



# **TECHNICAL PUBLICATION 88-8**

## **HERBICIDE MONITORING PROGRAM FOR THE ACTIVE INGREDIENT FLURIDONE {SONAR<sup>(R)</sup>}**

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**Richard J. Pfeuffer**

**Water Quality Division  
Resource Planning Department  
South Florida Water Management District**

## ABSTRACT

The herbicide active ingredient fluridone was monitored in the Monkey Box area of Lake Okeechobee to determine any dissipation anomalies specific to south Florida which may not be included in the product registration or the technical literature. For this study area, the water column field half-life of 4.3 days falls in the range of the field half-lives of 1 to 11 days reported in the literature. Dispersal and dilution were probably the prominent factors responsible for the disappearance of the fluridone not adsorbed by the target plants. Fluridone did not routinely disseminate in detectable quantities more than 1 km from the area of application. The highest quantity detected in the water did not represent a possible adverse health effect based on the Environmental Protection Agency developed acceptable daily intake. Hydrosol residues did not accumulate in amounts greater than the reported literature values.

The use of fluridone in small areas of Lake Okeechobee does not appear to present any environmental or health problems since the dissipation occurred at an expected rate for this compound.

**Key Words:**

pesticide, herbicide, fluridone, residue

## EXECUTIVE SUMMARY

The South Florida Water Management District (District) applies a significant amount of herbicides throughout the District as part of an established right of way, ditchbank, and aquatic weed management program. These herbicides were studied at a variety of field locations throughout the nation and are registered by the Environmental Protection Agency (EPA) and the Florida Department of Agriculture and Consumer Services for the appropriate site and vegetation types. However, due to concern about herbicide use and possible adverse health and/or ecological effects, an investigation into a south Florida field application was undertaken. This investigation was designed to determine how quickly the active ingredient in a District applied herbicide would dissipate in a south Florida environment.

This is the second in a series of District applied herbicide monitoring studies. The first publication monitored the active ingredient glyphosate. Future reports will address the compounds fluridone and its photodegradation product, N-methyformamide and the active ingredient 2,4-D.

This study determined the dissipation rate of the herbicide fluridone (1-methyl-3 phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone). Fluridone was applied to four 10.1 hectare (25 acre) treatment plots of hydrilla (Hydrilla verticillata) in the Monkey Box area of Lake Okeechobee at a rate of 2 quarts of aqueous suspension per acre (2.24 kg of active ingredient/ha of surface water) via a hand-held spray gun. Surface water and hydrosol samples were taken the day before spraying, one-half hour after spraying, the following day, 7 days, and 14 days after spraying. Water samples were then taken 21 and 28 days after spraying while hydrosol sampling continued 35 and 118 days after application.

For the study area, the water column field half-life of 4.3 days falls in the range of the field half-lives of 1 to 11 days reported in the literature. Dispersal and dilution were probably the prominent forces responsible for the disappearance of the fluridone not adsorbed by the target plants. Fluridone did not disseminate in detectable quantities more than 1 km from the area of application. The highest quantity detected in the water did not represent a possible adverse health effect based on the EPA developed acceptable daily intake. Hydrosol residues did not accumulate in amounts greater than the reported literature values.

The use of fluridone in small areas of Lake Okeechobee does not appear to present any environmental or health problems since the dissipation occurred at an expected rate for this compound. The application rate and method resulted in surface water concentrations below EPA established acceptable residue levels for fluridone in potable water.

In addition to this study, the District also evaluated the differences in nutrient release and phytoplankton biomass between the treatment plots and the control plots. The results of this evaluation will be published in a separate report. The Institute of Food and Agricultural Sciences at the University of Florida evaluated the biomass of vegetation within and around the treatment plots. The Florida Game and Fresh Water Fish Commission assessed the fish and invertebrate populations before and after application.

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## LIST OF ABBREVIATIONS

The following is a list of terms and abbreviations used in the text:

kg: kilogram or kilograms,  $1 \times 10^3$  grams

ha: hectare or hectares, 100 m x 100 m, 1 hectare equals 2.47 acres.

mg: milligram or milligrams,  $1 \times 10^{-3}$  grams

$\mu\text{g}$ : microgram,  $1 \times 10^{-6}$  grams

l: liter

ml: milliliter or milliliters,  $1 \times 10^{-3}$  liter

$\mu\text{l}$ : microliter or microliters,  $1 \times 10^{-6}$  liter

ppm: parts per million, i.e. mg/l or mg/kg

ppb: parts per billion, i.e.  $\mu\text{g/l}$  or  $\mu\text{g/kg}$

mg/l: milligrams per liter

$\mu\text{g/l}$ : micrograms per liter

$^{\circ}\text{C}$ : degree centigrade

mm: millimeter or millimeters,  $1 \times 10^{-2}$  meter

nm: nanometer or nanometers,  $1 \times 10^{-9}$  meter

**LD<sub>50</sub>:** Abbreviation of median lethal dose, MLD. It indicates the amount of toxicant necessary to effect a 50 percent kill of the organism being tested. It is expressed in weight of the chemical per unit of body weight (mg/kg). LD<sub>50</sub> is used to measure the acute oral and dermal toxicity of a chemical.

**LC<sub>50</sub>:** Abbreviation denoting median lethal concentration, rather than median lethal dose as in the case of LD<sub>50</sub>.

**TL<sub>50</sub>:** Abbreviation denoting median tolerance level. It indicates the amount of toxicant tolerated by 50 percent of the organism being tested.

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## INTRODUCTION

With the increased concern pertaining to nutrient dynamics in Lake Okeechobee and related socioeconomic impacts, the South Florida Water Management District (District) has designated the management of Lake Okeechobee as a top research priority. As part of this effort, a research demonstration project on the herbicide product Sonar<sup>(R)</sup> was initiated. Sonar<sup>(R)</sup> has recently received full state and national registration for aquatic plant control. Since Sonar<sup>(R)</sup> will be used for aquatic plant management on Lake Okeechobee, the objective of this portion of the project is to determine the concentration and persistence of the herbicide Sonar<sup>(R)</sup> (active ingredient: fluridone) in the water and hydrosol within and surrounding the areas of application.

Fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl) phenyl]-4(1H)-pyridinone) is a relatively new herbicide developed in the mid-1970's. Fluridone is manufactured for aquatic plant control under the trade name of Sonar<sup>(R)</sup> (Elanco Products Co., Indianapolis, Indiana). It controls many species of submersed and emerged aquatic vascular plants including hydrilla (*Hydrilla verticillata*). A major advantage of using fluridone for hydrilla control is that this plant is highly sensitive to low concentrations of the herbicide compared to native plants such as peppergrass, tapegrass, and bulrush (Anonymous, 1981). Fluridone is not effective, however, against floating plants such as water hyacinth and water lettuce, and has little effect on algae. Sonar<sup>(R)</sup> was evaluated for the control of hydrilla in several Florida lakes under Environmental Protection Agency's (EPA) experimental use permit during 1981 through 1985. Full registration of the product was granted by the EPA in 1986. Plants absorb fluridone through the leaves, roots, and shoots. Fluridone inhibits carotenoid synthesis, which ultimately results in the formation of albescent tissue in susceptible plants (Beste, 1983). These yellow carotenoid pigments are an important part of the photosynthetic system and protect the plant's chlorophyll from photodegradation. In their absence, the chlorophyll is gradually destroyed and the plant's ability to produce carbohydrates through photosynthesis decreases. The phytotoxic effects of fluridone on susceptible aquatic plants may begin 7 to 10 days after treatment; however 30 to 60 days are necessary before control is observed. The visual symptom is bleaching of the terminal bud or growing points of the plant. This slow herbicidal response causes minimum affect on the water quality (Arnold, 1979; McCowen et al., 1979). The gradual death and decay of vegetation prevents the decline of dissolved oxygen that may lead to fish kills, and prevents

nutrient release pulses from decaying vegetation that might trigger an algae bloom. It is assumed that the mature leaves and stems continue photosynthesis and production of oxygen until death (Anonymous, 1981). These studies appear to show that the natural cycles of decomposition-respiration and reaeration remain in balance as the vegetation decays.

## LITERATURE REVIEW

Fluridone is moderately susceptible to decomposition by ultraviolet irradiation in an aqueous solution but is stable to hydrolysis at pH 3, 6, and 9 (McCowen et al., 1979). Field studies in Michigan and New York indicated that fluridone exhibited a half-life of 14 days or less in pond water with application rates of 0.1 and 0.3 ppm, respectively. At the Michigan site, fluridone was below detection limits (0.0005 ppm) after 54 days while water residues of 0.023 ppm were still present at the New York site after 84 days. In Michigan a 0.1 ppm application rate resulted in a calculated half-life of 7 days, while in New York a 0.3 ppm application rate resulted in a calculated half-life of 37 days. McCowen et al. (1979) concluded that rapid uptake by the aquatic plants, hydrosol adsorption and photodegradation contributed to the dissipation of fluridone from the water. Estimated half-lives were not calculated for the hydrosol at these study sites where a 0.035 ppm fluridone residue was still present after 54 days and 0.078 ppm residue present after 84 days at the same Michigan and New York sites, respectively.

In a Hialeah, Florida, pond studied by Arnold (1979), water and hydrosol had detectable residues of 0.003 and 0.021 ppm, respectively, 187 days after application of 1.12 kg/ha or approximately 0.02 ppm fluridone. Utilizing the data presented, a 51 day half-life in the water column was calculated. At the application rate of 1.67 kg/ha, or approximately 0.03 ppm, the water and hydrosol had detectable residues of 0.011 and 0.031 ppm 187 days after treatment, with a 69 day half-life for the water.

Water and hydrosol samples were analyzed for fluridone residues at a Memphis, Tennessee, lake after an application of the 4AS (aqueous suspension) formulation at 0.45 kg/ha (Grant et al., 1979). These samples showed that the highest concentration occurred between 3 and 14 days after treatment. After this period, fluridone began to dissipate and no residue was detected in the hydrosol after 120 days. However, the water still contained 0.015 ppm fluridone 120 days after treatment. From the data presented, a water column half-life of 42.5 days can be calculated.

Water samples taken in a western pond treated with fluridone 4AS at 0.45 kg/ha using a bottom-layered application technique, had a maximum concentration of 0.090 ppm 1 day after treatment (Rivera et al., 1979). The concentration steadily decreased with time to 0.003 ppm 117 days after treatment. A half-life of approximately 17 days in the pond water was reported. In the same pond, hydrosol residues gradually increased to a maximum of 0.2 kg/ha at 27 days after treatment. This value represented 50 percent of the initial 0.45 kg/ha application rate. The concentration of fluridone in the hydrosol then declined to 0.04 kg/ha, or 8 percent of the applied fluridone, after 117 days.

Muir et al. (1980) reported half-life values in the water column of an artificial Canadian pond from 4 days (at an application rate equivalent to 0.7 ppm) to 7 days (at 0.07 ppm treatment level). Temporal changes in fluridone concentration decayed logarithmically showing good agreement with the integrated form of first-order kinetic rate equations for about 12 weeks after application. Fluridone levels in water samples taken from 12 to 17 weeks after treatment were relatively constant, possibly reflecting equilibrium with residues in the hydrosol.

The rate of disappearance of fluridone in the study by Muir et al. (1980) was similar to that reported by West et al. (1979) who found an average half-life of 5 days in water of several ponds and lakes under several different climatic conditions. In general, the ponds located in a temperate climate of New York and Michigan demonstrated the longest half-lives while the half-lives calculated from the sub-tropical Florida study ponds were less. The study areas of a tropical climate in Panama had the shortest half-life. However, these half-life calculations were based upon the length of time required for dissipation to 50 percent of the maximum concentration and not utilizing all the field results. Therefore, these half-lives could be low. West et al. (1979) concluded that dissipation was due to deposition on hydrosol and uptake by aquatic plants, although photolysis may play an important role. Their laboratory study has shown that fluridone degrades rapidly in deionized water (half-life of 23 hours) under artificial sunlight.

Muir et al. (1980) also reported fluridone half-lives in the hydrosol to be greater than 1 year since relatively little change in herbicide concentration was seen after the maximum concentrations were reached. Similar persistence in hydrosol was noted by West et al. (1979), who monitored fluridone residues for up to 12 months after treatment at sites in Florida. The Orlando, Florida, treatment pond had hydrosol residues of 0.356 kg/ha after 364 days from an initial

application of 2.0 kg/ha. Fluridone residue following application at 1.1 kg/ha to a pond in Hialeah, Florida, was 0.056 kg/ha after 272 days, but was reduced to undetectable levels in 364 days. The second Hialeah pond, with an application rate of 1.7 kg/ha, had no detectable hydrosol residue after 364 days but did have a water column residue of 0.003 ppm.

The adsorption coefficients ( $K_{oc}$ ) of fluridone in the six Canadian hydrosols investigated by Muir et al. (1980) indicated that the herbicide is strongly sorbed to hydrosols of high organic matter and silt content. Percent desorption was greatest from hydrosols of low organic carbon content.

West and Parka (1981) studied the rate of fluridone dissipation from the water and hydrosol of two ponds in central Indiana following application by two different methods. The data indicated that fluridone dissipated at a similar rate with both the surface and bottom application techniques. Reported half-lives, determined from a least-squares line obtained by plotting the concentration of fluridone in water versus the number of days after treatment on a semilogarithmic scale, were 21 and 26 days for the surface and bottom application, respectively. Only 4 percent of the initial fluridone concentration remained in the water of either pond 110 days after treatment. The residue pattern of fluridone in the hydrosol was also similar for both types of application. In both ponds, maximum fluridone residues in the hydrosol were observed 14 days after treatment and were equivalent to 7 and 9 percent of the total amount of fluridone applied to the ponds. Fluridone was not detected in the hydrosol of either pond 56 days after treatment.

In the laboratory (Marquis et al., 1982) fluridone persisted in the water longer than other field studies reported in the literature since this study eliminated photolysis, plant uptake and minimized hydrosol adsorption. However, it is not possible to calculate an aqueous half-life since the initial fluridone concentration was not determined as the fluridone was added to the hydrosol and not the water.

Muir and Grift (1982) reported the average fluridone half-life in three hydrosol types at 12 months under laboratory conditions (25°C) and about 17 weeks under field conditions. A water column half-life of 2 to 3.5 days was reported in two ponds treated at 0.1 ppm.

West et al. (1983) summarized the results of 40 pond and lake trials and concluded that fluridone dissipated with an average half-life of 20 days in pond water and 3 months in pond hydrosol.

For comparison, the half-life of fluridone in the water column is much shorter than that for the terrestrial herbicides simazine (Mauck et al., 1976), and terbutryn (Muir et al., 1979), or the aquatic herbicide dichlobenil (Rice et al., 1974). The aquatic herbicides endothall and diquat (Sikka and Rice, 1973; Simsiman and Chesters, 1976) have been observed to have somewhat shorter disappearance times from the water columns of lakes, small ponds, or simulated lake impoundments. In summary, fluridone dissipates in water gradually. Its half-life ranges from 5 to 60 days depending on environmental factors, with an average half-life of about 20 days (West et al., 1983; EPA, 1986). In lakes where only a portion of the water body is treated, the concentration rapidly decreases due to dilution. Other methods of dissipation are photodegradation, plant and fish metabolism, and hydrosol adsorption. Photodegradation is considered one of the primary process of dissipation (West et al., 1979; Muir and Grift, 1982; Saunders and Mosier, 1983). The rate of photodegradation is affected by the intensity and duration of sunlight and the clarity and depth of water.

Fluridone residues in the hydrosol reach maximum concentration 1 to 4 weeks after treatment and usually decline to a nondetectable level after 16 to 52 weeks depending on environmental factors. Dissipation occurs gradually by desorption back into the water where the residues can be photodegraded. The half-life in hydrosol is estimated to be 90 days (West et al., 1983; EPA, 1986).

Under the EPA guidelines for pesticide registration, Sonar<sup>(R)</sup> was shown not to cause significant detrimental environmental impacts when used as an aquatic herbicide. These conclusions are a result of extensive testing showing very low toxicity after short and long term exposure of selected animals to the herbicide. Laboratory and field tests found that fluridone has a low order of toxicity to fish, invertebrates, birds and other nontarget organisms (Table 1).

Fluridone does not accumulate in the fatty tissues of animals and, consequently, should not persist in the aquatic food chain. There is no evidence of a carcinogenic effect of fluridone in mammals, and this herbicide does not pose a risk as an acute poison or chronic toxicant to humans when used as directed.

## FIELD SAMPLING

Four 10.1 hectare (25 acres) treatment plots were selected by the District's Resource Operations Department in the Monkey Box area on the west side

of Lake Okeechobee (Figure 1). A large hydrilla bed of approximately 400 hectares (1,000 acres) in size exists in this area. The water depth at the time of application was approximately 1.5 meters (5 feet). The boundaries of the spray plots were marked using floating markers.

Sonar<sup>(R)</sup> is formulated as 4 pounds active ingredient per gallon aqueous suspension (4AS) and as a 5 percent pellet (5P). After applying the recommended rate of the 4AS (liquid solution) formulation, the concentration of fluridone in the water is approximately 0.1 ppm, considerably less than the 12 ppm solubility of fluridone. Because of slower release, the concentration resulting from the 5P is theorized to be less immediately after treatment than the AS formulation. However, the active ingredient, fluridone, is expected to dissipate at the same rate. Although two formulations of fluridone were utilized at distinct treatment plots, only the 4AS formulation was monitored. True half-life values are difficult to accurately estimate for lakes treated with Sonar<sup>(R)</sup> 5P because the fluridone concentration represents a net value reflecting both dissipation from the water and the continued gradual release of more herbicide into the water as the clay pellets dissolved. With the 5P formulation, the random inclusion or exclusion of the formulated pellets in the collected samples could also contribute to extreme fluctuations in hydrosol residues (West et al., 1979).

The herbicide was applied on March 3, 1987. Application rates vary according to plant, type of water body, and depth; however, for this treatment site, a rate of 2 quarts per acre (2.24 kg of active ingredient/ha of surface water) of the aqueous suspension was utilized via a hand-held spray gun.

The fluridone monitoring program consisted of five sampling sites located within and near one of the test plots treated with fluridone in the aqueous suspension form. Three sites within the spray plot were spaced at 76 meters (250 feet) intervals on a northeast to southwest transect. The middle site was located in the center of the 10.1 hectare (25 acres) area. The control site near the area of application, utilized two sampling stations spaced similarly. These five sampling sites were identified with floating markers. The critical period for monitoring the dispersion and dissipation of fluridone were in the first few weeks after treatment. The sampling frequencies for the fluridone monitoring is shown in Table 2, beginning the day before treatment.

Both water column and hydrosol samples were collected in sample containers provided by the contract

**TABLE 1. ACUTE TOXICITY FOR FLURIDONE<sup>1</sup>**

<u>Species</u>	<u>Material</u>	<u>Route</u>	<u>Toxicity</u>
Rat	Technical	Oral	LD <sub>50</sub> > 10,000 mg/kg Almost Non-Toxic
	4AS	Oral	LD <sub>0</sub> > 0.5 ml/kg
	Technical	Subcutaneous	LD <sub>0</sub> > 500 mg/kg
	Technical	Inhalation	LC <sub>0</sub> > 2,130 mg/M <sup>3</sup> of Air
	4AS	Inhalation	LC <sub>0</sub> > 9.6 ml/M <sup>3</sup> of Air Moderately Toxic
Mouse	Technical	Oral	LD <sub>50</sub> > 10,000 mg/kg
	Technical	Subcutaneous	LD <sub>50</sub> > 500 mg/kg
Cat	Technical	Oral	LD <sub>0</sub> > 250 mg/kg
Dog	Technical	Oral	LD <sub>0</sub> > 500 mg/kg
Rabbit	Technical	Dermal	LD <sub>0</sub> > 500 mg/kg No Irritation
	Technical	Ocular	Moderate Irritant (44 mg/Eye)
	4AS	Dermal	LD <sub>0</sub> > 2 ml/kg Slight Irritant
	4AS	Ocular	Very Slight Irritant (0.1 ml/Eye)
Mallard Duck	Technical	Diet, Four Days	LC <sub>0</sub> > 5,000 ppm
	Technical	Acute Oral	> 2,000 mg/kg Slightly Toxic
BobWhite Quail	Technical	Diet, Four Days	LC <sub>0</sub> > 5,000 ppm
	Technical	Acute Oral	LD <sub>0</sub> > 2,000 mg/kg Slightly Toxic
Bluegill	Technical	Static Water, 96 Hours	LC <sub>50</sub> >9<12.5 ppm Moderately Toxic
Rainbow Trout	Technical	Static Water, 96 Hours	LC <sub>50</sub> 11.7 ppm Moderately Toxic
Daphnia	Technical	Static Water, 48 Hours	EC <sub>50</sub> 6.3 ppm Moderately Toxic
Sheepshead Minnow	Technical	Static Water, 96 Hours	LC <sub>50</sub> 10.9 ppm Moderately Toxic

<sup>1</sup>FROM M<sup>c</sup>COWEN ET AL., 1979; BESTE, 1983; BERG, 1985; AND EPA, 1986

**TABLE 2. SAMPLING FREQUENCIES FOR FLURIDONE MONITORING PROGRAM**

<u>Sampling Event</u>	<u>Days Following Treatment</u>	<u>Water</u>	<u>Hydrosol</u>
1	-1 (Background)	X	X
2	0 (Day of Treatment)	X	X
3	1	X	X
4	7	X	X
5	14	X	X
6	21	X	-
7	28	X	-
6	35	-	X
7	118	-	X

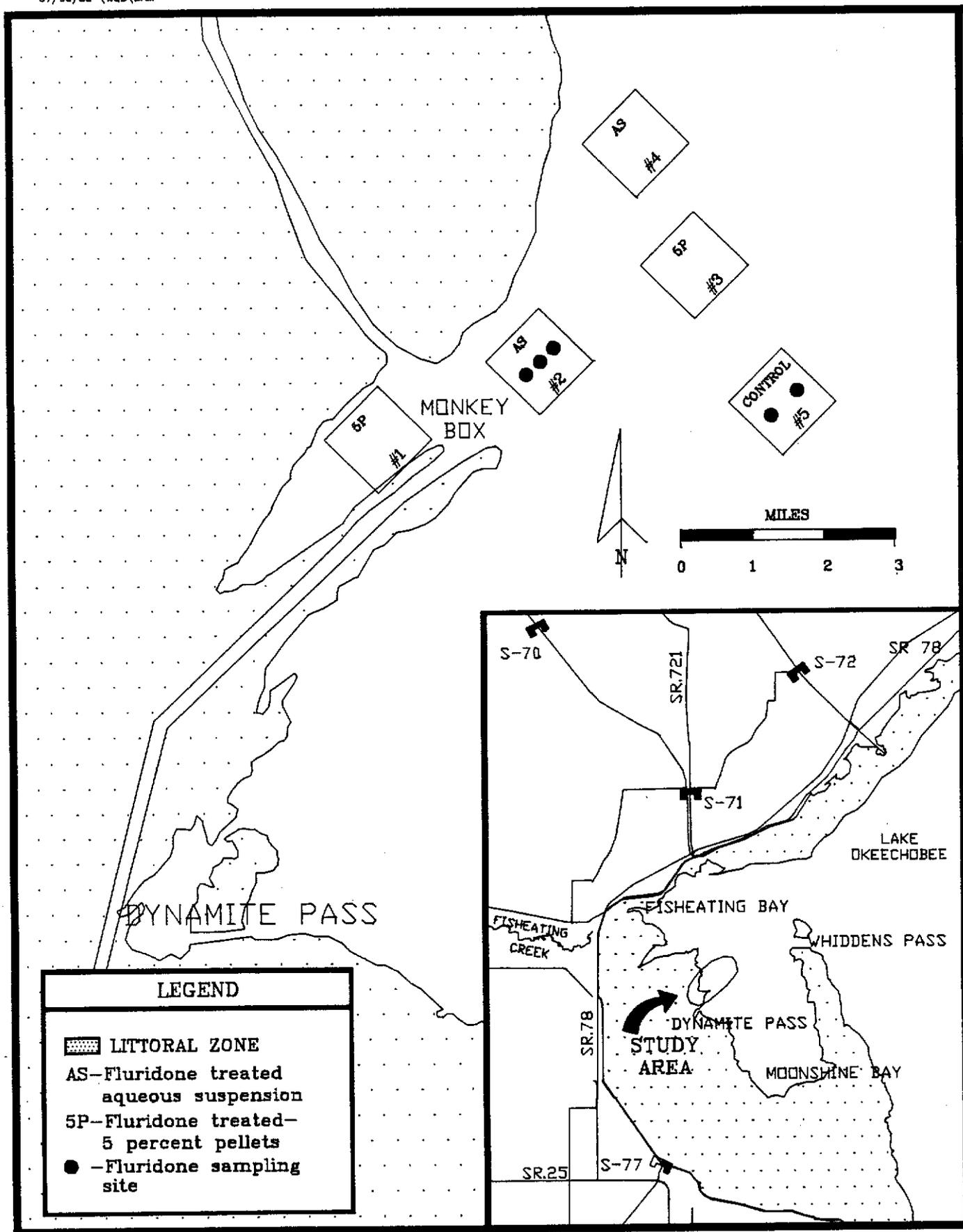


Figure 1. Fluridone Sampling Sites

laboratory (CH2M Hill, Inc., Montgomery, Alabama) and specifically prepared for herbicide residue sampling. The water column samples were surface grab samples. The top 7 cm layer of hydrosol was obtained using a 7.62 cm (3 inches) diameter hydrosol corer (West et al., 1979). Duplicate samples were obtained within the application area as well as the control site to insure quality assurance. All samples were stored on ice or refrigerated until analyzed.

## EQUIPMENT AND LABORATORY PROCEDURES

A capillary gas chromatograph with thermionic specific detection (GC/TSD) was utilized by CH2M Hill, Inc. (Montgomery, Alabama) for the analysis of fluridone in the water and hydrosol samples. For water samples, a 500 ml aliquot was added to a separatory funnel, fortified with a treflan surrogate, and extracted one time with 100 ml of methylene chloride. The extract is dried by passing through a 19 mm ID column of anhydrous sodium sulfate (10 cm layer) and concentrated to 1 ml using standard Kuderna Danish techniques. Internal standards of atrazine and pydrin were added to the final extract immediately before analysis by GC/TSD. For the hydrosol samples, a 10 gram aliquot of sample was weighed into a 400 ml beaker and mixed with enough granular anhydrous sodium sulfate (approximately 20 gms) to dry the matrix. The sample was fortified with a treflan surrogate and then extracted three times using 100 ml portions of methylene chloride and ultrasonication (Model 375C Ultrasonics Inc., Plainview, New York). The sample was sonicated for

three minutes at a 100 percent duty cycle. The combined extract is dried, concentrated, and analyzed as outlined above for the water samples.

A Varian Model 3700 (Palo Alto, California.) gas chromatograph equipped with a fused silica capillary column (5 percent phenyl, 95 percent methylsilicone bonded stationary phase, 21m X 0.32mm I.D., 0.25 um film thickness) set at 100°C for 1 minute increasing to 320°C at a 10°C/minute interval was utilized for the gas chromatography. The injector temperature was set at 250°C and the detector at 350°C with the helium carrier inlet pressure at 10 psig, using splitless injection, 1.5 µl, split opened at 0.95 minutes. Data was analyzed using a Varian Vista 402 Data System.

## RESULTS AND DISCUSSION

The results of the water and hydrosol sampling are presented in Tables 3 and 4, respectively. Since all samples were assayed within a 1 month holding time, the resulting data accurately reflect the concentration of fluridone in the water (West and Parka, 1981). The initial uneven dispersal of fluridone during application is reflected in the results of sampling event two, as this sampling was done one-half hour after treatment. One of the four samples taken did not have a detectable residue. All of the duplicate samples had residue concentrations the same or very similar, which indicates that acceptable analytical techniques were utilized by the laboratory. Based on a 2.24 kg active ingredient/ha (2 lbs/acre) uniform application rate and assuming the total water column or 1.5 meters (5 feet) as a mixing zone for the applied

**TABLE 3. CONCENTRATION OF FLURIDONE RESIDUES IN PPM FOR WATER SAMPLES**

Station	Days Following Treatment Sampling Event and Date						
	-1 #1 03/02/87	0 #2 03/03/87	+1 #3 03/04/87	+7 #4 03/10/87	+14 #5 03/17/87	+21 #6 03/24/87	+38 #7 03/31/87
AS2A	<0.005 <sup>1</sup>	<0.005	<0.005	0.006	0.007	<0.005	<0.005
AS2B	<0.005	0.146	<0.005	0.006	0.007	<0.005	<0.005
AS2B <sup>2</sup>	<0.005	0.134	<0.005	<0.005	0.006	<0.005	<0.005
AS2C	<0.005	0.132	0.016	0.008	0.008	<0.005	<0.005
C1A	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1B	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1B <sup>2</sup>	<0.005	<0.005	<0.005	<0.005	<sup>3</sup>	<0.005	<0.005

<sup>1</sup>MINIMUM DETECTION LIMIT

<sup>2</sup>DUPLICATE SAMPLE

<sup>3</sup>SAMPLE CONTAINER BROKE

**TABLE 4. CONCENTRATION OF FLURIDONE RESIDUES IN PPM FOR HYDROSOIL SAMPLES**

Station	Days Following Treatment Sampling Event and Date						
	-1 #1 03/02/87	0 #2 03/03/87	+1 #3 03/04/87	+7 #4 03/10/87	+14 #5 03/17/87	+35 #6 04/07/87	+118 #7 08/03/87
AS2A	<0.25 <sup>1</sup>	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2
AS2B	<0.25	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2
AS2B <sup>2</sup>	<0.25	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2
AS2C	<0.25	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2
C1A	<0.25	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2
C1B	<0.25	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2
C1B <sup>2</sup>	<0.25	<0.25	<0.25	<0.250	<0.250	<0.2	<0.2

<sup>1</sup>MINIMUM DETECTION LIMIT

<sup>2</sup>DUPLICATE SAMPLE

chemical, since fluridone rapidly disperses throughout the entire water column (Rivera et al., 1979), it can be calculated that a 0.149 ppm concentration of fluridone would be present in the water at the time of application. The average value of fluridone detected on the day of application was 0.137 ppm. This value is similar to the quantity calculated as potentially being present in the water column. Approximately 5 percent of the initial fluridone concentration remained in the water 14 days after application (Figure 2).

By plotting log percent of initial fluridone concentration remaining in the water versus time (in days), which follows pseudo-first order kinetics, the rate constant,  $k_1$ , can be determined by multiplying the slope of the line by -2.303. The units of  $k_1$  are reciprocal time or day<sup>-1</sup>. The half-life time was calculated according to the following equation:

$$t_{1/2} = \frac{0.693}{k_1}$$

The half-life calculation is based upon percent of maximum concentration observed rather than percent of initial concentration due to uneven dispersal of the fluridone 4AS on the initial sampling date (West et al., 1979). The field half-life of 4.3 days was similar to that reported by West et al. (1983) and EPA (1986). West et al. (1979) observed half-lives of from 1 to 11 days (mean of 5 days) for dissipation of fluridone from various ponds, while Muir et al. (1980) found half-lives of from 4 to 7 days during similar experiments. Though some of the observed dissipation was due to adsorption by hydrosol, both authors

suspected that fluridone was degrading in water by another mechanism, possibly photolysis. True field half-life values could not be estimated for lake trials because the dissipation was largely due to dispersal and dilution rather than degradation or hydrosol adsorption, especially when small areas are treated in large lakes. This is also supported by West et al. (1983) who stated that applications of Sonar<sup>®</sup> to small plots (0.8 to 4.0 ha) in large lakes resulted in lower fluridone concentrations and more rapid dissipation into the surrounding untreated water than when entire ponds were treated. Dispersal and dilution reduce the apparent half-life in lake water to less than 1 week (West et al., 1983). During this study period, dispersal and dilution were potentially enhanced by the weather conditions, as the first week after application consisted of wind and rain.

In this study, measurable fluridone concentrations were not detected in the water at the control site, which was a distance of approximately 1 km from the treated area. This agrees with data from some other test lakes (West et al., 1983). In Gatun Lake of the Panama Canal, fluridone concentrations of 0.006 and 0.014 ppm were found 1 day after treatment in water samples located approximately 0.2 and 0.5 km from the nearest treatment plot. Fluridone levels of 0.005 ppm were measured in Lake Pierce, Florida, 14 days after treatment at control sites 0.9 km from the treatment area. From this work and these studies, fluridone does not routinely appear to disseminate over 1 km from the area of application.

Since the 0.137 ppm of fluridone detected in the water column on the day of application was assumed to be the maximum quantity available in the water, then

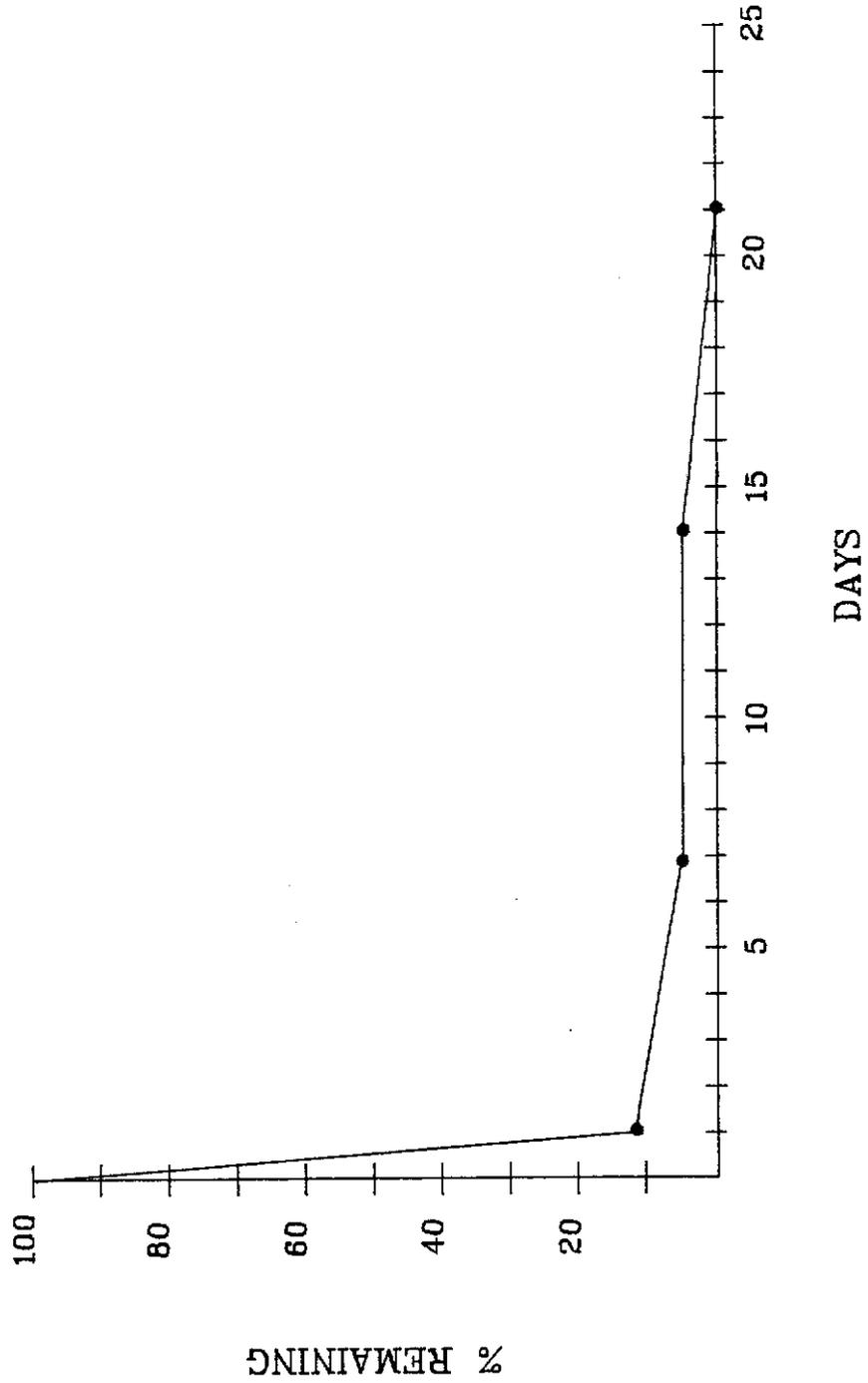


Figure 2. Persistence of Fluridone in Water at the Monkey Box Area Treatment Plots in Lake Okeechobee

no immediate cause for environmental or health concern was indicated. The EPA designated an acceptable residue level for fluridone in potable water of 0.15 ppm (EPA, 1986). Additionally, it is possible to calculate the level of a contaminant in drinking water below which adverse health effects would not be anticipated. Using an EPA developed acceptable daily intake value of 0.08 mg/kg/day (EPA, 1986), a 2.8 ppm contaminant level was calculated. This value represents the maximum contaminant level in drinking water at which adverse health effects would not be anticipated in the average adult, based on a 70 kg body weight and ingesting 2 liters of water a day. This calculated value is over 20 times greater than the average maximum quantity detected. This value also reflects the appropriate safety margin when extrapolating the animal no-observed-effect-level (NOEL) to the human population. If this calculation is performed for a small child of 10 kg body weight and consumes 1 liter of water per day, the maximum contaminant level is 0.8 ppm. Again, this value is over 5 times more than the maximum average field result. Therefore, based upon these calculations, the levels of fluridone detected did not represent a possible adverse health effect.

All of the hydrosol samples were below the minimum detection limit (Table 3). Muir et al. (1980) reported hydrosol residues accumulating in three different ponds treated with the aqueous suspension at three different concentrations, to maximum levels 6 to 10 weeks after application. This phenomenon was attributed to the release of accumulated fluridone when the aquatic plants died. Rivera et al. (1979) found the greatest hydrosol residue accumulated 27 days after treatment at 50 percent of the applied rate. The hydrosol residues studied by Arnold (1979) increased to 27 percent of the applied compound 29 days after treatment and steadily declined to a nondetectable level after 364 days. West et al. (1983) reported that the average 4AS formulation reached a maximum value 1 month after application, with residues declining to approximately 2 percent of the application rate within a year. As hydrosol samples were taken 35 days after treatment, the timing was appropriate for sampling at the potentially highest concentration. However, for this particular site and study, the accumulated hydrosol residue did not exceed the 0.25 ppm minimum detection limit.

An additional factor affecting the hydrosol residues would be that the treatment of small areas (0.8-4.0 ha) in large lakes results in a more rapid dissipation due to dispersal of fluridone into the surrounding untreated water before significant deposition to the hydrosol can occur (West et al. 1983). This effect, coupled with the windy conditions during the beginning of the experiment, may have been the dominant force responsible for the dissipation of the fluridone. Although the hydrilla at the study site was dense and could potentially store significant amounts of fluridone which could be released upon dying, this process may not have been sufficient to control fluridone dispersion in this Lake Okeechobee experiment. Without a lower hydrosol minimum detection limit, the exact fluridone concentration in the hydrosol cannot be determined.

## CONCLUSIONS

The water column field half-life of fluridone (4.3 days) was approximately the same as the average field half-life (5 days) as reported by West et al. (1983) and the EPA (1986). Dispersal and dilution was probably responsible for the disappearance of the fluridone in the treated area. Fluridone did not disseminate in detectable quantities over 1 km from the area of application.

The highest quantity of fluridone detected in the water did not represent a possible adverse health effect based on the EPA developed acceptable daily intake value.

Hydrosol residues did not accumulate in amounts significantly greater than the reported literature values. However, due to a high detection limit, the exact extent of residue accumulation cannot be determined.

The use of fluridone in small areas (<10 ha) of Lake Okeechobee did not appear to present any environmental or health problems since the dissipation rate occurs as expected for this compound.