
Shown as a Percentage of Annual Total in California

Month	Emissions (1000 lbs.)	Percent of Annual Total (%)
January	15,286	8.4
February	12,155	6.7
March	12,496	6.8
April	31,574	17.4
May	20,841	11.5
June	24,298	13.4
July	15,269	8.4
August	18,044	9.9
September	11,166	6.1
October	6,071	3.3
November	13,064	7.2
December	1,755	0.9
TOTAL	182,019	100%

standard violations occur in California. As seen in Table 6-4, the June-October period accounts for more than one-third of the total annual TOG emissions from pesticide oil applications.

Table 6-5 depicts a breakdown of statewide monthly TOG emissions by chemical. Petroleum hydrocarbons are by far the largest source of emissions from formulation 10 oil applications. Petroleum oil-unclassified, and diesel and miscellaneous oils are the only other significant source of emissions. Despite the large quantities applied relative to other chemical types, creosote accounts for only a small fraction of TOG emissions. This is due to the very low rate of volatilization of creosote and the way it is applied to wood products.

Table 6-6 is a summary of statewide monthly TOG emissions by pesticide type. Herbicides account for the vast majority of emissions with insecticides a distant second. Emissions resulting from the application of other pesticide types are practically insignificant by comparison, except for defoliant emissions in June and August. Herbicide emissions were mostly the result of applications classed as non-acreage, whereas insecticide emissions were nearly all from acreage applications.

Table 6-7 shows the distribution of emissions in each of the 58 counties of California for each month of 1977. The annual TOG emissions from formulation 10 oil pesticide applications varied from only 4,000 pounds in Alpine County to nearly 30 million pounds in San Joaquin County. Two facts are evident from this table, and Table 6-8, which shows the monthly emissions in the top 17 counties in California in order of total annual

TABLE 6-5

Summary of Monthly Emission Distribution of Formulation 10 Chemicals Applied in California in 1977

Chemical	Emissions (1000 lbs.)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Mineral Oil	217	301	211	152	147	168	144	205	131	140	72	50	1,938
Petroleum Hydro-carbon	9,450	6,930	8,896	28,947	17,093	19,533	11,816	11,993	6,474	3,220	11,576	400	136,328
Aromatic Petroleum Solvents	273	230	2	13	16	62	32	89	66	6	0	0	789
Petroleum Distil-lates	2	7	14	88	123	406	667	898	429	238	26	6	2,904
Petroleum Oil, Unclassi-fied	5,085	4,330	2,551	1,766	1,653	1,132	843	1,418	2,190	1,778	1,082	1,007	24,835
Diesel & Miscell-aneous Oil	124	223	636	528	1,434	2,837	1,579	2,985	1,529	502	146	24	12,547
Creosote	134	134	187	80	375	161	187	455	348	187	161	268	2,677
TOTAL	15,285	12,155	12,497	31,574	20,841	24,299	15,268	18,043	11,167	6,071	13,063	1,755	182,018

TABLE 6-6

Summary of Monthly Emission Distribution of Formulation 10
Oil Pesticide Applied in California in 1977

Pesticide Type	Emissions (1000 lbs.)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Adjuvants													
-A-	1	7	5	10	27	17	11	18	20	9	3	1	129
Herbicide													
-A-	2,515	5,531	5,190	3,984	1,610	1,632	1,979	2,219	1,110	1,149	667	174	27,760
-O-	7,318	1,849	4,329	25,411	16,792	18,083	11,206	11,289	6,427	2,595	11,159	233	116,691
Insecticide													
-A-	5,203	4,475	2,693	1,993	1,956	1,779	1,584	2,240	2,922	2,029	1,020	1,045	28,939
-O-	58	30	15	52	38	98	243	454	55	61	31	15	1,150
Fungicide & Insecticide													
-A-	0	0	0	0	0	0	0	0	0	1	0	3	4
Herbicide & Insecticide													
-A-	12	11	12	18	29	36	43	34	33	31	22	16	297
Defoliant													
-A-	44	86	64	26	15	2,490	9	1,328	250	2	1	1	4,316
-O-	0	32	0	0	0	1	6	6	1	7	0	0	53
Wood Preservative													
-O-	134	134	187	80	375	161	187	455	348	187	161	268	2,677
TOTAL	15,285	12,155	12,495	31,574	20,842	24,297	15,268	18,043	11,166	6,071	13,064	1,756	182,016

-A- Acreage
-O- Non-Acreage

TABLE 6-7

Summary of Monthly Emission Distribution of Formulation 10 Oil
Pesticides Applied in Each of the 58 California Counties in 1977

COUNTY	Emissions (1000 lbs.)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Alameda	54	35	54	170	119	115	77	93	41	31	73	10	872
Alpine	0	0	0	1	1	1	0	1	0	0	0	0	4
Amador	1	0	1	4	4	3	3	3	2	3	0	1	25
Butte	65	102	115	62	45	34	27	31	19	11	16	7	534
Calaveras	11	17	17	46	29	28	20	20	9	5	17	1	220
Colusa	3	8	31	13	12	20	9	11	6	4	5	4	126
Contra Costa	32	23	29	93	70	68	22	60	27	18	44	9	495
Del Norte	1	0	1	4	2	3	1	2	1	1	2	0	18
El Dorado	10	7	9	19	21	19	11	14	5	3	7	1	126
Fresno	1,096	652	523	2,180	1,383	3,974	1,000	949	311	202	906	89	13,265
Glenn	6	28	54	36	39	40	13	14	13	5	9	2	259
Humboldt	10	4	9	29	23	21	13	20	10	6	14	3	162
Imperial	507	311	365	1,401	871	931	575	857	360	931	865	78	8,052
Inyo	3	2	10	13	9	7	6	8	5	3	4	2	72
Kern	1,346	641	1,411	2,606	1,385	1,562	1,072	1,534	1,046	261	892	103	13,859
Kings	45	282	112	66	49	38	31	1,131	237	29	10	4	2,034
Lake	6	11	7	11	12	8	6	13	2	1	4	1	82
Lassen	7	5	10	11	17	11	10	19	13	7	9	8	127
Los Angeles	241	105	219	732	539	589	514	693	256	194	347	53	4,482
Madera	1,017	502	436	260	714	778	467	477	145	259	596	119	5,770
Marin	14	5	12	43	31	29	19	24	10	7	19	8	221
Mariposa	1	0	1	5	3	3	1	2	1	1	2	0	20
Mendocino	7	4	8	19	18	14	10	16	9	6	11	4	126

TABLE 6-7 (cont'd)

COUNTY	Emissions (1000 lbs.)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Merced	1,524	1,022	521	1,151	734	775	475	523	205	98	87	125	7,140
Modoc	5	4	6	8	13	8	6	14	9	5	7	6	91
Mono	6	2	2	4	3	3	2	2	1	1	1	0	27
Monterey	1,239	768	1,616	5,147	3,310	3,786	2,918	2,534	3,454	362	1,888	69	27,091
Napa	7	4	6	22	16	15	9	14	6	4	9	3	115
Nevada	2	1	3	8	6	5	4	5	3	2	3	1	43
Orange	103	53	108	345	244	231	150	230	115	92	156	18	1,845
Placer	8	5	9	24	20	18	12	21	23	6	12	4	162
Plumas	3	3	4	6	9	6	5	10	7	4	5	4	66
Riverside	74	49	66	132	109	111	128	260	236	285	189	77	1,716
Sacramento	999	915	964	2,351	1,856	1,591	940	1,111	434	210	842	26	12,239
San Benito	22	5	7	19	16	14	9	12	5	3	9	1	122
San Bernardino	86	68	107	188	153	136	110	390	510	317	192	80	2,337
San Diego	84	42	86	250	173	213	140	205	166	141	139	30	1,669
San Francisco	13	3	7	44	29	30	19	20	7	4	20	1	197
San Joaquin	2,294	3,178	2,656	5,877	3,661	3,716	2,478	2,401	846	560	2,246	59	29,992
San Luis Obispo	176	101	87	402	248	279	249	252	80	45	169	5	2,093
San Mateo	35	14	22	77	57	53	31	43	19	13	36	4	404
Santa Barbara	61	217	136	639	246	255	383	295	141	296	103	58	2,830
Santa Clara	80	45	71	190	142	139	84	107	45	33	87	13	1,036
Santa Cruz	37	23	24	50	35	33	21	26	11	7	21	3	291
Shasta	10	4	17	40	38	55	54	66	32	16	15	3	350
Sierra	2	0	1	4	3	2	1	3	2	1	1	1	21
Siskiyou	9	5	10	21	22	17	14	25	13	8	12	7	163
Solano	211	316	275	431	276	271	198	154	56	37	150	6	2,381

TABLE 6-7 (cont'd)

COUNTY	Emissions (1000 lbs.)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Sonoma	17	7	15	49	37	34	21	29	13	10	23	4	259
Stanislaus	1,551	979	607	1,401	867	982	696	819	237	208	617	72	9,036
Sutter	77	81	71	41	30	28	10	11	6	3	6	8	372
Tehama	8	7	64	41	25	18	10	15	6	4	12	3	213
Trinity	2	1	2	13	6	5	3	5	2	1	3	0	43
Tulare	1,540	740	787	3,662	2,307	2,446	1,654	1,546	517	367	1,513	121	17,200
Tuolumne	2	1	3	5	5	5	3	5	2	2	3	1	37
Ventura	197	212	281	809	541	562	448	824	1,379	883	595	418	7,149
Yolo	243	439	273	231	139	77	48	57	25	25	14	6	1,577
Yuba	74	99	157	66	74	82	18	16	9	38	22	7	662
TOTAL	15,284	12,157	12,504	31,572	20,846	24,287	15,258	18,042	11,150	6,079	13,059	1,751	181,989

TABLE 6-8

Summary of Monthly Emission Distribution of Formulation 10
Oil Pesticides Applied in Each of the Top 17 California Counties in 1977 (1000 lbs.)

COUNTY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
San Joaquin	2,294	3,178	2,656	5,877	3,661	3,716	2,478	2,401	864	560	2,246	59	29,990
Monterey	1,239	768	1,616	5,147	3,310	3,786	2,918	2,534	3,454	362	1,888	69	27,091
Tulare	1,540	740	787	3,662	2,307	2,446	1,654	1,546	517	367	1,513	121	17,200
Kern	1,346	641	1,411	2,606	1,385	1,562	1,072	1,534	1,046	261	892	103	13,859
Fresno	1,096	652	523	2,180	1,383	3,974	1,000	949	311	202	906	89	13,265
Sacramento	999	915	964	2,351	1,856	1,591	940	1,111	434	210	842	26	12,239
Stanislaus	1,551	979	607	1,401	867	982	696	819	237	208	617	72	9,027
Imperial	507	311	365	1,401	871	931	575	875	360	931	865	78	8,052
Merced	1,524	1,022	521	1,151	734	775	475	523	205	98	87	125	7,240
Ventura	197	212	281	809	541	562	448	824	1,379	883	595	418	7,149
Madera	1,017	502	436	260	714	778	467	477	145	259	596	119	5,770
Los Angeles	241	105	219	732	539	589	514	693	256	194	347	53	4,482
Santa Barbara	61	217	136	639	246	255	383	295	141	296	103	58	2,830
Solano	211	316	275	431	276	271	198	154	56	37	150	6	2,381
San Bernardino	86	68	107	188	153	136	110	390	510	317	192	80	2,337
San Luis Obispo	176	101	87	402	248	279	249	252	80	45	169	5	2,093
Kings	45	282	112	66	49	38	31	1,131	237	29	10	4	2,034
TOTAL	14,130	11,009	11,103	29,303	19,140	22,671	14,208	16,490	10,232	5,259	12,018	1,485	167,048[a]

a. 91.8% of statewide use.

emissions. First, the counties with the greatest annual emissions are also nonattainment areas for ozone. Consequently, these emissions exacerbate existing standard violations.

Secondly, individual counties have individual temporal distributions of emissions which may differ considerably from the statewide average depicted in Figure 6-3. Examples of counties showing such differences are San Joaquin, Monterey, and Fresno. As described earlier, the statewide average curve in Figure 6-3 peaks strongly in April, then gradually tapers off for the rest of the year with successively smaller peaks in June, August and November. In contrast, San Joaquin County emissions peak in April but taper off gradually without peaks through October. The Monterey County emission pattern is similar to the statewide average except that emissions in September peak at a level comparable to that in May. Fresno County emissions show an annual peak in June rather than April, and June emissions are nearly twice as great as those in April.

Table 6-9 summarizes the monthly distribution of emission by usage and pesticide type for formulation 10 oil applied in San Joaquin, Monterey and Tulare Counties, the top 3 counties for oil pesticide use. The percentages of annual total emissions which occur during the months of June through October in these three counties range from 33 percent in San Joaquin County to 48 percent in Monterey, with Tulare County in the middle range at 38 percent. The emissions from all three counties are mainly derived from two usages: general weed control and agricultural

TABLW 6-9

1977 Summary of Monthly Emission Distribution from Formulation 10 Pesticide Application in 13 Top Counties in California by Use and Type

COUNTY/USE/TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
San Joaquin County													
Agriculture													
Herbicide	509,193	2,288,966	1,667,688	620,003	164,822	91,971	106,543	101,161	15,056	32,378	244	4,017	5,602,042
Insecticide	362,362	548,397	204,302	120,781	199,396	41,846	19,194	9,886	2,507	1,974	781	934	1,512,360
Non-Crop													
Herbicide	0	0	0	1,607	0	9,600	69,992	45,258	69,722	35,079	3,683	368	235,309
Insecticide	0	0	643	3,216	26,352	45,579	105,028	135,249	142,444	60,020	1,908	5,921	526,359
Spreader Sticker													
Adjuvants	0	0	0	1,890	16,320	8,493	0	0	0	0	0	0	26,702
Insecticide	2,797	4,308	1,925	856	466	314	183	105	62	36	22	20	11,095
General Weed Control													
Herbicide	1,415,228	332,403	775,505	5,126,861	3,242,501	3,513,575	2,171,056	2,096,092	623,717	424,821	2,233,893	40,103	21,995,756
Wood Preservation													
Insecticide	3,931	3,931	5,503	2,358	11,005	4,717	5,503	13,364	10,219	5,503	4,717	7,861	78,612
TOTAL	2,293,511	3,178,005	2,655,566	5,877,572	3,660,862	3,716,095	2,477,499	2,401,115	863,727	559,811	2,245,248	59,224	29,988,235
Monterey County													
Agriculture													
Herbicide	37,671	476,726	956,146	840,112	567,060	845,072	1,091,679	766,093	56,044	981	326	28,197	5,666,106
Insecticide	5,154	2,700	2,030	754	374	196	140	96	13	34	0	0	11,491
Non-Crop													
Herbicide	0	0	36	220	329	465	234	442	0	0	0	178	1,904
Insecticide	234	28	78	78	70	765	1,511	214	1,706	562	3,516	2	8,765
Spreader Sticker													
Adjuvants	1,112	6,330	3,079	5,850	7,444	7,282	6,709	10,048	11,247	1,579	1,063	396	62,140
Herbicide	0	0	69	641	93	0	0	31	0	0	0	0	835
General Weed Control													
Herbicide	1,192,125	279,142	650,079	4,297,176	2,726,159	2,928,279	1,813,499	1,746,946	3,377,413	354,996	1,879,486	33,714	21,279,013
Wood Preservation													
Insecticide	2,949	2,948	4,127	1,769	8,254	3,537	4,127	10,022	7,664	4,127	3,537	5,896	58,956
TOTAL	1,239,245	767,874	1,615,644	5,146,600	3,309,783	3,785,596	2,917,899	2,533,892	3,454,087	362,279	1,887,928	68,383	27,089,210
Tulare County													
Agriculture													
Herbicide	170,755	97,470	128,598	867,931	536,231	536,271	334,109	277,089	65,920	60,164	330,640	56,154	3,461,332
Insecticide	598,162	433,521	231,728	112,109	66,558	52,853	138,402	97,687	42,297	32,800	8,798	32,048	1,846,963
Fungicide & Insecticide	0	0	0	0	0	0	0	0	238	14	4	2	258
Herbicide & Insecticide	458	404	518	603	568	574	499	419	7,576	5,710	2,702	1,862	21,893
Non-Crop													
Insecticide	0	0	245	4,879	3,020	15,590	38,528	55,995	62,397	37,626	5,036	0	223,316
Spreader Sticker													
Adjuvants	14	14	17	19	16	14	11	7	4	343	78	31	568
Insecticide	743	2,070	3,018	782	368	173	62	128	105	0	0	0	7,449
General Weed Control													
Herbicide	734,725	173,459	404,134	2,661,389	1,682,659	1,832,858	1,134,879	1,098,115	326,805	222,152	1,159,966	20,996	11,452,137
Wood Preservation													
Insecticide	4,807	4,807	6,729	2,884	13,459	5,768	6,729	16,343	12,497	6,729	5,768	9,613	96,133
TOTAL	1,509,664	711,745	774,987	3,650,596	2,302,879	2,444,101	1,653,219	1,545,783	517,839	365,538	1,512,992	120,706	17,110,049

applications. The percentage of emissions contributed by general weed control and agricultural use respectively are: 73 percent and 24 percent in San Joaquin County, 78 percent and 20 percent in Monterey County, and 67 percent and 31 percent in Tulare County. A further breakdown by commodities for sources of emissions under these two usages in the same three counties is presented in Table 6-10.

In some counties, pesticide applications account for a very large proportion of TOG emissions. Based upon the CARB's 1976 Emission Inventory[a] and the pesticide emission figures in this report, the TOG emissions resulting from formulation 10 oil applications were 64 percent of TOG emissions from all stationary sources in Monterey County and 55 percent in San Joaquin County. Most of the other counties listed in Table 6-5 were in 20-50 percent range, although Kern County, with large oil production operations, was only 5.5 percent. In summary, the emissions resulting from formulation 10 pesticide applications are highly significant in a number of California counties and undoubtedly make a substantial contribution to the ambient ozone standard violations occurring in them.

6.4 Conclusions and Recommendations

A methodology for estimating emissions from applied NSHC

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[a]State of California, Air Resources Board, Emissions Inventory 1976, Sep. 1979. When determining the percent fraction of stationary source TOG emissions attributable to pesticide oil emissions, the pesticide emissions figures reported in the ARB inventory were replaced by those figures reported in this study.

TABLE 6-10

Emission Sources of Major Oil Pesticide Applications by Uses, Types and Commodities in 3 California Counties in 1977

County	AGRICULTURAL USE						GENERAL WEED CONTROL				
	HERBICIDE (%)			INSECTICIDE (%)			HERBICIDE (%)				
	Total	Field Crops & Hay	Fruit & Nut Crops	Total	Field Crops & Hay	Fruit & Nut Crops	Total	School District	Non-Crop	Field Crops & Hay	Fruit & Nut Crops
San Joaquin	19%	18% (alfalfa)	-	5%		5% (Deciduous)	73%	0.2%	14.1%	9.9%	48.8%
Monterey	20%	17% (carrots)	-		-	-	78%	0.2%	15.1%	37.9%	24.8%
Tulare	20%		20% (citrus)	11%	-	11% (Deciduous)	67%	0.3%	12.9%	0.5%	53.3%

pesticides was developed. This method depends primarily on a model developed by Hartley for pesticide volatilization from surface deposits. The basic equation for emission rate estimation is derived from physical principles. After the initial rate is established, the emission rate is considered to follow a time-course through each month which is first order or a summation of two first order time courses.

The factors considered in the methodology include:

. Emission during pesticide application;

. Sorption and sequestering of pesticide;

. Degradation of pesticide;

. Emission from surfaces of soil, vegetated land and water;

. Time-dependent change in emission rate.

Depending on the weather variables during applications and emissions, emission rates calculated with this methodology range from 85 percent to 95 percent of the applied pesticides.

The emission methodology developed in this study is the most comprehensive effort attempted for estimating hydrocarbon emissions resulting from pesticide applications. Attempts were made to include most of the recent published experimental data in the model. There still remain, however, areas in need of additional experimental data to validate and strengthen the model. These areas may include particularly estimation of emission during application, time-dependent changes in emission rate and pesticide degradation.

The 1977 statewide emissions due to formulation 10 NSHC pesticide applications amount to 182 million pounds of TOG or

249 TPD. Compared to the CARB's 1976 Emission Inventory data, these TOG emissions represent 10.7 percent of TOG emissions from all stationary sources in California. The emissions from formulation 10 NSHC pesticide applications varies in individual counties, however. Expressed as a percentage of TOG emissions from all stationary sources, the TOG emissions resulting from NSHC pesticide applications ranged from 64 percent in Monterey County to 5.5 percent in Kern County. It is evident that emissions from NSHC pesticide use in some counties have become a major stationary source of emissions which may have significant impacts on the air quality.

The emission sources of NSHC pesticides come from primarily two usages: agricultural use and general weed control. Data on agricultural use were derived from well supported survey data. The general weed control use data were derived from a limited number of survey responses. The emission data resulting from NSHC pesticide use for general weed control represents the best available data to date.

Based on the findings in this chapter, there are several areas that deserve attention and/or further consideration of research effort. First, some of the parameters (e.g. emission during application, pesticide degradation and soil adsorption) considered in the emission estimation methodology are based on limited available published data. As experimental data becomes available in the future, the methodology should be reviewed and revised.

Secondly, the current emission inventory was based primarily on survey sales and use data. A study of this kind definitely has some advantage in that a large quantity of data can be obtained in a relatively short time in order to generate an approximate estimate. This type of study, however, has some limitations with regard to assuring the accuracy and representativeness of data. Data generated by this approach should be validated by source reconciliation field studies by monitoring and measuring chemically the pollutants which are unique to different emission sources. Validation should include intensive survey of end-users in the studies areas. Such an effort is especially important in better defining the pesticide uses in what are now included in the category of weed control unclassified.

Finally, if emission data presented in this study are to be used to formulate air quality attainment strategies, attention should be directed towards data for specific areas, and control strategies should be based upon the oil pesticide use patterns and the hydrocarbon emission loads during the smog season in each area.

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7.0 ALTERNATIVES TO PESTICIDE OIL USE

7.1 Introduction

This chapter presents alternative methods of pest control which may be used to reduce or substitute for the present use of petroleum oil for pest and weed control in California.

Recommendations for oil use and for alternative pest control methods are described briefly for specific crops and other major uses of pesticide oil. The pest control problem for each crop is presented in more detail in relation to pesticide use, geographical distribution and available alternatives in Appendix A.3.0. Alternatives presented here are not applicable to home and garden uses.

The crops and other uses selected for consideration are those with applications of pure oil (Formulation 10, F-10) of 500 thousand pounds or more. Excluding creosote usage, these applications made up 97.5 percent of the total estimated pure oil application in California in 1977. Oil applications of 500 thousand pounds or more were used for pesticidal control on 12 tree crops, 1 field crop, 1 vegetable crop, unclassified weed control, vector control, and by school districts. The remaining oil use is distributed into 47 other categories in the PUR. Of the 17 commodities listed below, weed control unclassified was by far the largest single recipient of pure oil pesticide application (61.8 percent). With the exception of vector control,

Alfalfa	Grapefruit	Plum
Almond	Lemon	Prune
Apricot	Nectarine	School District
Avocado	Orange	Vector Control
Carrot	Peach	Weed Control Unclassified
Citrus	Pear	

all commodities listed above will be included in this chapter for the consideration of pest control alternatives to oil.

The primary use of oil pesticides in vector control is for mosquito abatement. The only alternative to oil use is synthetic pesticides. However, resistance to synthetic pesticides has been developed and observed. At the present time, there appears to be no alternative approach to mosquito control which is better than the use of oil.

In addition to vector control, there is no apparent substitute for creosote in wood preservation. Creosote is still the primary preservative used for treating wood, but it is increasingly being replaced, where possible, with oil and LPG borne pentachlorophenol and water borne metallic salts. The primary items treated with creosote are railroad ties and piling. Creosote is preferred for these wood products because it has been proven effective in numerous tests during the past century.

Pentachlorophenol (Penta) in oil has been proven an acceptable alternative to creosoted ties in the northern latitudes, but its acceptability in the dry, arid southern latitudes is yet unproven. Penta in oil treated wood costs about the same as creosote treated wood, but cannot be considered an acceptable alternative to creosote for several reasons:

. The oil carrier used with pentachlorophenol has many of the same objectional aromatic hydrocarbons found in creosote and would also have some evaporative hydrocarbon losses.

- Oil is a primary fuel product that has many other uses, but creosote is a by-product with relatively few other uses than wood preserving.
- Penta in oil has not been proven to be as effective as creosote.
- Pentachlorophenol is more toxic than creosote.

Waterborne salts are not acceptable as an alternative to creosoted ties because they provide no lubrication of the wood which results in early mechanical failure of the tie.

Possibly the only promising alternative to creosoted ties is the relatively new use of concrete ties, but as yet sufficient testing has not been completed.

The pest control alternatives to oil considered in this chapter which were found to have some effectiveness for the major oil using crops are the following:

- Use of synthetic pesticides
- Improved oil application methods
- Biological control
- Integrated pest management (IPM)
- Mechanical and cultural control methods.

Although IPM is not a separate pest control method but rather a pest management approach, it is included since it is an alternative under which information is substituted for labor to achieve the most appropriate use of available pest control methods.

Data sources for these alternatives include: an extensive literature search, project consultants, farm advisors in counties where specific oil using crops are grown, researchers at the University of California who are studying pest control on these same crops, and communication with pest control specialists.

7.2 Oil Treatment

7.2.1 Introduction

Whether they are for insecticidal or weed control purposes, petroleum oil pesticides are usually used for specific pests. Those pests which are the targets of oil treatments on individual crops and the treatments recommended for their control are listed and described in this section. Alternatives are considered in relation to the ability of each to control the same pests and to reduce the use of oil below recommended amounts.

7.2.2 Pest Problems

7.2.2.1 Insect and Mite Pests of Citrus

Insecticidal oil use on citrus trees is almost entirely for the control of scale insects and mites. There is infrequent treatment required for citrus aphids. The key pests of citrus which need to be watched and may require annual control measures are California red scale, citrus red mite and citrus bud mite. The major pests of different citrus varieties are for the most part similar except that serious infestations of the citrus bud mite are almost entirely restricted to lemon.[1,2] Each of these citrus pests can cause losses in fruit production by directly damaging fruit, by causing defoliation or fruit drop or by causing general or localized tree debilitation.[3,4]

The pests of the three major citrus growing areas of the state differ as a result of differences in climate and crop varieties grown. In the California Central Valley, California red scale, citracola scale and citrus red mite cause the greatest problems; in the South Coast area, the citrus red mite, the California red scale and the citrus bud mite are the major pests; and in the Southern Interior area, the California red scale and citrus red mite need most attention.

The pest problems vary somewhat in different areas because of the degree to which biological control can be relied upon. In the South Coast area, conditions for biological control are more favorable especially against red scale. Treatment with oils is more extensively used there to pose less interference to the biological control agents. Biological control is less effective in the Southern Interior and are least effective in the San Joaquin Valley. Greater quantities of synthetic pesticides are used in the latter two areas.[5,6]

7.2.2.2 Insect and Mite Pests of Deciduous Tree Crops

Table 7-1 is a key to the insect and mite pests of deciduous fruit trees for which insecticidal spray oil is recommended as a control method. This table shows if the pest is a major pest, an occasional pest, or a secondary outbreak pest and the past distribution among the deciduous fruit trees in the state.

All trees in the group considered serve as hosts to the European red mite, Brown apricot mite, Two-spotted mite and

TABLE 7-1

Pests of Selected Deciduous Fruit Trees
Against Which NSHC Spray Oils are Used as Insecticides

PEST	Almond	Apricot	Nectarine	Peach	Pear	Plum	Prune
Aphids		OS	OS	OS	OS	OS	MS
Black Scale	OS	OS				OS	MS
Brown Apricot Scale	OS	OS	OS	OS	OS	OS	MS
Brown Mite	MS	OS	2S	OS	2S	MS	MS
European Red Mite[a]	2S	OS	OS	OS	MS	OS	MS
Mealy Bugs		OS			OS		
Olive Scale (Parlatoria)	OS		OS	OS		OS	OS
Pacific Mite	2S		2S	OS	2S		
Peach Twig Borer	MS	MS	MS	MS		OS	OS
Pear Psylla					MS		
San Jose Scale	MS	OS	MS	MS	MS	MS	MS
Two Spotted Mite[a]	MS	OS	2S	2S	2S	OS	OS
Walnut Scale	OS		OS	OS			

Key: M - major pest; 0 - occasional or minor pest; 2 - Secondary outbreak pest;
S - Statewide pest

a - The Two-spotted Mite and European Red Mite are annual pests but are in some cases, minor pests.

Brown mite. All but the apricot are also attacked by the San Jose scale. Vitality of the tree, photosynthetic capacity and fruit quality are effected by these pests and control is essential for commercial fruit production. Several of these insect and mite pests are released from their natural control as a result of certain synthetic chemical applications to control pests such as codling moth, navel orange worm, fruit tree leaf roller, omnivorous leaf roller and tentiform leaf miner (see Table 7-1 - secondary outbreak pests).[8-12]

The pear psylla is unique to pears and is a serious pest because it is a carrier of pear decline disease. Lake County has a greater problem with psylla than any other region in the state.[7]

7.2.2.3 Weed Pests of Alfalfa and Carrots

Weeds have always been considered a contaminant in alfalfa hay, but in recent years the severity of the problem has been increasing in alfalfa in the Central Valleys. There are two distinct weed populations in California: the winter annual weeds which germinate with winter rains, and the summer annual weeds consisting primarily of grasses which germinate in early spring and exist through the summer. Alfalfa and carrots are contaminated with both broadleaf and grassy annual weeds. Carrots are being increasingly infested with nutsedge which is becoming a weed pest of increasing importance.

7.2.2.4 Weed Pests of Orchards, Vineyards and Non-Crop Areas

The weeds which grow on orchard floors (including citrus and nut groves), in vineyards and non-crop areas can include almost every kind of weed pest ranging from annual, broadleaf plants such as chickweed (Stellaria media), to annual and perennial grasses and even perennial shrubs such as blackberry (Rubus). Weed oil is used extensively on these areas particularly when non-cultivation is practiced. Weed oil is toxic to nearly all weeds but the degree of control from oil use varies for different weeds.

7.2.3 Recommended Oil Treatments and Current Practices

Pesticide oil treatment recommendations are compiled for those tree crops, field crops, and other reported usages over 500 thousand pounds.

Treatments are required for specific pests of individual crops. The oil treatments for susceptable pests of each crop are identified, and the importance of individual pests on each crop are evaluated. Some pests may require 3 pesticide treatments per season for adequate control. However, if one pesticide treatment is applied for one pest it may also control other pests and thereby substitute for individual treatments. These factors are taken into account in the determination of the average annual pesticide treatments required.

Information for treatment recommendations, number of treatments and the status of different pests were from various literature sources including University of California Extension Service Bulletins, product labels and the EPA Compendium of

Registered Pesticides and also from product consultants, farm advisors in a number of different counties and other experts in the University of California Extension Service. Oil usage in non-crop areas was researched primarily through interviews with persons in the Department of Food and Agriculture, Flood Control Districts, Mosquito Abatement Districts, other governmental agencies and representatives of companies manufacturing pesticide products.

7.2.3.1 Recommended Oil Treatments - Agricultural Crops

Citrus. The amount of oil needed to control insect and mite pests is shown in Table 7-2 for citrus crops. Published recommendations in most cases give the amount of pesticide active ingredient (ai) to be added to each 100 gallons of spray solution. The quantities shown in Table 7-2 are based on estimated average high volume sprays of 1500 gallons per acre. Low volume or concentrate spray recommendations are usually made on a per acre basis.

Across from each crop heading, the estimated annual total amounts of oil required are shown. If oil is used at the appropriate time for the control of one major pest, other oil susceptible pests will also be controlled without the need for separate treatments of each.

Deciduous Fruit Tree Crops. Recommended oil treatments for insect and mite pests of the seven tree crops being examined are outlined in Table 7-3.[8-12] Also included are the estimated annual recommended applications per acre and actual applications

TABLE 7-2

Recommended Oil and Fortified Oil Treatments for Control of Insects and Mites of Citrus Crops

Crop and Pest	Recommended Quantity of Oil per Acre (gallons)	Recommended Quantity of Active Ingredient/Acre (pounds)	Total Gallons of Spray/Acre	Number of Applications/Year	Reported Application Rate (Gal/Acre)	Est. Annual Recommended Gal of Oil per Acre	Reported Annual Application Rate (Gal/Acre)
<u>Citrus Crops</u>							
(Grapefruit, lemon, Orange)	D 23-26[a]		1500	1.25	17.8	29-32	22.3
RS,YS,PS,BS,CS	D 23-26[a]		1500	1.25		29-32	
RM,	D 23-26[a]		1500	1		23-26	
SM,TM	C 10-15[a]		100	1		10-15	
CM (Lemon only)	D 23-26[a]		1500	1		29-32	
RS,YS,PS,BS	D 23-26[a]	Malathion 3.6	1500	1		23-26	
		Carbaryl 14.6					
		Guthion® 2.9					
CM (Lemon only)	D 23-26[a]	Chloro-benzilate 2.26	1500	1		23-26	

Application Rate
D = Dilute or High Volume Spray
C = Concentrate or Low Volume Spray
A = Aerial Spray

a = U.C. Extension Recommendation
b = EPA Compendium
c = Manufacturer's Label
d = Dormant Oil Spray
f = Foliar Oil Spray

Pests
RS = Calif. Red Scale
YS = Yellow Scale
PS = Purple Scale
BS = Black Scale
CS = Citricola Scale
Br = Brown Soft Scale
SS = San Jose Scale
Pa = Parlatoria Scale
OS = Oleander Scale
BA = Brown Apricot Scale
RM = Citrus Red Mite
SM = Pacific Spider Mite
TM = Two-Spotted Mite
CM = Citrus Bud Mite
PM = Pear Rust Mite
EM = European Red Mite
BM = Brown Mite
PL = Pear Leaf Blister Mite
CA = Citrus Aphid
Py = Psylla
PB = Peach Tree Borer

TABLE 7-3

Recommended Oil and Fortified Oil Treatments for Control of Insects and Mites in Deciduous Fruit Tree Crops

Crop and Pest	Recommended Quantity of Oil per Acre (gallons)	Recommended Quantity of Active Ingredient/Acre (pounds)	Total Gallons of Spray/Acre	Number of Applications/Year	Reported Application Rate(Gal/Acre)	Est. Annual Recommended Gal of Oil per Acre	Reported Annual Application Rate (Gal/Acre)
Almond	D 4-7.5			4	4.9	16-30D	19.5
	C 4-6.5			4		12-26C	
Mite eggs	C 8 a,d	Parathion 1.5	100	1		8	
PB,Scales	D 12 a,d	Parathion 2.0	400-450	1		12	
Mites	D 4-6 a,f		400-500	2		4-18	
	C 4-6 a,f		100	2			
SS	D 4 a,f	Diazinon or Ethion 1.0	400-500	2			
BM,SM,TM,EM	C 4-6 a,f	Diazinon or Ethion .75	100				
Apricot	8.7-10.7			3	3.0	26-32	9
Scales	D 12-16 a,d		400-500	1			
	C No concentrate recommendations given a,d						
PB	D 10-12 a,f	Parathion 2.0	400-450	1			
	C No recommendation given a,f						
Mites	D 4 a,f		400-500	1			
Peaches & Nectarines	4-7.5			4		16-30	
				4		15-27	5.1
Scales, Mites (&eggs	D 6-8		400-450	1		6-8	
PB	C 6		100			6	
Scale & Mites	D 4	Parathion 1.0	400-450	1		4	
	C 3	Parathion .75	100			3	
Mites	D 6 a,f		400-500	2		6-18	
	C 6 a,f		100			6-18	
Plums & Prunes	D 2.4-7.5			4.25	4.6	10-32	19.6
	C 2.2-6.8			4.25		9-29	
Scales, Mites (&eggs	D 4-5 a,f	Parathion 2.	400-450	1.25		4-10	
PB	C 3-4 a,f	Parathion 1.5	100			3-8	
SS	D 2-4 a,f	Parathion 4	400-450	1		2-4	
	C 2-3 a,f	Parathion 4	100			2-3	
Mites	D 4-6 a,f		400-500	2		4-18	
	C 4-6 a,f		100			4-18	
Pears	7.5 - 8.7			4.25	5.1	32-37	21.7
Py,SS	D 16-20		400-450	1.25			
Brown Apricot Scale and other scales	C 10-15		100				
Mite eggs and other insects	D 4-6	Parathion 1.0 or Diazanon 1.0	400-450	1.25			
	C 4	Parathion or Diazanon 1.0	100				
or	D 4-6	Guthion-R 1.	400-450				
	C 4	Guthion-R 1.	100				
EM,TM,SM,BM	D 4		400-450	2			
	C 2		100				
Aphids, SM,PL,Py	D 4	Diazinon 1.	400	1			
	C 4	Diazinon 2.	100				

Application Rate

D = Dilute or High Volume Spray
C = Concentrate or Low Volume Spray
A = Aerial Spray

a = U.C. Extension Recommendation
b = EPA Compendium
c = Manufacturer's Label
d = Dormant Oil Spray
f = Foliar Oil Spray

Pests

RS = Calif. Red Scale
YS = Yellow Scale
PS = Purple Scale
BS = Black Scale
CS = Citricola Scale
Br = Brown Soft Scale
SS = San Jose Scale
Pa = Parlatoria Scale
OS = Oleander Scale
BA = Brown Apricot Scale
RM = Citrus Red Mite
SM = Pacific Spider Mite
TM = Two-Spotted Mite
CM = Citrus Bud Mite
PM = Pear Rust Mite
EM = European Red Mite
BM = Brown Mite
PL = Pear Leaf Blister Mite
CA = Citrus Aphid
Py = Psylla
PB = Peach Tree Borer

per acre based on U.C. Extension recommendations and PUR data, respectively. Oil applications were mostly supreme or superior type oils. Because such a large percentage of use is highly refined oil types, emphasis will be given to recommendations for supreme oils. Formulation 10 agricultural insecticide applications for the seven deciduous fruit crops totaled 16,039,000 pounds. A more detailed breakdown of individual spray recommendations for the seven different tree crops and the home and garden use on deciduous fruit trees is located in Appendix A.3.0.

Alfalfa and Carrot. Non-selective weed oils are very phytotoxic and are used for winter weed control in alfalfa fields when the alfalfa is dormant. The above ground portion of the alfalfa is killed back with the weeds but regrows from the crown when dormancy breaks. Weed oils are used before seeding or transplanting and after harvest for general contact weed control in carrots. Use patterns derived from 1977 PUR data show that selective weed oils or stoddard solvents are applied both pre-emergent and postemergent for carrots. Weed oils are effective in controlling most weed species when adequate amounts are applied, but they have no residual effect on controlling weeds that germinate after treatment. Additionally, for carrots, weed oil is the only herbicide currently available in Kern County for controlling yellow nutsedge which is becoming an increasingly important weed pest.[13] Table 7-4 describes the recommended oil and fortified oil treatments for alfalfa and carrots.

7.2.3.2 Recommended Oil Treatments - Orchards, Vineyards and Non-Crop Areas

TABLE 7-4

Recommended Oil and Fortified Oil Treatments for Weed Control in Field and Row Crops

Crop and Pest	Recommended Quantity of Oil per Acre (gallons)	Recommended Quantity of Active Ingredient/Acre (pounds)	Total Gallons of Spray/Acre	Number of Applications/Year	Reported Application Rate (Gal/Acre)	Est. Annual Recommended Gal of Oil per Acre	Reported Annual Application Rate (Gal/Acre)
Alfalfa Winter Weeds	Weed Oil D 25-70 [c]		75-210[c]	1	27	25-70	27
	Weed Oil D 2 [a]	Diuron 1.25 DNBP 2.5[a]	75[a] 75[a]	1		75 75	
	Weed Oil D 30-40 [a]	DNBP 1.25	60-80[a]	1		30-40	
	Weed Oil A 10 [a]	DNBP 1.25[a]	10[a]	1	13	10	13
Summer Desiccation	Weed Oil D ≤ 40 [c]		120[c]			50	
	Weed Oil A ≤ 15 [c]		15[c]	1.25	10	19	15
Carrots Annual Weeds	Carrot Oil Stoddard C 50-100[a]		50-100[a]	1.25	69	63-125	86

Application Rate

D = Dilute or High Volume Spray
C = Concentrate or Low Volume Spray
A = Aerial Spray

a = U.C. Extension Recommendation
b = EPA Compendium
c = Manufacturer's Label
d = Dormant Oil Spray
f = Foliar Oil Spray

Weed oils of the general contact type are usually applied for weed control in orchards, vineyards and non-crop areas. Recommended application rates for these uses are shown in Table 7-5.

There is no herbicide oil use reported for these categories in the 1977 PUR. Actual use of weed oil for these purposes appears to be very high as noted in the use pattern discussion (Section 5.3.3). It is probable that most of the weed oil which is placed in the category of Weed Control Unclassified in the Application Inventory, Use Patterns and other sections of this report was applied for the uses indicated here. The applications are made by farmers and others on their own land in which case no reporting is required.

There is some uncertainty involved with estimating the amount of weed oil which is used per acre of fruit crops and on non-crop areas. In orchards different patterns of herbicide use may be employed. The complete orchard floor may be sprayed or only a strip along the tree row. If non-cultivation is practiced, frequent spraying initially may be followed by spot treatments where weeds reappear.[14,15] In non-crop areas the number of applications in one year depends much on the amount and timing of rainfall. Spot applications are frequently used in non-crop areas, also.[16,17]

7.2.3.3 Pesticide Oil Use in Non-Agricultural Practice

The pesticide oil uses considered here are those of non-agricultural usages over 500 thousand pounds or more. These categories include school districts and vector control. The

TABLE 7-5

Recommended Oil and Fortified Oil Treatments for Control of Weeds in Fruit and Nut Crops and Non-Crop Areas[a]

Crop	Recommended Quantity of Oil Per Acre (Gallons)	Recommended Quantity Synthetic Ingredients Per Acre (Pounds)	Total Gallons of Spray Per Acre	No. of Applications Per Year	Estimated Gallons Oil Per Acre
Almonds, Apples, Apricots, Avocados, Cherries, Dates, Grapes, Grapefruit, Lemons, Oranges, Nectarines, Olives, Peaches, Pears, Plums, Prunes, Walnuts	1. Pure Oil 40-100[b]		100-200	1-4	40-400
	2. Fortified Oil Weed Oil[c] 2-25	Dinoseb 1.25-10	100	1-4	2-100
Non-Crop Land	1. Pure Oil 30-80[c]		30-160	1-4	30-320
	2. Fortified Oil Weed Oil 5-25[d]	Dinoseb 2.25-3.75	100	1-4	5-100

a - Recommended quantities are not for use as a guide for application of pesticides.

b - Source, U.C. Extension Recommendations.

c - Source, Manufacturers Labels.

other area, weed control unclassified, which falls partly under this category, is discussed in Section 7.2.3.2.

School Districts. Oil use by school districts contributed 1.8 percent to the state's total estimated F-10 oil usage in 1977. Herbicidal oils accounted for 87 percent of the 3,979,000 pounds of F-10 oil used by the school districts, and insecticidal oils accounted for the remaining 13 percent.

Herbicides were primarily applied to maintain ball field boundaries, to keep sprinklers clear of weeds, and to control weeds along fencelines and around buildings. Because it has a relatively slight health impact on humans, its use is preferred by school districts.[18,19] One synthetic herbicide, Roundup® (glyphosate), at four quarts per one hundred gallons of water is recommended as a perennial weed control agent around school yards and buildings.

The majority of insecticidal oil use was with the product GB-1111, a mosquito larvicide, applied by a school district in Los Angeles County.

Vector Control. The primary thrust of vector control is misquito abatement. This purpose is accomplished by three methods:

1. biological control,
2. physical control (source reduction), and
3. chemical control.

Chemical control in 1977 involved herbicide and insecticide applications. Of the states total nonsynthetic hydrocarbon usage, vector control contributed 0.2 percent to the herbicidal usage and 1.8 percent of the insecticide total. A total of 4,438,000 pounds was estimated for vector control usage of which 92 percent (4,077,000 pounds) were insecticides and the remaining 8 percent (361,000 pounds) were herbicides. Herbicide use is a type of source reduction whereby potential mosquito habitat is eliminated.[20]

Nonsynthetic hydrocarbons as herbicides were mostly used in one county. An estimated total of 247,097 pounds or 69 percent of the state's total was used in San Joaquin County. Herbicides are reportedly used for weed control around filtration and water treatment ponds to eliminate mosquito habitat.[21]

San Joaquin County supports a large dairy industry which provides prime habitat for mosquitos. Dairy drains are difficult habitats for controling mosquitos because of the high organic and particulate matter in the effluent. Weed oils are used as a dual purpose herbicide/larvicide at rates of at least 30 gallons per acre depending on individual locations.

Vector control is currently using large quantities of synthetic pesticides in the mosquito abatement programs. Table 7-6 lists some of these chemicals, their effective target stages, and the total pounds of each compound reported in 1977.

Problems of resistance in mosquitos is common with organophosphate compounds and they must be used with discretion.

Malathion is a preferred control agent because of its effectiveness against adults and larvae. However, it is also very toxic to honeybees.[21]

TABLE 7-6

Synthetic Pesticides Used in Vector Control

Pesticide	Target Stage[a]	Pounds Used
Malathion	AL	154,960
Baytex (Fenthion)	La	16,991
Baygon (Propoxus)	Al	5,027
Dursban	Al	3,963

[a]Upper case letters indicate primary use A - adulticide
L - Larvicide,
Lower case letters indicate secondary use a - adulticide
l - larvicide.

Another synthetic pyrethroid, Pydrin, receiving research attention may be valuable in the future. However, it is a biocide and kills a broad spectrum of aquatic organisms. Because of this, it's use is being discouraged in aquatic environments by the manufacturers.[22]

Dursban is an extremely effective larvicide early in the year because of its residual action; however, this chemical is usually applied once at the beginning of the season because larval resistance develops rapidly as the season progresses, and as resistance increases, the only practical means of control are oil sprays.

7.2.4 Discussion and Recommendations

7.2.4.1 Citrus

Oil sprays are used on citrus because they can control several different insects and mites while parasites and predators of these pests are relatively little affected.

There are two ways that can be employed to modify the oil spraying method on citrus, and at the same time result in a reduction of oil use. One way is to make more widespread use of low volume sprays for mite control in accordance with Extension Service recommendations. The savings from this would be about 10 to 15 percent of current use on citrus. The second method would be the adoption of air tower sprayers for all high volume applications. This has been shown to give adequate spray coverage with about 25 percent less oil. About 10 to 15 percent of total use on citrus might be saved by use of this method for all high volume spraying since it is already being used to some extent.

The published recommendations for pest control in citrus crops include the use of oil fortified with added synthetic pesticides. In almost all of these recommendations, the same amount of oil is used whether it is fortified or not. Therefore, fortified oil will not be considered as an alternative for reduction of oil usage.

7.2.4.2 Dormant Season Control of Deciduous Fruit Trees

Dormant season control of mites, scale insects, and psylla is essential in keeping these pests below economically damaging levels. This is reflected in the fact that 87 percent of the reported oil usage was applied during the three month dormant season and that all U.C. recommendations show extensive dormant season programs. Both supreme and superior oils and dormant oils are applied at this time while only the more highly refined supreme and superior oils are applied during the foliar season. The amount of dormant oils used per acre could be reduced 50 percent if growers now spraying less refined dormant oils at rates of 16 gallons per acre change to the highly refined supreme or superior oils which are applied at 8 gallons per acre. Use of these lighter products have several limitations among which are shorter residual action, less suffocating power, and failure to stimulate uniform bud break. However, the total savings would be relatively small since 95 percent of the reported dormant oil use is already supreme and superior oil types.

Approximately 50 percent of the deciduous fruit tree acreage for the seven crops being considered is sprayed with dilute or high volume sprays. A 20 percent reduction in oil use could be achieved by growers who are currently using dilute spray methods (400 or more gallons per acre) if they would switch to concentrate spray treatments (100 gallons or less of spray per acre).[7]

Approximately 25 percent of the commercial growers using dilute spray techniques still exceed U.C. recommendations for this method.[7] Excessive dilute sprays (greater than 500 gallons per acre) yield substantial loss due to runoff. Pears, for example, are planted approximately 120 trees per acre. A loss of 1 gallon of spray per tree would result in 120 gallons of spray lost per acre of approximately five gallons of oil (dilute spray).[7]

Fortunately, more and more growers are using the lower volume sprays that the U.C. Extension Service recommends as success is seen and satisfactory, money-saving methods are tried and developed by farmers and U.C. Extension workers.[23]

Dormant oil treatments which are fortified with synthetic pesticides require one third to one half the volume of oil applications without synthetic supplements. This is approximately 4.8 gallons less oil per acre for pears, peaches, and nectarines. When highly refined oils are used (supreme and superior types and light medium summer oils), no reduction in volume is recommended with the addition of synthetic chemicals.

7.2.4.3 Foliar Sprays

Recommended oil applications from bud break through the post harvest season and until leaf drop are for highly refined supreme and superior oil. Dormant oils are avoided because of their high potential for phytotoxic effects.

Foliar application with summer oil is preferred by pear and prune growers because of the effective control obtainable for mites and scale insects with one relatively inexpensive product.

Foliar oil use can be reduced as growers switch to low volume, concentrate sprays and adhere more closely to recommended application rates.

7.2.4.4 Row and Field Crops

The 1977 PUR shows the average application of weed oil to be 27 gallons per acre by ground and 13 gallons per acre by air for winter weed control in dormant alfalfa, and these applications are right in line with recommended rates of 30-40 gallons per acre by ground and up to 15 gallons by air.

In areas south of Delano, California where alfalfa is not as dormant and winter weeds are less of a problem, oil can be used at rates as low as 2 gallons per acre as an adjuvant when mixed with DNBP and diuron with diuron being the primary control chemical.[13] However, 98 percent of the 1977 PUR reported oil used for winter weed control on alfalfa was applied north of Delano; therefore, further reduction of the current weed oil application rates cannot be recommended for reducing the quantity of weed oils reported.

According to the 1977 PUR, the application rates for weed oil and carrot oil for use on carrots, are also right in line with recommended rates. Therefore, reduced oil application rates cannot be recommended. However, as most row crop weed control with oil is done by broadcast spraying, a combination of cultivating the furrow and band spraying on the seed bed could probably cut oil use in half but this may not be practical. These operations would have to be done together so that the sprinkler irrigation lines would only have to be broken and moved as few times as possible. Cultivating the furrows can be considered to be as effective as a contact weed oil for controlling weeds that have germinated but the cultivation will bring new weed seeds to the surface which will germinate after the next irrigation and will necessitate control again. Each additional cultivation would cost about $4 per acre for cultivating and $7 per acre for moving the sprinklers. Additionally, if the sprinklers are not reinstalled soon enough and the crop becomes drought stressed, there is a chance of reduced productivity.[13] The contact oil spray does not enhance new weed seed germination and can be considered the preferred treatment.

7.3 Pesticide Application Techniques

7.3.1 Introduction

The primary objective of locating alternatives is to eliminate or reduce the usage of nonsynthetic pesticides. The use of appropriate application techniques will not substitute for the use of oil pesticide but would definitely lead to a reduction of pesticide oil consumption. The purpose of this section is to examine the different techniques available for oil applications and the existing methods used for oil applications in California. An evaluation will be made of the current application practices to identify any unnecessary wastes and losses in oil usage.

7.3.2 Pesticide Application Methods and Equipment

The most important determining factor in selecting an appropriate application method is the pesticide formulation type. The formulation types can be classified according to their physical state.[24] Oil sprays are formulated as solutions and emulsions. The discussion here will be confined to the application methods and equipment used for oil spraying.

Spray applications vary greatly in methods of application and application equipment according to the crop types. For the purpose of this report, the discussion will be made for ground and aerial applications.

7.3.2.1 Ground Application

The primary target of ground spray are soil and plant surfaces. When oil is used for herbicidal and insecticidal purposes, the spray is applied to the weeds and plants directly. Due to the difference in plant height, oil application equipment for weed control in field crops (e.g. alfalfa and carrots) differs from that for spraying tree crops (e.g. citrus, prune, nectarine, etc.). The application methods for these two crop types are therefore presented separately.

Field Crops. There are two field crops considered in this study: carrots and alfalfa. Field crops are treated nearly exclusively with ground spray methods in herbicidal applications. Oil herbicides are applied to carrots both preemergent and postemergent. Alfalfa is primarily treated with oil spray during the dormant season, but oil is occasionally used as a preharvest dessicant when harvesting alfalfa seed. Oil pesticides are formulated as water emulsions and are formed with emulsifiable concentrates which are diluted with water before application.

There are two basic forms of application used in field crops.[25] They are broadcast and band applications. Broadcast applications are sprayed from nozzles mounted along a boom or mounted on the spray tank. Booms are carried on the tractor and fed from the spray tank. Boomless operations consist mainly of nozzles attached to the sides or back of the spray tank. Band applications cover areas of only 7-14 inches wide from nozzles mounted on a boom. Distances between bands can be adjusted according to the spacing between plant rows. In tall row crops such as corn, the booms and tractor used for transporting the spray nozzles are high-clearance and self-propelled units. The nozzles used for each of the two types of operations are:

(a) Broadcast applications may use fan spray and flooding nozzles mounted on booms and flat spray in boomless operations.

(b) Band applications may use fan spray nozzles.

The quantity of pesticide applied on each acre of field crop varies according to the nature of treatment. The amount of spray applied on a per acre basis is generally classified as ultra low volume (ULV), low volume (LV), or high volume (HV). The terms ULV, LV and HV are relative terms which are not precisely defined, and the volume per acre associated with each varies for different types of operations.[25] The volumes of spray per acre associated with ULV, LV and HV are defined for each crop type (e.g. field crops, tree crops) and application operation (e.g. ground and aerial applications).

ULV for field crop ground application is less than 10 gallons per acre for broadcast, band and foliar applications. LV is 10-40 gallons per acre for all three operations, and HV is greater than 40 gallons per acre for all three operations. Oil herbicides are usually applied in HV or LV.

Tree Crops. Oils are primarily used as insecticides and to a much smaller extent as herbicides on tree crops. Oil insecticides are sprayed on the trees from airblast machines and spray guns in ground operations. As in field crop applications, oil sprays are applied as emulsive formulations diluted with water.[23]

Oil sprays are applied on tree crops with either low-volume spray using airblast or with low-volume and high-volume using a vertical boom or an airblast technique. High-volume applications of foliar pesticides are achieved by wetting the trees to the runoff point in order to provide adequate coverage and uniform distribution. The spray tank is mounted on a truck, and normally automatic or hand-held spray guns are used. Airblast sprayers consist of a spray tank, large blower, and peripheral nozzle arrangements. The sprayers are usually mounted on tractors or trucks or are tractor drawn.[2,22]

The quantity of spray solution applied to tree crops by ground equipment is classified as LV (100 gallons per acre or less) or high-volume (over 100 gallons per acre). High-volume applications average about 400 gallons per acre on deciduous tree crops and about 1500 gallons per acre on citrus crops.[2,8-12]

7.3.2.2 Aerial Application

Most of the pesticide oils involved in aerial spraying are used as insecticides on tree crops in California. Some applications are performed on the field crops, alfalfa and carrot, but only on rare instances since most herbicides are applied as ground spray.

Aerial oil sprays are applied as emulsifiable concentrates. These formulations are usually applied with a broadcast spray over the entire crop. Aircraft used are either fixed wing or rotary type. These aircraft have components similar to ground rigs and continuous spray booms with nozzles spaced about 1 foot apart are mounted below the aircraft to spray the pesticide. The nozzles used with aircraft are hollow cone for fine sprays, and fan spray and jet nozzles are used for bigger droplets.[25]

The quantity of aerial sprays applied per acre can be either classified as LV (1-16 gallons per acre) with typical application rates between 3-5 gallons per acre, or ULV (below 1 gallon per acre) with typical application rates of 1-2 pints per acre.

The height from which an application is made varies with the type of crop being treated. Field crops are applied at 10-15 feet while tree crops are sprayed at heights just above the trees.

7.3.3 Potential Wastes and Losses in Pesticide Application

For the purposes of this study, the definitions of pesticide wastage and losses are adopted from a 1975 EPA study.[25] Pesticide wastage is defined as pesticide use which is unnecessary and over used. Unnecessary use of pesticide is the use of a pesticide in the absence of an established need to control or suppress the target pest. A case in point is the use of pesticides in preprogrammed application schedules based on the calendar instead of actual need. Overuse of pesticide is the use of pesticide at a rate of application higher than necessary for the intended pest control or suppression purpose. Pesticide overuse may result from lack of information or misinformation on the part of the applicators or from equipment problems. Pesticide overuse may occur during application as a result of miscalibration of application equipment, driving at a slower speed than the equipment is calibrated for or excessive overlaping of application areas.

Pesticide losses are defined as unwanted pesticide deposits or pesticide quantities that do not reach the intended target. These losses, therefore, do not contribute to the control purposes of the application. Drift during application and runoff after application are two typical losses.

In exploring pesticide wastes and losses, the emphasis will be placed on pesticide overuse during application and losses which occur during and after application. Unnecessary pesticide use is a practice which is difficult to quantify. The question of whether and to what extent pesticides are used unnecessarily cannot be answered in general terms but in relation to specific crops. Such an answer would involve extensive efforts in data collection which is beyond the scope of this study. Therefore, unnecessary pesticide use in California will not be considered.

7.3.3.1 Potential Pesticide Wastes

Overuse of pesticide is one of the primary sources of pesticide wastage occurring during application. This overuse of pesticides occurs mainly because of physical equipment problems or problems in operating the equipment properly. Efficient use of pesticide depends on proper use of the application equipment. Improper use of equipment, either due to defects in equipment construction or calibration or due to improper operation will result in nonuniform pesticide distribution which in turn will lead to an increased requirement of chemicals in order to achieve the desired control.[25]

Pesticide overuse will be discussed under two headings: the physical equipment factors and equipment operation factors. Discussion will be made regarding the way these factors effect the efficient use of pesticides.

7.3.3.1.1 Physical Equipment Factors

Since oil pesticides are primarily applied by spraying, the discussion will be confined to spray equipment. The spray equipment features examined here which affect the rate and uniformity of application are nozzles and spray tank agitation.

<u>Nozzles</u>. Spray nozzles, together with discharge pressure, control the rate of application and size of the sprayed droplets. Nozzles vary in types, orifice size, and material of construction.[25] Each of these variables is important in determining the effectiveness and efficiency of the spray application.

When nozzles are improperly used, overuse of chemical may occur due to nonuniform distribution and overapplication. This occurrence is derived from improper atomization, clogging and nozzle wear.

Improper atomization takes place when droplets are formed either too large or too small. If they are too large, coverage is often spotty and nonuniform. If they are too small, droplet drift increases, and deposition on the target is less likely. Even when the proper nozzles are used on a boom-type applicator, problems can still occur. The rate of application is a function of the spacing of the nozzles on the boom, nozzle orifice size, nozzle pressure, and speed of travel. All these factors have been calibrated and tested to obtain a specific application rate. A variation of any one of these factors from recommended specifications may lead to overapplication.

Clogging occurs when nozzles are not properly maintained. This occurrence is more prevalent with small orifice nozzles. When clogging occurs, the uniformity of application is adversely affected.

Nozzle wear is mainly a problem with the use of abrasive wettable powder formulations. The wear is especially rapid in nozzles constructed with brass.[4] As the wear increases, the increased application rate will lead to overapplication. Nozzle wear is much less a problem in oil pesticide usage.

Spray Tank Agitation. Pesticide holding tanks used in spray application are agitated mechanically or hydraulically. Mechanical agitation is normally used for oil emulsions and wettable powders, where as hydraulic agitation is commonly used for soluble or self-emulsifying solutions. Agitation is necessary to keep the spray ingredients uniformly mixed, especially in the case of oil emulsions. If they are allowed to stand, the formulations may separate from the water. When separation does occur, the uniformity of application is adversely affected.[26]

7.3.3.1.2 Equipment Operation Factors

In order to minimize overapplication and nonuniform distribution of pesticide, the application equipment must be operated properly. The primary factors of concern include equipment calibration, proper travel speed of carrier, proper height of spray boom, proper pesticide formulation, and aircraft spray distribution.

Equipment Calibration. In order to insure a proper application rate, the spray equipment must be calibrated prior to operation.

One of the major problems associated with equipment calibration is that operators do not follow recommended procedures for calibration but rather rely on their own judgment and experience. These practices may lead to over or under application rates.[25]

Another problem is caused by the fact that spray calibrations are made with water. This practice can cause difficulties because the viscosity or density of the pesticide formulation often varies from that of water. The application rate of the pesticide could be higher than that of the water. In these cases, the equipment should be rechecked or recalibrated with the pesticide at the beginning of crop treatment. This same problem may also exist between application of different pesticides. The calibration of equipment for the use of one formulation may not be appropriate for a different formulation. A risk of overapplication results if recalibration is not done.

One last problem is associated with human error in calibration. Mathematical miscalculations can occur at the time of calibration, and the actual application rate may be different from the calculated one.

Proper Carrier Travel Speed. The rate of application varies inversely with the travel speed of the applicator carrier. A constant application rate requires maintaining a constant carrier speed. This is difficult to do under certain operating conditions such as uphill slopes, turning around, or encountering obstacles. Overapplication occurs when the vehicle is operated slower than is required. Conversely, an excessive speed may cause underapplication and poor pest control, a result which may lead the grower to overcompensate by using higher application rates the following season.

Height of Spray Boom. Booms of ground spray equipment that hold the nozzles must be operated at the proper height. Since nozzles are normally designed to spray at a high rate directly beneath, and at a lower rate at the periphery of the spray pattern, a 50 percent overlap between nozzle spray patterns is frequently used to provide uniform coverage. Once the nozzle spacings on the boom are fixed, the height of the boom determines the distribution pattern.

Whenever using fan-spray, solid-cone, or hollow-cone nozzles, the distribution pattern of the spray is affected less by having the boom too high than by having it too low. High boom settings cause excessive overlap while low boom settings cause insufficient overlap.[27]

Improper Pesticide Formulation. Incorrect concentration of mixed formulation can be caused by improper measurements, misinterpretations of the label recommendations or miscalculations on the part of the applicator. When the concentration is higher than that intended, overapplication will result.

Aircraft Spray Distribution. Fixed-wing aircraft flying at low levels have wide variations in the spray deposit pattern on the ground beneath them. This nonuniform distribution of deposit pattern occurs regardless of the nozzle size and nozzle spacing arrangements.[28] Much effort has been extended in the search for a solution. The problem, however, appears to be insolvable since no nozzle arrangement or spacing can accommodate the many atmospheric conditions that exist in actual field operations.[29]

7.3.3.2 Potential Pesticide Losses

Pesticide loss occurs both during and after its application. Pesticides are lost into the environment at the time of application when they drift away from the crop being treated and impact away from the target area. After the pesticides are applied, a portion of the deposit on the crop may be washed off. The principal mechanisms of pesticide transport away from treated fields after the application are surface runoff, volatilization and leaching.[25] Generally, surface runoff and volatilization are the dominant mechanisms for post application pesticide loss from cropland. Volatilization, however, is a process which is beyond the control of the applicator once the pesticide has been properly applied. Since this section deals primarily with wastes and losses associated with application methods and equipment, only loss due to drift will be considered.

Drift is a very complex mechanism which is determined by different interrelated factors. The potential for the occurrence of spray drift depends primarily upon meteorological conditions, properties of the particle itself, and operational application techniques.

Important factors under particle properties which affect drift include particle density, particle shape and particle size. Of the three factors, particle size is by far the most important factor affecting the drift potential. The particle size itself is affected by operational application parameters. The most important variables affecting the size of spray particles are:

- Nozzles - types, sizes and orientation
- Discharge pressure
- Liquid properties - viscosity, vapor pressure, density and surface tension
- Additives and formulations

Pesticide sprays when released into the air are subject to drift from the target area as a result of atmospheric transport. The meteorological conditions which affect drift the most are:

. Wind direction and velocity

. Turbulence

. Relative humidity and air temperature

. Atmospheric stability

Besides the above general parameters, there are other specific parameters such as sedimentation and impaction which will also have affects on the pesticide drift potential. Sedimentation is simply the settling of a particle in the air onto a surface.[2] Pesticide particles when released into the air are attracted by gravitational forces and settle toward the earth. They accelerate until they reach a constant velocity known as the terminal velocity. Particle resistance to drift is directly related to this terminal velocity since the time the particle remains in the air is dependent upon this velocity. As terminal velocity increases, the drift potential decreases.

Impaction is the collection of a particle carried in an airstream upon the vertical surface of an object.[25] Pesticides released into the air are subject to diversion from their vertical path towards the earth by horizontal movement. The particles tend to follow a divergent flow around the target and not to impact. The degree to which impaction occurs is referred to as the impaction efficiency, expressed as a percent of the particles collected to those that would have collected on the object had they not been deflected from their original course.

Based on studies of the relationships between drift, sedimentation and impaction and size spectrum and particle evaporation, Von Rumker et. al. made the following conclusions:[25,30-37]

(1) All pesticide droplets in water carriers having an initial droplet size less than 120μ have a greater than 50 percent chance of drifting 1000 feet or more in 3 to 5 mph winds when applied by aircraft flying 10 feet or more above the ground.

(2) All pesticide droplets in water carriers having an initial droplet size less than 80μ have a greater than 50 percent chance of drifting 100 feet or more in 3 to 5 mph winds when sprayed from ground equipment from a height of 3 feet above the ground.

(3) All pesticide droplets in water carriers having an initial droplet size less than 50μ have a greater than 50 percent chance of drifting 100 feet or more in 3 to 5 mph winds when sprayed from ground equipment from a height of 6 inches above the ground.

Combining these conclusions with information on particle size, release height and drift potential in relation to application equipment and application methods to application target and volume of spray, Von Rumker et. al. constructed a table to show the estimated likelihood of pesticide drift during crop treatment in agriculture.[25] The estimate of spray drift by method of application is presented in Table 7-7.

TABLE 7-7

Likelihood of Pesticide Drift During Agricultural Crop Treatment with Different Methods of Application

Formulation	Equipment Type	Pesticide Application Methods	Target	Spray Application Volume	Estimated percent Drift over 1,000 Feet from Target
Spray	Tractor, boom sprayer	Ground, foliar	Plants	ULV	5-10
		Ground, foliar	Plants	LV	1
		Ground, broadcast	Soil	LV	Negligible
		Ground, broadcast	Soil	HV	Negligible
		Ground, band	Soil	ULV	Negligible
		Ground, band	Soil	LV	Negligible
	Tractor, boomless sprayer	Ground, broadcast	Soil	LV	Negligible
		Ground, broadcast	Soil	HV	Negligible
	Spray gun	Ground, foliar	Trees	HV	3-5
	Orchard airblaster	Ground, foliar	Trees	ULV	40-70
		Ground, foliar	Trees	LV	10-40
	Aircraft, boom sprayer	Air, foliar	Trees	ULV	40-60
		Air, foliar	Trees	LV	10-40
		Air, foliar	Plants	ULV	40-60
		Air, foliar	Plants	LV	10-40
		Air, broadcast	Soil	LV	10-40

7.3.4 Quantifying Wastes and Losses

Based on the above discussions, wastes resulting from overuse and losses from drift involve many factors which frequently are site and crop specific. Quantification of the overuse wastes and drift losses appears to be very difficult. The pesticide overuse caused by nozzle problems and poor tank agitation can be quantified. Such an effort which involves an inventory of the number of nozzles that clog or wear out during application and the number of tanks that are improperly agitated would require time and data far beyond that available to this project. Quantification of operational factors is even more difficult.

Quantification of drift losses for the 14 crops and three usages considered in this study would involve even more time and resources. Such an effort would require consideration of specific application methods and equipment, application rates, formulation types, application time, and specific meteorological parameters associated with the application time and site. A detailed treatment of this subject is outside the purview of this project.

A limited consideration on quantifying the overuse waste and drift loss resulting from oil application on the 14 crops in California is presented below. Due to the limited data and resources, this consideration is necessarily based on certain assumptions. No waste and drift estimates were made of the non-acreage oil use for vector control, school districts, and weed control unclassified. In the absence of acreage data, it is difficult to arrive at reasonable estimates.

7.3.4.1 Current Pesticide Application Practices in California

Prior to quantifying wastes and losses, a brief description of the application practices currently used in California for the 14 crops that are considered in this report is in order. The following information was obtained from farm advisors and researchers.[27-29]

Field and vegetable crops are always sprayed with ground equipment using horizontal booms except when the fields are too wet to get in with spray rigs. Application of weed oil and water mixtures of up to 200 gallons of spray per acre requires large tanks and high pressure systems (40 to 80 psi) to deliver that amount of spray. Efficient spraying practices usually require the use of 1 or 2 vehicles to nurse the spray rig with water and oil. Ground spraying with fortified weed oil or water based synthetics at rates of 40 - 100 gallons of total spray per acre requires less spray pressure (30 psi) and means that more acreage can be covered between filling operations.[28]

Aerial application of weed oil for annual weed control in carrots is rarely practiced. Aerial spraying of alfalfa is almost completely limited to seed crop desiccation as the large quantities of oil required for effective winter weed control make aerial application prohibitively expensive. Aerial application of weed oils for seed desiccation is used to reduce the loss of seed from seed pod shattering which can occur with ground spray equipment.

Winter weed control with nonselective weed oil in dormant alfalfa, and prior to planting carrots is usually done with ground spray rigs using horizontal booms to apply a broadcast spray. In areas of the state where winter rains turn the fields muddy, the spray rigs are equipped with high flotation tires. Occassionally, however, the fields become too wet for any vehicle to get in and aerial spraying may be used. Spring and summer weed control in carrots using carrot oil or stoddard solvent as selective weed oils is also done as a broadcast spray using horizontal booms on ground spray rigs.

Under the assumption that all acreage sprayed by aerial application is representative of that reported in the PUR, 1 percent of the alfalfa seed acreage was desiccated by aerial applications in 1977. These applications are usually done with undiluted, fortified oil.

Ground application is the primary method used for spraying deciduous and citrus tree crops. Aerial applications of deciduous tree crops accounts for approximately 20 percent of the total oil spray applications.[22]

For citrus tree crops, spraying is done by ground rigs using a vertical boom or by air blast sprayers. Most applications are high volume and about 20 percent are low volume applications. For deciduous fruit trees, ground applications are conducted primarily with air blast sprayers.[22]

Table 7-8 summarizes the application methods used in California for the 14 crops which are considered in this study. Estimated percentages of use of each method is also included.

TABLE 7-8

Summary of Application Methods and Percentage of Practice Used for Each Crop in California

Crop	Aerial Application (%)	GROUND APPLICATION (%)			
		Boom		Air Blast	
		Horizontal	Vertical	Dilute	Concentrate
Insecticide					
Grapefruit			40	40	20
Lemon			40	40	20
Orange			40	40	20
Almond	20			50	30
Apricot	20			50	30
Nectarine	20			50	30
Peach	20			50	30
Pear	20			50	30
Plum	20			50	30
Prune	20			50	30
Herbicide					
Alfalfa Weed		100			
Desiccation	1	99			
Carrot		100			
Avocado		100			
Citrus		100			
Vector Control		100% applied by dripping method or spray			
School District		100			
Weed Control Unclassified		100			

7.3.4.2 Overuse Waste

As discussed earlier, overuse wastes may result from different physical equipment factors and operational factors. In this limited presentation, only oil overuse due to excessive application rate is considered. Excessive application rate may be the result of one or more of the following reasons:

. Miscalculations by applicators

. Misinterpretation of label recommendations

. Inappropriate application rate recommendations

. Not following recommended rate of application

An oil overuse or overapplication estimation was made for the 14 crops. The use of oil on these crops was for agricultural and home and garden purposes. The oil application rate recommended for each of these crops by the University of California Extension Service was primarily used as the reference application rate. There is more than one recommended rate for each of the tree crops depending on the volume of oil applied, and these rates were weighted (see Table 7-9) in order to arrive at one average recommended rate for each crop. The actual rate reported by the end-users was compared to the recommended rate, and if the difference between the two rates was positive, the difference is considered to be overuse.

Table 7-10 presents the estimated oil waste due to overapplication on 14 crops in California in 1977. The total estimated waste amounted to 678,838 lbs. or 1.1 percent of the reported oil applied. The waste was not great considering the quantity of oil applied.

TABLE 7-9

Weighted Average of Recommended Application Rates
for 10 Tree Crops in California, 1977

Crop	Estimated Oil Volume Applied (%)		Oil Type Applied by Volume (%)[c]				Recommended Application Rate (gal/acre)				Weighted Average Recommended Application Rate (gal/acre)
			Foliar		Dormant		Foliar		Dormant		
	HV	LV	HV	LV	HV	LV	HV	LV	HV	LV	
Almond	50[a]	(30+20)[b]	49.8	49.8	0.2	0.2	5	4	12	8	4.53
Apricot	50[a]	(30+20)[b]	49.85	49.85	0.15	0.15	5	4	16	12	4.53
Peaches	50[a]	(30+20)[b]	46.8	46.8	3.2	3.2	7	6	16	12	6.98
Nectarines	50[a]	(30+20)[b]	48.85	48.85	1.15	1.15	7	6	16	12	6.67
Plum	50[a]	(30+20)[b]	49.5	49.5	.05	.05	4	3	10	7	3.55
Prune	50[a]	(30+20)[b]	39.45	39.45	10.55	10.55	4	3	10	7	4.55
Pears	50[a]	(30+20)[b]	46.95	46.95	3.05	3.05	5	4	18	12.5	5.16
Citrus (Grapefruit, Lemon, Orange)	80[a]	20[b]	80	20			24.5	12.5			22.1

[a]HV = high volume by ground application

[b]LV = low volume application, first number in parenthesis is % oil applied by ground, second number is % applied by aerial method. Number without parenthesis is oil % applied by ground method.

[c]Oil type data derived from PUR.

TABLE 7-10

Overapplication of Reported Nonsynthetic Pesticide for Agricultural Use on 14 Crops in California in 1977

Crops	Reported Application Rate (gal/acre)	Recommended Application Rate (gal/acre)	Over-Application (gal/acre)	Total Acreage	Total Over-Application (gallons)
Spray Oils					
Almond	4.9	4.53	0.37	212,000	78,440
Apricot	3.0	4.53	N/A	23,000	
Nectarines	5.3	6.67	N/A	19,000	
Peach	5.0	6.98	N/A	68,000	
Pear	5.1	5.16	N/A	31,000	
Plum	4.8	3.55	1.35	23,000	31,050
Prune	4.2	4.55	N/A	31,000	
Grapefruit	18.3	22	N/A	4,000	
Lemon	17.8	22	N/A	48,000	
Orange	17.6	22	N/A	30,000	
Weed Oils					
Alfalfa Weeds	27	25-70	N/A	127,000	
Desiccation	13	$\leq$ 15	N/A	647	
Carrots	69	50-100	N/A	25,000	
Citrus	11	40-100[a]	N/A	43,000	
Avocado	32	40-100[a]	N/A	5,000	
TOTAL					109,490 gal.

Total over-application in pounds: 109,490 gal. ≈ 678,838 lbs.

Total oil applied on these 14 crops: ≈ 60,393,000 lbs.

Percent of overapplication: 1.1%

a - No application of fortified oil was assumed.

7.3.4.3 Drift Losses

In estimating the likelihood of oil pesticide drift losses, the estimated statistics compiled by Von Rumker et. al. were used (see Table 7-7).[25] In their compilation, Von Rumker et. al. categorized the estimated drift losses according to formulation types, equipment types, application methods, targets and application volume. These drift statistics were based on several assumptions:

- Wind speed - 3-5 mph
- Atmospheric stability - neutral
- Air temperature - above 60°F
- Relative humidity - 50% or less

These assumptions were adopted for the drift estimation made for the 14 crops considered in this study. The relevant data on equipment types, application methods and percentage of equipment and application methods used for each crop were estimated by county farm advisors and researchers. Information on formulation types and application volumes were obtained from manufacturers labels and the PUR respectively.

Table 7-11 summarizes the relevant information on application methods, target spray volume and estimated percent drift over 1000 feet from the target for each crop. Based on these data the drift loss resulting from application was estimated for each crop and is shown in Table 7-12. The primary source of drift losses was due to aerial application of insecticides on tree crops. The insecticide loss amounted to 1,438,610 pounds of 31.4 million pounds applied. Loss due to herbicide

TABLE 7-11

Summary of Application Method, Spray Volume and Estimated Drift Loss for 14 Crops

Crops	Application Methods	Target	Spray Application Volume (gal./acre)	Est. % Drift > 1000 Feet From Target
<u>Citrus, Insecticide</u> (Grapefruit, Lemon, Orange, Citrus)	Ground - Boom (40%) Ground - Airblast (60%)	Tree	1500 1500 (40%) 100 (20%)	negligible negligible 4%
<u>Deciduous Fruits</u> (Almond, Apricot, Nectarine, Peach, Pear, Plum, Prune)	Aerial (20%) Ground - Airblast (80%)	Tree	12 - 16 400 (50%) 100 (30%)	25% 4% 4%
<u>Alfalfa</u> Weed Desiccation	Aerial (0.5%) Ground - Horizontal (99.5%) Aerial (1%) Ground - Horizontal (99%)	 Foliage Foliage Foliage	 54 - 81 10 - 15 26 - 39	 negligible 25% 1%
<u>Carrots</u>	Ground - Horizontal (100%)	Foliage	86	negligible
<u>Avocado</u>	Ground - Horizontal (100%)	Foliage	30 - 180	negligible
<u>Citrus, Herbicide</u>	Ground - Horizontal (100%)	Foliage	30 - 180	negligible

TABLE 7-12

Estimated Drift Loss During Oil Applications on High Use Commodities in 1977

Crop	% by Aerial Spray 12-16 gal. per acre	% by Ground Boom: 1500 gal. per acre	% by Ground Boom: 30 gal. oil/acre	% by Airblast Ground Spray: 1500 gal. per acre	% by Airblast Ground Spray: 400 gal. per acre	% by Airblast Ground Spray: 100 gal. per acre	Total % of Drift Loss	Total Reported Poundage in 1977 (in 1000 lbs.)	Estimated Drift Loss (in 1000 lbs.)
Insecticide Oils									
Lemon		40%		40%		20%	0.8%	6,554	54.43
Orange		40%		40%		20%	0.8%	3,779	30.23
Grapefruit		40%		40%		20%	0.8%	507	4.06
Almond	20%				30%	30%	8.2%	8,157	668.89
Apricot	20%				30%	30%	8.2%	638	52.23
Nectarine	20%				30%	30%	8.2%	830	68.06
Peach	20%				30%	30%	8.2%	2,711	222.30
Pears	20%				30%	30%	8.2%	2,307	189.17
Plums	20%				30%	30%	8.2%	824	67.57
Prunes	20%				30%	30%	8.2%	946	81.67
Vector Control			100%					4,077	0.00
Subtotal: Spray Oil								31,380	1,438.61

Crop	% by Aerial Spray 10-15 gal. per acre (loss ≈ 25%)	Ground Boom Horizontal on Foliage: 26 - 49 gal./acre (Est. loss ≈ 1%)	Ground Boom Horizontal on Foliage: 54 - 86 gal./acre (Est. loss ≈ 1%)	Total % of Drift Loss	Total Reported Poundage in 1977 (in 1000 lbs.)	Estimated Drift Loss (in 1000 lbs.)
Weed Oil Spray						
Alfalfa,	0.5%		99.5%	0.13%	12,473	16.21
Weed Desiccation	1.0%	99%		1.24%	4,569	56.66
Avocado		100%		0.00%	1,240	0
Carrots			100%	0.00%	11,098	0
Citrus		100%		0.00%	3,650	0
School Districts		100%		0.00%	3,449	0
Weed Control Unclassified		100%[a]		0.0 %	117,912	0
Subtotal: Weed Oil					154,391	72.87
				Total:	185,771	1,511.48

a - This represents the most probable mode of application for this category. The actual percentages are not known.

application was 72,870 pounds. The total drift loss was 1,511,480 pounds which represented a 0.8 percent loss.

7.3.4.4 Potential Use Reduction

Application methods are considered here which have the potential of reducing the quantity of oil applied to California crops if they are implemented.

It has been noted above that excessive amounts of spray are used when there is unnecessary spray drift, unnecessary spray run-off or uneven distribution of spray material. There are no currently available methods whereby drift losses can be decreased in the applications of oil sprays to crops. A possible exception would be through a reduction of aerial spraying, but aerial spraying is sometimes the only method that can be used when crop land is too wet.

There are two ways through which applications can be reduced to a limited extent by presently used methods. These achieve adequate pest control by a more even distribution of a smaller quantity of spray solution. These methods are the low volume spray applications as recommended in U.C. Extension bulletins and the use of the recently developed air tower sprayers for more even spray distribution in citrus.[2,8-12,38]

The estimated reductions in total applied oils which could be attained through complete implementation of LV spraying is 10-15 percent for deciduous fruit crops, 15 percent for grapefruit and orange, and 10 percent for lemon. These estimates of possible reductions are based on the following assumptions which in turn are derived from estimates made by researchers and others involved with crop spraying practices:[23,39-41]

- 50 percent of deciduous tree spraying could be converted to LV
- A 25 percent reduction in oil use per acre can be attained by conversion to LV in deciduous tree spraying
- 30 percent of grapefruit and orange and 20 percent of lemon acreage could be converted to LV
- A 50 percent reduction in oil use per acre could be attained by conversion to LV in citrus spraying

The estimated reduction in oil application which could be attained through conversion to use of air tower sprayers is 10 percent for grapefruit and orange and 13 percent for the lemon crop. These estimates are based on information from research workers, farm advisors and literature sources used to make the following assumptions:

- The uses of air tower sprayers can be used to reduce HV oil application volumes by 20 percent
- 50 percent of the grapefruit and orange and 65 percent of the lemon spraying could be converted to spraying with air tower sprayers

Conversion of all spraying operations in deciduous fruit and citrus crops to LV and air tower spraying would entail a considerable cost primarily for the purchase of new equipment. For LV spraying some presently used sprayers can be readjusted to low volume use. For air tower spraying, a completely new sprayer would be needed and it is doubtful that this expense could be justified solely for the purpose of obtaining a 20 percent reduction in spray oil use.

7.3.5 Conclusion and Recommendations

Based on a limited scale of analysis, there is no obvious evidence that oil pesticides have been used in an inefficient or wasteful manner. Our findings of 1 percent oil overuse was based on the reported data. The 1 percent of oil overuse may in part be due to the fact that in practice, persons recommending or making pesticide applications often have no certain way of knowing the most appropriate rate or the need of applying the pesticide.

There was an estimated drift loss of 0.8 percent for the oil applied on the 14 crops under study. The drift loss is more of a technological problem than a management problem. The drift loss can be reduced by using electrostatic charged sprays. This approach is being investigated now by Akesson et al.,[30] and could be available for general use if the demand justified the cost of producing these sprayers.

An estimated 10 to 15 percent of oil use reduction could be achieved by full implementation of low volume spraying methods in all fruit tree crops and conversion of all high volume citrus crop spraying to the use of air tower sprayers. Conversion to these alternative spraying methods should be encouraged, but the cost of total conversion in a short time would be excessive.

As a general recommendation to reduce pesticide waste and loss, the pesticide end-users should be educated on a continuous basis in pest management and pesticide use in order to eliminate any unnecessary waste and overuse of agricultural chemicals. The current economic conditions and the continued increase in pesticide costs, especially pesticide oils, may provide a good economic incentive to farmers for accepting and exercising sound pest management practices.

As a means of improving current pesticide application techniques, there is no better substitution than continued research effort in vital areas such as formulations and techniques in drift reduction. With improved formulations, losses due to dripping and drifting may be reduced.

7.4 Synthetic Pesticides

7.4.1 Introduction

There is a large selection of synthetic pesticides currently available to California growers. Synthetic pesticides applied at recommended rates can provide excellent control of many oil susceptible pests that are of economic importance to growers. However, there are still certain pests for which oil or oil fortified with synthetics are the only recommended control treatments. The recommended treatments for these pests are described in Section 7.2.3.2.

The scope of this section is to describe the different synthetic pesticides available as feasible alternatives to the NSHC pesticidal oils currently being used by California producers on the selected crops being dealt with in this report. The synthetic alternatives that will be discussed for each crop are those that have been suggested by either project consultants or University of California (U.C.) extension advisors and literature.

7.4.2 Synthetic Alternatives

The recommended alternative synthetic pesticide treatments for the selected crops being examined in this report are summarized in Tables 7-13 to 7-16. The data sources for these tables are U.C. extension literature,[8-12] the Environmental Protection Agency compendium of registered pesticides[42] and the manufacturer's label.

The recommended application rates for each synthetic listed in Tables 7-13 to 7-16 are given in pounds of active ingredient (ai) required for each acre treated per application. The number of applications per year found opposite the crops in the tables is the estimated number of applications of synthetics that would be needed to control the oil susceptible pests listed under each crop. The estimated annual pounds of ai per acre is given as a range of the minimum and maximum amounts of synthetic that would be needed to control the pests listed under each crop for one year.

Probably all or nearly all of the pest control in citrus which is currently done with petroleum oil could also be done by using synthetic pesticides. Undoubtedly, there would be additional problems in some orchards due to the resultant suppression of beneficial predator and parasite populations. However, this problem could be minimized by appropriate pest

TABLE 7-13

Recommended Synthetic Pesticide Treatments for Control of Insects and Mites in Citrus

Crop and Pesticide	Oil Susceptible Pests Controlled	Number of Applications per Year	Est. Annual lbs. Active Ingredient per acre	Recommended lbs Active Ingredient/Acre per Application
Grapefruit and Oranges		2	3.5 - 18.4	
Lemons		3	4.0 - 20.1	
Parathion[a]	RS,YS,PS,BS,CS	1		D 4.8 - 5.8
Malathion[a]	RS,YS,PS,BS,CS,Br,CA	1		D 8.7 -12.3
Parathion plus Malathion[a]	RS,YS,PS,Bs,CS,Br	1		D 3.6 + 5.8
Carbaryl[a]	RS,YS,PS,Bs,Br	1		D 11.5 -13.9
Guthion®[a]	RS,YS,PS,BS,Br	1		D 6.0 - 7.4
Supracide®[a]	RS,YS,PS	1		D 2.5
Dioxathion[a]	Br,RM,SM,TM	1		D 7.2 C 4.0
Ethion	RM,SM,TM	1		D 3.5
Omite®[a]	RM,SM,TM	1		D 3.2 C 4.5
Plictran®[a]	RM,SM,TM	1		D 1.4 C 1.5
Morestan®[a]	RM,SM,TM	1		C 1.0
Vendex®[a]	RM,SM,TM	1		D 1.3 - 2.5 C 1.5 - 2.0
Kelthane®[a]	RM,SM,TM	1		D 4.0 C 4.0
Rotenone[a]	CA	0.2		C 0.1
Chlorobenzilate[a] (lemon only)	BM	1		D 1.7 C 1.5
		1.25	D 3.75	

Application Rate
D = Dilute or High Volume Spray
C = Concentrate or Low Volume Spray
A = Aerial Spray

a = U.C. Extension Recommendation
b = EPA Compendium
c = Manufacturer's Label
d = Dormant Oil Spray
f = Foliar Oil Spray

Pests
RS = Calif. Red Scale
YS = Yellow Scale
PS = Purple Scale
BS = Black Scale
CS = Citricola Scale
Br = Brown Soft Scale
SS = San Jose Scale
Pa = Parlatoria Scale
OS = Oleander Scale
BA = Brown Apricot Scale
RM = Citrus Red Mite
SM = Pacific Spider Mite
TM = Two-Spotted Mite
CM = Citrus Bud Mite
PM = Pear Rust Mite
EM = European Red Mite
BM = Brown Mite
PL = Pear Leaf Blister Mite
CA = Citrus Aphid
Py = Psylla
PB = Peach Tree Borer

TABLE 7-14

Recommended Synthetic Pesticide Treatments for Insect and Mite Control in Almond, Apricot, Peach, Nectarine, Plum, Prune and Pear Trees

Crop and Pesticide	Oil Susceptible Pests Controlled	Number of Applications per Year	Est. Annual lbs. Active Ingredient per acre	Recommended lbs. Active Ingredient per acre per Application
Almond		2.5	1.9 2.5	
Ethion[a]	mites	2.5		D 1.0 C 0.75
Carbophenothion	mites	2.5		D 1.0 C 1.0
Apricot		2	2.0 - 3.8	
Kelthane®[a]	EM,TM	1		D 1.9
Carbophenothion	EM,TM	1		1.0
Peaches and Nectarines		3.5	2.9 - 6.8	
Guthion®[a] and Carbaryl	SS,Pa	1		1.0 + 2.0
Kelthane®[a]	mites	2.5		D 1.9 C 1.4 - 1.75
Carbophenothion[a]	mites	2.5		D 1.0 C 0.75
Omite®[a]	mites	2.5		D 1.3 C 1.5
Plums and Prunes		2	1.5 - 3.8	
Kelthane®[a]	mites	2		D 1.9 C 1.6
Carbophenothion[a]	mites	2		D 1.0 C 0.75
Pears		4.5	3.5 - 8.0	
Diazanon[a]	PM,Py	1.5		D 1.0 C 1.1
Plictran®[a]	mites	1.5		D 0.5 C 0.5
Endosulfan[a]	PM	1.5		D 2.0 C 2.5
Kelthane®[a]	SM,TM	2		D 2.0 C 2.1
Ethion[a]	PM,EM,TM,BM,SM	2		D 1.0 C 1.0
Carbophenothion[a]	EM,TM,BM,PM	2		D 1.0 C 1.0

Application Rate

D = Dilute or High Volume Spray
C = Concentrate or Low Volume Spray
A = Aerial Spray

a = U.C. Extension Recommendation
b = EPA Compendium
c = Manufacturer's Label
d = Dormant Oil Spray
f = Foliar Oil Spray

Pests

RS = Calif. Red Scale
YS = Yellow Scale
PS = Purple Scale
BS = Black Scale
CS = Citricola Scale
Br = Brown Soft Scale
SS = San Jose Scale
Pa = Parlatoria Scale
OS = Oleander Scale
BA = Brown Apricot Scale
RM = Citrus Red Mite
SM = Pacific Spider Mite
TM = Two-Spotted Mite
CM = Citrus Bud Mite
PM = Pear Rust Mite
EM = European Red Mite
BM = Brown Mite
PL = Pear Leaf Blister Mite
CA = Citrus Aphid
Py = Psylla
PB = Peach Tree Borer

TABLE 7-15

Recommended Synthetic Pesticide Treatments
for Selected Field and Row Crops

Crop and Pesticide	Pests Controlled	Number of Applications per Year	Estimated Annual lbs. Active Ingredient	Recommended lbs. Active Ingredient per Acre, per Application
Alfalfa		1	0.5 - 4.0	
Diuron[a]	Winter Weeds	1		D 1.6 - 2.4
DNBP[a]	Winter Weeds	1		D 1.25 - 1.9
Paraquat[c]	Winter Weeds	1		D 0.5 - 0.75
CPIC[a]	Winter Weeds	1		D 2.0 - 4.0
Metribuzin[a]	Winter Weeds	1		D 0.25 - 1.0
Terbacil[c]	Winter Weeds	1		D 0.4 - 1.2
Alfalfa		1.25	0.4 - 0.9	
Endothall[c]	Preharvest Desiccant	1.25		D 0.33 - 0.75
Carrots		1	0.75 - 6.0	
Trifluralin[a]	Annual Weeds	1		D 0.75
Linuron[a]	Annual Weeds	1		D 0.75 - 1.5
TOK-25®[b]	Annual Weeds	1		D 6.0
CIPC[a]	Annual Weeds	1		D 4.0

a = U.C. Extension Recommendation
b = EPA Compendium
c = Manufacturer's Label

TABLE 7-16

Recommended Treatments for Selected Synthetic Herbicides on Fruit and Nut Crops and Non-Crop Areas[a]

Crop and Pesticide	Pests Controlled	Total Gallons Spray Per Acre	Number of Applications Per Year	Recommended Pounds Active Ingredients Per Acre Each Application	Estimated Annual Pounds Active Ingredients Per Acre (Pounds Oil)
<u>Almonds</u>	weeds				
Dinoseb + Oil (2 gal./acre)	c	100	1-4	1.25 - 10	1.25 - 40 (14-56)
Simazine	d	50	1	1.6 - 4.0	1.6 - 4.0
Paraquat	d	100	1-4	0.5 - 1.0	0.5 - 4.0
<u>Apples, Apricots, Nectarines, Pears, Plums and Prunes</u>	weeds				
Dinoseb + Weed Oil (2 gal./acre)	d	100	1-4	1.25 - 10	1.25 - 40 (14-56)
Paraquat	d	100	1-4	0.5 - 1.0	0.5 - 4.0
<u>Dates</u>	weeds				
Dinoseb + Oil (2 gal./acre)	d	100	1-4	1.25 - 10	1.25 - 40 (14-56)
<u>Grapefruit, Lemon and Orange</u>	weeds				
Dinoseb + Oil (2 gal./acre)	d	100	1-4	1.25 - 10	1.25 (14-56)
Diuron	d	100	1-2	1.6 - 3.2	1.6 - 6.4
Simazine	d	100	1	2.0 - 4.0	2.0 - 4.0
Paraquat	d	100	1-4	0.5 - 1.0	0.5 - 4.0
<u>Avocado</u>	weeds				
Simazine	a	50	1	2.0	2.0
Paraquat	d	100	1-4	0.5 - 1.0	0.5 - 4.0

TABLE 7-16 (cont'd)

Crop and Pesticide	Pests Controlled	Total Gallons Spray Per Acre	Number of Applications Per Year	Recommended Pounds Active Ingredients Per Acre Each Application	Estimated Annual Pounds Active Ingredients Per Acre (Pounds Oil)
Walnuts	weeds				
Dinoseb + Oil (2 gal./acre)	d	100	1-4	1.25 - 10	1.25 - 40 (14-56)
Diuron	d	100	1-2	1.6 - 3.2	1.6 - 6.4
Simazine	d	100	1	2.0 - 4.0	2.0 - 4.0
Paraquat	d	100	1-4	0.5 - 1.0	0.5 - 4.0
Grapes	weeds				
Dinoseb + Oil (10-20 gal./ acre)	d	100	1-4	1.25 - 2.5	1.25 - 10 (69-138)
Diuron	d	100	1	1.6 - 4.8	1.6 - 4.8
Simazine	d	100	1	2.0 - 4.8	2.0 - 4.8
Paraquat	d	100	1-4	0.5 - 1.0	0.5 - 4.0
Non-Crop Areas	weeds				
Amitrole	d		1-4	1.89 - 9.9	1.89 - 39.6
Cacodylic Acid	d		1-4	5.0	5.0 - 20.0
Dinoseb	d		1-4	1.25 - 3.75	1.25 - 15
Diuron	d		1	3.2 - 4.0	3.2 - 4.0
Glyphosate	d		2	1.5 - 3.0	3.0 - 6.0
Simazine	d		1	10 - 40	10 - 40
Paraquat	d		1-4	0.5 - 1.0	0.5 - 4.0

a - Recommended quantities are not for use as a guide for application of pesticides.
b - Source, U.C. Extension Recommendations.
c - Source, Manufacturers' Labels.
d - Source - Weed Control Manual, Meister Publications Company, 1978.

management. More frequent applications of synthetic pesticides would likely be necessary in many cases although the total quantity of pesticide applied would be considerably less. There is already some use of synthetic pesticides for each of the major citrus pests in each of the main citrus growing areas of California.[43,44]

At the present time, there are no recommended synthetic alternatives to replace oils as dormant season insecticides for any of the seven deciduous fruit tree crops discussed in this report.[14-19] One possible alternative to dormant oil sprays on pear trees is the synthetic pyrethroid Pydrin. It is currently being used on experimental plots and test farms under the direction of the U.C. Extension Service to test the compound for efficacy and problems. Early data reveal excellent dormant control of psylla, but further testing will be required to determine the feasibility of its wide spread use.

Supracide® is registered for use on peaches, almonds and prunes, and there is some feeling that this product may be useful as a dormant spray. Investigation is currently underway to evaluate its effectiveness.

Foliar season oil applications on deciduous fruit trees are directed against mites and scales. Oils are often used in combination with synthetic pesticides because of the synergistic effect of the two compounds. Application of foliar oil sprays constituted only 9.5 percent of the combined dormant and foliar oil applications, and foliar sprays of pear and prune trees was reported to be 85 percent of the total foliar season applications.

All foliar season oil sprays could be replaced with synthetic pesticide sprays; however, mite resistance has been observed with extensive use of the chlorinated hydrocarbon compounds Kelthane® and tetradifon and the organophosphate acaricides ethion and carbophenothion. Plictran is an excellent miticide but ineffective against scale insects. When mites and scales are the target pests and plictran is to be used, an additional insecticide such as carbaryl or Guthion® must be added for scale control.

Of the several synthetic herbicides registered for use in alfalfa for the control of winter annual weeds, terbacil is only registered for use north of Interstate 80 which limits its use as an alternative. Also, paraquat has the restriction that it cannot be applied to alfalfa if there is more than two inches regrowth due to high residue problems, and this will limit the number of situations where paraquat can be used.

Chloroxuron, a very effective herbicide for broadleaf weeds in carrots is no longer being manufactured, and this will make the continued availability of stoddard solvent even more vital to carrot producers. Linuron might be used following an early oil spray to give control of late germinating weeds. However, it fails as a complete substitute for oil because currently it cannot be used in Kern County where yellow nutsedge infests 50 percent of the carrot acreage.[13] Kern County produced 43 percent of California's carrots in 1977.[45]

Most of the weed oil used in orchards and vineyards could be replaced by the use of synthetic herbicides. Some examples of herbicides which can be used to replace oil were listed in Table 7-16. There are others which could be used. No single synthetic herbicide can substitute for weed oil in continuous use. This is because for all of the existing synthetics, there are some weeds which are resistant. These resistant weeds will become dominant in time and another herbicide must be used to control them.

For non-crop use, a considerable amount of oil could be substituted by synthetic herbicides. There are also some uses in which synthetic substitutes are not readily available usually because of the potentially greater health hazard to humans or animals and a possibly greater hazard to crop plants. Some areas where oil use may be less hazardous are: near crop irrigation canals and ditches, where animals will feed or graze, in home and garden use and in some school yard areas.

7.4.3 Summary, Discussion and Recommendations

As there is already some use of synthetic pesticide for each of the major oil susceptible citrus pests in each of the major citrus growing areas in California, it appears feasible that synthetic pesticides can be recommended to replace all the oil sprays that are being used as pesticides in these same areas.

At the present time, there are no recommended alternatives to replace oil as dormant season pesticides for any of the seven deciduous fruit trees considered in this study. Therefore, oil alone or oil fortified with synthetic pesticides are the only recommended control methods available.

Table 7-3 which shows the recommended oil and fortified oil treatments for deciduous fruit trees makes it apparent that more growers are currently using synthetic pesticides during the foliar season for insect and mite control, and this may be due to reports that oils sprayed on the foliage can damage the trees. Therefore, it can be recommended that all foliar oil sprays of deciduous fruit trees be substituted with the recommended synthetic pesticide sprays. This would account for a reduction of 9.5 percent of the total spray oils that are applied annually to deciduous fruit trees. However, complete use of synthetics can breed the problem of pest resistence, and replacing all foliar season oil sprays with synthetics would run contrary to U.C. extension recommendations which currently suggest that more spray oils be used during the foliar season for pest control in deciduous fruit trees.

The quantity of weed oils used for winter weed control in alfalfa can be reduced by spraying early when the weeds are small, easier to cover and require less oil to be killed. In some areas of the state, the use of weed oil fortified with synthetic herbicides can reduce the quantity of oil needed to the point that the oil becomes an adjuvant. A complete replacement of weed oils by synthetic herbicides is not practical due to the restrictions placed on terbacil and paraquat. In addition, a loss of weevil control would result for those growers who rely on the ovicidal effect of the weed oil to control weevils along with winter weeds.[46] A safe assumption would be that 50 percent of the weed oil used for winter weed control could be replaced effectively with synthetic herbicides, and 100 percent of the summer desiccation of both alfalfa and clover could be replaced with synthetic desiccants or windrowing; however, windrowing is not widely practiced due to the large amount of seed loss that can occur due to seed pod shattering.

Continued availability of linuron to carrot producers could significantly reduce their use of stoddard solvents for controlling broadleaf weeds. If CDFA would permit usage of linuron in Kern County, it has been estimated that the use of oil on carrots could be reduced 60 percent in Kern County.[13] Without the availability of linuron and chloroxuron, carrot oil or stoddard solvent is essential for weed control in carrots grown in Kern County. Synthetics could probably be used effectively on half the acres outside of Kern County where oil is used for weed control in carrots.

Synthetic herbicides could replace nearly all of the weed oil used in California orchards and vineyards.

An estimated 50 percent of weed oil used in non-crop areas could be substituted by synthetic pesticides without loss of over-all effectiveness and without introducing excessive risk to humans, animals or plants.

The synthetic pesticides that have been recommended as alternatives are only recommendations and should not be considered the only synthetics that can be used as replacement chemicals for oil. Different areas of the state have different problems and will require use of the best chemical for that particular area and problem.

In those cases where NSHC pesticidal oils can be effectively replaced by alternative controls, synthetic pesticides are possibly the most efficient short term alternative. Over the long term, however, there would be an accelerated development of pest resistance to synthetics especially if larger quantities were used. This would mean that other pesticides would have to be found to replace those that became ineffective.

7.5 Other Alternatives

7.5.1 Introduction

Methods of pest control being considered here include integrated pest management (IPM), biological control, cultural practices, mechanical control and flaming. The success of reducing oil use with these different alternatives varies from insignificant to 50 percent reduction.

IPM and biological control programs require transition periods of up to four years before full integration is achieved.[47,48] Education of growers as to successful, non-chemical control methods is another difficulty in implementing these programs.

Most of the control methods discussed here share the common limitation of exerting only partial control over target pests, and pesticide applications are still necessary to achieve commercially acceptable levels of pest control.

7.5.2 Integrated Pest Management

7.5.2.1 Introduction

Integrated pest management (IPM) programs are being used in citrus, pears and almonds. The program for almonds was initiated in 1978 and efficiency of the program has not been determined. IPM influence is being felt in peaches, apricots and nectarines. Where IPM programs and principles are being used, growers have experienced acceptable levels of pest control while reducing the total volume of pesticides and number of applications. Subsequently, pest control costs have been reduced. Pesticide types and volumes saved have not been specifically identified in the literature, and at this point the exact impact on oil use for most crops is not available.

7.5.2.2 IPM in Citrus

More than one IPM program has been developed for California citrus crops. Independent pest management consultants have applied IPM to citrus and have brought reductions of up to two thirds in the cost of pesticides applied to citrus in the San Joaquin Valley.[49] In National Science Foundation sponsored projects, IPM methods have been tested for 3 years in the Southern California interior, and other experiments have been done in the Coastal district and in the San Joaquin Valley.[6] In the most effective of these reported IPM programs, petroleum oil was used at a rate about 50 percent less than that usually recommended. An alternative IPM program using only synthetic pesticides was less effective in controlling pests although crop yield did not suffer in those tests carried out.[6]

Analyses of the use of pest control consultants by San Joaquin Valley citrus growers showed that those who used IPM in this way has the same average profit, reduced pest management costs and applied about 50 percent less pesticides. The kind of pesticide involved, however, was not specified in those studies.[49-51]

7.5.2.3 IPM in Pears

Successful programs for pear pest management have been developed by U.C. Extension workers, University experts and independent agricultural consultants.[52-56] Approximately twenty percent of California's pear growers are involved in IPM programs.[57] Costs of pesticides for IPM growers has been up to 70 percent less than non-IPM growers, and the number of applications has been reduced in some cases.[53,54]

IPM programs in pears rely heavily upon oils as insecticides for dormant sprays against pear psylla, scale insects and several mite stages. Precise timing of cover sprays based on accurate orchard monitoring made pesticide applications most effective.[58,59] Programs will vary from orchard to orchard depending upon location and particular pest problems each season, but general methods and materials remain similar throughout the state.

Nonsynthetic hydrocarbon use should not increase with the further implementation of IPM practices but also should not be viewed as a means of significantly reducing oil use.[60]

7.5.2.4 IPM in Other Deciduous Fruit Trees

For most deciduous fruit tree crops, IPM programs are still in their infancy as effective programs require years of study to formulate and implement.[7,61,62] IPM influence can be seen in peaches, nectarines and apricots where growers are beginning to monitor pest populations more closely and are cutting back on insecticides where possible. Spiraling costs are contributing to the implementation of IPM methods by an increasing number of growers.

7.5.2.5 IPM in Field and Row Crops

IPM programs for weed control in field and row crops are not available and offer no alternative to weed oil applications at the present time. IPM is available for insect pest control in alfalfa, and this could indirectly reduce the amount of herbicides needed for weed control by providing for more vigorous and competitive alfalfa. However, an estimation in the possible reduction of weed oil required for winter weed control as a result of using IPM in alfalfa is not available.

7.5.2.6 IPM for Weed Control in Orchards, Vineyards and Non-Crop Areas

There is no specific IPM program for weed control in fruit crops, but IPM of a sort is already practiced in that some growers combine the use of herbicides and other practices such as cutting or flaming for weed control in orchards. No estimate of savings can be made.

In non-crop weed control there is no IPM program for which benefits may be assessed.

7.5.2.7 Summary and Recommendations

The most effective IPM programs in citrus have yielded reductions in total oil usage by 50 percent with no reduction in control effectiveness. Citrus IPM programs where oil is completely replaced by synthetic pesticides have shown to be less effective in controlling pests yet no apparent yield reductions were noted. Pear pest management depends upon dormant pest control strategies in order to keep pest levels low. Oils are essential for commercial control at the present time, but development of a new synthetic pyrethroid is showing promise as a dormant season control spray compatible with IPM programs. The costs of overall pesticide applications have seen substantial reductions, and this should encourage wider use of IPM. Research is still needed in the development of IPM programs for most deciduous tree crops. IPM is an effective means of reducing the overall pesticide burden on the environment, and its research and development should be encouraged.

7.5.3 Biological Control

7.5.3.1 Introduction

Biological control agents of insect pests are numerous for citrus and deciduous fruit tree crops. Predator species will exert some degree of control on the host pests wherever they are found. However, for biocontrol to be most effective, cultural and pruning practices and pesticide applications must favor predator populations.[4,51,52] Where nondisruptive pesticides are used or in unsprayed orchards, predator species can control some oil susceptible pests below economically damaging levels without sprays.[62] However, not all pests can be controlled by natural enemies, and chemical control is necessary where such pests exist.

Biological control demands expert supervision to avoid losses due to occasional pest outbreaks. Also required is a period of adjustment to phase out pesticide dependence and allow biocontrol agents to become fully established.

7.5.3.2 Biological Control in Citrus

In California there are many biological control agents which operate to reduce populations of economic agents of citrus. Of the citrus pests controlled by oil only, the citrus bud mite lacks natural enemies capable of giving complete control at least in some areas.

In Coastal citrus areas growers in a number of large districts rely almost exclusively on biological pest control at the present time.[57] Such reliance on biological control does require expert supervision and requires an adjustment period of 2 to 4 years.[47,49]

The methods of applying biological control in citrus crops and the reduction of pesticide oil through application of biological control are essentially the same as that attained through through use of IPM.

7.5.3.3 Biological Control in Pears

Predator populations in unsprayed pear orchards can keep mites, scales and psylla below pest status levels.[7,62] The major pear pest, the codling moth, has numerous natural enemies but is not adequately controlled by them, and 40 to 60 percent fruit infestation occurs in the absence of insecticide use. When codling moth is chemically controlled to the commercially acceptable 1 percent fruit infestation level, natural enemies of the mites, scales and psylla are also destroyed, and pest populations develop rapidly to damaging levels. Development of an effective, nondistruptive codling moth control is essential before biological control in pears can be fully developed. One possible agent for codling moth control is a granulosis virus specific to codling moth. It is currently receiving much research attention but is still in the experimental stage.

7.5.3.4 Biological Control in Other Deciduous Fruit Trees

Predator species which attack mites, scales, aphids and other soft bodied pests exert some pressure on pest populations but control is usually not adequate to eliminate nonsynthetic hydrocarbon use. Biological control is an integral part of any IPM program, and reduction in oil use due to biocontrol agents would be reflected in such management programs.

7.5.3.5 Biological Control in Field and Row Crops

Biological control is at present effective on only a very few weed species on non-crop land. Russian thistle is controlled to some extent in certain areas of the state but not in others. Biological control of agricultural weed pests is currently of little significance and offers little alternative to the use of weed oils as herbicides.

7.5.4 Cultural Practices

7.5.4.1 Introduction

Cultural practice can be an important factor in pest and predator population development in field and row crops as well as in tree crops. Considered below are methods used in deciduous fruit trees and field and row crops to aid in the control of pest species. Cultural practices in citrus have little bearing on pest populations.

7.5.4.2 Cultural Practices in Deciduous Fruit Trees

Healthy cover crops are important in keeping consperse stink bugs from entering pear trees.[52,63] Proper cover crop selection and management will also increase predator mite populations. Management of weeds around orchard perimeters will reduce a potential source of mites, aphids and bugs.

Removal of box elder and maple trees from around pear orchards will help prevent box elder bugs from rising to pest status.

7.5.4.3 Cultural Practices in Field and Row Crops

Fields that are infested with difficult to control perennial and annual weeds should not be planted with field or vegetable crops if at all possible.

Preplant irrigation to germinate weed seeds followed by light disking is an effective preplanting weed control technique.

Planting the best variety for a particular locality is one of the best ways of assuring good crop vigor and increased ability to out compete weeds.

The proper timing of irrigation water alleviates the problem of plants being drought stressed if a set irrigation schedule is followed.

Reduced wheel traffic in alfalfa fields can result in less soil compaction and less inhibition of root growth and result in more vigorous plant growth.

Good insect pest management can significantly increase the growth and competition of a crop and possibly reduce the amount of herbicides needed for effective weed control.

Clean farming, whereby undesireable vegetation (mostly weeds) is removed from around the borders of a field, can reduce the quantity of weed inoculum available for causing pest problems in the field. Cutting frequency of alfalfa stands can dramatically affect the amount of weeds that will infest the fields.

7.5.5 Mechanical Control and Flaming

Mechanical control and flaming to control insects is not practical at the commercial level, therefore, only weed control will be considered here.

7.5.5.1 Mechanical Control in Field and Row Crops

Mowing and mechanical renovation such as harrowing of alfalfa fields have negative impacts such as soil compaction and crown damage resulting in secondary damage from disease and are not good alternatives for the use of weed oils.

Mechanical cultivation of weeds in vegetable row crops is used to control those weeds between the rows but has no effect on those weeds close to the plants that compete the most. Weeding costs with hand labor in the past have run to $300 per acre and would be greater today if hand labor was available.

7.5.5.2 Mechanical Control of Weeds in Orchards, Vineyards and Non-Crop Areas

Mechanical methods such as cultivation of the grounds, mowing, and hand howing and cutting are already used for weed control in many areas where it is considered practical. One of the most notable examples is the mowing of weeds along the sides of many highways. In many places weeds are cut in yards and utility areas. If these efforts were extended, probably 10 to 20 percent of the oil use in non-crop areas could be eliminated although weed control cost in most cases would increase.

7.5.5.3 Flaming

Flaming is only applicable to weed control in field crops. Flaming alfalfa during the dormant season can give excellent winter weed and weevil control.[46] However, flaming is not practices to any extent in California for several reasons:

(1) It is expensive by requiring 30-40 gallons of propane or diesel per acre

(2) The flamer must move slowly to be effective, and flaming can only be done profitably after the dew has evaporated and the soil is dry thus limiting its feasibility

(3) Flaming can only be done legally on burndays, requires a burn permit, and in Imperial and Sacramento Counties an additional burning fee is required

(4) Flaming is done most efficiently when the air is calm which further restricts its use

7.5.6 Summary and Conclusion

All the various alternative methods of pest control have an impact upon the total pesticides required to achieve acceptable levels of control. However, due to the nature of these alternatives, quantifications of potential reductions in oil use for most crops is not possible at this time. Research is continuing in IPM, biological, and cultural control methods and practices, and as discoveries are made and proven effective, reductions in pesticide use may be further realized.

Implementation of integrated pest management programs by citrus growers have yielded 50 percent reductions in the volume of oil used, yet IPM in pears has provided no decrease in oil consumption. Still, pear growers using IPM techniques have seen decreases in pest control costs as the number of cover sprays and amounts of synthetic pesticides used have been reduced. Other tree, field and row crops are receiving some benefits from these different practices, but again, exactly how much influence is being exerted remains undetermined.

7.6 Summary of Alternatives to Oil Use

7.6.1 Citrus Crops

In all of the citrus growing areas of the state, synthetic pesticides could be used in substitution for essentially all of the oil used for insect and mite control in citrus crops (grapefruit, lemon and orange). Such substitution of synthetic chemicals would undoubtedly lead, at times, to an increased need for chemical control treatments, especially following improper pest management decisions. The situation would be aided by the selection of pesticides which are reported to be less toxic to predators and parasites of pest species. Some examples of these pesticides are Supracide®, Guthion®, Plictran®, Vendex® and Omite®.

IPM methods could reduce oil use in citrus crops up to 90 percent or more where it is implemented. However, IPM cannot be easily implemented since there are not enough of the required trained pest control operators to administer more than a fraction of those needed for full implementation.

7.6.2 Deciduous Fruit Trees

The most effective method for reducing pesticide oil use on deciduous fruit trees (almonds, apricots, nectarines, peaches plums, prunes and pears) is by increasing the use of low volume spray applications in place of the high volume sprays which are now used on about 50 percent of the acreage. The expected reduction is about 12-13 percent of current application.

Oil use could be reduced to a small extent by the use of narrow-range and superior oil sprays in place of dormant oil. However, this change would have little impact because nearly all the oil used in these crops is already superior or narrow-range.

Almost all of the oil insecticide used on deciduous tree crops is applied in the dormant season. There is no synthetic pesticide recommended for use in the dormant season, and the pests controlled by dormant season oil applications cannot be effectively controlled in other seasons. There is some use of foliage sprays of oil which can be substituted by synthetic chemicals. These substitutions could lead to a reduction of about 7 percent in oil used for these tree crops.

The synthetic pesticide Supracide® is not now recommended for dormant season insect control on deciduous trees, but experiments are going on which suggest it may be an effective substitute for oil.

Pear is the only deciduous tree crop with a developed IPM program, and the use of dormant season oil spray is an integral part of the program. No reduction in oil use can be expected from present IPM methods on pears.

7.6.3 Alfalfa

In areas south of Delano, California, it has been suggested that just 2 gallons of weed oil mixed with DNBP and diuron in 75 gallons of water per acre is sufficient for winter weed control in dormant alfalfa.[13] Assuming 30 gallons of weed oil per acre to be a standard application,[64] a 93 percent reduction in the amount of weed oil used would be realized. However, the overall reduction in oil use would be small as only two percent of the reported oil used for winter weed control in alfalfa was used south of Delano.

The use of an emulsifiable DNBP formulation containing 30 percent oil by volume and 1.25-1.9 pounds ai/acre would result in reducing the amount of weed oil used by more than 99 percent. (This treatment may give satisfactory control of broadleaf weeds but probably would not give satisfactory control of grassy weeds.) Use of synthetics like diuron, paraquat, CIPC, metribuzin and terbacil for controlling annual winter weeds could significantly and effectively reduce the use of weed oils on probably 50 percent of the alfalfa acreage. Cultural practices for reducing the growth of weeds and increasing the vigor of alfalfa are good management practices that reduce weed oil use and can be easily incorporated into alfalfa production, but reduction in the amount of oil that would be saved is not readily quantifiable.

Synthetic desiccants like endothall and paraquat are good alternatives for complete replacement of using weed oil and are readily applied by air; however, aerial spraying involves the risk of spray drift damage to adjacent susceptable crops.

7.6.4 Carrots

Trifluralin, linuron, nitrofen, and CIPC are all good synthetic alternatives for reducing the amount of weed oil or stoddard solvent that is used for annual weed control in carrots. Upon exempting Kern County where linuron is unavailable, 48 percent of the reported oil use on carrots could probably be replaced with synthetic herbicides. Weed oil remains the only control for nutsedge in Kern County where half the acreage is infested.[7]

Mechanical cultivation between the rows followed by band spraying the crop with oil could reduce the amount of oil that would normally be applied as a broadcast spray by 50 percent; however, cultivating can bring up new weed seeds that will germinate at the next irrigation and require additional control.

7.6.5 Orchards, Vineyards and Non-Crop Areas

Synthetic chemicals are effective alternatives for weed oil in orchards and vineyards and could substitute for essentially all (>90%) of such use. In non-crop areas, weed oil use can be reduced about 50 percent by use of synthetics as alternatives.

About 10 percent of weed oil use in these fruit and non-crop areas could be eliminated by increased use of mowing, cutting and cultivation.

7.6.6 Promising Alternatives

A recent discovery of a biological control for nutsedge could significantly reduce the amount of oil used on this pest each year in carrots. However, the control will probably not be available for a few years.

7.6.7 Conclusions and Recommendations

Applications of petroleum oil pesticides in California can be significantly reduced by the substitution of alternative pest control methods. The estimated pounds and percentage reduction in oil use which could be obtained by substitution of 4 alternative methods is shown in Table 7-17 for 14 crops and 4 nonacreage applications.

Synthetic Pesticides. The use of synthetic pesticides is by far the most effective of the presently available substitutes for oil. Table 7-17 indicates this alternative would have significant effectiveness for oil in 14 of the high oil useage categories and could reduce oil applications by up to 15,176,813 pounds. Synthetic chemicals would not be an effective substitute for all of the oil use without a serious loss of effectiveness. Synthetics are useful only as a partial substitute for oil in some crops because (1) only some pests of a crop can be controlled with synthetics, (2) the synthetics are effective in only some parts of the state or (3) substitution of synthetics is acceptable only part of the time, e.g. when weather conditions are favorable.

As an alternative to the use of petroleum oil pesticides in California, the use of synthetic pesticides should be considered technically the most complete and satisfactory substitute.

Application Methods. The use of alternative application

TABLE 7-17

Estimated Potential Reduction in F-10 Oil Use by Alternative Control Methods

Crop or Other Application	Oil Use[a] (in 1000 lbs.)	Synthetic Pesticides		Application Methods		Integrated Pest Management (IPM)		Mechanical & Cultural Control	
		Oil Use Reduction		Oil Use Reduction		Oil Use Reduction		Oil Use Reduction	
		(%)	(weight in 1000 lbs.)	(%)	(weight in 1000 lbs.)	(%)	(weight in 1000 lbs.)	(%)	(weight in 1000 lbs.)
<u>Insecticide</u>									
Grapefruit	499.0	100	499	LV 15 Spr 10	74.9 49.9	45-90	225- 449.1	0	0
Lemon	6,122	100	6,122	LV 10 Spr 13	612.1 795.7	45-90	2,754.9- 5,509.8	0	0
Orange	3,543	100	3,543	LV 15 Spr 10	531.4 354.3	45-90	1,594.3- 3,188.4	0	0
Almond	8,157	< 1	0	LV 10- 15	815.7- 1,223.6	N/A	0	0	0
Apricot	635	< 1	0	LV 10- 15	63.5- 95.3	N/A	0	0	0
Nectarine	736	< 1	0	LV 10- 15	73.6- 110.4	N/A	0	0	0
Peach	2,576	3	77.3	LV 10- 15	257.6- 386.4	N/A	0	0	0
Pear	2,293	20-30	458.6- 687.9	LV 10- 15	229.3- 343.9	Negligible	0	0	0
Plum	714	2	14.3	LV 10- 15	71.4- 107.1	N/A	0	0	0
Prune	938	20-30	187.6- 281.4	LV 10- 15	93.8- 140.7	N/A	0	0	0
Vector Control	4,433	0	0	0	0	N/A	0	0	0
<u>Herbicide</u>									
Alfalfa	12,473	50	6,236.5	0	0	N/A	0	0	0
Alfalfa (Desiccant)	4,570	100	4,570	0	0	N/A	0	0	0
Avocado	1,240.2	100	1,240.2	0	0	N/A	0	0	0
Carrot	11,099	48	5,327.5	0	0	N/A	0	50[imp]	5,550
Citrus	3,650	100	3,650.0	0	0	N/A	0	0	0
Weed Oil Unclassified	117,812	75	88,359	0	0	N/A	0	10	11,781
School District	3,502	50	1,751	0	0	N/A	0	0	0
<u>Other</u>									
Wood Preservative	26,550	0	0	0	0	N/A	0	0	0
TOTAL:			122,036- 122,359		4,023.2- 4,825.7		4,574.2- 9,147.3		11,781

a - Application under Home & Garden excluded.

LV - Low volume spray application.

Spr - Improved coverage sprayer application method.

N/A - No available method.

imp - Considered impractical due to excessive labor and cost.

methods could lead to a considerable reduction in applied pesticide oil. Alternative application methods could be used for application to the crops in Table 7-17 to give reductions of 10 to 25 percent in oil use for each crop. The application methods which can be used are the use of low volume sprays and the use of tower sprayers for improved spray distribution on citrus. Both of these methods are now used to some extent on those tree crops where they are applicable. There could be excessive cost involved with a short-term conversion to these methods.

The use of low volume spray methods for fruit trees and improved coverage sprayers for citrus crops should be promoted and encouraged as a means of reducing the use of petroleum oil pesticides.

Integrated Pest Management. Tested IPM methods could be used on citrus in those areas of the state where most pesticide oil is applied. This use of IPM could lead to reduction in oil applications on citrus crops of 40 to 90 percent depending upon whether low volume use of oil or synthetic chemicals were used in the program for mite control.

IPM could not bring reductions in oil use on most crops because they do not have developed and tested IPM programs. In the IPM program for pears, oil use is part of the established method, and it cannot be substituted with other chemicals.

IPM methods of control are not readily implemented since trained supervisors are needed for its use. Additionally, there is a lack of trained IPM supervisors, and growers are reluctant to use their services.

The use of integrated pest management (IPM) methods should be promoted and encouraged as a means of reducing pesticide oil use in citrus crops. Research should be encouraged for the development of IPM methods for other crops which can reduce the use of petroleum oil pesticides.

Mechanical and Cultural Control. Application of mechanical and cultural control methods can have only a very limited affect on pesticide oil usage. In tree crops there are no direct mechanical or cultural methods against insects and mites. Mechanical or hand cultivation can be used to remove weeds from row crops but is considered prohibitively expensive.

Research towards the development and testing of mechanical and cultural methods capable of reducing petroleum oil pesticide use should be promoted and encouraged.

7.7 References

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8.0 IMPACT POTENTIAL OF PESTICIDES

8.1 Introduction

The technical feasibility of using nonsynthetic and synthetic pesticides or other alternatives to control insects and weeds has been discussed in Chapter 7.0. Technical effectiveness should not be the sole criterion of selecting a chemical for pesticidal purpose. Environmental and economic impacts of a chemical should be among the primary criteria considered.

In this chapter, analyses of health, energy, economic and environmental impacts resulting from the use of different pest control methods are presented. Since the major emphasis of this study is on air pollution emissions, air quality analysis is the primary consideration in the environmental impact evaluation section.

8.2 Health Impact Assessment

8.2.1 Introduction

Chemical pest control is brought about by the toxic effects of the chemicals. It should be recognized, therefore, that pesticides by nature are biologically active chemicals which are toxic not only to the target pests but also to nontarget organisms.

Among the nontarget organisms are higher animals and man. Toxicity to humans may result from direct exposure by inhalation, ingestion and/or through skin contact. Some pesticides cause irritation to the skin and eyes and/or cause allergic skin reactions. Toxicity may also result from ingestion of toxic residues on food or feed.[1]

As part of the pesticide registration requirements, manufacturers are required to submit toxicity data relevant to their products. Most of these data, however, are from toxicity studies with small mammals. In California, concern has been developed for possible health hazards to pesticide operators and workers. Applicators must file an accident report if any of the pesticide operators or workers become ill or injured as a result of their jobs. These occupational accident reports have provided a data base relating different pesticides directly to human health hazards.

In evaluating the hazards of pesticides to humans, it is necessary to consider both animal toxicity data and epidemiological data such as the occupational accident reports. While data from animal toxicity studies are not directly applicable to human and field conditions, they give an indication of the general order or the toxicity of the pesticide and of the possible hazard to humans and other mammals. Epidemiological data, on the other hand, may be more realistic than animal toxicity data, but these data may be the result of exposure to pesticides plus other factors such as malnutrition and pre-existing ill health. Also, workers may have been exposed to several pesticides over a period of time. Health effects which are not serious or acute may also go unreported. Because of the nature and insufficiency of toxicity and epidemiological data, the evaluation of pesticide health implication to humans presented here is necessarily a qualitative one. In general, synthetic pesticides are more toxic than non-synthetics (see the relative threshold limit values shown in

Table 8-1). A more comprehensive analysis of comparative health impacts is beyond the scope of this study.

8.3 Energy Use Assessment

8.3.1 Introduction

The total amount of energy expended in the use of pesticides in California in 1976 was estimated to be 1.09×10^{12} kcal.[3] This figure is based on reported pesticide use only, and therefore should be considered conservative. This energy figure includes the energy content of active ingredients and solvents of reported pesticides and energy consumed in the form of fuels during application. If unreported pesticides are also considered, the total energy use figure is considerably higher.

Energy is used in two different manners for pest control purposes:

(a) Direct energy use in transporting and applying pesticides.

(b) Indirect energy use in producing pest control materials and equipment.

The purpose of this section is to provide a rough estimate of both the direct and indirect use of energy for oil pesticides and alternative chemicals recommended for the 18 commodities considered in this study. The estimates considered included direct energy use of pesticide applications and indirect energy use for the production of pesticide active ingredients and related solvents.

8.3.2 Estimation Approach for Energy Use

TABLE 8-1

Threshold Limit Values of Synthetic and Nonsynthetic Pesticides[2]

Pesticides	ppm[a]	mg/m3[b]
Aldrin-Skin		0.25
Ammonium sulfamate (Ammate)		15
Arsenic and compounds (as As)		0.5
Azinphosmethyl-Skin		0.2
Calcium arsenate		1
Carbaryl (Sevin®)		5
Chlordane-Skin		0.5
Chloropicrin	0.1	0.7
Crag® herbicide		15
Cresol (all isomers)-Skin	5	22
DDVP, see Dichlorvos		
Demeton®-Skin		0.1
Dichlorvos (DDVP)-Skin		1
Dimethyl 1,2-dibromo-2,2-dichlorethyl phosphate, (Dibrom)		3
EPN-Skin		0.5
Ethylene dibromide, see 1,2-Dibromoethane		
Guthion®, see Azinphosmethyl		
Heptachlor-Skin		0.5
Lindane-Skin		0.5
Malathion-Skin		15
Methoxychlor		15
Naphtha (coaltar)	100	400
Naphthalene	10	50
Pyrethrum		5
Rotenone (commercial)		5
Stoddard solvent	500	2,950
Systox, see Demeton		
2,4,5T		10
TEPP-Skin		0.05

TABLE 8-1 (continued)

Pesticides	ppm[a]	mg/m^3[b]
Toxaphene, see Chlorinated camphene		
Nitrotrichloromethane, see Chloropicrin		
Oil mist, mineral		5[4/]
Paraquat-Skin		0.5
Parathion-Skin		0.11
Pentachlorophenol-Skin		0.5
Petroleum distillates (naphtha)	500	2,000
Phosdrin (Mevinphos®)-Skin		0.1

a. Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 mm Hg pressure.

b. Approximate milligrams of particulate per cubic meter of air.

The CDFA method for estimating the energy consumption associated with each pesticide application was adopted for similar use in this study.[3] The total energy use for each chemical includes the energy consumption rates of pesticide application, energy inputs for manufacturing the active ingredients of the pesticide and solvents. The total annual energy use for each chemical is obtained as follows:

Total Annual Energy Use = Total annual poundage (kcal/lb of active ingredient + kcal of solvents used/lb of active ingredients) + total annual acreage (kcal consumed in fuel/acre application).

For pesticides for which energy information if not obtainable, the energy required to manufacture related compounds is used. If energy information for related compounds is not available, the average required energy of 11,000 kcal to manufacture one pound of active ingredient is assigned to the pesticide. Estimates derived in this manner are understandably very rough approximations. In the absence of complete data, the approach used in this study to arrive at the energy use for a qualitative impact assessment is a reasonable one.

Table 8-2 presents data on energy inputs associated with the manufacturing of those pesticides under consideration for agricultural use in this report. These pesticides are either applied by ground equipment of aerial equipment. The energy consumption associated with these two modes of application is as follows:

TABLE 8-2

Energy Inputs for Selected Pesticides

Pesticide	Reference Chemicals	Kcal/lb of Active Ingredient	Kcal of Solvent used/lb of Active Ingredient	Reference
Chlorobenzilate	Toxaphene	6200	46400	4,5
Endosulfan	"	"	"	"
Kelthane®	"	"	"	"
Carbophenothion	Parathion	17100	"	"
Diazinon	"	"	"	"
Ethion	"	"	"	"
Guthion®	"	"	"	"
Malathion	"	"	"	"
Parathion	"	"	"	"
Supracide®	"	"	"	"
Carbaryl	Carbofuran	48400	"	"
CIPC	"	"	"	"
Morestan®	"	"	"	"
Trifluralin	Trifluralin	22000	--	6
Omite®	not available[a]	11000	not available	6,7
Plictran®	"	"	"	
Diuron	"	"	"	"
Linuron	"	"	"	"
Prometryn	"	"	"	
Metribuzin	"	"	"	"
Terbacil	"	"	"	"
Endothall	"	"	"	"
TOK-25®	"	"	"	"
DCPA	"	"	"	"
Vendex®	"	"	"	"
DNBP	DNBP	8500	--	4,5
Paraquat	Paraquat	49000	--	"
Petroleum	Petroleum	22900	--	7

[a]not available - an average value of 11,000 kcal/lb is used.

. Ground application = 0.15 gallons gasoline fuel per acre or 4,825 kcal/acre.[3]

. Air application = 0.16 gallons aviation fuel per acre or 4,978 kcal/acre.[3]

In the assessment of energy impact, three alternatives which can be used for oil use reduction were considered. These three alternatives are synthetic pesticides, improved application methods and IPM. As discussed in Chapter 7, these alternatives can be used as substitutes to oil use in only some of the crops. In considering the energy impact of synthetic alternatives, the energy use for the manufacturing and application of the quantity of synthetic pesticides required to replace oil was compared to the energy use of the reduced amount of oil. For improved application methods and IPM alternatives, the energy use for the reduced quantity of oil was reported as energy saving.

8.3.3 Energy Use Evaluation

The detailed estimates of energy use or savings for the different alternatives are presented in Tables A.4-3 to A.4-6 in Appendix A.4, and Table 8-3 presents a summary of these data. To put the energy data in a better perspective, the energy data were expressed in "barrel equivalents of crude oil" where 1 barrel = 1,461,600 kcal.

Energy use reduction and/or savings were observed for all three alternatives. In using synthetic pesticides, energy use was equivalent to 23,995 barrels of crude oil as compared to

TABLE 8-3

Summary of Energy Use or Saving Resulting From Use of Alternatives to Pesticide Oil

Crop	Synthetic Pesticides: Oil Use Reduction		Synthetic Pesticides: Synthetic Substitutes		Application Method		IPM	
	Energy Content (Kcal x 10^6)	Barrel Equivalent Crude Oil[a]	Energy Content (Kcal x 10^6)	Barrel Equivalent Crude Oil[a]	Energy Saving (Kcal x 10^6)	Barrel Equivalent Crude Oil[a]	Energy Saving (Kcal x 10^6)	Barrel Equivalent Crude Oil[a]
Grapefruit	11,445	7,830	430	294	2,861	1,957	4,578-10,289	3,132-7,039
Lemon	140,424	96,076	8,011	5,481	31,618	21,632	56,158-126,239	38,422-86,370
Orange	81,265	55,600	2,278	1,558	20,315	13,899	32,504-73,066	22,239-49,990
SUBTOTAL		151,676		7,333 (4.8% of replaced oil)				
Almonds	--	--	--	--	9,307	6,368	N/A	--
Apricots	--	--	--	--	430	294	N/A	--
Nectarines	--	--	--	--	548	375	N/A	--
Peaches	1,780	1,218	13	9	7,404	5,066	N/A	--
Pears	23,831	16,305	168	115	2,771	1,896	Negligible	--
Plums	329	225	7	5	2,045	1,399	N/A	--
Prunes	5,407	3,699	143	98	3,539	2,421	N/A	--
SUBTOTAL		21,447		208 (0.1% of replaced oil)				
Alfalfa	247,758	169,511	1,372	939	N/A	--	N/A	--
Avocado	21,324	14,589	107	73	N/A	--	N/A	--
Carrot	122,053	83,506	414	283	N/A	--	N/A	--
Citrus	62,895	43,032	4,417	3,022	N/A	--	N/A	--
SUBTOTAL		310,638		4,317 (1.4% of replaced oil)				
School Districts	40,120	27,449	244	167	N/A	--	N/A	--
Weed Control Unclassified	2,024,543	1,385,155	17,496	11,970	N/A	--	N/A	--
SUBTOTAL		1,412,604		12,137		55,307		63,793-143,399
TOTAL		1,899,365		23,995 (1.3% of replaced oil)				

[a] 1 barrel crude oil = 1,461,600 Kcal (Cervinka *et al.*, 1974).

N/A = Not available.

1,899,365 barrels of crude oil equivalent for nonsynthetic pesticides. The energy content of the synthetic alternatives was approximately 1.3 percent of the reduced oil use. In other words, if synthetic pesticides were used to substitute oil pesticides, an average energy use reduction of 98.7 percent would result. When these data are examined by crop types, the breakdown of energy use reduction is as follows:

Crop Type	Energy Use Reduction (%)
Citrus	95.2
Deciduous	99.9
Vegetable Crops (Weed Control)	98.6
General Weed Control	99.1

The energy saving by increasing the use of low volume and alternative sprayer application techniques would be 55,307 barrels of crude oil equivalent, and the IPM practice would result in saving 63,793-143,399 barrels of crude oil equivalent.

In summary, a word on data accuracy is in order. The estimated energy data for synthetic pesticides are probably on the conservative side. The reduction of energy use resulting from the use of synthetic alternatives should be less than the estimates presented here. The primary reason for this is the conservative data used in estimating the manufacturing energy inputs of synthetic herbicides. In most cases, energy input data for the active ingredients of specific herbicides and their associated solvents were not available. A conservative figure of 11,000 kcal/lb of active ingredients was used as the total manufacturing energy input for most of the herbicides; therefore, the energy use estimate for herbicides may be subject to considerable error. In spite of the possible errors in the herbicide estimates, the overall conclusions of energy use reduction by switching to alternative synthetics is still valid.

In looking at the energy saving estimates due to IPM practice, one has to realize that these estimates were the first year estimates. In most IPM practices, chemical treatments may not be necessary every year; therefore, the energy saving figure presented here may be underestimated for IPM.

8.4 Economic Impact Assessment

8.4.1 Introduction

One of the primary considerations in the recommendation of alternatives is the possible economic impact on the end-users. During times of economic uncertainties, such a consideration is especially essential to the small farmers. Even though environmental impacts are important factors of decision-making, the environmental impact consideration should be balanced with equal emphasis on the economic feasibility of different pest control alternatives.

8.4.2 Evaluation Approach

In evaluating the economic feasibility, cost comparisons were made between oil treatment and the different alternatives that might lead to an oil use reduction. Alternatives included in the analysis were synthetic pesticides, application methods and IPM.

The actual cost of each alternative consists of the cost of materials, application, the cost in terms of crop loss or gain due to the alternative treatment, and the cost in terms of public health hazards from application of chemicals for pest and weed control. The cost to the public in terms of health hazards is not considered in this study due to the lack of information and data. The percentage of crop loss from the use of a specific alternative is also taken to be zero based on the assumption that no crop loss would occur if each alternative is used according to the recommended application.

Based on the above discussion, the principle items of expense in each alternative can be broken down into three categories:

. Material cost.

. Equipment cost.

. Labor cost.

In most cases, the information on labor cost and equipment cost are not available separately, but the summation of those two is given as an application cost. Therefore, the total cost can be categorized as application costs and material costs.

Application Cost. There are two major types of application methods, ground application and aerial application. The cost of ground application depends on many factors such as the type of land, the number of acres to be treated and the application rate. The aerial application costs depend on length of spray run in the field to be treated and the application rate.

Information required for computing the application cost was obtained from the U.C. Agricultural Extension Service[8] and through interviews with two commercial pesticide applicators: Farm Air Flying Service Inc., a specialist in air spray; and Orchard Supply Company, a ground spray specialist.

Table 8-4 summarizes the application cost information.

Material Cost. Materials under consideration in this study are synthetic and nonsynthetic pesticides. The cost information pertaining to these pesticides was obtained through telephone interviews of pesticide dealers and manufacturers. Cost information secured from dealers and manufacturers was product cost while the cost analysis was for active ingredients. The cost of a pound of synthetic active ingredient was computed based on product cost and percentage of active ingredient in the product. The cost presented here is the cost of product per pound of active ingredients. Detailed data for the derivation of the annualized costs for nonsynthetic and synthetic pesticides are summarized in Tables A.4-7 and A.4-8 in Appendix A.4.

Total Annual Cost. The estimated total annual cost was computed by considering the application rate, number of applications per year and the materials and application costs. The computation can be expressed as follows:

Total Annual Cost/Acre = (1977 application rate/acre) x (No. of applications/year) x (Price of active ingredients) + (Application cost/acre) x (No. of applications/year)

TABLE 8-4

Summary of Application Costs

Application Methods		Application Rate (Gallon/Acre)	Cost ($/Acre)
Ground Spraying	Boom	20-40	3.50
		40-80	4.00
		80-100	5.00
	Air Blast	100-1500	10.00
Aerial Spraying	Airplane	10[a] (Length of run: 0-0.3 miles)	3.25
		10 (Length of run: 0.3-0.6 miles)	3.10
		10 (Length of run: 0.6 miles and over)	2.85

[a]Over 10 gallon/acre add 10 percent cost per gallon.

In computing the total annual cost for synthetic pesticides for citrus crops, peaches, nectarines and pears, the annual treatment cost includes the costs of more than one group of chemicals. This is due to the fact that there is more than one major group of synthetics needed to treat the different groups of pests.

8.4.3 Impact Evaluation

Tables 8-5 and 8-6 summarize the annual treatment costs by nonsynthetic and synthetic pesticides and IPM procedures. Table 8-7 presents the cost saving due to the partial change of application methods.

With the exception of herbicide use for school district and weed control unclassified, the average synthetic herbicide treatments cost less, and the average synthetic insecticide treatment costs more for citrus crops and costs less for deciduous tree crops than their corresponding oil pesticide treatments. The annual cost of synthetic herbicide treatment ranged from \$14.50 to \$108.10 per acre compared to the weed oil cost of \$12.50 to \$69.60 per acre. In the cases of carrots, weed control by synthetic herbicide was about 3 times lower than control by weed oil. The synthetic insecticide average treatment cost ranged from \$31.70 to \$97.50 per acre while the average treatment cost of oil insecticides ranged from \$60.90 to \$103.40 per acre. For citrus crops, oil treatments were about \$20.00 to \$36.00 per acre cheaper than synthetic treatments. For deciduous

TABLE 8-5

A Summary of Annual Treatment Costs with Nonsynthetic and Synthetic Pesticides

Crops	Non-Synthetic Pesticides		Synthetic Pesticides	
	Average ($/acre)	Range ($/acre)	Average ($/acre)	Range ($/acre)
Herbicides				
Alfalfa, Weed Oil	30.00	17.50-42.50	14.50	8.10-21.80
Desicaant	12.50	12.50	14.50	8.10-21.80
Carrots	69.60	47.75-91.50	23.00	10.00-46.00
Avocado	66.30	47.50-85.00	58.80	7.25-48.40
Citrus	66.30	47.50-85.00	41.55	11.70-71.40
School Districts	63.00	38.00-88.00	108.10	25.20-177.75
Weed Control Unclassified	63.00	38.00-88.00	72.55	22.50-134.00
Insecticides				
Almond	61.35	53.05-69.65	31.70	23.00-39.00
Apricot	78.19	72.94-83.43	38.30	38.00
Grapefruit	60.90	58.00-63.80	82.40	38.70-138.30
Orange	60.90	58.00-63.80	82.40	38.70-138.30
Lemon	60.90	58.00-63.80	97.50	50.80-156.40
Peach & Nectarine	77.15	66.10-88.20	59.30	45.90-82.30
Plum & Prune	94.40	83.30-105.50	36.80	18.20-55.30
Pear	103.40	97.10-109.70	66.80	37.20-97.60

TABLE 8-6

Annual Costs for Two IPM Programs

IPM - Oil					
Citrus	Application Acreage (1977 data)	Lbs. of Oil Saved (1977 data)	Lbs. of Oil Saved Per Acre	Synthetic Lbs/Acre Used	Oil Used Under IPM Lbs/Acre
Grapefruit	3,376	224,520	66.5	0	66.5
Lemon	42,879	275,228	64.0	0	64.0
Orange	24,301	1,594,203	65.5	0	65.5

IPM - Synthetic					
Citrus	Application Acreage (1977 data)	Lbs. of Oil Saved (1977 data)	Lbs. of Oil Saved Per Acre	Synthetic & Biological Used Under IPM Lbs/Acre	Lbs/Acre of Oil Used
Grapefruit	3,376	449,040	133	17.79	0
Lemon	42,879	5,508,640	128	17.79	0
Orange	24,301	3,188,407	131	17.79	0

Annual Cost ($/Acre)				
Citrus	Application Acreage	IPM - Oil	IPM-Synthetic	Non-IPM Oil Use
Grapefruit	3,376	69.76	105.20	54.96
Lemon	42,879	68.90	105.20	53.30
Orange	24,301	69.20	105.20	54.25

TABLE 8-7

Cost and Oil Use Reduction Due to
Use of Low Volume Application Methods

Crop	Oil Use Reduction (1000 lbs.)	Cost Reduction: Total Saving (dollars)	Cost Reduction: Dollars Per Acre
Grape-fruit	49.9-74.9	12,743-19,097	6.80-16.99
Lemon	612.1-795.9	156,171-156,253	7.84-19.59
Orange	354.3-551.4	90,382-576,625	6.53-16.32
Almonds	869.6	260,760	2.46
Apricots	79.4	20,150	1.76
Nectarines	92	23,404	2.75
Peaches	322	82,336	2.53
Pears	286.6	73,052	4.90
Plums	89.3	22.789	2.23
Prunes	117.3	29,911	1.95

tree crops, synthetic treatments were less costly than oil control, and the difference in cost ranged from about $18.00 to $65.00 per acre.

There is a significant difference in annual costs observed between IPM procedures and non-IPM oil use (see Table 8-6). The annual cost of non-IPM oil use is about half of that IPM practice with synthetic pesticide ($105.20 per acre), while the annual cost of IPM practice with oil is in the middle range ($69.00 per acre). The cost presented here for IPM, however, is for first year expenses. In some cases, a treatment is not required every year in the IPM procedures. In these cases, IPM practice will generally cost less in the long run.

Table 8-7 presents the cost reduction estimated to occur for crops where oil use may be reduced by partial switching of high volume applications to low volume and alternative sprayer application techniques. The total annual cost saving that can be realized ranged from $12,743 to $782,280 or $5.28 to $20.83 per acre. In considering the cost reduction from switching to more efficient application methods, it should be mentioned that such a change involves initial investment in the purchase of new equipment and other tools. This initial cost was not considered in our cost analysis. However, this equipment cost, when averaged over a period of ten years, becomes a relatively small investment when compared to the cost savings realized from oil use reduction.

8.5 Air Quality Impact Assessment

The alternatives to the current use of oil as pesticides were evaluated from the perspective of air quality impacts. This evaluation consisted of estimating the net reduction in total hydrocarbon emissions (if any) which would result from the implementation of the various alternatives and then determining the significance of these reductions in terms of total hydrocarbon emissions from pesticide applications and from other source categories. The three counties with the greatest estimated use of pure oil pesticides were used as examples for purposes of evaluating potential impacts on ambient ozone levels. The cost effectiveness of the various alternatives for reducing hydrocarbon emissions was also calculated.

8.5.1 Evaluation Approach

The alternative pesticide control methods and their respective reductions in oil applications were discussed in the previous chapter. To determine the net reductions in hydrocarbon emissions from each of the alternatives, both the reduced quantities of applied hydrocarbons and the respective emissions of synthetic and nonsynthetic pesticides were considered. For example, it was determined earlier (Table 7-17) that synthetic pesticides could be substituted for 100 percent of the pure oils applied to grapefruit and that only a very small quantity of synthetic pesticides was needed to achieve the same results as the pure oils. As a consequence, a statewide reduction in oil applications to grapefruit of 499,000 pounds could have been achieved using this alternative. Combined with this information was the respective hydrocarbon emissions from synthetic and nonsynthetic pesticides. The emission factor for nonsynthetic pesticide emissions was based on the percentage of emissions shown for each commodity, and the emission for synthetic pesticides was based upon information obtained from the Fresno County emission inventory study by Leung, et al. 1978.[9] By applying the first factor to the quantity of pure oil <u>not</u> used as a consequence of substituting synthetics and the second factor to the quantity of synthetics substituted, and then determining the difference between the results, the emissions reduction figure of approximately 438,000 pounds shown in Table 8-8 was calculated for grapefruit. Similar calculations were performed for all other crops and applications in the synthetic pesticide substitution category of alternatives. For the remaining alternative categories (application and IPM methods), the emission reductions were calculated by multiplying the percentage of oil reduction obtainable through the use of alternative methods with emissions of individual commodities.

The costs of emission reduction for each alternative to oil pesticide use were calculated from the average pounds per acre of application and emission recorded for each commodity in the application and emission inventories. The relative cost per ton of emission reduction was calculated as:

$$R_c = \frac{2{,}000 \text{ lbs./ton}}{E_n - E_a} (C_a - C_n)$$

TABLE 8-8

Estimated Cost of Emission Reduction by Different Alternatives

Crop or Other Application	Synthetic Pesticides: Percent of Possible Substitution for Oil[a]	Synthetic Pesticides: Estimated Oil Use Reduction (1000 lbs)	Synthetic Pesticides: Estimated Emission Reduction (1000 lbs)	Synthetic Pesticides: Relative Cost of Emission Reduction ($/ton)[b]	Synthetic Pesticides: Actual Cost of Emission Reduction	Application Methods: Percent of Use Reduction Per Acre	Application Methods: Estimated Oil Use Reduction Total (1000 lbs.)	Application Methods: Estimated Emission Reduction (1000 lbs)	Application Methods: Relative Cost of Emission Reduction ($/ton)[b]	Application Methods: Actual Cost of Emission Reduction ($/ton)	IPM: Percent Substitution Possible	IPM: Estimated Oil Use Reduction (1000 lbs)	IPM: Estimated Emission Reduction (1000 lbs)	IPM: Relative Cost of Emission Reduction ($/ton)[b] IPM-Oil	IPM: Relative Cost of Emission Reduction ($/ton)[b] IPM-Synthetic	IPM: Actual Cost of Emission Reduction ($/ton) IPM-Oil	IPM: Actual Cost of Emission Reduction ($/ton) IPM-Synthetic
<u>Insecticides</u>																	
Grapefruit	100	499	438	511	1,543	LV 50 Sp 20	74.9 49.9	65.8 43.8	-581 -581	923 3,178	45-90	224.6-449.1	197.2-394.3	642	1,008	3,073	2,110
Lemon	100	6,122	5,551	562	1,527	LV 50 Sp 20	612.1 795.7	955.2 721.7	-562 -563	849 2,968	45-90	2,754.9-5,509.8	2,498.7-4,997.4	702	1,048	3.104	2,125
Orange	100	3,543	3,111	566	1,612	LV 50 Sp 20	531.4 354.3	466.6 310.1	-581 -581	937 3,214	45-90	1,594.4-3,188.7	1,398.9-2,799.7	674	1,041	3,121	2,149
Almonds	0	0				LV 25	815.7-1,673.6	745.5-1,164.1	-559	3,945							
Apricots	0	0				LV 25	63.5-95.3	58.6-88.0	-561	4,789							
Nectarines	0	0				LV 25	73.6-110.4	68.7-103.1	-546	3,616							
Peaches	3	77.3	72	-1,371	3,683	LV 25	257.6-306.4	239.8-359.7	-529	3,810							
Pears	20-30	573.3	496	-1,661	2,187	LV 25	229.3-343.9	198.6-297.8	-589	2,968							
Plums	2	14.3	13	-2,969	2,511	LV 25	71.4-107.1	65.2-97.8	-558	4,191							
Prunes	20-30	234.5	217	-3,019	2,864	LV 25	93.8-140.7	86.6-130.0	-608	4,945							
SUBTOTAL (Spray Oil)		11,063.4	9,898														
<u>Herbicides</u>																	
Alfalfa, Weed Oil	50	6,236.5	5,608	-16	183												
Alfalfa, Defoliant	100	4,570	4,276	-70.25	257												
Avocado	100	1,240.2	1,160	-52	393												
Carrot	48	5,328	5,053	-152.60	81												
Citrus	100	3,650	3,462	86	1,194												
School District	50	1,751	1,662	1,287	2,130												
Weed Control Unclassified	75	88,351	84,038	-83	401												
SUBTOTAL (Herbicide Oil)		111,127	105,259														
TOTAL		122,190	115,157				4,023.2-5,275.7	3,626.2-4,403.7				4,573.9-9,147.6	4,094.8-8,191.4				

a. Applications under Home and Garden are excluded.

b. Relative cost is the cost of an alternative minus the cost of oil use.

where: R_c = relative cost of alternative ($/ton).

E_n = emission rate using oil pesticide (lbs/acre).

E_a = emission rate using alternative (lbs/acre).

C_n = total cost (material and application costs) for application of oil ($/acre).

C_a = total cost (material and application cost) for application of alternative ($/acre).

The actual cost per ton of emission reduction for each alternative was:

$$A_c = \frac{2{,}000 \text{ lbs./ton}}{E_a} (C_a)$$

where: A_c = the actual cost (material and applications costs) of alternative ($/ton) and other symbols are the same as above.

The percentage emission from reduced oil application in any alternative was considered the same as the average estimated for each commodity.

When determining the percent fraction of stationary source, TOG emissions attributable to emissions from pesticide oil or its substitutes, the pesticide emission figures reported in the CARB inventory[10] were replaced by those figures reported in this study.

8.5.2 Impact Evaluation

Table 8-8 summarizes the estimated statewide reduction in hydrocarbon emissions which can be achieved by any of three alternatives to the use of pure oils for pest control. A fourth alternative, mechanical and cultural control, is judged to be largely impractical (see Chapter 7) and will not be discussed further. Table 8-8 lists the reductions in hydrocarbon emissions by crop and application and also the estimated costs associated with implementing each alternative (see Section 8.4 for cost estimation basis). The substitution of synthetic pesticides for nonsynthetics is the most effective alternative in terms of total emissions reduction. This alternative would have reduced statewide reported hydrocarbon emissions in 1977 by approximately 115.2 million pounds, or 157.8 tons per day on the average. The most recent emissions inventory published by the California Air Resources Board[10] indicates that in 1976 the total organic gas emissions from all stationary sources statewide were 2,412 tons per day. The reduction in statewide organic gas emissions achieved through the implementation of synthetic alternatives would therefore amount to about 6.5 percent of the total. The IPM alternative, a long-range approach, would be the next most effective alternative, reducing 1977 emissions by about 6.1 million pounds (average) or 8.42 tons per day. This figure amounts to 0.4 percent of the total statewide stationary source emissions in 1976. Finally, the application method alternative would reduce 1977 hydrocarbon emissions by approximately 4.0 million pounds (average) or 5.50 tons per day. This amounts to only 0.2 percent of the total 1976 statewide stationary source emissions.

While the emissions reductions achieved through the substitution of alternatives to pure oil use seem very small relative to statewide stationary source organic gas emissions, these reductions are more significant at the county level in those counties where large quantities of nonsynthetic pesticides are used. As an illustration, the effect of the achievable emission reductions was examined in the three counties which are the biggest users of pure oil pesticides: San Joaquin, Monterey and Tulare. Data of emission reductions by crop and application types achievable in each county by each of the alternatives are presented in Tables A.4-9 through A.4-11 of Appendix A.4. Table 8-9 summarizes these emission reductions by calendar quarters. Table 8-10 summarizes the significance of the emissions reductions relative to the total 1976 stationary source organic emissions. As can be seen in this table, the synthetic pesticide alternative would reduce hydrocarbon emissions in these three counties by an amount equivalent to 32-55 percent of the total organic gas (TOG) emissions from stationary sources in those counties in 1976. This is particularly significant in that two of those counties (San Joaquin and Tulare) have been identified by the CARB as nonattainment for the national ambient air quality standard for ozone. Also, as indicated in Table 8-9, the bulk of the pure oil applications in these two counties was applied during the period of summer and fall months which is the period during which ambient ozone levels are highest and the control of organic emissions is most important.

TABLE 8-9

Summary of Emission Reductions from Different Alternatives in Three California Counties by Calendar Quarter

County / Calendar Quarter	Emission Reduction (lbs.)		
	Synthetic Pesticides	Application Methods	IPM
San Joaquin			
1st	4,119,565	111,399	245
2nd	9,324,193	31,981	266
3rd	3,685,864	2,229	2,563
4th	2,032,209	459	1,540
TOTAL	19,161,831	146,068	4,614
Monterey			
1st	2,241,405	1,098	N/A
2nd	8,484,506	156	N/A
3rd	5,789,166	17	N/A
4th	1,699,751	0	N/A
TOTAL	18,214,828	1,271	
Tulare			
1st	1,416,123	152,205	707
2nd	6,590,728	24,700	12,712
3rd	2,628,643	6,316	23,849
4th	1,517,401	6,873	13,523
TOTAL	12,152,895	190,094	50,786

N/A = Alternative method not applicable.

TABLE 8-10

Summary of Estimated Emission Reduction as a Percentage of 1976 TOG Stationary Source Emissions from Different Alternatives in Three California Counties

County	Average Emissions Reductions (TPD)[a]/Reductions as a % of 1976 TOG[b] Stationary Source Emissions in County		
	Synthetic Pesticide (TPD/%)	Application Method (TPD/%)	IPM (TPD/%)
San Joaquin	26.3/44.2	0.2/0.3	negligible
Monterey	25.0/54.5	negligible	0/0
Tulare	16.7/32.4	0.3/0.6	0.1/0.2

a. TPD = Tons Per Day

b. TOG = Total Organic Gases

Both the relative and actual costs for reducing one ton of hydrocarbon emission was calculated. The relative cost is the cost above or below the cost of oil use when an alternative is implemented. The actual cost is the total cost incurred when an alternative is implemented. Both costs were computed for the synthetic pesticide substitution, alternative application methods and IPM procedures (see Table 8-8).

The costs of these alternatives in reducing emissions varies accordingly: the least effective alternative is the cheapest and the most effective is generally the most expensive. The application method alternative results in large savings to the user since significant reductions in pure oil use is realized, and the relative cost ranges from a savings of $529 to $608 in reducing one ton of TOG emission. The relative cost of IPM ranges from an increase of $642 to $1,041 per ton of emissions reduced. an increase of $642 to $1,041 per ton of emissions reduced. The relative cost of synthetic pesticide substitution ranges from a high of about $1,287 per ton of emissions reduced for the school district to a savings of approximately $3,019 per ton for prunes. The actual costs for implementing the synthetic pesticide and IPM alternatives to reduce hydrocarbon emissions are quite reasonable. Synthetic pesticide substitution costs range from $81 to $3,683 in reducing one ton of emissions while the costs for using more efficient application methods and IPM procedures are $849-$4,945 and $2,110-$3,121 respectively. In terms of cost effectiveness for emission controls, the alternative control costs are quite acceptable compared to the cost of emission control for service station operation at $2,200-$3,500 per ton of emission reduction or the cost for dry cleaning operation at $400-$1,500 per ton of emission reduction.[11]

8.6 Conclusion and Recommendations

8.6.1 Summary

Based on evidence presented in Chapter 7, there are technically feasible alternatives available to either partially or completely substitute for pesticidal oil use. Synthetic pesticides are available for all commodities considered in this report with the exception of almonds, apricots and nectarines. Oil use reduction can be achieved by using low volume and new sprayer techniques in some applications of all citrus and deciduous tree crops. IPM procedures have been developed for grapefruits, lemons, oranges and pears.

These alternatives were evaluated in some detail for their impacts on energy consumption, costs and air quality, and these impacts are summarized qualitatively in Table 8-11. All alternatives resulted in reduced hydrocarbon emissions. Table 8-11 presents a summary of comparative impacts among the alternative pest control methods discussed in this study. In arriving at these comparative impacts, impacts of oil pesticides on energy consumption, economics and air quality were used as reference points. Impacts of other alternative methods which are either above or below those of oil pesticides are judged as having

TABLE 8-11

A Summary of Comparative Impact Formulation of Alternative Pest Control Methods for 16 Commodities

Crop	Energy Impact[a]				Economic Impact[b]				Air Quality Impact[c]			
	Oil	Synthetic[d]	Application[e]	IPM[d]	Oil	Synthetic[d]	Application[e]	IPM[d]	Oil	Synthetic[d]	Application[e]	IPM[d]
Grapefruit	0	-	-	-	0	+	-	+	0	-	-	-
Lemon	0	-	-	-	0	+	-	+	0	-	-	-
Orange	0	-	-	-	0	+	-	+	0	-	-	-
Almond	0	NA	-	NA	0	NA	-	NA	0	NA	-	NA
Apricot	0	NA	-	NA	0	NA	-	NA	0	NA	-	NA
Nectarine	0	NA	-	NA	0	NA	-	NA	0	NA	-	NA
Peaches	0	-	-	NA	0	-	-	NA	0	-	-	NA
Plum	0	-	-	NA	0	--	-	NA	0	-	-	NA
Prunes	0	-	-	NA	0	--	-	NA	0	-	-	NA
Pears	0	-	-	0	0	--	-	++	0	-	-	0
Alfalfa	0	-	NA	NA	0	--	NA	NA	0	-	NA	NA
Avocado	0	-	NA	NA	0	-	NA	NA	0	-	NA	NA
Carrot	0	-	NA	NA	0	--	NA	NA	0	-	NA	NA
Citrus	0	-	NA	NA	0	-	NA	NA	0	-	NA	NA
School District	0	-	NA	NA	0	+	NA	NA	0	-	NA	NA
Weed Control Unclassified	0	-	NA	NA	0	+	NA	NA	0	-	NA	NA

[a] Energy Impact
0 = energy use by oil pesticides and serves as reference point of comparison with other alternatives.
- = decrease or saving in energy use as compared to oil pesticides.
+ = increase in energy use as compared to oil pesticides.

[b] Economic Impact
0 = cost of using oil pesticides ($/acre), and serves as reference point of comparision with other alternatives.
- = decrease in cost ($/acre) by 1X as compared to oil pesticides.
-- = decrease in cost ($/acre) by 2X or more as compared to oil pesticides.
+ = increase in cost ($/acre) by 1X as compared to oil pesticides.
++ = increase in cost ($/acre) by 2X or more as compared to oil pesticides.

[c] Air Quality Impact
0 = hydrocarbon emission of oil pesticide and serves as reference point of comparison with other alternatives; it also represents hydrocarbon emissions of other alternatives similar to oil use.
- = decrease in hydrocarbon emission as compared to oil pesticide.
+ = increase in hydrocarbon emission as compared to oil pesticide.

[d] NA = not available
[e] NA = not applicable

increased or decreased impacts. A detailed explanation of this comparative impact rating system is presented as footnotes to Table 8-11.

The potential annual emission reduction ranged from a low of 4 million pounds by switching to more efficient application methods to a high of 122 million pounds for synthetic pesticide substitution. A similar trend of reduction in energy consumption among the alternatives was also observed.

The results of the cost analysis of different alternatives provided a somewhat different impact pattern. The costs of synthetic pesticides and their application on citrus were higher than for oil use and were lower on deciduous tree crops. In vegetable crops the cost of synthetic herbicidal treatment was about three times lower than the cost for control with weed oil. For herbicidal purposes for school districts and weed control unclassified, however, the cost was higher when synthetic pesticides were used. Costs for IPM-synthetic and IPM-oil practices were both higher than non-IPM oil use for the three citrus crops. These costs, however, were the cost for the treatment year. With IPM, treatment may not be required each year. For the long term consideration, the cost for IPM will be reduced and become very competitive with conventional oil application.

8.6.2 Conclusions and Recommendations

Based on the impact assessments of the different alternatives summarized earlier, the following conclusions are made with consideration goven to hydrocarbon emission reduction, cost, and energy use in descending order of priority.

(1) Synthetic insecticides and herbicides are available as substitutes for some or all of the oil use for all but three of the crops considered in this report. The synthetic insecticide use has been shown to be more costly with some crops. The synthetic herbicides, on the other hand, are generally with lower costs.

(2) Oil use reduction can be achieved in part by increasing the use of low volume and new sprayer techniques for some of the oil application on deciduous and citrus tree crops.

(3) IPM procedures may or may not result in immediate oil use and cost reduction. However, in the long term consideration, oil use and cost reduction can be achieved.

Based on data presented and discussion made in Chapter 7 and 8 on the technical feasibility and various possible impacts of different alternatives, three recommendations are made as options for implementation to reduce hydrocarbon emissions resulting from oil pesticide use.

Use of More Efficient Application Methods. The "application methods" alternative, although the least effective alternative in terms of reducing hydrocarbon emissions from pure oil applications, is by far the most cost effective approach. By switching to more efficient, lower volume and air tower sprayer application methods, the pesticide user saves a significant amount of money. These savings alone should serve as an incentive to implement this alternative, and compliance with this approach could be entirely voluntary. If necessary, however, enforcement procedures could be developed.

Implementation of a voluntary program would require a user education program. Such a program could be carried out by either the county agricultural commissioners office (possibly with state funding or assistance) or at the state level by the Department of Food and Agriculture and/or the U.C. Extension Service. Implementation of an enforced system would be more complex. All nonsynthetics could be added to the list of restricted pesticides thereby placing stringent controls over the labeling of such substances and the manner in which they could be applied. Such an action would require action by the CDFA and quite probably a change in existing law governing the classification of pesticides. Actual enforcement would be left up to the county agricultural commissioners.

Other approaches to modifying application methods for pure oils could conceivably include the "burn day" concept currently applied to agricultural burning, or regulating the time of day at which oils could be applied. The burn day concept would theoretically restrict pure oil applications to days on which meteorological conditions favor rapid dilution and dispersal of organic gases, preventing significant build-up of ozone in the ambient air. The time of day approach would theoretically reduce the impact of hydrocarbon emissions by insuring that the pure oil pesticides would be applied at a time, such as late afternoon or early evening, when solar insolation would be insufficient to result in ozone formation. Both the burn day and time of day approaches would fail to be completely effective, however, because the evaporation of pure oils is slow enough that the resulting hydrocarbon emissions will carry over into the next day or even much longer. In addition, meteorological conditions would often likely be detrimental to effective spraying late in the day or on "no-burn" days. Additionally, it is generally of critical importance to apply pesticides within a narrowly-defined time period. By forcing the pesticide user to wait several days or even weeks, as in the "burn day" approach, irreversible crop damage may be suffered.

Synthetic Pesticide Substitution. The substitution of synthetic herbicides for nonsynthetics, is clearly the most effective alternative for reducing hydrocarbon emissions.

The implementation of the synthetic substitution alternative could be achieved by actions similar to those described previously for the application methods alternative. Implementation could be on either a voluntary or on an enforcement basis. Through the education efforts outlined earlier, pesticide users could be encouraged to shift from nonsynthetics to synthetics in those cases where synthetics would cost the same of less and would have equivalent toxicity ratings. For those crops and applications where synthetics are more expensive and are relatively low in health impacts, some added incentive to use synthetics could possibly be provided by government refunds of the mill tax (originally charged to the manufacturer of synthetics) directly to the user who substitutes synthetics for nonsynthetics during the summer and fall smog season in certain areas. This latter governmental incentive (or any other similar incentive involving payments or tax credits) would require changes in existing tax laws. Implementation of the synthetic substitution alternative by enforcement may involve the classification of nonsynthetics as restricted pesticides as discussed previously.

Development of IPM Procedures. IPM is probably the best long term alternative. IPM involves a complex interaction of pest control methods, biological controls, crop management practices and other techniques. Under the IPM procedures, pesticides are applied on a need basis only. To fully implement IPM will take years of research and extensive education of growers and others who currently use pesticides. Additional trained personnel will be needed to implement the IPM program. Although existing agricultural agencies in California (CDFA, county agricultural commissioners, etc.) will have most of the responsibility for implementing IPM, additional help is needed to speed up the establishment of IPM as a routine practice. Air pollution regulatory agencies, including the CARB, could be an important influence in establishing IPM through funding research and education programs and/or influencing public policy decisions on IPM implementation by stressing air quality benefits.

In summary, a more effective approach to reduce hydrocarbon emissions from oil pesticide applications involves the use of all three alternatives. The end-users of oil pesticides should be educated to use the more efficient application methods. Synthetic herbicides with low toxicity and costs and existing available IPM procedures should be advertised for wider acceptance. The recommendation of combining different alternatives for oil use reduction is a reasonable approach from the standpoint of cost effectiveness, health and air quality impact.

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