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OFFICE OF ENFORCEMENT

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DESICCANT USE OBSERVATIONS

ELLIS COUNTY, TEXAS

(SEPTEMBER 21-27, 1976)

ENFORCEMENT INVESTIGATIONS CENTER

DENVER, COLORADO

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I. INTRODUCTION

Annually, millions of pounds of arsenic acid are used by farmers in the United States to desiccate cotton prior to harvest. Arsenic is an environmentally persistent, toxic material, and is a suspected carcinogen.^{1,2} The Environmental Protection Agency (EPA) is concerned about the continuing and extensive use of arsenic acid as a preharvest cotton desiccant.

To monitor the effects of arsenic acid use, the National Enforcement Investigations Center (NEIC) and EPA Region VI conducted a desiccant use observation study. This study was accomplished at a cotton farm approximately 30 miles south of Dallas, Texas, from September 22 through 28, 1976. The objectives of the study were as follows:

1. Ascertain through on-site observations whether the use of the desiccant, arsenic acid, on cotton was in accordance with label requirements and appropriate regulations.
2. Document the environmental fate of an arsenical desiccant.
3. Identify use observation techniques of value to the EPA and to other pesticide regulatory agencies.

The study determined residue levels of arsenic in ambient air, vegetation, soil, water and fish samples collected before or after desiccant application. Storage, handling, mixing and application of the desiccant were observed. Weather conditions were monitored during and

after the application. Various types of spray droplet cards and high- and low-volume air sampling devices were used to characterize spray drift.

II. SUMMARY AND CONCLUSIONS

In September 1976, the NEIC and Region VI conducted a 7-day study in Ellis County, Texas to monitor the ground application of arsenic acid used as a preharvest cotton desiccant. On-site observations, combined with the use of various monitoring techniques, enabled the EPA to determine user compliance with label instructions and to evaluate both beneficial and harmful effects associated with the chemical desiccation of cotton.

GENERAL CONCLUSIONS

On-site observations revealed that the applicator used a registered chemical desiccant in a manner inconsistent with labeling and Federal Regulations.

Environmental sampling showed that cropland, pasture and nearby ponds were contaminated by the use of arsenic acid.

The most valuable techniques used to document the practices and environmental effects of the ground application were on-site evaluations by trained observers and analyses of air, water and soil to determine arsenic residues at the study site.

SPECIFIC CONCLUSIONS

1. Pre-application sampling revealed arsenic residues in soils from the study site as high as 20 µg/g. Additionally, five

nearby ponds contained 9 to 870 $\mu\text{g/l}$ arsenic. Of the two most contaminated ponds, one containing about 50 $\mu\text{g/l}$ arsenic was used for livestock watering. The water of neither of the ponds is safe for use as a domestic or livestock supply.

2. During mixing and loading operations, human health hazards were observed. Workers handling the desiccant were not wearing adequate safety apparel. Arsenic contamination in the mixing area was of further concern because a residence and livestock area were located within 100 m.
3. Chemical analysis showed that one of five batches of desiccant was diluted improperly. This mixture contained half the concentration of arsenic acid recommended on the desiccant label.
4. During the ground application, additional practices were observed that were inconsistent with the desiccant label instructions. Application was at a rate of 12 gal/acre rather than the rate of 5 gal/acre; therefore, four of the five batches introduced more than twice the arsenic onto the field than was recommended. Application occurred when the wind gusted to 15 mph, thus increasing off-field drift. The applicator did not use an approved respirator as recommended on the desiccant label.
5. Observations by NEIC and Region VI personnel, after application and prior to harvest, revealed that an application of 9.5% arsenic acid, as recommended on the label, enhanced harvesting. It minimized regrowth and produced a more brittle, non-pliable foliage than did the lower concentration which was half the recommended concentration.

6. During and following application, as much as 1,600 μg arsenic was found in the ambient air collected 90 m (300 ft) downwind from the treated field.
7. Clean-up and disposal practices were inconsistent with the label instructions and with Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended, Regulations. Liquid wastes were flushed from spray equipment onto the ground instead of being disposed of in a pit, as directed on the label. Additionally, unrinsed plastic jugs previously containing arsenic acid were burned on-site rather than being buried with the rinse water or encapsulated and buried in a specially designated landfill, as designated in the regulations promulgated pursuant to authority in FIFRA (40 CFR 165).
8. The arsenic residues on treated foliage and cotton fiber were as high as 46 $\mu\text{g/g}$. These levels pose a health hazard to wildlife, stock or humans entering the treated field. Furthermore, such levels could pose a health hazard to gin and mill workers who handle the cotton on a day-to-day basis.
9. Post-application sampling revealed an increase in arsenic levels in vegetation and water samples collected from fields bordering the treated cotton. Increased arsenic levels in these neighboring areas appeared to be the result of spray drift and contaminated runoff from the target field. Arsenic contaminated both the foliage of nearby pastures and ponds used for stock watering.
10. Analysis of tadpoles obtained from a pond (Station 5) revealed an arsenic level of 86 $\mu\text{g/g}$. This indicated that arsenic

accumulation in the aquatic food chain had occurred. Although arsenic was not detected in fish, the potential for this contamination exists.

11. On-site observations and residue analysis for arsenic in air, soil, water, and biota were the most valuable techniques for evaluating the use and impact of arsenic acid. Spray-droplet cards and slides were of limited value because of the sparsity of droplet impressions collected. Tracer-dye studies were unsuccessful because the fluorescence of the dye apparently was quenched by the acidic properties of the desiccant or because the dye concentration was too low.

III. DESCRIPTION OF STUDY AREA

Ellis County is in northeast Texas approximately 30 miles south of Dallas and Fort Worth. Gently rolling grasslands with numerous small ponds characterize the area. Although the land is used primarily for pasture, thousands of acres are cultivated in cotton, sorghum, soybeans, vegetables, and grains.

The site selected for the desiccant use observation study was a 79 ha (196 acre) cotton field in Ellis County, 4 miles west of Palmer, Texas [Fig. 1]. The field was sloped with the highest point toward its northern edge. Surface runoff drained from the cotton field, across adjoining pastures, and into nearby ponds or small creeks.

The ponds at Stations 1, 2, 3, 4, 7 and 8 are used primarily for stock watering. The pond at Station 5 is used by the applicator as a supply for diluting pesticides and desiccants. The pond at Station 6 is fenced, preventing its use for livestock watering.

On the southwest side of the cotton field is a group of farm buildings including a residence and a barn. The barn serves as a storage shelter for small amounts of fertilizers, chemicals, and various farming implements. The area to the east and south of the barn is used for mixing and loading chemicals for ground application equipment. An abandoned airstrip bisects the field from near the residential area toward the northwest. Mixing and loading of chemicals for aerial applications once occurred at the northwest end of the airstrip.

Twenty-nine sampling stations were established in the study area. These sampling sites were located in areas believed to have a high

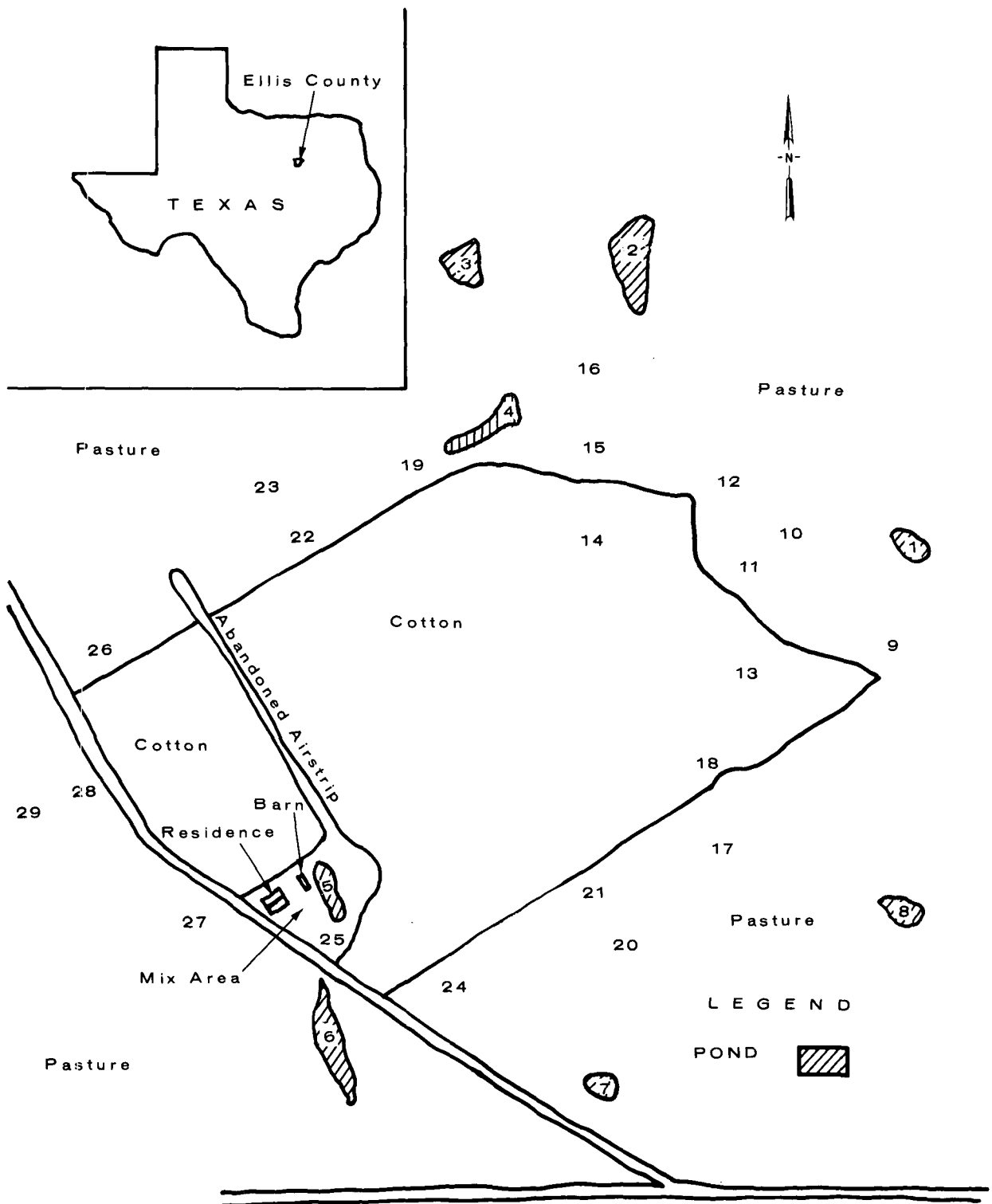


Figure 1. Study Area and Station Locations
Ellis County, Texas

potential for receiving drift or surface water runoff from the treated cotton field. Three stations were located in the cotton field; seventeen in surrounding pasture land; eight in nearby ponds; and one near the farm buildings on the southwest side of the field [Fig. 1]. Air, vegetation, soil, water and aquatic biota were collected at selected times and locations in this sampling network [Table 1]. Samples were analyzed to determine the environmental fate of arsenic sprayed on the field to desiccate the cotton plants.

Table 1

SAMPLING STATIONS
ELLIS COUNTY, TEXAS
September 1976

Station Number	Water	Soil Vegetation	Droplet ¹ Cards	MgO Slides	Greenburg- Smith Impinger High-Volume Air Samplers	Aquatic Biota
1	*					
2	*					
3	*					*
4	*					
5	*					*
6	*					
7	*					
8	*					
9			*	*		
10		*			*	
11			*	*		
12			*	*		
13		*				
14		*				
15			*	*		
16			*			
17			*	*		
18	*					
19			*	*		
20		*			*	
21			*	*		
22			*	*		
23		*			*	
24			*	*		
25		*	*	*	*	
26			*	*		
27		*	*	*		
28			*	*		
29			*			

¹ Mylar sheets, Thermofax, Linagraph

IV. USE OBSERVATIONS

PRE-APPLICATION

Sampling

On September 24, environmental samples were collected to establish background arsenic levels prior to ground application of arsenic acid [Table 2]. Soil from the cotton field contained water-soluble arsenic residues ranging from 0.75 to 0.95 $\mu\text{g/g}$, while soil from the mixing and loading site (Station 25) contained 16 $\mu\text{g/g}$.

Arsenic was not found in the cotton from the study field or in grasses from nearby pastures. However, vegetation at the mixing and loading site (Station 25) contained 20 $\mu\text{g/g}$ arsenic. The presence of arsenic in the cotton field soils and in the mixing area indicated the persistence of arsenical desiccants used by the farmer in previous growing seasons.

Five of eight ponds near the cotton field also contained arsenic. A pond north of the study field contained 9 $\mu\text{g/l}$ arsenic, while the four ponds to the south had from 9 to 870 $\mu\text{g/l}$. The two ponds having the highest amount of arsenic contamination (49 and 870 $\mu\text{g/l}$) were either adjacent to, or drained, the mixing and loading area. According to the 1976 *Quality Criteria* for water, published by the EPA, water is unsafe as a domestic or livestock watering supply when arsenic concentrations exceed 50 $\mu\text{g/l}$.³ Therefore, the use of these two ponds for farming activities is limited. Previous use of arsenic compounds on the farm has contaminated cropland and nearby bodies of water.

Table 2
 ARSENIC IN THE ENVIRONMENT
 ELLIS COUNTY, TEXAS
 September 1976

Station Number	Type Sample *	Arsenic Residue		
		Pre-Application	Application	Post-Application
1	Water	ND**	--	ND
2	Water	ND	--	ND
3	Water	9	--	ND
4	Water	ND	--	9
5	Water	49	--	51
6	Water	870	--	890
7	Water	9	--	16
8	Water	15	--	20
18	Water	--	--	61
10	Soil	ND	--	ND
13	Soil	0.95	--	1.6
14	Soil	0.75	--	2.0
20	Soil	ND	--	ND
23	Soil	ND	--	ND
25	Soil	16	--	16
27	Soil	ND	--	ND
10	Vegetation	ND	--	5.6
13	Vegetation	ND	--	15
14	Vegetation	ND	--	46
20	Vegetation	ND	--	ND
23	Vegetation	ND	--	8.5
25	Vegetation	20	--	5.9
27	Vegetation	ND	--	ND
3	Sunfish	--	--	ND
3	Bass	--	--	ND
3	Crappie	--	--	ND
5	Small fish	--	--	ND
5	Tadpoles	--	--	86
10	High-Volume Air Sampler	--	—————→	53
20	High-Volume Air Sampler	--	—————→	1,300
23	High-Volume Air Sampler	--	—————→	1,600
25	High-Volume Air Sampler	--	—————→	43
10	Greenburg-Smith Impinger System	ND	0.002	0.002
20	Greenburg-Smith Impinger System	ND	0.002	ND
23	Greenburg-Smith Impinger System	ND	ND	ND
25	Greenburg-Smith Impinger System	ND	0.002	0.001

* Values expressed: water - ug/l; air - ug; all other samples ug/g.

** ND = not detected.

Prior to observing mixing and loading operations, sampling devices were placed around the cotton field to evaluate drift of the desiccant during ground application. These devices included: Greenburg-Smith impinger units; high-volume air samplers, spray-droplet cards (Linagraph and Thermofax paper); magnesium-oxide-coated glass slides, and mylar sheets [Figs. 2, 3]. Each device is described in the Appendix of this report.

The Greenburg-Smith impinger units were operated at four locations (Stations 10, 20, 23 and 25) several hours before mixing, loading and applying the arsenical desiccant. The reference air sample collected by the impingers revealed no detectable arsenic ($<0.001 \mu\text{g}$ of arsenic) in the air during this pre-application period [Table 2].

A meteorological station was assembled on the property near the mixing site [Figs. 4, 5], to measure and record wind direction and velocity, air temperature, lapse rates and precipitation. These factors were recorded during and following the chemical treatment of the cotton field; results were used to evaluate the influence of atmospheric conditions on the translocation of arsenic beyond the target field.

Mixing and Loading Activities

On the morning of September 25, farm workers began the mixing and loading of the chemical. Three lots, containing 175 one-gallon plastic jugs of Hi-Yield^R H-10,* were stacked neatly on the ground beside a tractor and spraying rig. An acid-resistant 55 gal (208 liter) stainless steel drum was used to premix the desiccant. The applicator hoped to demonstrate to the EPA that the concentration specified on the label was ineffective for preharvest cotton desiccation. The applicator planned

* Hi-Yield^R H-10 EPA Reg. No. 7401-195.



Figure 2. Greenburg-Smith impinger unit, droplet card platform, High Volume Air Sampler.

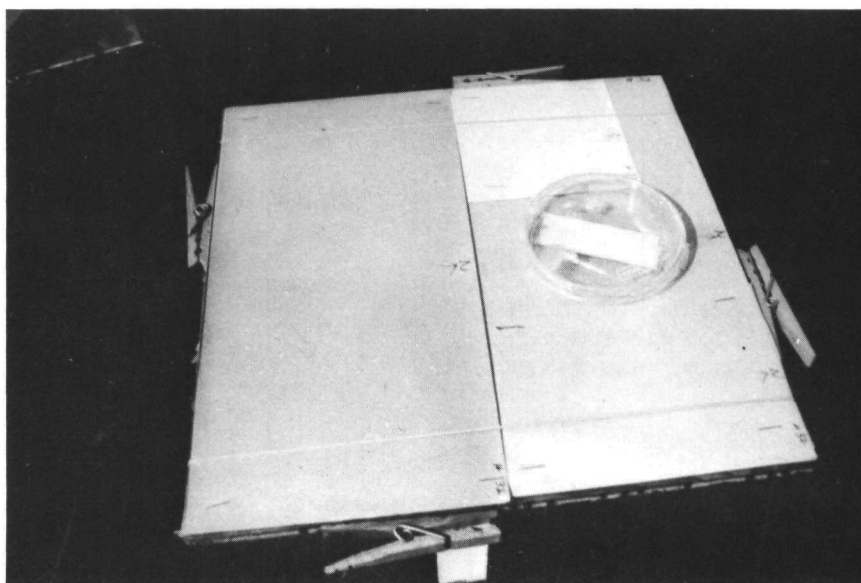


Figure 3. Spray droplet card cluster and magnesium oxide slides.



Figure 4. EPA Meteorological Station.

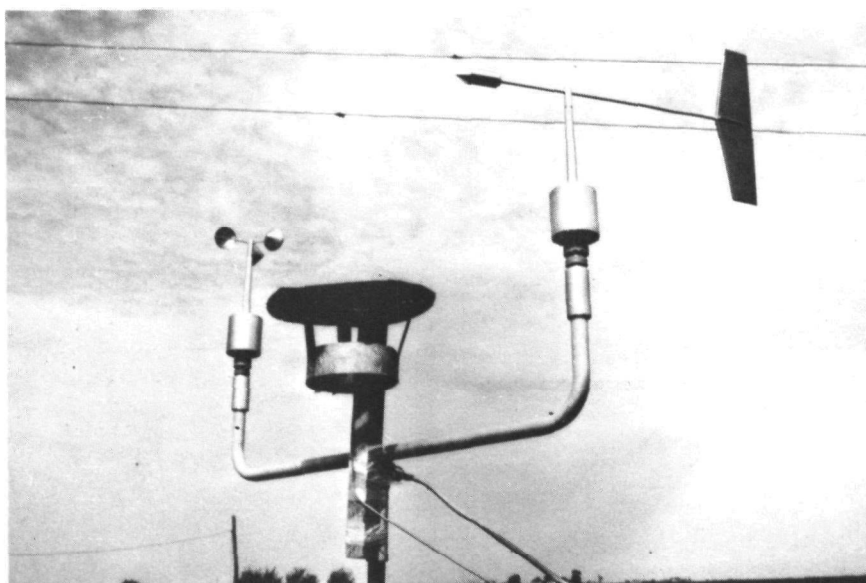


Figure 5. Anemometer, wind vane, and 2-meter temperature probe.

to mix one batch at recommended label concentration, and the four remaining batches at a higher concentration.

The low concentration batch was mixed by pouring 15 gal of Hi-Yield H-10 and 1 pt wetting agent into a stainless steel drum. Two jugs of the concentrated desiccant were poured simultaneously so their flow streams intermingled and splashing was minimized [Fig. 6]. The chemical mixture was pumped into the spray tank and water was added to increase the volume to approximately 500 gal. The high concentration batch was mixed by increasing the volume of 40 gal Hi-Yield H-10 and 1 qt wetting agent to approximately 500 gal.

Chemical analysis confirmed that the low concentration batch was diluted to half the label recommendation, and the other four batches had arsenic concentrations within the label recommendation [Table 3].

At the request of the EPA investigators a fluorescent tracer dye (Rhodamine WT) was added into each batch in the tractor-mounted spray tank. The use of this dye will be discussed later. During the mixing and loading operation, farm workers were careful not to spill the chemical mixture on their clothing, the tractor rig or the ground. In addition to regular clothing, workers wore rubber gloves. Work crews did not wear respirators, goggles or coveralls. Protective clothing worn by EPA observers consisted of long-sleeved coveralls, gloves, boots, face shields, hats, rubber apron, and approved canister-type respirators [Fig. 7]. Protective clothing was worn by the EPA team both during and after application.



Figure 6. Worker mixing desiccant.

Table 3

*Formulation and Diluted Material Analysis
(% by Weight)*

<u>Brand Name</u>	<u>Arsenic Content Indicated on Label</u>	<u>Desiccant Concentrate</u>		
		<u>Actual Arsenic Content</u>	<u>Arsenic Acid Content Indicated on Label</u>	<u>Actual Arsenic Acid Content</u>
Hi-Yield H-10	39.61%	41.61%	75.00%	78.84%

Use Dilution Preparation

<u>Batch Number</u>	<u>% Arsenic</u>	<u>% Arsenic Acid</u>
1	4.89	9.26
2	5.76	9.02
3	2.60	4.93
4	5.14	9.74
5	5.09	9.64

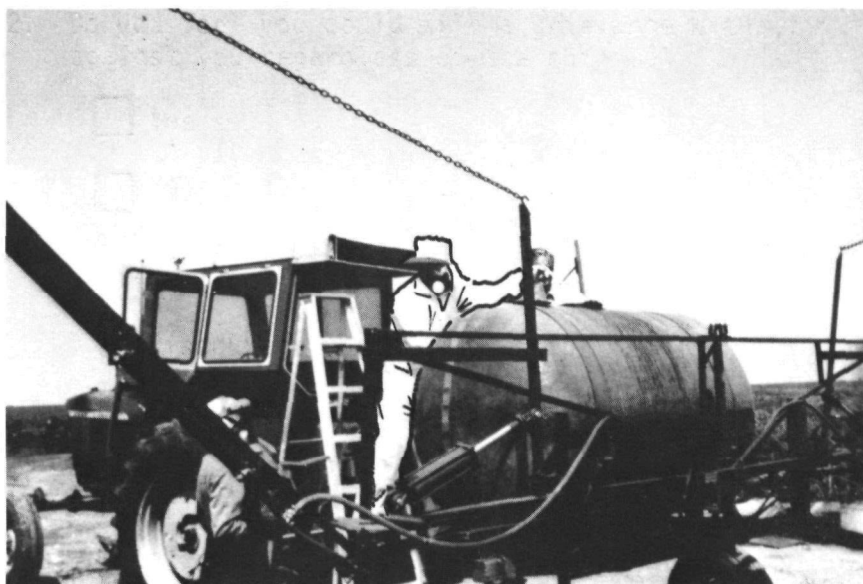


Figure 7. Inspector samples desiccant mixture.



Figure 8. Tractor-towed Trumbull Spray Rig.

APPLICATION

On-Site Observation

On September 25, between 10:30 a.m. and 7:30 p.m., arsenic acid desiccant was applied to the study field. Application was delayed because heavy dew, which would reduce the effectiveness of arsenic acid, covered the field. Five loads (approximately 2,500 gal) of diluted Hi-Yield H-10 and wetting agent were sprayed on the cotton with a tractor-drawn rig.

Warm and sunny weather prevailed during application [Table 4]. Air temperature ranged from 77 to 90°F, and no inversions were detected. Winds were variable, predominantly from the south at 3 to 8 kmh (2 to 5 mph) with occasional gusts to 24 kmh (15 mph).

The Trumbull Spray Rig [Fig. 8] was used to apply the desiccant. The tractor-towed rig consisted of three spray booms; the center boom was mounted permanently to the frame while the two lateral booms were movable. The booms were equipped with a total of 25 spray nozzles (D3-45), evenly spaced, 51 cm (20 in) apart.

The three booms were preset to a height of 1.2 m (4 ft) above the ground. This position allowed a few centimeters' clearance between the boom and the top of the cotton plants. The desiccant was sprayed at 4.23 kg/cm^2 (60 psi) uniformly over the plants at a rate of 12 gal/acre (112 liter/ha). A twelve-row swath of cotton was treated in a single pass.

As discussed previously, two concentrations of desiccant were applied to demonstrate that the recommended mixture was ineffective.

Table 4

Weather Conditions During Application

Batch Number	Time of Application	WIND			AIR TEMPERATURE		
		Speed mph	Direction	Duration minutes	10 m °F	2 m °F	Lapse* Rate
1	1030-1200	<1 to 8	SW	8.0	77 to 81	77 to 82	0.5 (lapse)
			S	74.0			
			SE	8.0			
2	1230-1400	5 to 11	SW	7.8	83 to 86	83 to 87	0.5 (lapse)
			S	71.0			
			SE	11.2			
3	1410-1530	2 to 15	SW	13.0	85 to 86	86 to 88	1.5 (lapse)
			S	62.2			
			SE	4.8			
4	1545-1750	4 to 13	SW	5.7	86 to 87	87 to 90	2.0 (lapse)
			S	99.7			
			SE	19.6			
5	1810-1930	1 to 3	S	55.4	84 to 86	83 to 87	0 (normal)
			SE	24.6			

* A numerical classification relating to air stability.

Four batches were prepared in accordance with the label which states "Mix 1 to 1 1/2 qt with sufficient water to make 5 gal of spray and apply to each acre of cotton."

The high concentration of desiccant was applied to approximately 64 ha (157 acres) of cotton, while the lower concentration was sprayed on the remaining 16 ha (39 acres). The low concentration batch was prepared at half the recommended concentration (1/2 qt/5 gal).

Since these mixtures were applied to the cotton at the rate of 12 gal/acre rather than the recommended rate of 5 gal/acre, application of the four batches mixed at the proper concentration resulted in more than twice the recommended amount of arsenic acid being applied to each acre of cotton.

Although the improperly diluted low concentration batch resulted in applying the recommended amount of arsenic acid to each acre of cotton, the mixture was too dilute to desiccate the cotton effectively.

The EPA observation team reported no *visible* spray mist beyond the target field. The tractor operator turned off the spray pump when he left the field at the end of each treated row. This technique reduced off-field contamination of grass lands (pasture) and soils. The applicator was not observed to be wearing a respirator to protect him from spray drift, as directed on the label. However, he was enclosed in a tractor cab; the degree of protection afforded was not evaluated but should be in future use studies.

POST-APPLICATION

Mixing Area

Upon completing the desiccant treatment, the applicator drove tractor and spray-rig to the mixing area to be cleaned. Clean-up

procedures consisted of mixing approximately 2.7 kg (6 lb) of sodium bicarbonate with about 250 gal of water in the spray tank. Sodium bicarbonate neutralizes acidity but may not degrade arsenic. The mixture was discharged through the nozzles at the edge of the treated cotton field (about 35 yd from the mixing area). A dike around a small pond (Station 5) adjacent to the rinse-water dump site prevented runoff from the cleaning area into the pond. However, surface water drainage from this area was to the southwest toward another nearby pond (Station 6). This clean-up procedure was not in compliance with instructions on the Hi-Yield H-10 label which states "Rinse spray equipment and containers and dispose of liquid wastes in a pit in non-cropland located away from water supplies."

The following day, the empty plastic jugs and cardboard boxes that previously contained the desiccant were burned [Fig. 9]. The EPA specifically recommends against the open burning of containers formerly used for arsenic compounds. The regulation (40 CFR 165.9) recommends that arsenic containers be triple-rinsed, punctured and buried with the rinsings. Otherwise, the unrinsed container should be encapsulated and buried in a specially designated landfill.

In addition to this improper procedure for disposing of empty desiccant containers, the applicator has the further problem of disposing of empty pesticide containers. Currently, no landfill is available to local farmers and applicators for the disposal of used chemical containers. Figure 10 is a photograph of the applicator's aircraft loading zone at the northwest end of his airstrip. The applicator stated that he hasn't used this airstrip for several years. Empty pesticide containers and general litter at the loading zone illustrates the magnitude of this applicator's disposal problem.



Figure 9. Disposal of empty desiccant containers by burning.



Figure 10. Empty pesticide containers at northwest end of airstrip.

Soil and vegetation samples from the mixing site (Station 25) were analyzed for arsenic residues. The soil contained an arsenic concentration of 16 $\mu\text{g/g}$, while vegetation contained as much as 5.9 $\mu\text{g/g}$ [Table 2]. This environmental contamination was of concern because a residence and a livestock area were within 100 meters of the arsenic mixing site. Although adverse health effects were not observed, the potential was high for arsenic contamination in food or water consumed by humans and farm animals that occupied the neighboring area.

Cotton Field

Within hours of being sprayed, the cotton leaves were wilting and turning brown. Destruction of the foliage appeared to be most rapid in portions of the field treated with the higher concentration of arsenic acid. Figures 11 and 12, photographed at the same location before and after application, illustrate the efficacy of desiccation with arsenic acid.

Three days after the desiccant application, the Region VI Consumer Safety Officer photographed areas of the cotton field which had been treated with either high or low concentrations of arsenic acid. The mixture containing approximately 5% arsenic acid allowed some leaves to remain healthy (green and sappy) [Fig. 13]. Conversely, the mixture containing about 9.5% arsenic acid appeared to desiccate the cotton plants completely. The higher concentration produced brittle, non-pliable foliage [Fig. 14].

Local cotton growers strive for a degree of desiccation that produces brittle plants and minimizes leaf regrowth. These conditions enhance harvesting efficiency and permit earlier harvesting. Consequently,



Figure 11. Cotton before desiccant application.



Figure 12. Same location 3 days after application.



Figure 13. Cotton desiccated with 4.93% Arsenic Acid (72 hours after application).



Figure 14. Cotton desiccated with 9.74% Arsenic Acid (72 hours after application).

local growers use 9.5% arsenic acid as a preharvest cotton desiccant. This is the recommended concentration. However, the applicator observed in this study wasted arsenic acid by applying at more than double the recommended rate.

As discussed earlier, cotton plants and soil from the study field were analyzed for arsenic residue prior to the desiccant treatment. The plants contained no measurable amount of arsenic. However, the soil in which the cotton was grown contained as much as 0.95 $\mu\text{g/g}$ arsenic [Table 2]. Apparently, uptake of measurable quantities of arsenic from the soil and storage in the cotton plants did not occur.

After the cotton crop was chemically desiccated, soil and cotton were again collected from the treated field for arsenic analysis. The samples were collected from two areas: one treated with 5% arsenic acid (Station 13); and the other treated with 9.5% (Station 14). Arsenic concentrations in soils from these areas were 1.6 and 2.0 $\mu\text{g/g}$, respectively, about 70 to 170% increase. Arsenic concentration in the cotton plants contained 15 to 46 $\mu\text{g/g}$ arsenic, respectively, in the 5 and 9.5% treated areas [Table 2].

These arsenic residues in soils and cotton are significant because of their relationship to environmental and human health hazards. Some of the important issues are illustrated by precautions on the desiccant label stating:

"Hi-Yield H-10 containing T-49 is a very poisonous material and should not be applied under any circumstances to cotton that will be harvested by humans.

"Avoid contamination of food and water to be consumed by humans or animals.

"Do not graze or use treated plants or gin trash for feed or forage. Keep livestock, poultry and pets off of treated areas.

"This product will kill fish and wildlife. Do not contaminate streams, lakes, ponds, woodlands or other non-crop areas. Birds and other wildlife in treated areas may be killed. Apply this product only as specified on this label."

Another significant issue related to arsenic residue on cotton is that it could pose a health hazard to: (1) gin and mill workers who handle the raw cotton on a day-to-day basis; (2) persons using cotton seed oil for food; and (3) livestock consuming cotton seed meal.

Surrounding Areas

Drift

Following the completion of the desiccant application, EPA teams entered the study site (target field and surrounding area) to retrieve spray-droplet cards and slides. Spray-droplet images were readily visible on Thermofax cards and glass slides at two locations (Stations 16 and 29) each 90 m (300 ft) north and west of the field, and at numerous other locations surrounding the field [Table 5]. Droplets were not detected on the Linagraph cards. To obtain a Volume Mean Diameter (VMD)* of spray droplet size, a minimum of 200 droplet impingement craters must be measured on magnesium-oxide-coated slides. None of the slides exposed during the desiccant application showed a sufficient

* VMD is that volume which divides the droplet diameter into two equal parts, one-half above and one-half below the median or 50% cumulative point.

Table 5

Droplet Impingements on Thermofax Paper

Station Number	Distance from Cotton	Direction from Field	Wind Direction and Speed	Droplets/cm ²
9	30M (100ft)	E	from SE to SW, 4-9mph	22
11	30M (100ft)	N	from SE to SW, 4-9mph	16
12	30M (100ft)	N	from SE to SW, 4-9mph	11
15	30M (100ft)	N	from SE to SW, 3-7mph	37
16	90M (300ft)	N	from SE to SW, 3-7mph	5
17	30M (100ft)	S	from SE to SW, 1-3mph	10
19	30M (100ft)	N	from SE to SW, 3-7mph	12
21	30M (100ft)	S	from SE to SW, 1-3mph	17
22	30M (100ft)	N	from SE to SW, 3-7mph	16
24	30M (100ft)	S	from SE to SW, 1-3mph	32
25	30M (100ft)	S	from SE to SW, 8-15mph	24
26	30M (100ft)	N	from SE to SW, 3-7mph	10
27	30M (100ft)	S	from SE to SW, 8-15mph	22
28	30M (100ft)	W	from SE to SW, 8-15mph	25
29	90M (300ft)	W	from SE to SW, 8-15mph	22

number of craters to yield a VMD. Therefore, valid estimates of spray drift potential, based on droplet size, could not be made.

During application, air samples for arsenic analysis were collected by means of Greenburg-Smith impinger units in pastures bordering the treated cotton (Stations 10, 20, 23, and 25); each location was approximately 90 m (300 ft) from the target field. Air collected to the east and south (Stations 10 and 20), and at the mixing site (Station 25), contained 0.002 μg arsenic [Table 2].

The Greenburg-Smith impingers were set to collect a continuous, two-hour, post-application air sample. As these units were manually switched from one impinger to another during pre-application, application and post-application, the air inlet tubes of the impingers, not in use, were capped with desiccant-free aluminum foil to prevent contamination of the impingers.

Analysis of Greenburg-Smith impinger samples confirmed that arsenic remained in the ambient air after treatment of the cotton field [Table 2]. The impinger unit at Station 10, approximately 90 m (300 ft) northeast from the treated field, collected 0.002 μg arsenic, and 0.001 μg arsenic was collected at the mixing and loading site, Station 25.

High-volume air samplers, operated at four locations around the target field (Stations 10, 20, 23, and 25), collected a composite air sample during and following the desiccant application. These sampling devices collected arsenic at all four air sampling stations. On-site meteorological information showed that during the desiccant application the wind gusted to 15 mph from the south across the target field toward Station 23. The high-volume filtering unit operated in the northern pasture at Station 23 collected the largest amount of arsenic drift, 1,600 μg . The evening of September 25, after the desiccant application,

the wind direction changed. The wind blew from the north across the treated field toward a pasture located southeast. The filtering unit operated in this pasture, approximately 90 m (300 ft) downwind from the treated field, collected 1,300 μg of arsenic from the ambient air. Other air filtering units operated in the pasture northeast of the treated field (Station 10) and at the mixing area (Station 25) collected 53 and 43 μg of arsenic, respectively. These results showed that arsenic drifted into nearby fields a distance of 90 m (300 ft) or more.

The fluorescent tracer dye (Rhodamine WT) added to the desiccant and sprayed on the cotton was not detected in air samples collected by the Greenburg-Smith impinger units or by the high-volume samplers. Furthermore, spray droplets rinsed from mylar sheets, placed near the treated field, produced no measurable fluorescence. Because droplet cards and slides indicated drift, it was expected that the dye study should have also; however, no drift was detected by this means. Lack of fluorescent response may be attributable to the acidic properties of Hi-Yield H-10 destroying the fluorescent quality of the tracer dye. It is also highly probable that the dye concentration was undetectably low.

Prior to the application, arsenic was not detected on vegetation from pastures surrounding the cotton field [Table 2]; arsenic was present on vegetation at the mixing site (Station 25) both before and after the application. Vegetation collected after application from pastures to the northeast and north (Stations 10 and 23) had 5.6 and 8.5 $\mu\text{g/g}$ arsenic, respectively, while arsenic was not detected on the vegetation of pastures to the south or west. The contaminated vegetation was from pastures shown (by analysis of spray cards, Greenburg-Smith impingers, and high-volume air samplers) to have received drift from the arsenic acid application. Additionally, analyses revealed that the soils of pastures surrounding the cotton field did not contain water-soluble arsenic, either before or after the application [Table 2]. Therefore, it is concluded that the

arsenic contamination of pasture vegetation to the northeast and north of the cotton field resulted from drift, rather than uptake from the soil. Cattle observed grazing this vegetation would accumulate arsenic and could become sensitized to it, becoming more vulnerable to poisoning from future arsenic exposures.

Surface drainage collected after application from Station 18 on the southeast side of the field contained 61 $\mu\text{g/l}$ arsenic. Analysis of water from nearby ponds showed a pattern of increased arsenic contamination. Prior to treating the cotton field with arsenic acid, the three ponds south of the target field and the pond at the mixing area contained 9 to 870 $\mu\text{g/l}$ arsenic. Following the cotton desiccant treatment, arsenic concentrations in the four ponds generally increased to a range of 16 to 890 $\mu\text{g/l}$ [Table 2]. The most contaminated pond, Station 6, was located in the area draining the chemical-waste dump site. No control measures, such as diking, have been taken to prevent contamination of the pond (Station 6) by surface runoff from the dump site.

The maximum concentration of arsenic permissible in water used for livestock is 50 $\mu\text{g/l}$.³ The pond in the mixing area contained about 50 $\mu\text{g/l}$, and was used for livestock watering. The most contaminated pond (Station 6) was located in a wooded area which was fenced. The pond and adjacent woodland appeared to be a wildlife habitat but was not used for livestock grazing and watering.

On September 27, fish and tadpoles were collected from the ponds at Stations 3 and 5. Although none of the fish samples contained arsenic, tadpoles from the pond in the mixing area contained 86 $\mu\text{g/g}$ [Table 2]. Thus, arsenic accumulated in the aquatic food chain, and arsenic contamination in fish could occur in the future.

To summarize, arsenic from the desiccant application left the cotton field by drift and surface runoff. This arsenic contaminated both the foliage of nearby pasture lands and ponds used for livestock watering.

V. EVALUATION OF METHODS

Many of the techniques used by the EPA to monitor aerial applications of pesticides were less effective in monitoring ground applications. Nevertheless, two techniques proved useful: 1) on-site observations, and 2) arsenic-residue analysis of environmental samples collected from the study site. An evaluation of the techniques used in this study is presented below.

ON-SITE OBSERVATIONS

Visual observations provided first-hand information about the use practices of a preharvest cotton desiccant, arsenic acid. On-site visits also afforded the applicator an opportunity to discuss with EPA officials some of the agricultural problems caused by current pesticide and chemical-use regulations.

AIR SAMPLING DEVICES

High-volume air samplers and Greenburg-Smith impinger units captured measurable amounts of arsenic carried by wind currents off the target field. The high-volume air sampler appeared to be the more efficient device possibly because it sampled a larger volume of air or because the dry fiberglass filter used in it may have a better trapping efficiency than the 1% sodium hydroxide solution used in the Greenburg-Smith impinger device.

TRACER-DYE STUDIES

The dye studies performed to evaluate drift characteristics were unsuccessful. Fluorescent dye (Rhodamine WT) was not detectable after being added to the cotton desiccant mixture and sprayed on the field. It is believed that the fluorescence of the dye was quenched by the acidic properties of the desiccant (arsenic acid), or that the dye concentrations were undetectably low.

SPRAY-DROPLET CARDS AND SLIDES

Spray drift was detected successfully by droplet impressions on Thermofax cards and on glass slides coated with magnesium oxide. Droplets were not detected on Linagraph cards.

Ground application apparently minimized spray drift resulting in small quantities of droplets impacted on the slides. This sparsity of droplet impressions precluded size analysis.

ENVIRONMENTAL SAMPLING

One of the most useful monitoring techniques in this study involved pre- and post-application environmental sampling. Residue analysis for arsenic showed that application of the preharvest cotton desiccant contaminated adjacent fields and nearby surface waters.

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Appendix
Sampling Devices and Methods

SAMPLING DEVICES AND METHODS

Greenburg-Smith Impinger

This system is a semi-quantitative method for detecting airborne desiccant levels. The system consists of a pump which draws air through an impinger and auxiliary equipment to control and measure air flow.

Each unit was numbered, assigned to a station and used only at that station. Air-flow rates were set at $0.5 \text{ ft}^3/\text{min}$. Switching the flow from one impinger to another was done manually to insure the proper impinger was in operation during the pre-application, application and post-application sampling periods. Desiccant-free aluminum foil was used to cover the impinger air intake tubes before and after sample collection. The impingers were filled with approximately 150 ml of 1% sodium hydroxide solution.

To establish airborne arsenic levels around the field, the first impinger was operated for two hours before desiccant application. During application, a time span of approximately nine hours, the second impinger was in operation to capture desiccant drift. At the conclusion of application, the third impinger was in operation for approximately two hours to entrap residual desiccant that remained airborne after application.

High-Volume Air Samplers

This system uses a fiberglass filter $20 \times 25.4 \text{ cm}$, on which airborne particles and spray are trapped. In use, approximately $1 \text{ m}^3/\text{min}$

(35 ft³/min) of air is drawn through the filter. The system was operated for thirteen hours. A total of 772 m³ (27,300 ft³) of air passed through each filter. The filters were removed, stored in plastic bags and returned to the laboratory. The filters were prepared for analysis by eluting the entrapped material with 200 ml distilled water. The eluate was then analyzed for arsenic.

Magnesium-Oxide-Coated Slides

These slides were prepared by burning thin strips of magnesium beneath the slide to form a white, powdery coating. On impact with the stationary slide, the airborne droplet formed a crater which provided visible evidence of droplet impingement. Craters thus formed can be measured to within 5 microns at 100X magnification. Provided a minimum of two hundred craters can be measured on each slide, the Volume Mean Diameter of spray droplet size can be computed and an estimation of drift potential can be made.

Spray Droplet Cards

Spray card clusters were constructed by stapling Linagraph 480 paper, Thermofax 209 copy, type 640 paper and mylar sheeting onto 30 cm (12 inch) square poster-board base. The clusters were sited around the field atop 1 meter upright wooden platforms and attached by elastic bands.

Linagraph and Thermofax paper were extremely sensitive to water or petroleum-based droplets. Visual images were formed on the paper upon droplet contact. Spray droplet cards of 10 x 14 cm mylar sheets were used only to collect spray droplets for fluorescence analysis of tracer dye material (Rhodamine WT).

The droplet card impingements were counted at NEIC using a 30X binocular microscope. Cards with low numbers of impingements were counted in entirety. On cards having high density impingements, five random 2.5 cm (1 inch) square areas were counted and the average obtained. Droplet impingement counts were expressed as the number of droplets per cm^2 .

Fluorescence Analysis

Laboratory analyses for fluorescent response of tracer dye were done using a Turner Model 111 fluorometer with a high sensitivity door. Sample material from the Greenburg-Smith impingers was analyzed and compared with a 1% sodium hydroxide blank. Mylar sheets were washed with 100 ml of 95% ethyl alcohol and fluorescent response compared with an ethyl alcohol blank.

Analytical Methods

Water samples were analyzed by the graphite furnace flameless atomic absorption method. All other arsenic analyses were conducted using the silver diethyldithiocarbamate method as described in *Standard Methods*.⁴

Organic samples (fish, vegetation) were dried at 105°C and either leached or digested. For digestion, samples were ground in a blender and an aliquot was placed in a micro-Kjeldahl flask and digested with nitric and sulfuric acids according to AOAC preparation method number 25.008.⁵ Cotton boll samples were leached for two days with deionized water; the water was then squeezed out and analyzed.

Soil samples were dried at 105°C and ground to less than 300 mesh in a rotary mill. Ten gram aliquots were then leached with water. The

supernatant liquid was centrifuged twenty minutes at 2,000 rpm to remove solids and analyzed.

Minimum detection limits for the water sample analysis was $<9 \mu\text{g/l}$.
The lower limit on the Greenburg-Smith impinger unit samples was $<0.001 \mu\text{g}$.
The lower limit for organic samples was $<4 \mu\text{g/g}$.