ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

EPA-330/2-77-001

PESTICIDE USE OBSERVATIONS

IMPERIAL VALLEY, CALIFORNIA

(AUGUST 22– 31, 1976)

ENFORCEMENT INVESTIGATIONS CENTER

DENVER, COLORADO

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I. INTRODUCTION

In the past three decades the agricultural industry has grown increasingly dependent upon the use of chemical pesticides to maintain and increase crop yields. While the use of these materials increases annually, the accumulation of information useful for evaluating environmental hazards resulting from pesticide use has not been extensive. To assess the environmental hazards associated with pesticide use, the Environmental Protection Agency (EPA) has initiated monitoring activities in several parts of the country, the first phase of a National Pesticide Use Observation Program. The Imperial Valley area of California was selected to represent the southwestern agricultural region of the United States. Two cotton fields -- a 5.5 ha (13.5 acre) field near Calipatria, and a 28.4 ha (70 acre) field near Brawley -- were chosen for use observation. The primary objectives of the investigation were:

1. Determine if pesticide use is consistent with the label and other regulations.

2. Determine if pesticides, when properly used, cause environmental or health hazards.

3. Assess the effectiveness of a commercial pest management advisory program.

4. Identify use observation techniques of value to EPA and other pesticide regulatory agencies.

A ten-day use observation study was begun on August 22, 1976. Aerial application on the first field was made by helicopter on August 27 followed by an application on a second field by a fixed-wing aircraft on August 29. Pesticide residue analyses of soil, sediment, water, vegetation, and air were performed on samples gathered from the target fields and the immediate surrounding areas. Drift characteristics were defined by use of dye-tracer techniques and a variety of spray droplet cards and impaction devices. In addition, tests were done to evaluate the acetylcholinesterase (AChE) inhibition in channel catfish exposed in-situ in drains, canals, and rivers near the test fields.

Procedures followed by pesticide applicators were observed to determine if they: read and understood the product labels; followed directions and precautions on the label; properly cleaned, stored, and maintained application and safety equipment; and properly disposed of used pesticide containers.

A joint cooperative effort was made by the National Enforcement Investigations Center (NEIC) and the Imperial County Agricultural Commission to assess the pesticide drift from agricultural areas into the populated residential sectors of the Valley. Staff members of the Agricultural Commissioner's Office collected three sets of high-volume air samples within the city limits of Brawley, Calexico, and El Centro during July and August. Chemical analyses of the samples for selected pesticide residues were performed by NEIC.

II. SUMMARY AND CONCLUSIONS

During the summer months, cotton fields in Imperial Valley are subject to infestations of pest organisms, principally the pink bollworm (*Pectinophora gossypiella*). Control of this insect requires intense and repeated applications of various pesticides.

A field study was conducted by the National Enforcement Investigations Center from August 22 to 31, 1976, to evaluate pesticide handling prior to, during, and after treatment, and the effects of the treatments on the environment. Observations were made on the treatment of two cotton fields: field "A", where the application was by helicopter; and field "B", where treatment was by a fixed-wing aircraft.

A secondary investigation was conducted to determine if pesticide drift was entering metropolitan areas of Imperial Valley.

GENERAL CONCLUSIONS

1. Generally, pesticide use was consistent with label instructions and other regulations.

2. Although pesticides were applied properly, environmental and health hazards occurred.

3. The pest management program evaluated was beneficial economically and environmentally.

SPECIFIC CONCLUSIONS

The advisory firm responsible for the maintenance of both study fields exercised sound judgment in the selection of appropriate pesticides and application rates necessary for controlling the infestation of pest organisms. These recommendations were consistent with label instructions and Federal Regulations. The advisor further demonstrated obvious concern about possible environmental contamination by delaying the application of field "A" for 24 hours because of recent irrigation of this field.

Inconsistencies observed pertaining to label instructions and Federal Regulations were:

1. Improper recommendations by the advisory firm of a 36-hour re-entry time for field "A" (Federal Regulations specify a 48-hour period for Azodrin® *) and a 30-day delay period until harvest for field "B" (the container label for Nudrin® 1.8** specifies a 40-day delay period before harvest).

2. The container label for Ethyl-Methyl Parathion 6-3E recommends a re-entry time of 24 hours whereas Federal Regulations require a 48-hour period for parathion.

The advisory firm is also a pesticide distributor and formulator. Evaluation of this firm's premises showed storage facilities to be clean, well ventilated, and orderly, with appropriate precautionary signs visible.

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* *Azodrin® 5 - EPA Reg. No. 201-157-AA-Shell Chemical Co.*

** *Nudrin® 1.8 - Reg. No. 00201-00347AA-Shell Chemical Co.*

Observations and interviews by EPA personnel indicated both applicators were conscientious and well informed of the proper use of pesticides. Spraying operations were halted whenever weather conditions deteriorated. However, despite all efforts, potential environmental hazards occurred. Substantial spray drift resulting from the application on field "B" was shown to intrude onto nearby sensitive crops, a private orchard, and domestic dwellings. Analyses of ambient air samples of metropolitan areas of Imperial Valley showed that translocation of pesticide material into these areas does occur. Additional studies are required to assess the impact of such intrusion.

Fish exposed in-situ in the drainage ditch bordering field "A" suffered AChE inhibition resulting from exposure to anti-cholinergic compounds. Chemical analyses of water and sediment samples indicate that the contamination probably resulted from surface or tile drainage runoff, and not directly from pesticide drift.

The commercial pest management program evaluated during this study proved to be economically and environmentally beneficial. Crop damage resulting from pest insects was observed to be minimal. Application rates in all instances were less than the maximum allowable concentration recommended by the container label, minimizing intrusion of pesticide into the environment.

The procedures followed for handling, mixing and loading of pesticides for both applications were adequate. Workers were well informed of their duties and attired in appropriate safety apparel. All empty pesticide containers were rinsed at the loading site and contaminated water was added to the spray mixtures. Disposal of used pesticide containers was facilitated by county maintenance of four secured and posted container disposal sites. A similar disposal program should be initiated in all agricultural areas where intensive pesticide application is practiced.

Comparative chemical analyses of pesticide mixtures from the mixing tanks and the spray plane hoppers indicated that a loss of 14 to 25% active pesticide ingredients occurred during the mixing and loading operations. No specific cause for this phenomenon was determined. Additional chemical analyses showed the pesticide mixture applied on field "A" to be contaminated with 0.02% of both methyl and ethyl parathion.

Clean-up facilities for applicating equipment ranged from no permanent facility for the applicator of field "A", to a sloped concrete washing area and a large leach field to contain all contaminated rinse water for the field "B" applicator.

Pesticide spray drift from the target area was variable. The helicopter application on field "A" resulted in no significant drift beyond the target field. However, the application of field "B" by conventional aircraft resulted in substantial drift onto sensitive crops and domestic areas. It was further determined that workers employed as flaggers were exposed to pesticide drift. There is a need for better definition of adequate safety apparel for these workers by EPA and appropriate State regulatory agencies.

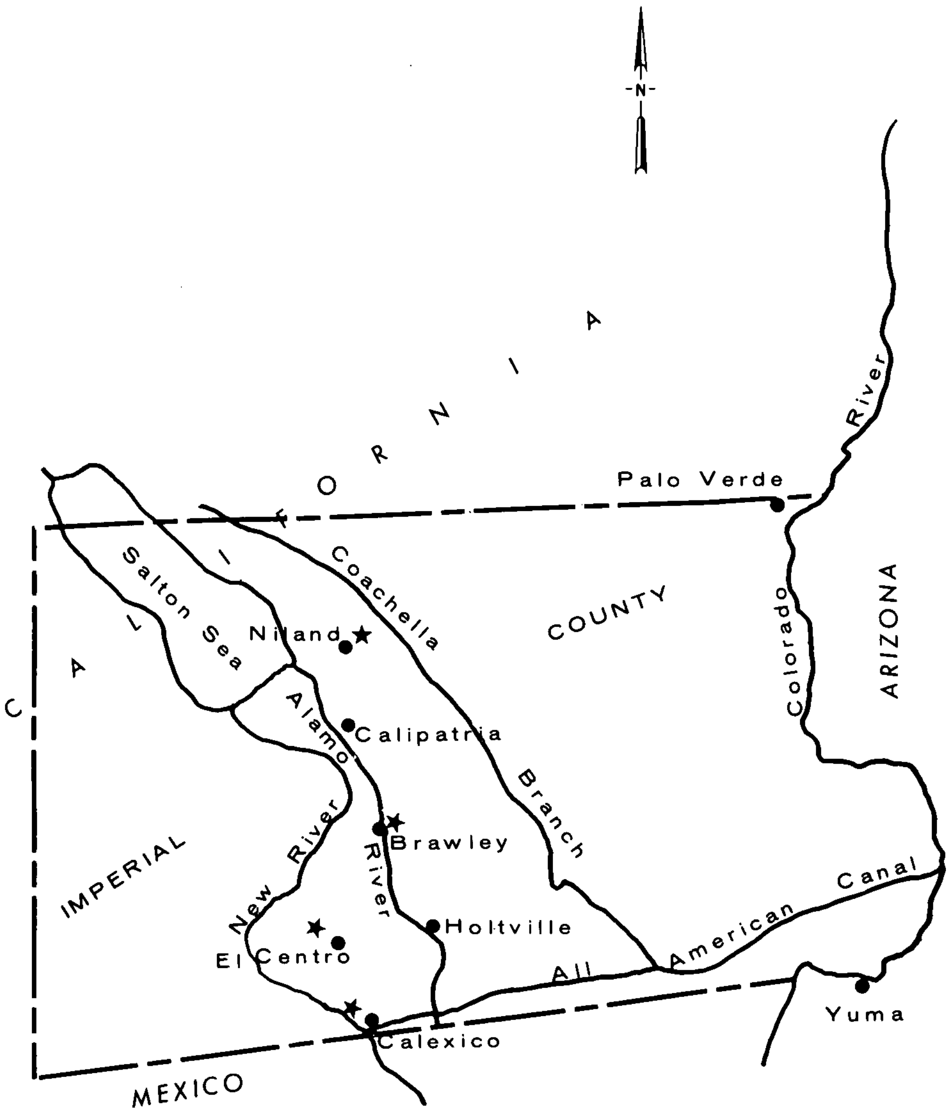
Immediately following the application of field "B", an application was made on the field directly to the west. Neither EPA or the landowner was aware of this second application. Regulations are needed which would require oral communication between the advisory firm and landowner prior to any pesticide application. In the event that this is impossible, the field should be conspicuously posted and dated indicating a safe re-entry time.

Of the various techniques employed to detect spray drift, high-volume air samplers and spray droplet cards were the most effective. The use of spray droplet cards should be of particular interest to State and local regulatory agencies because this technique involves little monetary investment and has minimal manpower requirements.

III. BACKGROUND

Imperial County is located in the southwest corner of California [Fig. 1] encompassing more than 10,800 km^2 (4,200 mi^2). The climate is that of a true desert, with an annual rainfall of less than 7 cm (2.75 in). Approximately 182,000 ha (450,000 acres) are under irrigated cultivation, making this the largest desert irrigation project in the western hemisphere. Water is supplied entirely by the Colorado River by way of the All-American Canal.[1,2]

Salt accumulation in the soil of Imperial Valley has been a problem for many years. This has resulted from a gradual increase in salinity of the Colorado River water due to salt loading and concentrating effects upstream of Imperial Dam.[3] Installation of a tile drainage system was initiated in the 1920's in order to maintain a proper salt balance in the soil. The system consists of tile drains 1.8 m (6 ft) beneath the surface of cultivated fields spaced from 15 to 90 m (50 to 300 ft) apart. Approximately 32,000 km (20,000 mi) of such tiles are now installed in Imperial Valley. When a field is irrigated, 10 to 25% more water is applied than is required by the plants. This permits the excess fresh water to pass through the soil to the 1.8 m (6 ft) level leaching out accumulated salts. The leach water is then collected by more than 2,200 km (1,400 mi) of open ditch drains, and ultimately reaches a catch basin, the Salton Sea, by way of the New and Alamo Rivers. At no point in the system is irrigation return water mixed with incoming fresh canal water. This system has proved successful in controlling the salt balance; however, it also offers the possibility of concentrating water soluble pesticides applied to the field.



★ County Maintained Pesticide Disposal Dump

Figure 1. Imperial Valley, California

For the past two years, Imperial County has generated an annual agricultural gross income of more than one-half billion dollars, ranking it among the top five agricultural counties in the United States. As a result of a twelve-month growing season, agricultural production is extremely diverse. During any month of the year, all three phases of agricultural development (planting, cultivation, and harvesting), as well as cattle feeding operations, can be observed. Extensive use of crop rotation is practiced so that over a two-year period most cultivated land will produce a series of three food and non-food products. As in most highly developed agricultural areas (especially cotton-growing areas), pesticide use is greatly relied upon to insure maximum production from the land.

The majority of the landowners in Imperial Valley employ commercial agricultural advisors. The advisor has the responsibility of identifying insect populations, recommending when a pesticide application is required, choosing the proper pesticide, and indicating the rate of application. In some instances, the advisor performs these duties and charges the grower for the service. It is then the responsibility of the landowner to make arrangements for the purchase and application of the pesticide. However, in other cases, the advisor performs his field evaluations free of charge, with the agreement that all pesticides be purchased through his distributing firm. In the latter case, the advisory firm may even do a portion of the formulating. Under this program, the advisor makes all necessary arrangements with the aerial applicator.

Certain aspects of aerial application in Imperial Valley differ from those observed at other areas of the country. A major portion of the applications are made at night by aircraft equipped with high intensity landing lights for illumination. There are two factors that make nighttime applications desirable: 1) the adult moth of the pink bollworm (*Pectinophora gossypiella* [Saunders]), a principal pest organism of cotton, is nocturnal and therefore most susceptible to pesticide spray after dark, and 2) apiaries comprise a million dollar industry in the Valley and daytime spraying while bees are foraging can be devastating to colonies.

Flight time is a critical factor, because of the large geographical area encompassed by Imperial Valley and the intensity of aerial application. To reduce flight time, few of the loading and mixing operations are performed at a fixed staging area. Numerous small dirt landing strips are located strategically throughout the valley in areas of the most intensive spraying. These airstrips are maintained and used by a cooperative effort of the applicator firms. No permanent facilities are provided at the airstrip; mixing and loading operations are dependent upon the use of mobile nurse rigs. These are specially designed tank-trucks which rendezvous with the aircraft at a strip nearest the target field and are capable of performing a complete mixing and loading operation. Dilution water is carried aboard the truck and replenished, as required, from the numerous irrigation canals in the area.

IV. DESCRIPTION OF STUDY AREAS

Field "A" was a 5.5 ha (13.5 acres) rectangular field which was planted in cotton. The field was surrounded by other cotton fields, alfalfa, fallow ground, orchards, domestic dwellings, a livestock area, and county roads [Fig. 2]. A lateral canal borders the southern and western portions of the field. A main collection drain runs south of the field (but does not drain the target field) and empties into the Alamo River to the west approximately 1.6 km (1 mi).

Twenty-four sampling stations were established in the study area. One station (36) was located on the target field. Five stations (4, 6, 7, 8, 32) were aquatic: two in the collection drain, one in the lateral canal, and two in the Alamo River. The remaining eighteen sites were located off the target field in areas likely to receive drift or where excessive drift would be of concern, such as onto sensitive crops or residences. The meteorological laboratory was located at station 45 [Fig. 2].

Air samples were collected by various methods on and surrounding the target field to determine drift characteristics [Table 1]. Soil, water, vegetation, and sediment samples were taken at appropriate sites for residue analysis. In-situ fish exposures were done in the lateral canal, drainage ditch, and Alamo River and the fish tested for AChE response.

Field "B" was 28.4 ha (70 acres) in area and was also planted in cotton. It was surrounded by cotton, alfalfa, county roads and residences [Fig. 3]. A lateral canal and small collection drain border the north edge of the field.

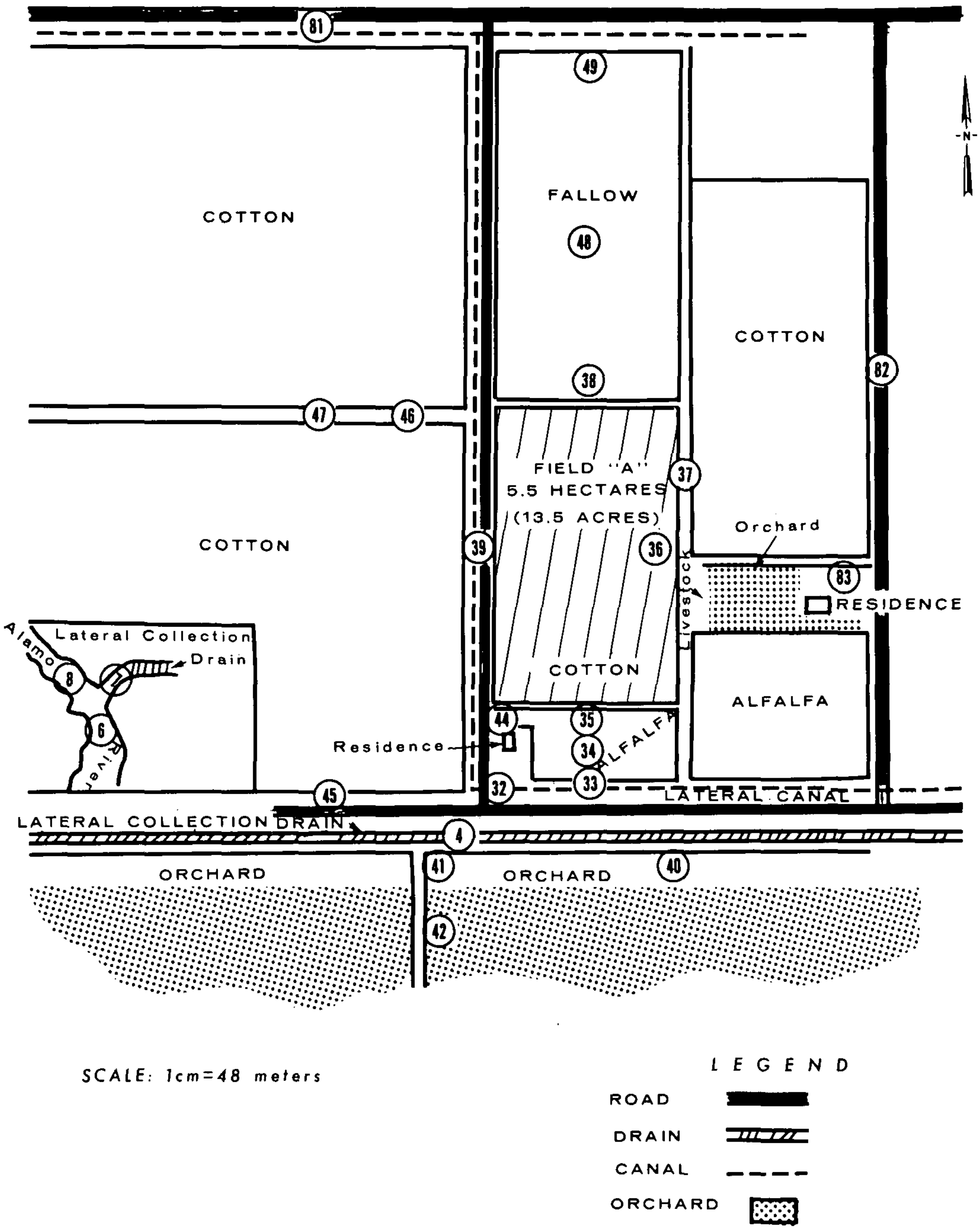


Figure 2. Station Locations Field "A"
Imperial Valley, California
August 1976

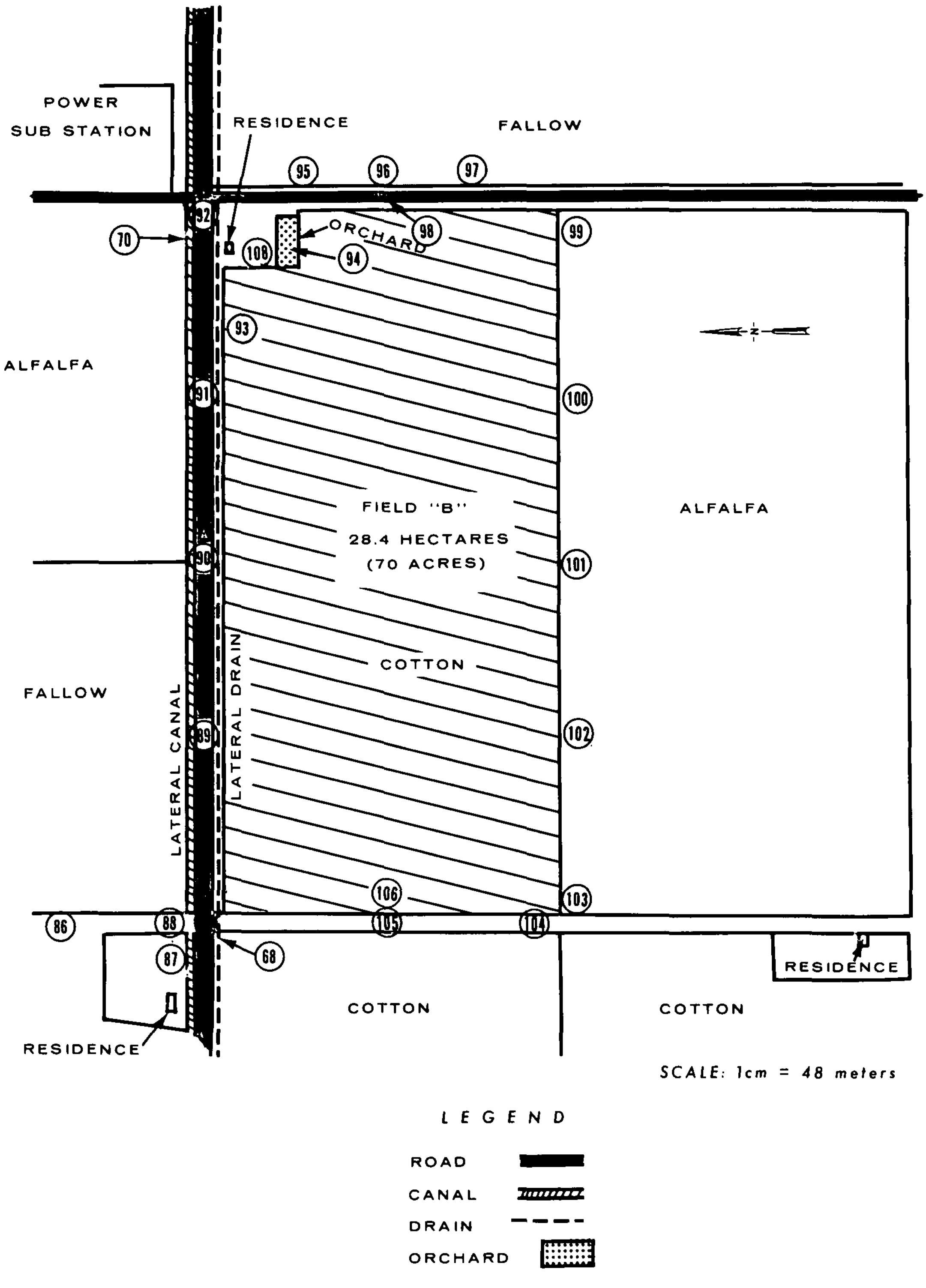


Figure 3. Station Locations Field "B"
Imperial Valley, California
August 1976

Table 1

SAMPLING STATIONS AND DEVICES
FIELD "A"
IMPERIAL VALLEY CALIFORNIA
August 1976

Station Number	Air Samplers: Greenburg-Smith Impinger	Air Samplers: High Volume	Spray Droplet Cards*	Magnesium Oxide Slide	Fish Exposure
4					X
6					X
7					X
8					X
32					X
33	X	X	X	X	
34			X	X	
35			X	X	
36	X	X	X	X	
37	X	X	X	X	
38	X	X	X	X	
39	X	X	X	X	
40			X	X	
41			X	X	
42			X	X	
44			X	X	
45			X	X	
46			X	X	
47			X	X	
48			X	X	
49			X	X	
81			X	X	
82			X	X	
83			X	X	

* *Kromecote, Thermofax, Linagraph, Mylar*

Twenty-four sampling sites were selected on and surrounding the field [Fig. 3]. Two stations were aquatic: one in the lateral canal and one in the collection drain. Air and other environmental samples were collected at pre-selected locations [Table 2]. Fish exposures were done in the canal and drainage ditch. The meteorological laboratory was located at station 88.

Table 2

SAMPLING STATIONS AND DEVICES
FIELD "B"
IMPERIAL VALLEY CALIFORNIA
August 1976

Station Number	Air Samplers Greenburg-Smith Impinger	High Volume	Spray Droplet Cards*	Magnesium Oxide Slide	Fish Exposure
68					X
70					X
86			X	X	
87			X	X	
88			X	X	
89			X	X	
90	X	X	X	X	
91			X	X	
92			X	X	
93	X	X	X	X	
94			X	X	
95			X	X	
96	X	X	X	X	
97			X	X	
98			X	X	
99			X	X	
100			X	X	
101	X	X	X	X	
102			X	X	
103			X	X	
104			X	X	
105	X	X	X	X	
106			X	X	
108			X	X	

Kromecote, Thermofax, Linagraph, Mylar

V. DISCUSSION AND RESULTS

PRE-APPLICATION FIELD "A"

Prior to any pesticide application, it is the responsibility of the agricultural advisor to identify insect populations, determine that pest organisms are present in sufficient numbers to require treatment, and recommend an appropriate pesticide and the application rate.

On August 24, adult moths of the pink bollworm began to appear in pheromone (insect sexual attractant) traps in field "A" [Fig. 4]. The advisor conducted a 20-minute evaluation using a sweep net and hand lens [Fig. 5]. This investigation confirmed the presence of the adult moth and egg masses clinging to the plant leaves. It also revealed the field was infested with lygus (*Lygus oblineatus* [Say]). On the basis of this evaluation, it was recommended that the field be treated with a mixture of 1.23 pt/acre (1.44 liters/ha) of Azodrin 5 to control the adult moth and lygus, and 0.615 pt/acre (0.72 liters/ha) Fundal 4*, an ovicidal pesticide, to prevent maturation of existing egg masses. An application rate of 5 gal/acre (46.8 liters/ha) was specified.

The advisor noted that the field had been irrigated recently and postponed spraying for 24 hours. Application was to be made the night of August 26. The infestation at that time was not severe enough that a 24-hour delay in treatment would endanger the crop. Prior to spraying, the advisory firm notified the landowner of the intended application.

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* *Fundal® 4 - Reg. No. 2139-100AA-NOR-AM® Agri. Products*

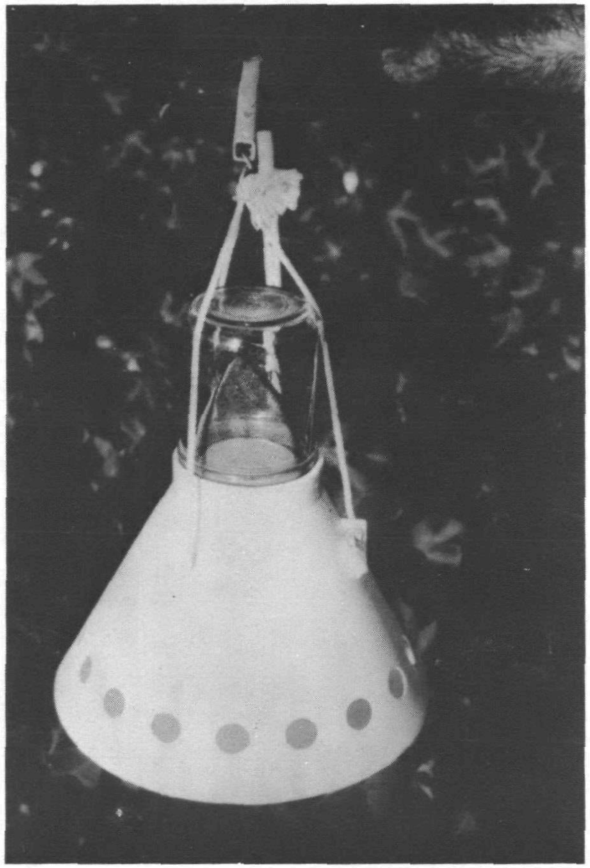

Figure 4. Pheremone trap.

Figure 5. Evaluating insect infestation.

Precautionary requirements were detailed indicating a 36-hour re-entry time, no grazing or feeding of plant material to livestock, and no harvesting of the crop within 21 days of treatment. Later examination of the pesticide labels and the *Code of Federal Regulations* showed the recommendations were correct with the exception of the re-entry period. The *Code of Federal Regulations* (Revised July 1, 1975) lists a re-entry time for Azodrin of 48 hours, not the 36-hour period recommended. It was noted that recommended pesticide concentrations were less than the maximum concentration permissible by the pesticide label. By using lesser concentrations, which experience had shown to be effective, the advisor demonstrated good judgment, which was beneficial both economically and environmentally.

The advisory firm is also a pesticide dealer and formulator; in addition to supplying the required pesticides, this firm made all further arrangements with the aerial applicator. The application was made by helicopter because this was an extremely small field, and maneuverability is very limited for a fixed-wing aircraft.

Since the advisory firm was also the pesticide dealer, members of the NEIC staff, and an EPA Regional pesticide inspector conducted an on-site evaluation of the storage facilities and handling procedures. Storage facilities were found to be excellent [Fig. 6]. The building was modern, clean and well ventilated. Pesticides were stored in an orderly fashion and grouped by compound type and brand. Sufficient space was maintained between each group of compounds to reduce the possibility of accidental mixing or contamination. Adequate safety equipment, such as protective clothing and respirators, was present and appropriate precautionary signs were posted in a clear and visible manner.

Installation of sampling devices to determine drift characteristics began on August 25. Air samplers (Greenburg-Smith impingers and

Figure 6. Pesticide storage facility.

high-volume samplers) were placed on the target field (station 36) and along each side of the perimeter, 30 m (100 ft) from the field (stations 33, 37, 38, 39) [Fig. 7 and 8]. Arrays of spray droplet cards (Kromecote, Thermofax, Linagraph) mylar sheeting (drafting plastic), and magnesium-oxide-coated glass slides were placed at 19 stations [Table 1]. Procedures used to determine drift characteristics are described in further detail in the Appendix. In-situ exposure of channel catfish was begun at stations 4, 6, 7, 8 and 32.

Contact was made with the aerial applicator who indicated field "A" would be sprayed at approximately 2300 hours on August 26. However, by 2100 hours that evening a steady south-southeasterly wind gusting from 13 to 22 km/h (8 to 14 mph) had arisen and spraying operations were postponed. The wind did not subside until approximately 0330 hours August 27, at which time wind velocities of less than 6.4 km/h (4 mph) were recorded.

At 0400 hours, the helicopter and nurse rig arrived at the corner of a vacant field about 2 km north of field "A" and the loading and mixing operation began. An assortment of various pesticides for the night spraying was stored in open compartments on the side of the truck. The vehicle contained a large-capacity water reservoir and a separate mixing tank. Only one member of the work crew was in the immediate vicinity of the truck when mixing operations commenced. This worker was observed wearing the necessary safety equipment required for a mixing operation: long-sleeved coveralls of tightly woven fabric, a large rubberized apron, heavy rubber gloves, boots, hat, protective eye goggles and a canister-type respirator. The worker first read a copy of the advisor's recommendations specifying the pesticides to be applied and the application rate. Containers of Azodrin 5 and Fundal 4 were removed from the truck and placed on the ground near the mixing hopper. The containers were intact and appeared to be free from pesticide

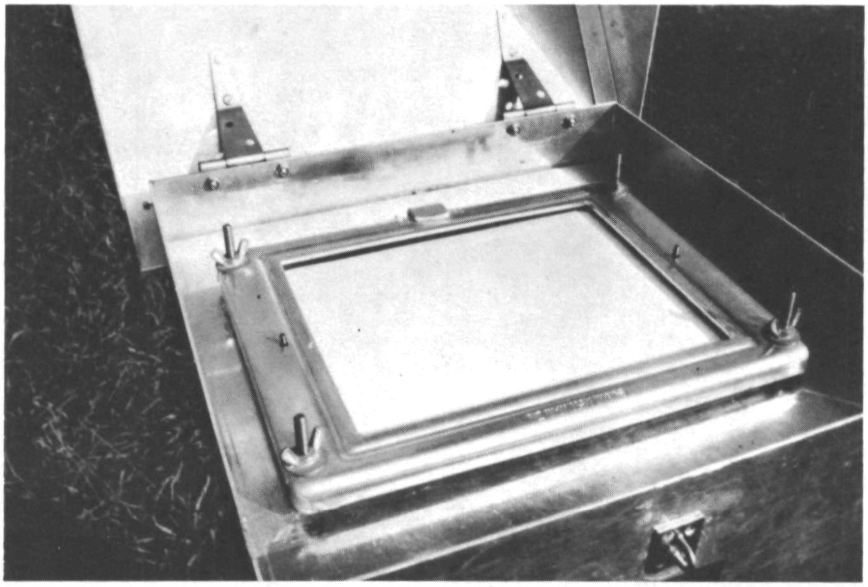

Figure 7. High-Volume Air Sampler with lid raised showing fiberglass filter.

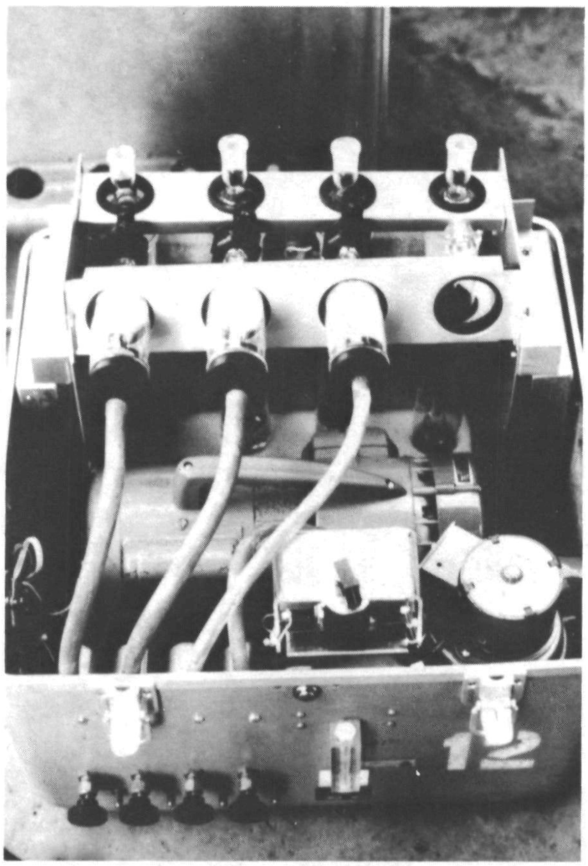

Figure 8. Greenburg-Smith air sampler with upper cover assembly removed to expose impinger train.

residue. The EPA inspectors confirmed these were the same compounds as listed on the recommendation and withdrew samples for later analysis. The mixing tank was of steel construction with a large hinged access door on the left side. Mixing was accomplished by a series of paddle-type rotary agitators. Approximately one-third the volume of water to be used was first introduced into the mixing hopper. Then 2 gal (7.6 liters) Azodrin 5, 1 gal (3.8 liters) Fundal 4, and 1 gal (3.8 liters) nutrient buffer were added. After the pesticide addition, EPA personnel added a tracer dye material (Rhodamine WT) to achieve a final dye concentration of 1,000 μg/l. Empty pesticide containers were rinsed and the wash water added to the mix tank. Next, the hopper door was closed and agitation begun while the volume of the mixture was increased to 65 gal (246 liters). After complete mixing of the material had occurred, the EPA inspector withdrew a sample from the mixing tank for pesticide analysis. The pesticide mixture was then pumped through a heavy-gauge, flexible hose into the aircraft hopper.

A tight seal was maintained between the hose coupling and the aircraft throughout the loading operation and no visible leakage occurred. The pump loading system was a type which, at the completion of loading, sucks any remaining material in the delivery hose back into the mixing tank. When the hose was disconnected from the aircraft, no residual pesticide mixture was seen to flow onto the ground. A second sample of spray mixture was collected directly from the aircraft hopper after loading was complete.

Empty, rinsed containers and refuse (paper cartons, wrappers, etc.) were placed aboard a separate truck and returned to the applicator's main property for proper disposal. Disposal of used pesticide containers does not pose the problem to applicators in Imperial Valley as has been seen to occur in other areas of the country. Four fenced, posted, and secured dumps [Figs. 1, 9, 10] are maintained by the County for the specific

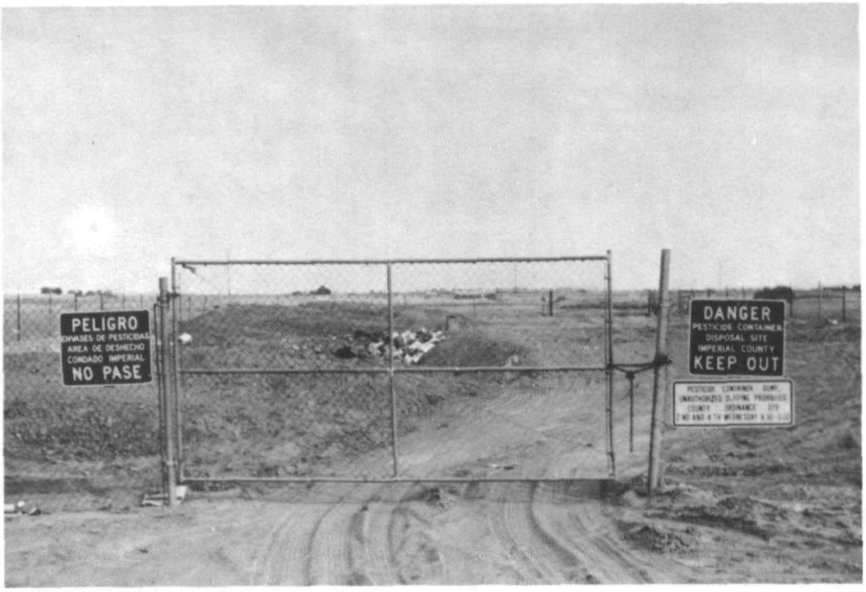

Figure 9. Pesticide container disposal site.

Figure 10. Fenced disposal site with perforated containers awaiting burial.

purpose of pesticide container disposal. The County assumes responsibility for proper burial of the containers.

The procedures followed by the applicator for mixing and loading were good. The worker involved in mixing and loading appeared conscientious, familiar with his job, and conducted the operation in a neat and orderly manner. All proper safety precautions were taken and adequate protective equipment was used in pesticide handling and mixing.

The applicator's temporary storage facility for used pesticide containers was good. Rinsed and perforated containers were stored in a slat-sided, open-topped trailer. A unique feature of this trailer was a trapdoor arrangement that allowed unloading of the containers at the dump site without being handled by the worker [Fig. 11]. The location of the trailer was poor, being in close proximity to livestock pens and an unprotected haystack. Various unperforated containers littered the ground near the trailer.

There was no evidence in the area of an adequate facility for cleaning and rinsing of applicating equipment.

Later analyses of the diluted samples taken from the mixing and spray tanks confirmed the presence of Azodrin and Fundal. However, a discrepancy was noted between the concentrations of pesticide in the mix tank and the spray tank. The total concentration of pesticides was 25% lower in the spray tank than in the mix tank [Table 3]. Several explanations are possible, but none is conclusive.

1. It is possible the sample was taken from the tank before total mixing of the material had occurred. This seems unlikely because the agitating system in the mix tank seemed efficient.

Figure 11. Temporary storage and transport vehicle designed to automatically unload empty chemical containers.

Figure 12. Hiller helicopter equipped with spray boom.

Table 3

PESTICIDE CONCENTRATIONS APPLIED
IMPERIAL VALLEY, CALIFORNIA
August 1976
Field "A"

Compound	Mixing Tank	Spray Tank	% Loss
Azodrin	1.21%	0.86%	29%
Fundal	0.24%	0.20%	17%
Methyl Parathion (Contaminant)	0.02%	0.02%	0
Ethyl Parathion (Contaminant)	0.02%	0.02%	0
Weighted average loss of active ingredients -			25%
Field "B"			
Lanate (Nudrin)	0.53%	0.45%	15%
Azodrin	0.94%	0.82%	13%
Methyl Parathion	0.56%	0.48%	14%
Ethyl Parathion	1.17%	1.02%	13%
Weighted average loss of active ingredients -			14%

2. Additional dilution water could have been pumped into the mix tank after the laboratory sample was taken. This was not observed to have occurred.

3. Material from an earlier application may have remained in the spray tank of the aircraft and diluted the new mixture. However, to cause a 25% dilution this would have required approximately 75 liters (20 gal) of residual material, which is unlikely.

A 25% loss of active ingredient is significant because it could result in reduced efficiency of the pesticide. It would be advisable to sample additional mixing and spraying tanks to determine whether the loss of active ingredient is real or artificially induced by sampling technique.

Analysis of the mix and spray tank material showed the presence of both ethyl and methyl parathion at concentrations of 0.02% each (200 mg/l each). The applicator had acknowledged having sprayed Lanate®*, phosphamidon, and diazinon that evening prior to the application on field "A". This indicates the residual parathion was persistent in the mixing tank for a minimum of 24 hours. The contamination of the spray mixture, in this case, does not constitute an inconsistency with Federal Regulations since both contaminants are registered for application on cotton. However, it does emphasize the need for thorough rinsing of mixing and spraying equipment because a violation could have occurred had the application been on a crop other than cotton. In addition, it is known that the combination of some pesticides may give rise to potentiation -- an increase in toxicity beyond that expected from a mere summation of the constituents.[4] This could be of obvious benefit to the

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* *Lanate is a Registered trademark, DuPont*

landowner in reducing insect pest populations; however, it could also produce environmental damage by affecting beneficial organisms known to be resistant to the intended pesticide application. It should not be overlooked that this was not the first application made with this equipment on that evening. If the contamination was, as it appears, in the mixing tank, earlier applications may have contained substantially larger concentrations of ethyl and methyl parathion. Analyses of the undiluted pesticides used for this application showed all materials to be formulated properly.

APPLICATION FIELD "A"

The aircraft used for this application was a Hiller helicopter [Fig. 12]. The spray boom was equipped with 46 Tee Jet®* spray nozzles, #45 whirlplates and operated at 2/kg/cm^2 (30 lb/in^2) pressure. The spray nozzles were not symmetrically arranged on the boom but were placed at varying angles from each other. This arrangement was intended to compensate for the vortices produced by the helicopter downdraft, and to insure uniform coverage. The aircraft sprayed a 12 m (40 ft) swath at approximately 65 km/h (40 mph).

The EPA observers were stationed 30 m (100 ft) from the field on each side of the perimeter. All personnel wore protective clothing consisting of long-sleeved waterproof coveralls, head and foot covering, gloves, a canister-type respirator, and protective eye goggles [Figs. 13, 14]. High-volume air samplers and the second impingers of the Greenburg-Smith units were turned on 45 minutes before spraying.

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* *Tee Jet is a Registered trademark, Spraying Systems Co.*

Figure 13. Protected worker examining spray droplet cards.

Figure 14. Removing equipment from a recently sprayed cotton field.

Two workers who served as flaggers arrived ten minutes before the application and stationed themselves at the north and south ends of the field. These workers were dressed in closely woven fabric long-sleeved coveralls and baseball-type caps. Respirators were not worn. Each person carried a luminous baton to increase their visibility to the pilot.

The initial pass by the helicopter was made at 0505 and the entire spraying operation was completed by 0516. The main application was made along the north-south axis of the field parallel to the cotton rows and required fifteen passes by the aircraft. Four additional passes were made along the east-west axis to trim the north and south edges of the field. Altitude of the aircraft appeared to be 3 to 4 m above the cotton. Flaggers remained stationary with their batons held aloft as the aircraft made its descent onto the field. As the helicopter approached, the flagger began walking to the next reference point so that the aircraft never passed directly overhead.

The physical characteristics of the spray droplets and local meteorological conditions determine the rate of transport of airborne spray particles from any target area. The larger the spray droplet, the less potential it has to drift from the area of intended application.[5] Meteorological conditions affecting drift are: wind direction and velocity, turbulence, relative humidity and air temperature and atmospheric stability. Wind direction and velocity are primarily responsible for lateral transport of particles, whereas turbulence induces vertical movements. Relative humidity and air temperature determine the rate of evaporation and thus influence the size of liquid droplets. Atmospheric stability characterizes the degree of turbulence associated with certain meteorological conditions. The most stable atmospheric condition is known as an inversion, which occurs when the overhead layer of air is warmer than air at ground level. This condition usually occurs between early evening and early morning and is characterized by low wind velocity and little vertical turbulence.[5]

During the application an inversion existed and atmospheric conditions were very stable. Air temperatures at the 2-m height ranged from 24.9 to 25.1°C (76.8 to 77.2°F) while the 10-m readings ranged from 26.4 to 26.8°C (79.6 to 80.2°F) [Figs. 15, 16]. As would be expected under inversion conditions, no lateral air movement was recorded. Relative humidity was 47%. In general, atmospheric conditions were adequate for aerial application with acceptable drift potential.

POST APPLICATION FIELD "A"

Four hours after the application, all sampling devices with the exception of the fish exposure cages were removed from the field and surrounding areas. Samples of soil, water, vegetation and sediment were taken at this time for pesticide residue analysis.

Air samples from the Greenburg-Smith impingers and high-volume samplers, as well as residue droplets on the mylar sheets, were analyzed at the field laboratory for fluorescent dye. None of the air sampling devices produced consistent results.

Analyses of the spray droplet cards indicated Kromecote was ineffective for an Azodrin-Fundal spray mixture; however, both Thermofax and Linagraph cards produced positive droplet impressions. The magnesium-oxide-coating on glass slides was totally destroyed by windborne dust particle abrasion that occurred prior to the application. This precluded any estimation of droplet size by the Volume Median Diameter (VMD) method.

Figure 15. Meteorological Laboratory with 10-meter temperature probe.

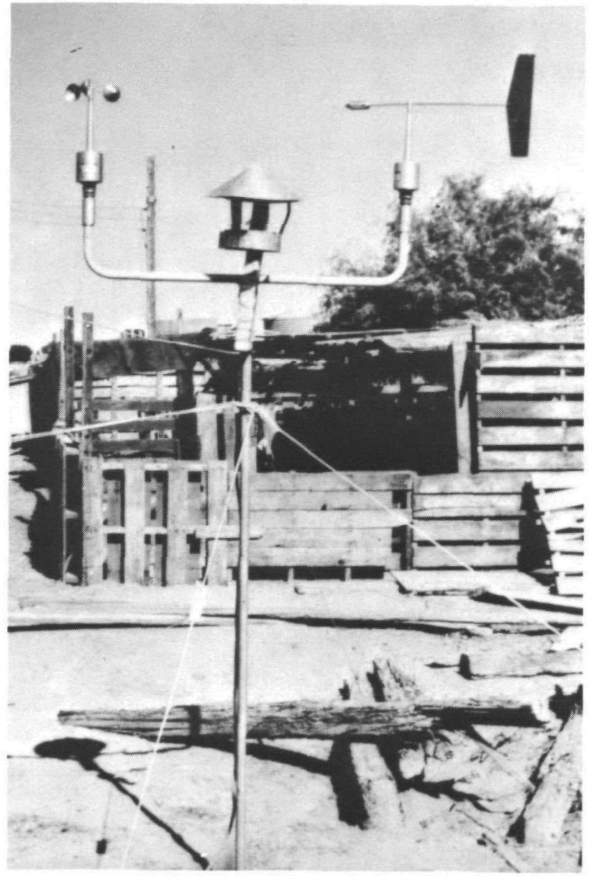

Figure 16. Meteorological unit with 2-meter temperature probe, anemometer and wind directional vane.

Examination of the Thermofax and Linagraph spray droplet cards indicates the applicating equipment produced an extremely coarse spray. Spray cards exposed on the cotton field were badly blurred from the excessive moisture of the large droplets but showed good spray coverage. Droplet counts of the spray cards revealed the applicator had done a commendable job of confining the spray material to the target field [Table 4]. Although spray drift was detected at all sampling stations, the majority of the off-field spray cards contained less than 0.2 droplets/cm^2 and a maximum count of 0.4 droplets/cm^2. Spray cards on the target field produced droplet counts in excess of 28 droplets/cm^2.*

Chemical analyses of the Greenburg-Smith impingers failed to detect the presence of Azodrin. This probably resulted from the propensity of Azodrin to hydrolyze. However, ethyl and/or methyl parathion were captured in all of the impinger units in concentrations ranging from 0.17 to 0.42 μg [Table 5].

The high-volume air samplers proved more efficient than the impingers in capturing pesticide drift, in general, and Azodrin, in particular. Ethyl parathion concentrations in the samples ranged from 0.99 to 3.2 μg, methyl parathion 0.16 to 0.42 μg and Azodrin 0.55 to 30 μg [Table 5]. The presence of Azodrin in the samples confirmed that the spray drift on the droplet cards resulted from the observed application.

Residue analyses of soil from the target field showed no trace of pesticides, indicating the spray was well confined to the foliage. Residues of methyl parathion and Azodrin (0.002 and 0.20 μg/g, respectively) were detected on leaf material of a commercial peach and apricot orchard about 180 m (600 ft) south of the target field (station 41). At the time of application, the orchard had already been harvested.

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* *Because of extreme running and blurring of this card, 28 droplets/cm^2 is a low count. The actual number of droplets is undoubtedly higher due to smaller droplet impressions being masked by excessive moisture.*

Table 4

*SPRAY DROPLET COUNTS**
FIELD "A"
IMPERIAL VALLEY, CALIFORNIA
August 1976

	Card Type	
Station Number	Linagraph	Thermofax
33	0.01	0
34	0.26	0.02
35	0.13	0.12
36	**	28.1
37	0.13	0.12
38	0.25	0.12
39	0.09	0.06
40	0.20	0.12
41	0.25	0.13
42	0.23	0.06
44	0.15	0.09
45	0.21	0.14
46	0.05	0.11
47	0.12	0.12
48	0.40	0.05
49	0.40	0.38
81	0.01	0
82	0.01	0
83	0.02	0.02

* *Values expressed as droplet impressions per* cm^2.
** *Droplet card excessively blurred, precluding a count.*

Table 5

PESTICIDE RESIDUE ANALYSES
Field "A"
IMPERIAL VALLEY, CALIFORNIA
August 1976

Station No.	Sample type	Ethyl Parathion	Methyl Parathion	Azodrin
36	Greenburg-Smith Impinger (μg)	0.42	0.30	ND*
37		ND	0.18	ND
38		0.37	0.25	ND
39		0.25	0.17	ND
37	High Volume Filters (μg)	0.99	0.16	0.55
39		3.20	0.42	30.0
	Environmental Samples			
04	Water (μg/l)	0.40	0.20	ND
	Sediment (μg/g)	ND	0.005	ND
32	Water (μg/l)	ND	ND	ND
36	Soil (μg/g)	ND	ND	ND
41	Vegetation (μg/g)	ND	0.002	0.20

Detection Limits	Ethyl Parathion	Methyl Parathion	Azodrin
Greenburg-Smith Impinger	0.01μg	0.01μg	0.1μg
High Volume Filters	0.01μg	0.01μg	0.1μg
Soil & Vegetation	0.002μg/g	0.002μg/g	0.02μg/g
Water	0.1μg/l	0.1μg/l	50 μg/l

* *Not Detectable*

In-situ fish exposures were terminated on August 30 and the channel catfish were analyzed at the field laboratory for acetylcholinesterase activity. The mean AChE activity for the reference group of fish (station 32) was 1.34 micromoles ACh (acetylcholine) hydrolyzed per milligram of brain per hour. An AChE activity 20% less than the reference group mean activity is considered abnormally low and indicative of the presence of a cholinesterase-inhibiting compound (organophosphate and carbamate pesticides). Laboratory tests have shown that some test fish can survive up to 80% AChE inhibition for short periods of time. However, even a mild decrease in AChE activity results in a decrease in the overall endurance of the fish. In a natural environment, this condition makes fish more susceptible to natural predation. AChE inhibition occurred at stations 4 and 7, both located in the lateral drainage ditch [Fig. 2]. AChE activity for fish exposed at these sites averaged 0.88 at station 4, and 0.79 at station 7, representing acetylcholinesterase inhibition of 34 and 41%, respectively. Fish exposed in the Alamo River upstream and downstream from the mouth of the drainage ditch had AChE activities averaging 1.26 and 1.17, respectively. These activities were not pathologically lower than the activities of the reference fish. However, the downstream fish with AChE activities of only 1.17 were in the low-normal range (an activity of 1.07 would constitute inhibition). It is likely that an extended exposure at this Alamo River site would have resulted in AChE inhibition in these test fish.

There is no indication that the AChE inhibition resulted directly from the pesticide application of field "A" since the reference group of fish at station 32 was equally exposed to potential spray drift. It is also unlikely that drift from other applications in the area was responsible for the pesticide contamination as the drain and canal flow parallel for several kilometers. Chemical analyses of the waters in the lateral canal and drain showed the canal (station 32) to be free of pesticide residue while the drain (station 4) contained measurable concentrations of ethyl parathion (0.4 μg/l) and methyl parathion (0.2 μg/l). Only a trace of methyl parathion (0.005 μg/g) was found in the sediment of the drain at station 4, indicating the pesticide residue in the water was not leaching directly from the sediment bed. This implies that the pesticide contamination of the water resulted from runoff of surface water or through the tile drainage system.

The fate of all drainage waters in Imperial Valley is the Salton Sea by way of the Alamo and New Rivers. If pesticide contamination of drainage water occurs commonly, the possibility exists that accumulation of pesticides is occurring in the waters and sediments of the Salton Sea. Even though most organophosphate pesticides are readily hydrolyzed some have been shown to be very persistent; for example, methyl parathion, one of the contaminants identified in the drainage water, can remain active in water for nearly two years.[6] It should be further recognized that water samples were analyzed only for three organophosphate compounds: methyl and ethyl parathion, and Azodrin. A multitude of other pesticides are used commonly in Imperial Valley and could have been present in measurable quantities. Additional sampling should be done to identify the full impact of drainage water contamination in this area.

PRE-APPLICATION FIELD "B"

The advisory firm that controlled pesticide application on field "B" was the same firm as was employed for field "A". The use of pheromone traps and net sweeping for identification of insect pests was identical to the procedures observed during the investigation of field "A". On August 26, it was determined that an infestation of bollworm (*Heliothis* sp.) and pink bollworm on field "B" was sufficiently severe to justify chemical control. It was also noted that numerous salt marsh caterpillars

(*Estigmene acraea* [Drury]) were present in the field; however, if bollworm and pink bollworm had been absent the caterpillar infestation by itself would not have posed a threat to the cotton crop serious enough to justify pesticide application. A recommendation was made that the field be sprayed with a mixture of 1.02 pt/acre (1.20 liters/ha) Azodrin 5, 0.80 pt/acre (0.94 liters/ha) Parathion 6-3E* and 1.94 pt/acre (2.27 liters/ha) Nudrin 1.8 at an application rate of 5 gal/acre (46.8 liters/ha). Application was to be made the night of August 28. Precautionary advice on the recommendation indicated the re-entry time to be 48 hours, a lapse period of 30 days until harvest and that the foliage was not to be used as animal feed at any future time. Later examination of the pesticide labels indicated the recommended pesticides were registered for use on cotton and the application rates were correct for the target insect pests. The re-entry time of 48 hours for this application is in compliance with the *Code of Federal Regulations*. However, the drum label for Ethyl-Methyl Parathion 6-3E (State Reg. No. 08434-50043-AA) recommended a re-entry time of 24 hours. This label should be updated to comply with the *Code of Federal Regulations*. The recommendation for a 30-day delay before harvest is incorrect. The 30-day period recommended is satisfactory for the Azodrin and parathion components; however, the drum label for Nudrin stipulated application should not be made within 40 days of harvest.

As in the previous application, arrangements were made with the aerial applicator by the advisory firm; spraying would be done by a fixed-wing aircraft.

Sampling devices were installed on field "B" on August 28. Air

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* *Parathion 6-3E is a formulation prepared by the advisory firm and consists of a mixture containing 6 lb ethyl parathion and 3 lb methyl parathion/gal.*

samplers (Greenburg-Smith impingers, and high-volume air samplers) were placed on the target field (station 93) and on each side of the perimeter, 30 m (100 ft) from the edge of the field (stations 90, 96, 101, 105). Three types of spray cards (Kromecote, Thermofax and Linagraph), mylar sheeting, and magnesium-oxide-coated glass slides were placed at 22 stations [Table 2]. Channel catfish were exposed in cages at station 68 and 70.

The mixing and loading operation began at approximately 0100 August 29 at an air strip 8 km (5 mi) from field "B". Only the pilot, a worker who mixed the pesticides, and EPA inspectors were present for this operation. However, the pilot took no active part in the mixing operation; he remained a safe distance away from the mixing area. The worker was properly attired in long-sleeved coveralls, a heavy rubber apron, foot coverings, heavy rubber gloves, hat, eye protectors and a canister-type respirator. After consulting the advisor's recommendation, the mixer removed the containers of Azodrin 5, Parathion 6-3E, and Nudrin 1.8 from a side compartment on the truck and placed them on the ground beside the mixing hopper. The containers were intact and free from visible pesticide residue. The EPA inspector confirmed these were the proper registered pesticides that appeared on the recommendation and a representative sample was collected of each compound for analyses. The nurse rig used for this operation was more sophisticated than that observed on the previous application in that it had the potential for a nearly completely closed mixing and loading operation [Fig. 17]. There were two methods by which pesticides could be introduced into the mixing tank. Small containers (1 to 5 gal) could be manually poured into an open hopper and pumped into the mix tank. For large bulk containers (30- to 50-gal drums) the truck was equipped with a specially designed hose and dipstick apparatus. This system could be inserted into the top bung hole of the container and meter pumped into the mix tank without exposing the pesticide to the air. There was no evidence of a rinsing

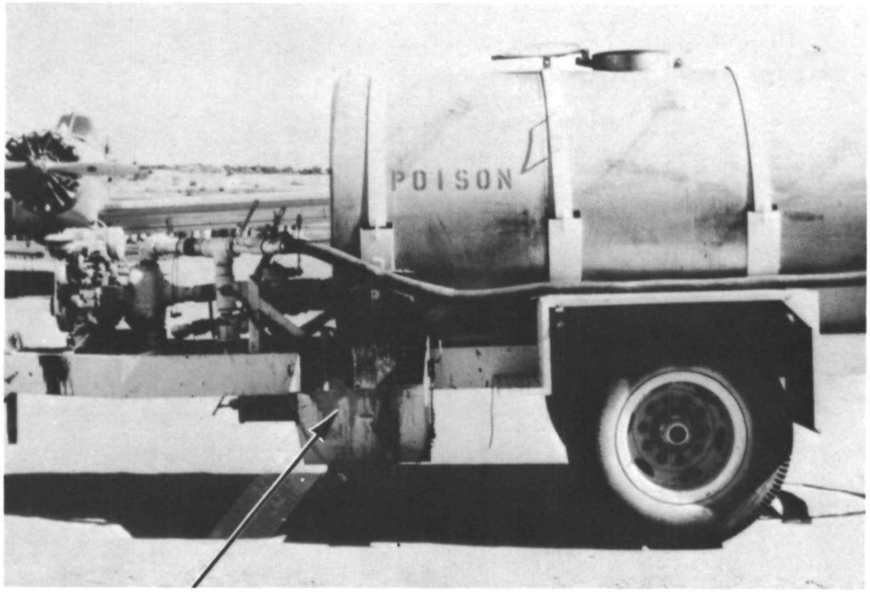


Figure 17. "Nurse Rig" with open hopper (arrow) and mixing tank.

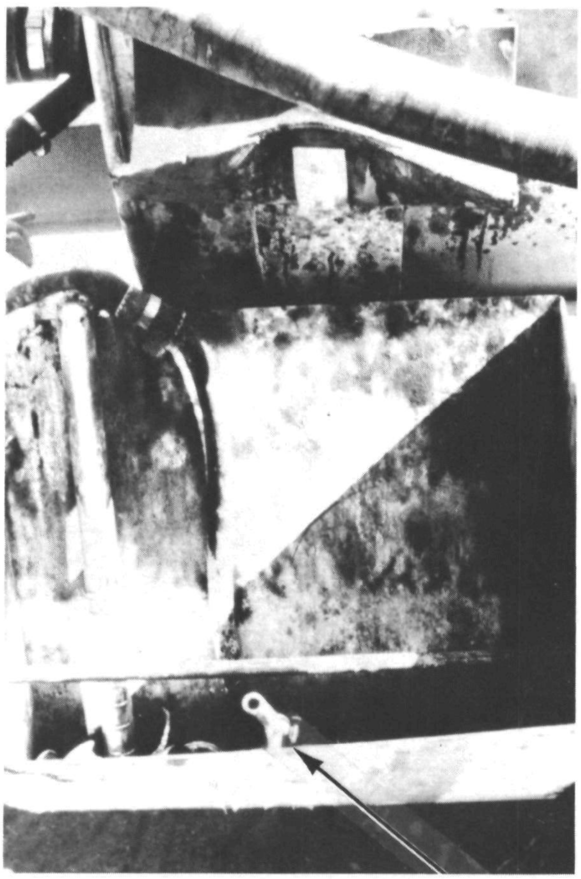


Figure 18. Close-up view of the open hopper showing "Jet-Rinse" apparatus (arrow).

apparatus for the dipstick, hose assembly or bulk container, thus preventing this system from being completely closed. Agitation within the mix tank was accomplished by a high-volume recirculating pump.

The mixing operation began by first pumping approximately 100 gal (378 liters) of dilution water into the mixing vat. The addition of 9 gal (34 liters) Azodrin 5, 17 gal (64 liters) Nudrin 1.8, and 1 gal (3.8 liters) nutrient buffer was made through the open hopper. A jet spray rinsing device was incorporated into the hopper. This consisted of a 1.27 cm (1/2 in) metal pipe about 30 cm (12 in) long, over which the empty container could be placed [Fig. 18]. A high-pressure stream of water was pumped into the empty container, flowed back into the hopper and was pumped into the mix tank. The rinsed containers were placed in a separate area on the truck along with miscellaneous paper cartons and refuse to be returned to the main staging area for later disposal at a County-maintained dump. The Parathion 6-3E was in a 30 gal plastic bulk container. The dipstick system was used to add 7 gal (26.5 liters) of the pesticide to the mixing tank. After all the pesticides had been added, EPA personnel introduced a fluorescent tracer dye (Rhodamine WT) into the mixture to achieve a final concentration of 2,000 μg/l. The volume of the mixture was then increased to 350 gal (1,325 liters), the correct volume for an application of field "B" at the rate of 5 gal/acre (46.8 liters/ha). After the mixture had been agitated for 15 minutes, EPA inspectors collected a sample for pesticide analysis.

During the final stage of the mixing operation, a gusting 16 km/h (10 mph) southeasterly wind arose. The pilot made radio contact with the flaggers, who had already arrived at the target field, and confirmed that the same windy conditions existed at the spray site. The worker at the mixing site was then instructed to hold the pesticide mixture on the tank truck, under agitation, until atmospheric conditions improved. The wind continued until about 0245, at which time the pilot determined conditions had stabilized sufficiently to permit aerial spraying. Before the loading operation was begun, the pilot again contacted the field site and learned that stable conditions existed there, also. Then, 175 gal (662 liters) of pesticide mixture was pumped aboard the aircraft through a heavy flexible hose. This loading system was a type similar to the one previously discussed and no pesticide was observed leaking onto the ground during the loading or uncoupling operation. After the aircraft was fully loaded, a second mixture sample was collected by the EPA inspector directly from the aircraft spray hopper.

The entire mixing and loading operation was performed in an exemplary fashion. The worker involved in mixing performed his tasks in a neat and orderly manner while observing all necessary safety precautions. The pilot exercised good judgment by postponing the scheduled application when weather conditions deteriorated, and also by maintaining radio contact with the field site.

The jet spray rinsing system is an excellent feature which should be used on other mixing systems whenever possible. The jet spray system eliminated the problem associated with rinse water disposal and reduced the hazard of handling and transporting empty containers, particularly glass. It is apparent that there is a need for more bulk packaging of pesticide material. Only one of the three pesticides used in this mixture was provided in a bulk container suitable for full utilization of the semi-closed mixing operation the nurse rig was capable of performing. It was also noted that the plastic bulk container was recyclable; the pesticide industry should be encouraged to use more recyclable containers to alleviate disposal problems.

An inspection by EPA showed that this applicator managed his premises in a commendable manner. All spraying equipment was neatly stored, segregated by specific type, and appeared clean and well maintained. The washing facility for spray equipment consisted of a large, sloping concrete apron. All contaminated water associated with washing and rinsing activities was collected from the apron, piped underground, and emptied into a leach field approximately 90 m (100 yd) away [Fig. 19]. A facility for temporary storage of rinsed and perforated pesticide containers was maintained about 90 m (100 yd) from the work area. The storage area was situated at the lowest section of the property to prevent contamination of other areas and was secured by a 2-m (6-ft) chain-link fence and conspicuously posted with appropriate warning signs [Fig. 20].

Chemical analysis of the mix and spray tank samples confirmed the presence of Azodrin, methyl and ethyl parathion, and Nudrin. However, pesticide concentrations averaged 14% higher in the mix tank than in the spray tank [Table 3]. The explanations for this are the same as those proposed in the pre-application discussion of field "A". Analyses of the undiluted pesticide used for this application showed all materials to be formulated properly.

APPLICATION FIELD "B"

The aircraft used for this application was a fixed-wing Snow Air Tractor. The spray boom was equipped with 36 Tee-Jet nozzles and #45 whirlplates arranged at equal intervals along its length. Spraying was done at an air speed of approximately 160 km/h (100 mph) at a boom pressure of 2.8 kg/cm^2 (40 psi) which produced a swath width of 18 m (60 ft).

The EPA observers were stationed 30 m (100 ft) from the field on each side of the perimeter. Protective clothing worn was the same as during the application on field "A".

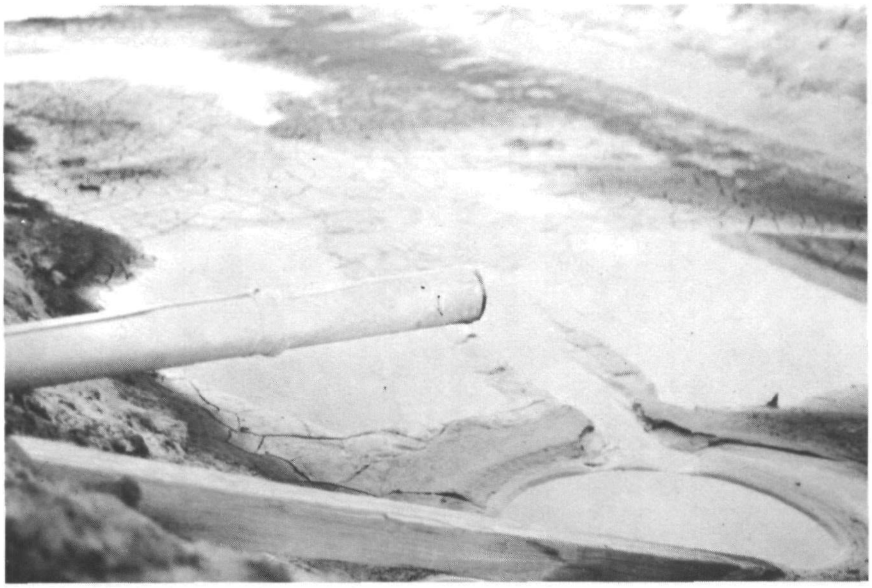


Figure 19. Leach field for contaminated wash water.

Figure 20. Temporary storage facility for used pesticide containers.

Two workers assigned as flaggers arrived at the field site approximately two hours before the application. These workers were in radio contact with the pilot, keeping him updated on changing wind conditions. Protective clothing worn by the flaggers consisted of tightly woven fabric long-sleeved coveralls, baseball-type caps and each had a canister-type respirator. No gloves, eye protection or special footwear were observed. Each worker carried a lighted baton.

Two 175 gal (662 liter) applications were required to spray the field. The first application began August 29 at 0317 and ended at 0342 and the second began at 0355 and was terminated at 0425. The application pattern consisted of first spraying the middle of the field along the east-west axis parallel to the cotton rows. The flaggers initially were stationed at the northwest and southeast corners of the field and worked towards each other as the pilot alternated passes from the north and south edges of the field inward. The ends of the field were sprayed along the north-south axis with a similar alternating pattern. It was noted the flagger at the western edge of the field wore a respirator during the application. The other worker on the eastern border of the field, being upwind, did not wear a respirator. Analysis of spray drift patterns will show that simply being upwind of the target field is no guarantee of escaping spray drift. During this particular application, the upwind (eastern) border of the field received substantially more drift than did the western edges.

Local atmospheric conditions during the application were stable with wind velocity less than 1.6 km/h (1 mph). Temperature measurements at the 2-m level ranged from 28.0 to 28.7°C (82.4 to 83.7°F) and from 29.1 to 29.9°C (84.4 to 85.0°F) at the 10-m height, with an average temperature differential of 1.3°C (2.4°F). This constituted an inversion condition. Relative humidity was measured at 61%. Visibility at ground level was good; however, it was poor in the warmer overlying air mass approximately 30 m above the ground. This condition made the application difficult. Often the pilot's visibility of the field and flaggers was obstructed and many approaches were aborted.

During the interview with EPA inspectors earlier in the evening, the pilot indicated an awareness of the close proximity of the alfalfa field bordering the southern edge of field "B". It was noted that during the application the pilot exercised extreme caution when trimming this section of the field. No mention was made of the somewhat more distant alfalfa field bordering half of field "B" to the north. Later analyses of spray cards showed the southern alfalfa field received minimal spray drift while the field to the north received substantial drift.

Approximately one hour after the observed application, a pesticide application was made on the cotton field bordering the western perimeter of field "B". Neither EPA personnel or the landowner, whose residence is at station 87, were aware that this application was scheduled. The advisory firm responsible for this cotton field was not the same firm as was contracted to maintain field "B". Contact was made the following day with the second advisory firm and it was learned the application had consisted of 1.053 pt/acre (1.23 liters/ha) Azodrin and 1.053 pt/acre (1.23 liters/ha) Fundal. The advisor informed EPA inspectors that, on the day prior to the application, he had attempted several times but had been unable to contact the landowner by telephone to inform him of the intended application. The landowner confirmed that he had been absent from his residence the previous day and had not returned until late evening on the night of the application. Had the residence not been close enough to the field for the noise of the spray plane to awaken him, the landowner would have been totally unaware that his field had been recently sprayed with pesticide. Conceivably, the landowner or laborers could have entered the field unprotected a few hours after the pesticide application. The lack of notification to the grower is not inconsistent with State pesticide regulations, which only require that a written notification be mailed prior to the application. However, it is doubtful that many landowners ever receive this notification prior to the application because spraying must often be done soon after an infestation is detected to minimize crop damage. On their own initiative, advisory firms attempt to inform landowners orally of intended applications.

It would be desirable to enact regulations to make verbal contact with the landowner or his responsible representative mandatory; in cases where this is impossible, the target field should be conspicuously posted and dated, specifying a safe re-entry time.

POST APPLICATION FIELD "B"

All sampling devices, except fish exposure cages, were removed from the target field and surrounding area five hours after the application. At this time, samples of soil, water and vegetation were taken for pesticide residue analysis.

Tracer dye (Rhodamine WT) was detected at inconsistent low levels in samples collected by the Greenburg-Smith impingers, high-volume filters, and in droplets deposited on mylar sheets. All three types of spray droplet cards (Kromecote, Linagraph and Thermofax) produced positive droplet images. Magnesium oxide coatings on glass slides were again destroyed by wind and dust particle abrasion.

Examination of the spray droplets showed a close correlation of droplet counts between Thermofax and Linagraph cards. Droplet counts for Kromecote cards, however, were consistently lower [Table 6]. Laboratory investigations conducted by NEIC and data obtained from previous studies indicate Kromecote is only sensitive to the parathion fraction of the spray mixture used. Except for the directional component, drift

Table 6

*SPRAY DROPLET COUNTS **
Field "B"
IMPERIAL VALLEY, CALIFORNIA
August 1976

Station No.	Kromecote	Linagraph	Thermofax	Vertical Kromecote*
86	3.1	17.1	18.8	S-SW
87	12.0	31.0	36.3	S-SE
88	9.6	30.0	28.4	S-SW
89	45.5	69.4	71.4	S-SW
90	11.2	38.7	38.2	S-SW
91	11.4	31.6	32.6	
92	10.3	20.4	20.2	
93	64.7	77.8	84.1	S-SE
94	28.6	34.0	39.1	
95	19.2	26.4	28.7	
96	24.7	38.8	38.5	S-SE
97	0.01	1.0	0.8	
98	37.8	68.1	70.0	
99	0.02	1.3	1.2	
100	0	0.08	0.09	
101	0.05	0.09	0.02	
102	0.02	0.04	0.03	
103	0	0.01	0.02	
104	0.01	0.01	0.02	
105	5.7	44.3	45.8	S-SE
106	11.4	32.3	33.3	
108	22.7	44.8	50.1	

* *Values expressed as droplet impressions per* cm^2.
** *Indicates approximate wind direction.*

characterizations discussed elsewhere in this report are based on Linagraph and Thermofax droplet cards.

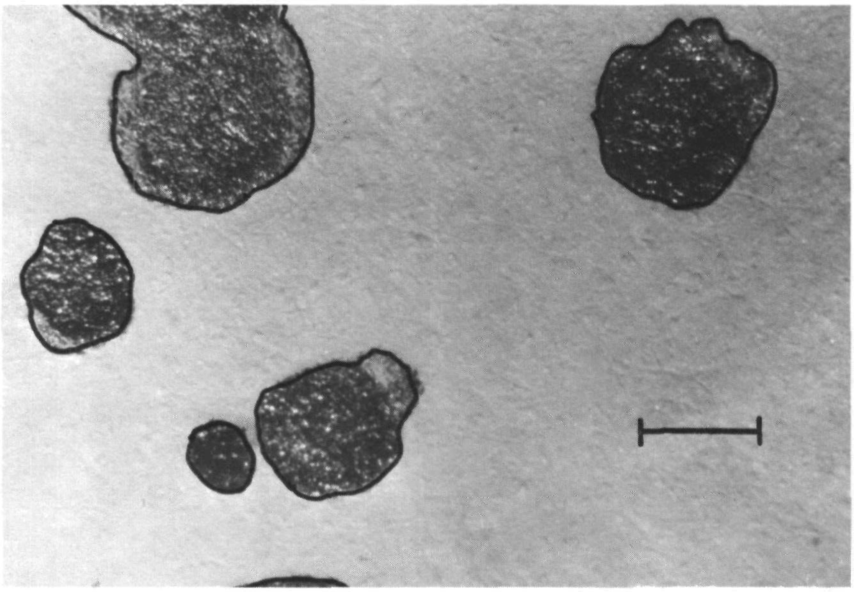
The spray droplets resulting from this application were considerably less coarse than those observed at field "A"; consequently, drift was more extensive [Fig. 21]. It is emphasized that droplet counts are not quantitative values and do not represent the actual amount of pesticide that contacted the droplet card. Spray cards from off the target field had numerical counts nearly as high as a card from on the field; however, they were composed of smaller droplet impressions, thus representing lower pesticide concentrations.

The vertically placed Kromecote cards showed the direction of drift to be basically to the north, occasionally changing to northeast and northwest. This correlated well with meteorological data which showed a prevailing south wind with minor variations from southeast and southwest. Spray drift occurred in all directions for a distance of at least 30 m from the target field and was detectable for a distance of 300 m (1,000 ft) to the northwest (station 86).

Drift to the south, over the alfalfa field, was less than in any other area. This resulted from a combination of pilot awareness of the alfalfa field and the prevailing southerly winds. Areas that received substantial spray drift included two domestic dwellings (stations 87 and 108), a private orchard and livestock enclosure (station 94) and a second alfalfa field directly north of the target field (stations 90, 91, 92).

Spray drift in the northwest section resulted from a combination of the observed application and the spraying that occurred an hour later on the cotton field to the west.

Field "A"



Field "B"

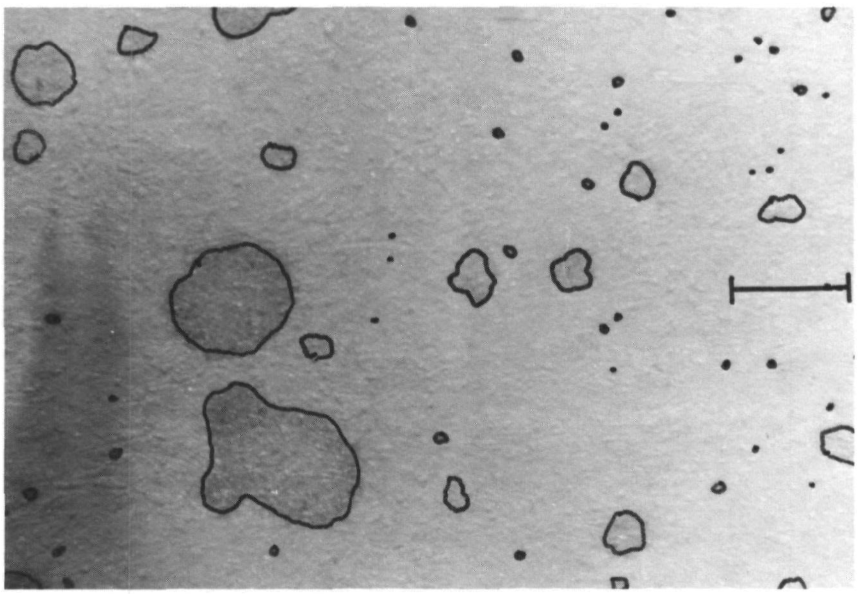


Figure 21. Visually enhanced droplet impressions on Linagraph paper (X15).

Chemical analysis of the Greenburg-Smith impinger samples was positive for methyl and ethyl parathion at all stations (90, 93, 96, 101, 105)[Table 7]. As previously noted, this sampling method was ineffective for the detection of Azodrin. At present, there is no adequate method of analysis for low concentrations of Nudrin.

Total concentration of pesticides (ethyl and methyl parathion) from the impinger units ranged from 2.4 to 16.9 μg [Table 7]. The impinger unit at station 90, north of the target field, entrapped 16.9 μg total pesticide compared to 14.1 μg at station 93, on the target field. There are two probable explanations for the target field sample being lower in pesticide concentration: the cotton was in full foliage and more than 1 meter in height, tending to form a protective canopy around the sampling unit; and, the nature of the sampler is such that air enters the system through an inverted J-shaped tube. It is likely this sampling device is selective for finer droplets. Consequently, the larger droplets being released over the target area would have a greater tendency to impact quickly and not be drawn into the sampler. The finer droplets tend to remain suspended for a longer period and drift from the target field with prevailing air currents, subsequently to be drawn into off-site sampling devices. In general, these results indicate that spray drift resulting from this application was most intense to the north and east. In addition, a lesser amount (6.3 μg) of ethyl and methyl parathion drifted south into the alfalfa field.

Residue analysis of the high-volume filters revealed the presence of Azodrin, ethyl and methyl parathion at all stations (90, 96, 101, 105) [Table 7]. Drift was most intense to the north (station 90), east (station 96), and west (station 105) where total pesticide residues of 1,290, 342 and 604 μg, respectively, were captured. As all other data have indicated, southern drift (station 101) was strikingly lower by comparison, having a total pesticide residue of only 31 μg.

Table 7

PESTICIDE RESIDUE ANALYSES
Field "B"
IMPERIAL VALLEY, CALIFORNIA
August 1976

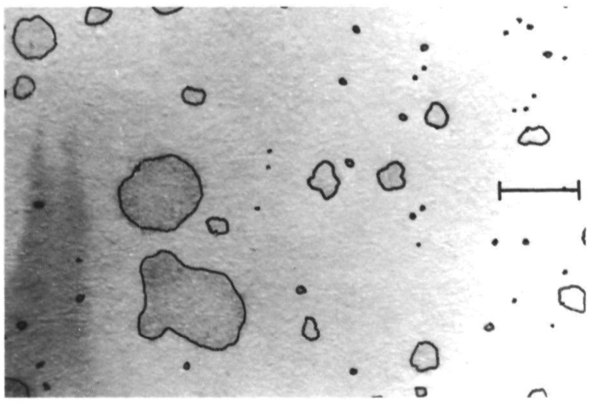
Station No.	Sample Type	Total Residue	Ethyl Parathion	Methyl Parathion	Azodrin
90	Greenburg-Smith Impinger (μg)	16.9	12.0	4.9	ND*
93		14.1	9.3	4.8	ND
96		9.1	6.4	2.7	ND
101		6.3	4.0	2.3	ND
105		2.45	1.7	0.75	ND
90	High-Volume Filter (μg)	1290	360	110	820
96		342	96	26	220
101		31	11	4	16
105		604	110	54	440
87	Thermofax Droplet Card (μg)	3.16	0.56	0.20	2.4
88		0.22	0.18	0.04	ND
93		31.5	16	3.5	12.0
94		11.4	4.6	1.4	5.4
96		2.9	1.1	0.2	1.6
99		0.1	0.09	0.01	ND
100		0.04	0.04	ND	ND
101		0.03	0.02	0.01	ND
105		95.0	4.0	1.0	90.0
106		4.1	1.3	0.36	2.4
108		0.71	0.6	0.01	0.1
	Environmental Samples				
68	Water (μg/l)		ND	ND	ND
70	Water (μg/l)		ND	ND	ND
93	Soil (μg/g)		ND	ND	ND
93	Vegetation (μg/g)	2.15	0.06	0.09	2.0
103	Vegetation (μg/g)	0.21	0.003	0.01	0.2
101	Vegetation (μg/g)	0.18	0.04	0.03	0.11

Detection Limits	Ethyl Parathion	Methyl Parathion	Azodrin
Greenburg-Smith Impinger	0.01μg	0.01μg	0.1μg
High-Volume Sampler Filters	0.01μg	0.01μg	0.1μg
Soil & Vegetation	0.002μg/g	0.002μg/g	0.02μg/g
Water	0.1μg/l	0.1μg/l	50 μg/l
Thermofax Cards	0.01μg	0.01μg	0.1μg

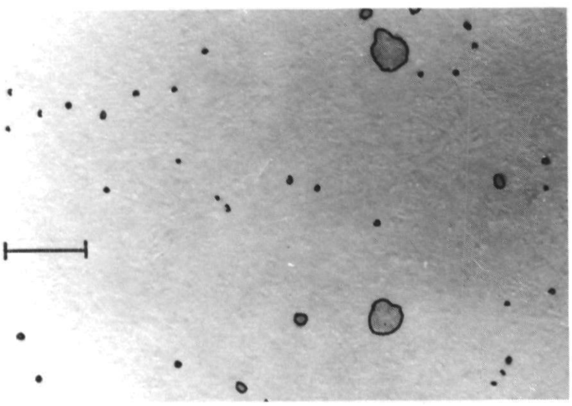
* *Not Detected.*

As previously discussed, droplet card counts alone can be misleading when attempting to quantify relative drift. In an attempt to use droplet spray cards for comparative data, the Thermofax papers were extracted and analyzed for pesticide residue. There are several apparent advantages in this method of residue detection when compared with vacuum type air sampling devices (Greenburg-Smith impingers and high-volume filters). The spray cards are exposed on raised platforms and are afforded no protection by the cotton foliage. The spray card is not dependent on an artificially produced air stream to draw the particles to it and is, therefore, not selective to a particular size range of spray droplets. Lastly, vacuum-type air samplers tend to concentrate pesticide residue whereas spray droplet cards retain only that residue which actually impacted at a given site. A non-technical aspect to be considered is that spray cards cost a few pennies each, whereas air samplers cost several thousand dollars. A disadvantage is the possible degradation of photosensitive pesticides if the cards are not retrieved within a few hours; however, this factor is compensated for because the possibility of hydrolysis, as occurred in the Greenburg-Smith devices, is reduced.

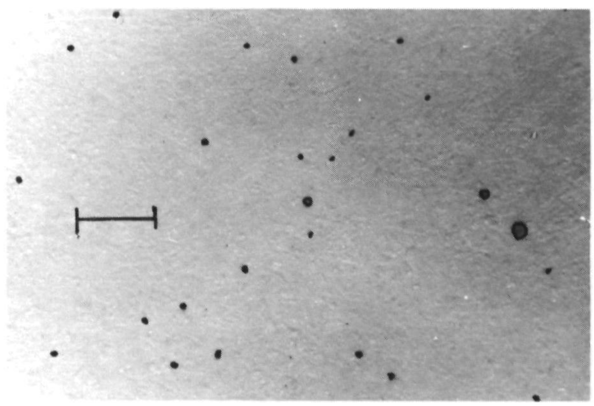
The spray droplet card located on the target field (station 93) had a total pesticide residue (Azodrin + methyl and ethyl parathion) of 31.5 μg [Table 7]. Station 94 located east of field "B" in a private orchard and livestock compound had a total pesticide residue of 11.4 μg, inferring that this off-field site received spray drift amounting to 36% of that deposited on droplet card in the target field. That this off-field site received such a large amount of drift is primarily due to the fact that it is bordered closely on two sides by the cotton field. The intense drift resulted from the necessity of trimming the target field from two directions, both bordering the orchard area [Fig. 22]. By comparison, the spray card at the domestic residence (station 108) approximately 60 m north and 30 m west of the orchard, had a total residue of 0.71 μg; only 2.2% of the comparable target field card. Although the total residue at station 94 was 16 times greater than that of station 108, the droplet count differed by only 22%.



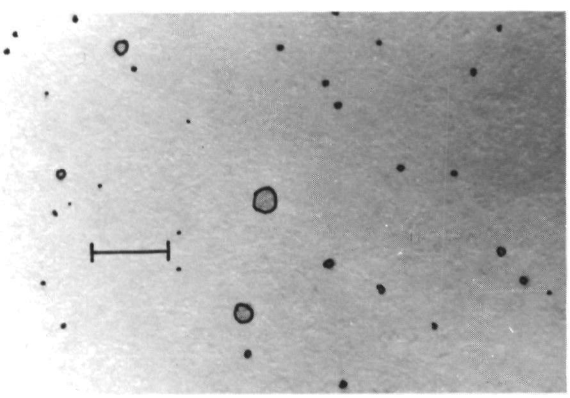
Station 93
(Treated Field)



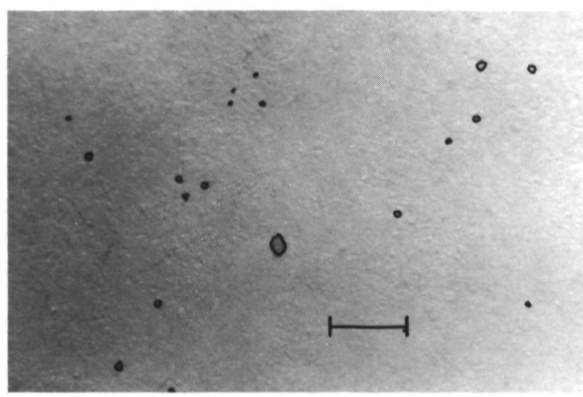
Station 94
(Private Orchard)



Station 108
(Domestic Residence)



Station 98
(Pathway Used by Flagger)



Station 90
(Alfalfa Field)

Figure 22. Visually enhanced pesticide spray droplets on Linagraph cards (10X).

Drift to the south, where pesticide residue on the spray cards averaged 0.06 μg (stations 99, 100, 101), was less than in other directions. The residues at stations 105 and 87 are notable in that they reflect the effect of the unexpected second application. Of the total pesticide residue, the Azodrin fraction, accounted for 76 and 97% at stations 87 and 105, respectively. Stations 93, 94, and 96 located at the extreme eastern area of field "B", remote from the second application, had Azodrin residues averaging only 47%. The drift at station 105 was of no consequence because this station is virtually on the edge of the cotton field west of field "B". Here, drift was simply from one cotton field to another. However, station 87 is a domestic dwelling and received total pesticide residue equivalent to 10% of the target field sample. This station, with a 76% Azodrin fraction, obviously received drift from both applications.

The pesticide residue values evaluated in this section are only comparative and do not reflect actual total pesticide residue. These spray cards were not analyzed for either Nudrin or Fundal, which were present in the first and second applications, respectively. If these compounds were also taken into account, the actual pesticide residue would undoubtedly be greater.

Analysis of environmental samples [Table 7] showed no pesticide residue on the soil of field "B" (station 93). Cotton leaves from the field contained pesticide residue at concentrations of 0.06 μg/g ethyl parathion, 0.09 μg/g methyl parathion, and 2.0 μg/g Azodrin. Alfalfa foliage at stations 101 and 103 had pesticide residues of ethyl parathion of 0.04 and 0.003 μg/g, methyl parathion 0.03 and 0.01 μg/g, and Azodrin of 0.11 and 0.20 μg/g. These values demonstrate that even when prevailing air currents were away from the sensitive area and the pilot obviously attempted to prevent drift, total pesticide residue on the alfalfa foliage averaged 9% of that which was found on the target cotton plant, and also that total drift control cannot be achieved.

The alfalfa field directly north of field "B" may have received pesticide drift at levels that may be of concern. Stations 90 and 101 [Fig. 3] are directly opposite each other at the north and south perimeter of field "B". At station 101, where alfalfa foliage had pesticide residue equivalent to 8% of the target cotton plants, total pesticide residue on the high-volume filter was only 31 μg. Station 90, within 15 m of the alfalfa field to the north, had a high-volume filter total pesticide residue of 1,290 μg; approximately 42 times greater than at station 101. This implies that the alfalfa field to the north, directly in the path of the prevailing air currents, received pesticide residue greatly in excess of the 9% observed at stations 101 and 103.

The in-situ fish exposures were terminated on August 31. The AChE activities for fish exposed in the lateral canal (station 70) and drain (station 68) were 1.44 and 1.40, respectively. No AChE inhibition resulted from exposure at either site. Both of these exposures were directly in line with a spray drift much more intense than the exposures at field "A" with no resulting inhibition. This fact reinforces the hypothesis that AChE inhibition found during the field "A" exposures resulted from surface or drain tile runoff, and not spray drift.

METROPOLITAN DRIFT POTENTIAL

A cooperative investigation involving the Imperial County Agricultural Commission and EPA was undertaken to assess the possibility of pesticide drifting into the metropolitan areas of Imperial Valley.

Permanently installed high-volume air samplers, maintained by the Agricultural Commission, were used to obtain 24-hour samples of ambient air at Brawley, Calexico, and El Centro, California. The air samplers were located atop the fire stations at Brawley and Calexico, and on the roof of the County Health Building at El Centro.

Three sets of 24-hour samples were taken on July 20, August 5, and August 28, 1976. The fiberglass sample filters were sent to NEIC for residue analysis.

Chemical analysis revealed measurable quantities of pesticide residue at all sampling sites during all sampling periods [Table 8]. Overall pesticide levels were higher at Brawley and Calexico, with residue concentrations for the three sampling periods averaging 3.48 μg (range 1.14 to 5.59 μg) and 2.88 μg (range 0.16 to 6.34 μg), respectively, as compared to 0.26 μg (range 0.17 to 0.32 μg) at El Centro. At Brawley and Calexico, the highest pesticide levels captured (5.50 and 6.34 μg, respectively) were on August 5. The El Centro air sampler operated only six hours during the July 20 period, but produced the highest total pesticide residue at this station for the three sampling periods. This indicates that either the spray drift was considerably more intense on this date or that the major portion of the pesticide residue is present in ambient air during the morning. Additional sampling should be done at shorter intervals to determine which of the above hypotheses is correct.

Since this was a preliminary investigation and consisted of few samples, only one definitive statement is justified: pesticide spray drift does enter metropolitan areas of Imperial Valley. Residue analyses were made for only three specific compounds: methyl and ethyl parathion, and Azodrin; therefore, these data represent minimum residue levels. In view of the large variety of pesticides used in Imperial Valley, total pesticides in the ambient air were undoubtedly higher.

These data are insufficient to project any possible environmental hazard which may result from spray drift, nor were the samples numerous enough to determine if these pesticide levels are representative of those normally present in the air.

Table 8

METROPOLITAN HIGH VOLUME AIR SAMPLES
IMPERIAL VALLEY, CALIFORNIA

Location	Date	Total Pesticide Residue (μg)	Ethyl Parathion (μg)	Methyl Parathion (μg)	Azodrin (μg)
Brawley	20 July 1976	3.8	ND*	0.10	3.7
Calexico		0.16	ND	0.06	0.1
El Centro**		0.32	ND	ND	0.32
Brawley	5 August 1976	5.59	ND	0.40	5.5
Calexico		6.34	5.5	0.28	0.56
El Centro		0.17	ND	ND	0.17
Brawley	28 August 1976	1.14	ND	0.20	0.94
Calexico		2.14	ND	0.14	2.0
El Centro		0.28	ND	ND	0.28

* *Not Detected.*
Detection Limits: Methyl Parathion 0.01μg, Ethyl Parathion 0.01μg, Azodrin 0.10μg.
** *This Sampler operated only six hours, from 0600-1200, July 20, 1976.*

A realistic assessment of the environmental impact of pesticide drift into populated areas should be made by instituting a long-range, intensive sampling program (minimum of 12 months). Twenty-four-hour sampling periods should be divided into at least six consecutive four-hour intervals. Pesticide residue analyses would have to be expanded into a broad spectrum to encompass the entire range of pesticides being applied during the sampling period.

VI. EVALUATION OF METHODS

AIR SAMPLING DEVICES

Greenburg-Smith impinger units and high-volume air samplers both proved capable of capturing pesticide drift; however, the high-volume sampler was considerably more efficient. There are several obvious advantages in using the high-volume air sampler: movement of air through the system is at least 40 times greater than in the Greenburg-Smith impinger; pesticide material is captured on a dry fiberglass filter, reducing the possibility of hydrolysis of the pesticide; and residue analyses are simplified when extractions are made from a dry medium. A disadvantage of the high-volume system is that the rapid air movement through the filter may tend to evaporate highly volatile pesticide material, and pesticide vapors may not be captured.

FLUORESCENT TRACER TECHNIQUES

Use of fluorescent tracer material (Rhodamine WT dye) was not effective. Analyses of ethylene glycol samples from the Greenburg-Smith impingers and solution washes of the high volume filters and mylar sheets produced erratic, low level or non-detectable fluorescent response. In contrast, pesticide residue analyses of samples from the Greenburg-Smith impingers and high-volume air samplers as well as visible droplet images on the mylar sheets confirmed that the pesticide spray mixture was captured by all three sampling devices. It appears that dye concentration mixtures ranging from 1,000 to 2,000 μg/l are not sufficient for accurate fluorescent determinations. It is also possible that the concentration of dye necessary for accurate detection may be so great as to prohibit its use in areas where the appearance of visible dye residue on sensitive crops or structures would be undesirable.

MAGNESIUM-OXIDE-COATED SLIDES

The use of magnesium-oxide-coated glass slides to determine drift characteristics and spray droplet size was not satisfactory in this study. However, the failure of this device was due to local environmental conditions, not the insensitivity of the slides to detect drift. When used in studies in areas where gusting wind and abrasive dust were not encountered, the method proved to be effective. Because the device is fragile, future use of magnesium-oxide-coated glass slides must be considered on a site-specific basis.

SPRAY DROPLET CARDS

All types of spray droplet cards used were effective to varying degrees in characterizing spray drift. Kromecote cards were the least effective; they appeared to be sensitive only to a particular pesticide mixture. Because of this limitation, extensive use of this card in future studies is not advisable.

Linagraph and Thermofax cards proved equally successful in recording spray droplet impressions. Acknowledging that these produce similar droplet counts, Thermofax cards have several characteristics which make it the more desirable droplet card material. These factors are: droplet impressions on a Thermofax card are a distinct brownish color against an off-white background. The color combination in conjunction with a finer paper texture produce an easily detectable droplet image, facilitating visual counting. Linagraph cards have a coarser texture and droplet impressions appear as dark gray images. The background, while initially a buff hue, gradually darkens upon exposure to sunlight to a medium gray color and makes droplet impressions more difficult to detect visually. Furthermore, residue analysis of Linagraph versus Thermofax cards indicates laboratory pesticide extraction efficiency for Thermofax is superior. For this study, results of pesticide residue on Thermofax paper were used only as comparative, not absolute, values. Additional studies need to be performed to determine the degree to which quantitative results can be expected from this method.

It is possible to obtain quantitative data from spray droplet images imposed on paper material. However, the specific spread factor (through blotting action, the degree to which the image of a liquid droplet will increase in size on a porous medium) for each pesticide mixture and droplet size, range first must be determined. At present, NEIC does not have the capability of determining specific spread factors. However, the EPA has contacted a government-contracted laboratory that currently has a functional program for the computerized analyses of spray droplet cards. The technique (QUANTIMET) is quantitative. By incorporating specific spread factors, it is capable of providing data consisting of droplet image size for each analysis and selected sub-groups of analyses: category size, droplet count in each category, droplet size and mass, cumulative mass percent, total mass, and deposition densities in mg/cm^2 and oz/acre. The cost of this analysis, approximately \$2.50 per card, is moderate in view of the quality and quantity of data obtained. Use of this technique will be incorporated in any further use observation studies undertaken by NEIC.

ENVIRONMENTAL SAMPLING

Residue analysis of environmental samples (water, vegetation, soil and sediment) was useful in substantiating the encroachment of spray drift into sensitive areas. It has also proved to be an aid in determining the mode of pesticide material translocation.

The in-situ exposure of live fish, and subsequent analysis for AChE activity was shown to be a sensitive test for indicating the presence of organophosphate compounds in the aquatic environment.

Results of these analyses indicate that pesticide residues exist in sufficient concentrations to have environmental impact.

OBSERVATION AND PHOTOGRAPHS

Observers equipped with cameras proved to be a valuable asset in this study particularly for recording mixing and loading procedures, storage, and disposal facilities for pesticides and clean-up operations. The use of multiple observers to document the application was of little benefit because all spraying was done at night and visibility was poor.

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Appendix

Description of Sampling Devices and Methods

DESCRIPTION OF SAMPLING DEVICES AND METHODS

GREENBURG-SMITH IMPINGER

The Greenburg-Smith impinger is a semi-quantitative air sampling device. The system consists of an air compressor arranged so the intake manifold draws air through a sampling train, and auxiliary equipment to control and measure air flow and switch the flow from one impinger to another after a preset time interval. The sampling train consisted of 3 glass impingers each containing 100 ml of ethylene glycol to capture pesticide material. An absorption tube packed with glass wool prevented splash-over or water condensation from being drawn into the compressor. After the air was pulled through an impinger, it passed through a solenoid valve controlled by a timer, through a control valve by which the air flow was set at the desired rate as shown on a flowmeter, through the flowmeter and finally through the compressor. A momentary contact switch may be closed to switch the air flow to a particular impinger so that its flow may be adjusted and read at any time.

To avoid contamination, impinger units were filled with 100 ml of ethylene glycol at an off-field staging area and the intake tubes sealed with pesticide-free aluminum foil. The timing mechanism was adjusted to provide three four-hour sampling periods and air flow was calibrated to 1.0 ft^3(.028m^3)/min. The first impinger cycle was activated four hours prior to the intended application. The second impinger cycle was activated during the loading of the spray plane and the units were then allowed to cycle automatically through the four-hour post application interval. At the completion of the cycle, the ethylene glycol was removed from the impingers and stored in separate 125 ml glass, screw top bottles. A 25 ml aliquot of the ethylene glycol was removed and analyzed at the field laboratory for fluorescence and the reamining sample was returned to the NEIC laboratory for residue analysis. After each application, all contact components in the sampling train were disassembled, washed with detergent and thoroughly rinsed with fresh water.

HIGH-VOLUME SAMPLERS

The high-volume air sampler uses a high-speed impeller to draw air through a 20 x 25.4 cm fiberglass filter on which airborne particles are trapped. The samplers were activated just prior to the application and operated for eight hours, drawing air through the filter at a rate of 35 ft^3 ($0.98m^3$) min. Filters were removed, stored in plastic bags and returned to NEIC for residue analysis.

SPRAY DROPLET CARDS

Spray card clusters were constructed by taping rectangular sheets of Kromecote, Linagraph, Thermofax and mylar onto a 30 cm (12 in) square cardboard base. The clusters were mounted with rubber bands atop a 1-m upright wooden platform.

Kromecote cards are a 10 x 12.5 cm finely textured, glossy photographic paper. They are dependent primarily upon deposition of tracer dye material to produce a droplet image. However, this and previous studies have shown Kromecote to be sensitive to parathion compounds.

Linagraph (480) cards are a more coarsely-textured, non-glossy photographic paper 15 x 25 cm in size. This paper is extremely sensitive to water droplets and produces a visual image within minutes of droplet contact.

Thermofax paper (209 copy, type 640) is a medium-textured, temperature activated material sensitive to both water and to petroleum-based droplets. Spray droplet cards were cut from large sheets into 10 x 12.5 cm rectangles. Several hours of exposure to moderate heat are required to produce a droplet image. Normal bright sunlight at Imperial Valley produced sufficient temperature to develop the cards; however, cards may be developed by exposure to incandescent lights or a low temperature drying oven.

Droplet counts were done at NEIC using a 30X binocular dissecting microscope. Cards with low numbers of droplet images were counted in entirety; however, for high density images four or more random 2.5 cm^2 (1 in^2) areas of the card were counted and the average value calculated. Final counts were expressed as number of droplets/cm^2.

Spray droplet cards made of 10 x 30 cm mylar sheets (commercially available plastic sheeting 5 mils thick commonly used by draftsmen) were used to collect spray droplets for fluorescence analysis of tracer dye material (Rhodamine WT).

FLUORESCENCE ANALYSIS

Field laboratory analysis for fluorescent response of dye tracers was done using a Turner Model 111 fluorometer with a high sensitivity door. Sample material from the Greenburg-Smith impingers was analyzed and compared with an ethylene glycol blank. Mylar sheets and high-volume filters were washed with 100 ml of 95% ethyl alcohol and fluorescent response compared to an ethyl alcohol blank solution.

MAGNESIUM-OXIDE-COATED SLIDES

Glass microscope slides were coated with magnesium oxide by burning thin strips of magnesium metal beneath the slide. Upon impact with the stationary slide, airborne droplets create visible impressions in the powder coating leaving a permanent record even after evaporation.

Craters formed by the droplet can be measured to within .5 μ by use of a microscope, measuring 200 impressions on each slide. These data can then be used to compute the volume median diameter of the spray mixture and estimation of drift potential.

ACETYLCHOLINESTERASE INHIBITION TESTS

Evaluation of AChE inhibition in channel catfish (*Ictalurus punctatus*) was accomplished by exposing twelve fish for four- to five-day intervals at each of seven stations in the river, drains and canals in the vicinity of the study fields. Fish used in the study were obtained from the California State Warm Water Fish Hatchery at Niland and ranged in size from 12 to 15 cm total length.

After the exposure period, the fish were removed from the cages and transported live to the field laboratory facility where the brains were removed for AChE analysis.

The principal equipment used for AChE analyses is a recording pH-stat. Briefly, the procedure was: brains of 3 fish from the same exposure site were pooled, wet-weighed, and homogenized in distilled water. The brei was diluted with distilled water to a final tissue concentration of 5 mg/ml. Four ml of diluted homogenate was then mixed with 4 ml of acetylcholine iodide (a specific substrate for the enzyme AChE). The pH-stat was used to titrate the acetic acid end-product of the anzyme substrate reaction with 0.01M NaOH. The test was performed at pH 7.0 and 22°C with a nitrogen purge over the surface of the reaction vessel to prevent absorption of atmospheric carbon dioxide.

Micromoles of acetylcholine hydrolyzed was calculated from the micromoles of NaOH required to neutralize the free acetic acid. The AChE activity was expressed as micromoles of acetylcholine hydrolyzed per hour per mg of brain tissue.