New Jersey Department of Environmental Protection
Compliance & Enforcement
Pesticide Evaluation & Monitoring Section

AQUATIC PESTICIDE USE IN NEW JERSEY LAKES 2010-2015

Aquatic Pesticide Permits

In 1983, the New Jersey Department of Environmental Protection Pesticide Control Program (PCP) implemented an Aquatic Pesticide Use Permit Program. The specific purpose of this program was to identify and control what pesticides are being applied to New Jersey's waterbodies. All permitted aquatic applicators are responsible for submitting Records of Actual Treatment (RAT) forms to the PCP by November 15th of each aquatic permit season (April through October) of a given year.

The RAT data are initially entered into the PCP's database and checked for any misapplications or other violations. The PCP then analyzes the treatment data and calculates the total amount of each aquatic pesticide used during the past aquatic permit season. In addition, the total pounds of active ingredient (a.i.) used is determined for each treatment record.

This information helps the PCP address the impacts, if any, of specific aquatic pesticides on the environment in a particular area, as well as track the use of these pesticides. However, aquatic ecosystems are quite dynamic and may change significantly from year to year which affects the trend of such usage over time. The RAT data is currently the only way to monitor these usage trends. There is no sampling requirement established as part of the permitting program to monitor the migration of these compounds beyond the application site.

Aquatic Herbicides

Of the more than 300 herbicides registered by the U.S. Environmental Protection Agency (USEPA), only 13 ai.i are registered for use in and around aquatic habitats (Netherland 2009). Most of these a.i. are used throughout NJ as part of aquatic vegetation management plans. In general, herbicides can be selective or broad spectrum, targeting one specific plant species or killing vegetation indiscriminately. A herbicide's mode of action is either by contact or systemic. Contact herbicides kill within hours or days of the initial contact with the plant tissue. Systemic herbicides must be absorbed into the plant tissue and death occurs days or weeks after the application. Aquatic herbicides can be applied as liquid or granular pellets directly to the water column or as a foliar spray.

An analysis of the RAT data was conducted for the 2004, 2008 and 2013 application seasons. Copper sulfate was, and continues to be, the most heavily used aquatic herbicide in NJ. Other compounds reported in the RAT data included glyphosate, diquat, 2,4-D, copper, endothall, flumioxazin, fluridone, imazapyr/imazamox, sodium percabonate and triclopyr.

While the same suite of aquatic herbicides has been used throughout NJ for nearly a decade, the total pounds of a.i. have decreased in that time period. RAT data indicates that pounds of a.i. applied to NJ waterbodies has decreased by more than 50% from 149,923 pounds of a.i. in 2004 to 73,206 pounds of a.i. in 2013 (Figure 1).

The use of copper compounds still accounts for approximately 50% of the total of a.i. applied. However, copper use has decreased from 87% to 50% of total a.i. applied from 2004 to 2013. Use of diquat, imazapyr/imazamox, endothall and 2,4-D has steadily increased since 2004.

Surface Water Monitoring

2009

PCP's Evaluation and Monitoring Section (PEMS) initiated a surface water monitoring program to identify any potential pesticide impacts to ground water. Several sampling sites were selected from each watershed management area throughout the State. Upstream sites contributing to potential runoff and surface water impacts included agriculture, golf courses and suburban/homeowner use.

Pesticides were detected in about half of the 50 sites sampled. The detections were at or below the reporting level. The reporting levels are based on the concentration of the lowest point of a linear calibration curve used to quantify results. Table 1 references available State or Federal guidelines for comparison purposes. Based on evaluation of the upstream land use, the compounds detected were not unusual, except for one. Fluridone was detected in a small, rural stream running through an agricultural area in Sussex County. Upon further investigation, a pond with permitted aquatic herbicide applications (including fluridone) was identified upstream of the sampling site.

2010—Fluridone Survey

In order to address the atypical fluridone detection in 2009, PEMS surface water monitoring program was expanded to include water bodies downstream of lakes and ponds being treated with aquatic herbicides, specifically fluridone. Fluridone was chosen as the first aquatic herbicide to survey because a method of extraction and analysis was already established by the PEMS.

Fluridone was registered by the USEPA in 1986. It is a systemic herbicide used exclusively to control unwanted aquatic vegetation. Fluridone is a slow acting herbicide and target vegetation must be exposed to a lethal dose for a minimum of 45 days (Netherland 2009). Plant death occurs 30 to 90 days after exposure. Treatment typically occurs in early May.

A review of past aquatic permits showed that most fluridone treatments occurred in Sussex, Morris and Bergen Counties. Once the permitted lakes and ponds were located on a map, a field inspection was necessary to determine the outflow point and a viable sampling site. In some cases, one or neither of these locations could be identified and a treatment site could not be included in the survey. PEMS was able to identify the outflow and a sampling site for 27 lakes/ponds.

Sampling began in early May. If a "Notification of Treatment" (Figure 2) was posted, the date was noted. Grab samples were collected, transferred to 950ml amber glass jars and transported to the PEMS according to the Standard Operating Procedure (SOP) for the Collection of Pesticide Samples. Each of the 27 sites were sampled at least once; 6 sites were sampled a second time in September for a total of 33 samples collected. Of the 27 sites sampled, 22 sites had fluridone detections in the outflow stream (Table 2). In addition, 5 of the 6 samples collected as a follow-up in September also had detections of fluridone. All of the detections were well below the NJ Interim Generic Groundwater Quality for Synthetic Organic Chemicals. However, the survey of these 27 lakes and ponds indicated that fluridone was moving out of the treated water body into non-targeted areas.

<u>2011—Fluridone Temporal Evaluation</u>

The data collected in 2010 established the movement of fluridone into water bodies downstream of the treated areas. The samples collected in September 2010 also indicated that fluridone persists in the aquatic environment well beyond the 90 days during which plant death typically occurs. Samples collected in 2011 were used to further evaluate the persistence of fluridone in non-target water bodies over time.

In order for a site to be included in the temporal evaluation, PEMS needed to be certain that an application of fluridone had taken place. Since RAT information is collected by the Department after the application season has concluded, the only way to determine if an application had occurred was to locate a Notification of Treatment posting. Based on this requirement, four sites were selected for evaluation and each site was sampled four times post fluridone application. Fluridone applications occurred in May and samplings occurred in May, June, July and August. Each of the four sites had fluridone detection in the first sampling post application (Table 3). Three of the sites showed fairly significant levels of fluridone throughout all four samplings. Again, all of the detections were well below the NJ Interim Generic Groundwater Quality for Synthetic Organic Chemicals. However, fluridone appears to be persistent in the environment long after the minimum 45 days required to kill vegetation.

<u>2012—Fluridone Distance Evaluation</u>

The data collected in 2010 and 2011 established that fluridone migrates to non-target water bodies and is persistent over time. Samples collected in 2012 were used to evaluate the distance fluridone travels from the permitted application site.

There were two requirements for site selection: 1) confirmation of a fluridone application by a Notification of Treatment posting and 2) accessibility of multiple sampling locations on the same outflow stream several miles downstream of the application site. Two lakes were selected based on these requirements. Lake A had five downstream sampling sites that covered a distance of

2.35 miles from the application site. Lake B had eight downstream sampling sites that covered a distance of 6.33 miles from the application site. Although the focus was not temporal persistence, sites were sampled approximately once per month to allow time for downstream movement. A pre-treatment sample was collected in April. Post-treatment samples were collected in May, June and July for both sites. Based on the results, samples were also collected in August and September for Lake B. Fluridone was detected 1.3 miles downstream (Site 3 of 5) of Lake A and 6.33 miles downstream (Site 8 of 8) of Lake B (Table 4). A trace level of fluridone was detected 6.33 miles downstream of Lake B nearly five months after the application.

<u>2013—Diquat Monitoring</u>

During the three years of fluridone monitoring, the PEMS developed a method to analyze water samples for diquat. After copper compounds and fluridone, diquat is the most commonly used aquatic herbicide in NJ. While copper use has steadily decreased since 2004, diquat use has steadily increased. The use of diquat has increased from 4,723 pounds a.i. in 2004 to 14,857 pounds a.i. in 2013.

Diquat is a fast-acting, contact aquatic herbicide that causes plant death in 1 to 3 days (Senseman 2009). It was registered for use by the USEPA in 1961 and is applied directly to the water column as a post-emergence treatment. Diquat is photo-sensitive and degrades rapidly in the aquatic environment, making sampling and analytic procedures challenging.

Five sampling locations were selected based on previous permitted applications of diquat to the upstream lakes. Each of the five locations was sampled four times—once in April (pre-treatment), May, June and July. The surface water was collected via a grab sample. The sample was transferred to a 50ml amber polypropylene tube to reduce the UV light transmissions that could degrade the photo-sensitive diquat. A second sample was also transferred to 950ml amber glass bottles for fluridone analysis. Samples were transported to the PCP Laboratory according to the SOP for the Collection of Pesticide Samples.

There were only 2 detections of diquat, both during the May sampling event (Table 5). There were no Notifications of Treatment for diquat posted at any point during the sampling season, and our selection of these sites was based on past permitted diquat use. The rapid degradation and photo-sensitivity of diquat also might have impacted our ability to detect the analyte.

However, it should be noted that fluridone appeared in nearly half of the samples taken. The only Notification of Treatment posted for fluridone was at Lake A and treatment occurred on the same day as the May sampling. In addition, prometon was detected during the April sampling at two of the sites. Prometon is not labeled for use as an aquatic herbicide. It is a broad spectrum herbicide used to control bare ground weeds around buildings and in industrial (non-crop) areas. The presence of prometon in these samples is most likely attributed to non-point source run off.

<u>2014—Imazapyr, Imazamox & Triclopyr Monitoring</u>

Imazapyr and imazamox both belong to the imidazolinone chemical family. They are systemic herbicides that are typically applied post-emergent. Susceptible plant growth stops immediately, but death does not occur until weeks later. The USEPA registered imazapyr for aquatic use in 2003.

Reported use of imazapyr has increased from 8 pounds of a.i. in 2004 to 1,383 pounds of a.i. in 2013. In 2004 and 2008, use of these compounds was so limited that their total pounds of a.i. were combined when reported. By 2013, use of imazapyr had far surpassed the use of imazamox and the compounds were reported separately (1,377 pounds of a.i. imazapyr; 6 pounds a.i. of imazamox).

Triclopyr is a selective systemic herbicide that was registered for aquatic use by the USEPA in 2002. Only 166 pounds of a.i. were reported in 2013.

After review of RAT data, several permitted lakes were evaluated for sampling feasibility. However, only one site was selected based on the identification of a downstream outflow and sampling site access. This site was located in Burlington County, as opposed to the northern counties where most permitted lake treatments occur.

The sampling matrix for imazapyr, imazamox and triclopyr was stream bed sediment, not surface water. The extraction and analysis methods for these three compounds in water did not allow detection levels low enough to capture the anticipated residue levels. A method for extraction and analysis of soil was already established and the limits of detection were far below any anticipated environmental residue levels. A 950ml amber glass jar was filled approximately half full with stream bed sediment. The samples were transported to the PCP Laboratory according to the SOP for the Collection of Pesticide Samples.

Samples were collected in May, June, July, August and October. There were no detections of imazapyr, imazamox or triclopyr.

<u>2015—2,4-D Monitoring</u>

2,4-D is a selective systemic herbicide that has been registered for aquatic use since 1959. Plant death occurs slowly, usually within 3 to 5 weeks after application. The use of 2,4-D in NJ has increased from 683 pounds a.i. in 2004 to 2,550 pounds a.i. in 2013.

Four sampling locations were selected based on previous permitted applications of 2,4-D to the upstream lakes. Three locations were in northern counties (Sussex and Warren) and the fourth location was in the south (Atlantic). Each of the four locations were sampled five times—once in April (pre-treatment), May, June, July and August. One site was sampled a sixth time in October. The surface water was collected via a grab sample, transferred to a 950ml amber glass bottle and transported to the PCP Laboratory according to the SOP for the Collection of Pesticide Samples.

2,4-D was only detected once at the southern site. The amount detected (6.1 µg/l) was well below the USEPA Drinking Water Standard of 70 µg/l (Table 1). The southern site was sampled a sixth time because chlorthal-dimethyl (DCPA), an agricultural herbicide most likely entering the stream through non-point source run-off, was detected at a trace level in all of the first five samples, as well as the sixth sample.

Figure 1. Pounds Active Ingredient of Aquatic Herbicides

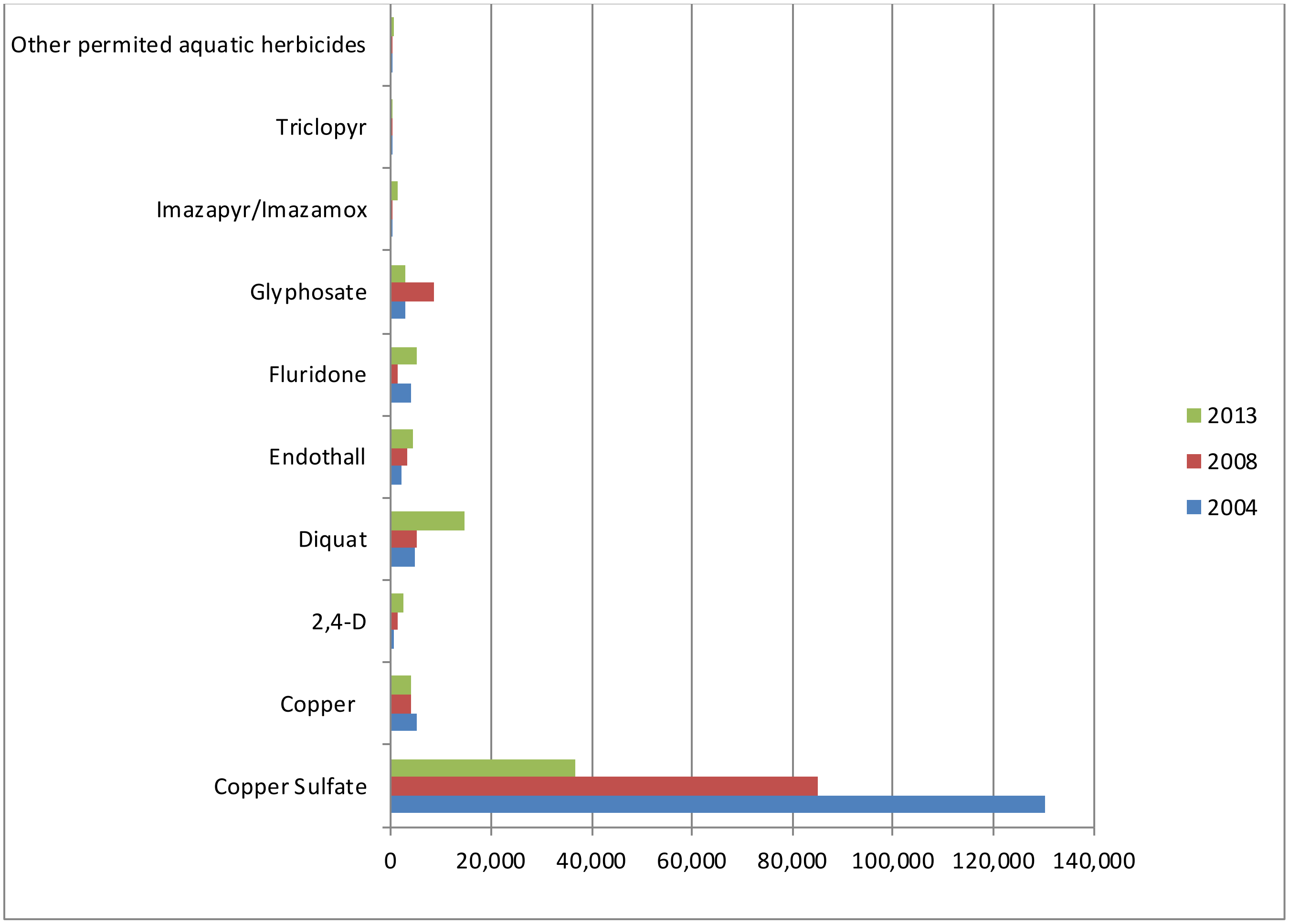

Figure 2. Notification of Treatment Posting

Table 1. Reference Levels of Selected Pesticide Active Ingredients from USEPA

Compound	Drinking Water Standard (MCL)	Health Advisory (Life-time)	Human Health Benchmark for Pesticides (Life-time)
2,4-D	70 µg/l	-	-
DCPA	-	70 µg/l	-
Diquat	20 µg/l	-	-
Fluridone	-	-	960 µg/l
Norflurazon	-	-	96 µg/l
Prometon	-	100 µg/l	-

Table 2. 2010 Fluridone Detections

Total of 33 surface water samples collected from 27 sites.

	# Sites with Fluridone Detections	# Samples with Fluridone Detections	Range of Detections µg/l
Sussex	9	12	0.4-18
Morris	7	7	trace-5
Passaic	4	6	0.55-6.6
Bergen	1	1	trace
Burlington	1	1	0.5

Trace = at or below reporting level

Table 3. 2011 Fluridone Temporal Evaluation

	Sparta Twp Sussex Treated 5/10/2011	Vernon Twp Sussex Treated 5/12/2011	West Milford Passaic Treated 5/12/2011	Ringwood Passaic Treated 5/9/2011
Sampling Date				
5/12/2011	1.7 µg/l	trace	3.0 µg/l	1.3 µg/l
6/16/2011	9.1 µg/l	13.0 µg/l	5.9 µg/l	nd
7/13/2011	4.0 µg/l	4.1 µg/l	2.0 µg/l	nd
8/9/2011	6.4 µg/l	5.2 µg/l	1.6 µg/l	nd

Trace = at or below reporting level
nd = no detection

Table 4. 2012 Fluridone Distance Monitoring

Lake A
Rockaway Twp, Morris County

	Site 1 0.20 miles	Site 2 0.95 miles	Site 3 1.30 miles	Site 4 1.90 miles	Site 5 2.35 miles
4/25/2012 (pre-treatment)	0.75 µg/l	--	--	--	--
Sonar treatment 5/18/12 (Fluridone application)					
5/23/2012	1.2 µg/l	1.7 µg/l	0.87 µg/l	--	--
6/15/2012	3.8 µg/l	3.7 µg/l	1.2 µg/l	nd	nd
7/25/2012	1.9 µg/l	--	nd	nd	--

Lake B
Sparta Twp, Sussex County

	Site 1 0.38 miles	Site 2 1.08 miles	Site 3 1.65 miles	Site 4 2.10 miles	Site 5 3.72 miles	Site 6 4.63 miles	Site 7 5.10 miles	Site 8 6.33 miles
4/25/2012 (pre-treatment)	1.6 µg/l	--	--	--	--	--		
Sonar treatment 5/7/12 (Fluridone application)								
5/23/2012	2.7 µg/l	2.3 µg/l	6.2 µg/l	--	--	--	--	--
6/15/2012	3.8 µg/l	3.3 µg/l	3.1 µg/l	3.2 µg/l	2.8 µg/l	--	--	--
7/25/2012	3.2 µg/l	--	1.6 µg/l	1.6 µg/l	1.3 µg/l	1.2 µg/l	--	--
8/22/2012	1.9 µg/l	--	1.0 µg/l	0.99 µg/l	0.99 µg/l	0.78 µg/l	0.77 µg/l	0.62 µg/l
9/27/2012	2.5 µg/l	--	1.4 µg/l	1.5 µg/l	1.3 µg/l	1.2 µg/l	1.1 µg/l	trace

-- = no sample
nd = no detection
Trace = at or below reporting level

Table 5. 2013 Diquat Monitoring

	Sparta Twp Sussex	Hopatcong Sussex/Morris	Byram Twp Sussex	Mount Olive Twp Morris	Byram Twp Sussex
4/17/2013	Fluridone 1.7 µg/l	--	Prometon 0.23 µg/l	--	Prometon 0.26 µg/l
5/22/2013	Fluridone 4.2 µg/l	**Diquat trace**	--	--	**Diquat 9.3 µg/l**
6/18/2013	Fluridone 6.2 µg/l	--	--	Fluridone trace	Fluridone 1.2 µg/l
7/17/2013	Fluridone 3.8 µg/l	--	--	Fluridone 0.4 µg/l	Fluridone 0.42 µg/l

Trace = at or below reporting level
-- = no detection

Table 6. USEPA Freshwater Aquatic Life Benchmarks

Extracted from: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-pesticide-registration

		Fish		Invertebrates		Nonvascular Plants	Vascular Plants
	Highest Concentration Detected **(µg/l)**	**Acute[1] Level (µg/l)**	**Chronic[2] Level (µg/l)**	**Acute[1] Level (µg/l)**	**Chronic[2] Level (µg/l)**	**Acute[5] Level (µg/l)**	**Acute[6] Level (µg/l)**
		-	-		-		-
Fluridone	18	2800	480	650	--	--	--
DCPA	<0.5	15000	--	13500	--	>11000	>11000
2,4-D	6.1	12075	14200	12500	16050	3880	13.1
Diquat	***9.3***	7400	122	385	<36	***9.4***	***0.75***
Prometon	0.26	6000	19700	12850	3450	98	--

[1] = Lowest 96 hour LC50 in a standardized test (usually with rainbow trout, fathead minnow, or bluegill), and the LOC is 0.5.

[2] = Lowest NOAEC from a life-cycle or early stage test (usually with rainbow trout, fathead minnow), and the LOC is 1.

[3] = Lowest 48 or 96 hour EC50 or LC50 in a standardized test (usually with midge, scud, or daphnids), and the LOC is 0.5.

[4] = Lowest NOAEC from a life-cycle test with invertebrates (usually with midge, scud, or daphnids), and the LOC is 1.

[5] = Toxicity value x LOC. For acute nonvascular plants, toxicity value is usually a short-term (less than 10 days) EC_{50} (usually with green algae or diatoms), and the LOC is 1.

[6] = Toxicity value x LOC. For acute vascular plants, toxicity value is usually a short-term (less than 10 days) EC_{50} (usually with duckweed) and the LOC is 1.

NOAEC = no-observed-adverse-effects concentration

LOC = level of concern

EC50 = 50 percent effect concentration

LC50 = 50 percent lethal concentration

Summary

During the course of this five year study, PEMS evaluated six aquatic herbicides commonly used in NJ. It should be noted that copper compounds and glyphosate are also commonly used treatments in NJ, but PEMS does not currently have methods to extract or analyze for these compounds. Although we had limited detections of diquat, imazapyr, imazamox, triclopyr and 2,4-D, the prevalence of fluridone in non-target areas downstream of treatment sites is evident. Fluridone can persist in the aquatic environment for several months after its minimum 45 day lethal dose. PEMS also demonstrated that fluridone can travel over 6 miles downstream of a treatment site and still be identified at levels above the reporting limits.

The levels of fluridone detected do not appear to pose a risk to human health. Even the highest concentration detected (18 µg/l) is far below the established Human Health Benchmark (960 µg/l) (Table 1). Based on the product label for fluridone (Sonar), there are no restrictions on swimming, fishing or drinking fluridone treated waters. However, irrigation using treated water is restricted for 30 days. These chemicals are herbicides and lethal to terrestrial plants as well as aquatic vegetation.

During the course of this study, it became apparent that we must also evaluate impacts to aquatic life other than vascular and non-vascular plants. The risk posed to aquatic invertebrates and fish in the non-target waterways must also be considered. Table 6 shows the freshwater aquatic life benchmarks established by the USEPA. The highest detections of fluridone, DCPA, 2,4-D and prometon do not appear to pose an acute risk to fish, invertebrates or plants in the downstream, non-target areas. There does appear to be a potential acute risk based on the highest detection of diquat. The detection of diquat (9.3 µg/l) is just below the acute toxicity level (9.4 µg/l) for nonvascular plants (Table 6). Nonvascular plants, such as green algae, are primary producers and play a significant role in the function of a healthy ecosystem. A lethal acute dose that migrates from a permitted aquatic treatment site into a non-target area can severely impair an aquatic ecosystem by negatively impacting the food web.

Citations

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