Pesticide Concentrations in Surface Waters of Mississippi Lakes and Reservoirs

Charles M. Cooper[1], Sammie Smith, Jr.[1] and Henry Folmar[2]
[1] United States Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS
[2] Mississippi Department of Environmental Quality, Office of Pollution Control, Biological Services Section, Pearl, MS

ABSTRACT

Surface water samples from lakes and reservoirs throughout Mississippi were collected and analyzed on a seasonal basis during 2002-2003 as part of a water quality survey. The purpose of the pesticide study was to produce a significant addition of baseline information to 1) ascertain current conditions and 2) provide concentrations of selected mainstream current-use and legacy pesticides for future comparisons. Over 100 sites were sampled during the year-long period, resulting in over 8000 individual analyses from 473 collections throughout the state. Temporal analysis reflected application timing, general runoff patterns and pesticide dissipation. Although the frequency of pesticide detection increased greatly from winter to spring (mean occurrence of analytes increased from 17% to 46%), concentrations above 0.1 µg/L were uncommon. Summer detections were also significantly fewer (20% mean occurrence) than spring for almost all compounds. Low concentrations (mean = 0.0474 µg/L) of ∑DDT were ubiquitous (95.8% occurrence). Detections of bifenthrin and λ-cyhalothrin, pyrethroid insecticides; methyl parathion, an organophosphate insecticide; atrazine, a triazine herbicide used primarily for corn; fipronil, a new residential, industrial and agricultural insecticide; and chlorfenapyr, a termiticide-insecticide, were widespread in the state, especially in spring samples. Overall, frequency of pesticide occurrence (97% of samples) was high, but concentrations were quite low (0.0301 µg/L). Of the pesticides that have United States Environmental Protection Agency (U.S. EPA) or state of Mississippi water quality criteria, only ten collections were excessive. Survey collections are not intended as substitutes for the robust sampling protocol needed for regulatory purposes, but they serve as an adequate screening tool for specific sites or pesticides. Understanding trends in pesticide presence could result in more effective methods to prevent environmental contamination.

INTRODUCTION

Use of pesticides plays a key role in preventing disease and producing food and fiber for our world, and is deemed a necessity in our modern culture. Pesticides are also used extensively in homes and businesses for pest control. Use of pesticides in agriculture has remained historically high for economic reasons. Consumer costs of agricultural commodities would double or triple without pesticide use (Caro, 1976). The combined domestic application of pesticide products in the United States totals about 2 billion lbs. of active ingredients annually (Lyon, 1996).

The first pesticides were actually metals such as arsenic and mercury, and crop dusting on cotton began in the Mississippi Delta in 1922. DDT was discovered in 1939, and, soon after, the organophosphate parathion was synthesized during World War II by German scientists experimenting with nerve gas. Early compounds were highly residual, and many of them are still measurable in one or more ecosystem components. Public awareness and concern over potential environmental hazards has risen greatly in recent decades. Residual organochlorines have been replaced with less persistent compounds, but some of these also find their way from their area of application into the environment. Federal and state activities associated with contaminant Total Maximum Daily Loads (TMDLs) created by the Clean Water Act have shown pesticide contamination to be a major factor in preventing attainment of functional ecosystems.

An opportunity to sample Mississippi's lakes was presented in 2002 when the Mississippi Department of Environmental Quality (MDEQ) began its lake and reservoir nutrient sampling program. USDA National Sedimentation Laboratory (NSL) personnel have conducted over 30 years of pesticide research and, thus, have acquired advanced analytical capacity as well as historical data at many aquatic sites in Mississippi. By combining efforts, the two agencies shared costs and acquired surface water pesticide concentrations that depict conditions in Mississippi lakes greater than 200 acres in size. The purpose of this pesticide study was to produce a significant addition of baseline information about large lakes of Mississippi to 1) describe current conditions of lake water pesticide presence and concentration and 2) provide measures of selected mainstream current-use and legacy pesticides for future comparisons.

Study Area

The state of Mississippi lies in temperate and subtropical zones of North America. The summer season has average temperatures in the low 80s (°F) with daytime highs commonly reach 90-100°F. Mild winters have mean temperatures that range from 40F in the north to 50F on the Gulf of Mexico coast. Annual rainfall averages about 50 inches in the northwest to 65 inches in the southeast. This climate of mild temperatures and a long growing season is conducive to both agriculture and forestry in the state.

Population centers include the Gulf coast, the capitol of Jackson and the northernmost region of the state that borders Memphis, Tennessee. The estimated year 2000 population of the state was 2,844,658 (US Census Bureau, 2002). State residents were housed in 1,161,953 housing units across the state. Census figures recorded a 10.5 percent population increase over 1990.

The 2002 Census of Agriculture (U.S. Department of Agriculture, 2002) showed there were 42,167 farms operating in Mississippi during 2002, virtually the same as 1997. Land in farms, at 11.1 million acres, was down 3 percent from 1997, and the average farm size, at 264 acres, was down 7 acres. Ninety-two percent of Mississippi agricultural operations are still run by individuals or families and most are still small farms. Seventy-four percent of operations had less than $10,000 in sales of agricultural products in 2002. Part-time farming continues to be a major part of Mississippi agriculture, as 29 percent of the principal farm operators worked 200 days or more off the farm, a 9 percent decline from 1997.

Global and National Pesticide Use

World pesticide usage amount exceeded 5.6 billion pounds in 1998 and 1999 (U.S.EPA 2001). Herbicides accounted for the largest proportion of total usage, followed by other pesticide usage, insecticide usage, and fungicide usage. Total world pesticide amount used was up slightly in 1999, due mainly to an increase in the use of non-conventional pesticides. Pesticide use in the United States in 1999 exceeded 2 billion pounds (Table 1) and accounted for more than 20% of total world pesticide use.

Table 1. Amount of U.S. pesticide usage. Estimates adapted from U.S. EPA, 2001.

Pesticide Group	Total (Mil lbs)	
Year	1998	1999
Conventional Pesticides	912	912
Other Pesticides	294	332
Specialty Biocides	309	343
Chlorine/Hypochlorites	2,532	2,609
Wood Preservatives	820	801
Total	4,867	4,997

Table 2 lists the most commonly used conventional pesticide active ingredients in the agricultural sector, home and garden market, and industry/commercial/government sector during 1999. 2,4-D was the most used active ingredient in non-agricultural markets, with between seven and nine million pounds used in the home and garden sector and between 17 and 20 million pounds used in the industry/commercial/government sector. Six of the top ten pesticides in the home and garden sector are herbicides and four are insecticides. Six of the top ten in the industry/commercial/government sector are herbicides, two are fungicides, and two are insecticides.

Residential Use

Household pesticide use is pervasive across North America. The U.S. Environmental Protection Agency (U.S. EPA, 2001) estimates that approximately 80 million pounds of pesticide active ingredients (9 percent of total conventional pesticide use in the United States) were used in homes and gardens in 1999. A 1992 survey conducted by the EPA found that 85 percent of households nationwide had at least one pesticide product stored in the home. The average number of pesticide products stored in homes is between three and four, and insecticides are the most common type of pesticide used in homes (U.S. EPA, 1997a). Many households still store banned, highly persistent and dangerous pesticides. An estimated one million households have products containing chlordane; 150,000 still have DDT; 70,000 have heptachlor, and approximately 85,000 still have Silvex® which contains dioxin (U.S. EPA, 1997b).

Most storage practices take few or no precautions to protect children from exposure. An estimated 47 percent of households with children under the age of five stored at least one pesticide within reach of small children (U.S. EPA, 1997c). Only 25 percent of all homes stored all pesticides securely (U.S. EPA, 1997d). A survey of pesticide use in 51 households in Sarasota County, Florida, found that the most common use of pesticides was direct application to carpets for control of fleas (Moses, 1995). This is particularly hazardous for children, who spend considerable time at ground level and can inhale pesticides in air and absorb pesticides from the carpet directly through their skin.

In an infamous case of misuse, state and federal officials evacuated 1,100 people from homes in Mississippi, Alabama, Louisiana, and Arkansas after residences and public facilities were treated with methyl parathion, a restricted use agricultural pesticide. In addition to homes, twelve businesses were closed, including eight daycare centers, a restaurant, and a hotel. Two unlicensed exterminators had sprayed the chemical in businesses and residences although it is only registered for agricultural use (U.S. EPA, 1996).

Even normal exposure to pesticides results in measurable concentrations in humans. In a National Institute of Environmental Health Sciences study quoted by Tvedten (2001), researchers reported that in a large random sample of the general population, DDT was found in 100% of the blood samples tested at an average level of 3.3 micrograms per liter (µg/L). Chlordane (a pesticide sprayed underneath homes for termite control and found to seep into the living airspace) was found in the blood of approximately 95% of the population. Other pesticides and chemicals found in over 90% of the population included dieldrin and lindane.

Table 2. National rank in prevalence of pesticides by weight of active ingredient applied during 1999 by type (H = herbicide, I = insecticide) and market (Agric. = agricultural, H&G = home and garden, I/C/G = industrial/commercial/government). Data were taken from public and proprietary U.S. EPA databases.

Active Ingredient	Type	Agric.	H&G	I/C/G
Atrazine	H	1		
Glyphosate	H	2	2	2
Acetochlor	H	4		
2,4-D	H	6	1	1
Malathion	I	7	9	9
Metolachlor	H	8		
Trifluralin	H	9		
Pendimethalin	H	10		4
Metolachlor-s	H	12		
Chlorpyrifos	I	16	6	5
MCPP	H		3	
Dicamba	H		4	
Diazinon	I		5	
Carbaryl	I		7	
Benefin	H		8	
DCPA	H		10	
MSMA	H			6
Diuron	H			8
Triclopyr	H			10

Note: Table 2 does not include the following fungicides and fumigants in the top 10 most common pesticides used in agricultural and industrial/commercial/government markets (and rank); Metam Sodium (agric. #3), Methyl Bromide (agric. #5), Copper Sulfate (I/C/G #3), and Chlorothalonil (I/C/G #7). No fungicides or fumigant information occurred for the home and garden market.

Pesticide residues in soft-drink samples were measured recently in India (CSE 2003). Lindane and chlorpyrifos were present in 100 percent of the samples analyzed. Lindane exceeded regulation limits in 33% of the samples, and chlorpyrifos exceeded the limit in 75% of the samples. DDT and its metabolites were present in 58% of soft-drink samples. Unknown compounds provide another challenge in the areas of both safety and contamination. Products may enter the U.S. from other countries with little or no labeling. EPA investigated an insecticide call "Miraculous Chinese Chalk" which was sold in stores featuring oriental products. No warning could be placed on the package because the maker changed active ingredient from batch to batch.

Table 3. Share of agricultural and non-agricultural market sector pounds of active ingredient during 1998 and 1999.

Year	U.S.	Agricultural Market		Non-agricultural Market	
	Mil lbs of a.i.	Mil lbs of a.i.	% of U.S.	Mil lbs of a.i.	% of U.S.
1998	912	724	79%	188	21%
1999	912	706	77%	206	23%

Agricultural Use

Agriculture accounted for 79% of the pesticides used in the U.S. during 1999 (Table 3). Since 1980, agricultural pesticide use has declined slightly from 1053 million pounds of active ingredient to 965 million pounds per year. In Mississippi in 2002, 1,410,000 acres planted in soybeans produced 1.37 million bushels while 1.87 million bales of cotton were harvested from 1.15 million acres. Rice (253,000 ac.), sorghum (83,000 ac.), and corn (53,000 ac.) were also major commodities. Catfish (23.9 million pounds) were sold from 390 operations (110,000 acres) in 2002. In livestock operations scattered across the state, Mississippi raised 63.88 million chickens in 2002. Two hundred and eighty-nine dairy farms produced milk. Red meat production was 25.2 million pounds in November alone. Fifteen hundred hog operations produced 0.46 percent of the nation's hogs. This diversity of crops in a warm, moist environment provides conditions for use of a suite of insecticides and herbicides.

METHODS

Study Sites and Field Methods

Sampling was conducted by three MDEQ teams, one team based at the Oxford office, one based at the Biloxi office, and one based at the central laboratory in Pearl, MS. Data collections began during November 2002 and continued through September 2003. Six total samples per site were anticipated, one each during the sampling visits in November 2002, and April, June, July, August and September 2003, but not all samples were analyzed from all sites due to factors precluding sample acquisition or loss of samples after collection. Sampling periods targeted the bulk of collections during peak agricultural activities. Samples were taken by boat as surface grabs into specially cleaned and solvent rinsed glass jars according to U.S. EPA recommendations and transported on ice to the NSL within 48 hours.

Table 4. Targeted pesticides and levels (ng/L) of detection (LOD) and quantitation limits (LOQ).

Pesticide	LOD	LOQ
Alachlor	0.5	5
Atrazine	1	10
Bifenthrin	0.1	1
Chlorfenapyr	0.5	5
Chlorpyrifos	0.1	1
Cyanazine	0.5	5
Dieldrin	0.1	1
Fipronil	0.1	1
Fipronil sulfone	0.1	1
l-Cyhalothrin	0.1	1
Methyl parathion	1	10
Metolachlor	1	10
Pendimethalin	0.5	5
Trifluralin	0.1	1
p,p'-DDD	0.1	10
p,p'-DDE	0.1	1
p,p'-DDT	1	10

Pesticide Analyses

The pesticides initially targeted for analysis, along with their levels of detection and quantitation, are shown in Table 4. Heptachlor, aldrin, endosulfan, dieldrin, endrin, methoxychlor and p,p'-DDT (metabolites p,p'-DDE and p,p'-DDD) are relatively persistent, chlorinated hydrocarbon insecticides with some history of past use throughout much of the Mississippi Delta. The other compounds are generally less persistent herbicides and insecticides that have been or are in current use. Analysis of water samples was similar to the method of Smith et al. (1994), with modifications by Bennett et al. (2000). Water samples were allowed to come to room temperature (about 25°C) and the volume measured and recorded. The entire sample was extracted by sonification (1 min/pulse mode/80% duty cycle) with 1g reagent-grade KCl and 100 mL pesticide-grade EtOAc, partitioning in a separatory funnel with the water phase discarded. The EtOAc phase was dried over anhydrous Na_2SO_4 and concentrated by rotary evaporation to near dryness. The extract was taken up in about 5mL pesticide-grade hexane, subjected to cleanup by silica gel column chromatography, and concentrated to 1mL for GC analysis. Mean extraction efficiencies, based on fortified samples, were >87% for all pesticides.

A multi-level calibration procedure was used with standards and samples injected in triplicate. Calibration curves were updated every tenth sample. Two Hewlett Packard model 6890™ gas chromatographs equipped with dual HP 7683 ALS autoinjectors, dual split-splitless inlets, dual capillary columns, a HP Kayak XA chemstation™, and a HP LaserJet 4000 printer™ were used to analyze water for pesticides. One HP 6890 was fitted with two HP µECDs and the other 6890 with one HP µECD, one HP nitrogen/phosphorus detector, and a HP 5973 mass selective detector (MSD).

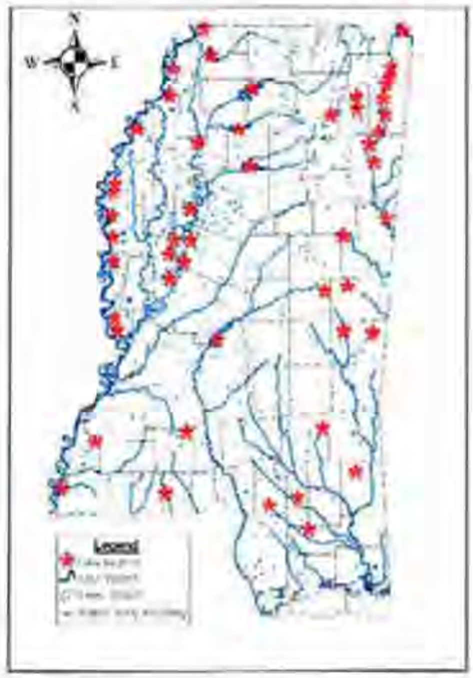
RESULTS AND DISCUSSION

Occurrence

Over 100 sites representing 50 Mississippi lakes and reservoirs (Fig. 1) yielded 473 collections and 8,041 individual analyses from samples obtained during November, 2002 and in April, June, July, August, and September, 2003. Pesticides were present in 96.62 % of the samples analyzed, but concentrations were generally quite low (mean=0.0301 µg/L). Of the 16 samplings that did not have any pesticide detections, 13 were in August, 2003, the period of least runoff. While both herbicides and insecticides were present in sub-µg/L concentrations during all sampling periods, highest mean concentrations were present for both pesticide groups in spring sampling (0.1101 µg/L for herbicides; 0.0188 µg/L for insecticides).

Mississippi does not have an uncommonly high rate of detection statewide. The National Water Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) found one or more pesticides in almost every stream sample collected across the United States. More than 95 percent of the samples collected from streams and almost 50 percent of samples collected from wells during that study contained at least one pesticide. Seventy-four of the 83 pesticide compounds analyzed in that study were detected at least once in streams or groundwater. Major rivers, as well as agricultural and urban streams, had relatively similar high frequencies of detection (Gilliom et al. 1999).

Figure 1. Locations of lake and reservoirs greater than 200 acres in size sampled for pesticide occurrence and concentration during 2002-2003.



As for occurrence of specific compounds in this study, low concentrations (mean = 0.0474 µg/L) of ∑DDT were present in almost all samples (95.8% occurrence). Use of DDT was banned in 1972; use actually peaked in 1968, but its application was so widespread from 1945 to 1972 that it is found in every watershed in the state of Mississippi. Cooper et al. (2002) observed that concentrations in lake water and sediment are gradually declining, but documented sources and sinks are common.

Bifenthrin, a pyrethroid insecticide, was found in 39.1 % of samples. Bifenthrin is sometimes applied to cotton and is labeled for use as an acaricide. It is, however, a common fire ant bait and home use insecticide.

Atrazine, a widely-used pre-emerge herbicide occurred in 37.8 % of the samples. Atrazine, a selective triazine herbicide, is the most commonly applied herbicide in the United States. It is used as a broadleaf and grass herbicide in both row-crop agriculture and silviculture and also as a non-selective herbicide on non-crop land. Between 74 and 80 million pounds were applied in the U.S. in 1999, nearly 90% of which was used on corn. It is also registered for lawn and turf use. It does not dissipate quickly and is the most common pesticide found in ground and surface water.

Chlorfenapyr was detected in 30.0 % of collections. It is a member of the chemical family "pyrroles" and was the first pyrrole submitted for U.S. registration. Chlorfenapyr has a unique mode of action. It is a pro-insecticide that is converted (or metabolized) to the active form by mixed function oxidases in the target pest. The active form acts on the mitochondria and uncouples oxidative phosphorylation which stops the production of ATP, the primary source of cellular energy. This action causes cell death, and ultimately, death of the target organism, the insect. However, the process interrupted is a process common to all living organisms, and so is of concern for non-target organisms. Chlorfenapyr, known in agriculture by its trade name Pirate®, was allowed a special use exemption in Mississippi in 1995-1999 for the treatment of beet armyworms and tobacco budworms in cotton. EPA cancelled requests from its manufacturer in 2000 because of evidence that showed detrimental effects on birds. Chlorfenapyr is currently registered and commonly used as a termiticide for residences and businesses and has been used on vegetables.

Lambda cyhalothrin (24.5 % occurrence) is a synthetic pyrethroid insecticide and acaricide registered to control a wide range of pests in a variety of applications. Controlled pests include aphids, Colorado beetles and butterfly larvae on cotton, cereals, hops, ornamentals, potatoes, vegetables or others (Kidd and James, 1991). It may also be used for structural pest management or in public health applications to control insects such as cockroaches, mosquitoes, ticks and flies which may act as disease vectors.

Methyl parathion, an orthophosphate and the most commonly used insecticide in cotton, was sixth in occurrence (21 %) across the state. It is restricted to agriculture only. An estimated 4.5 million pounds of methyl parathion are used annually in the U.S. Approximately 95 percent of this is used on cotton, soybeans, field corn, peaches, wheat, barley and rice.

Fipronil occurred in 20.5 % of the 473 samples. It is a member of the phenyl pyrazole class of pesticides, which are principally chemicals with a herbicidal effect. Fipronil, however, acts as an insecticide with contact and stomach action. Fipronil disrupts the insect's central nervous system by blocking the passage of chloride ions through the GABA receptor, an inhibitor of the central nervous system which causes hyper-excitation of contaminated insects' nerves and muscles. While many classes of insecticides affect the central nervous system, no other class has this specific effect. At this time, there is no known target resistance to fipronil. It is registered for insect control in corn, indoor pests and turf grass, and is gaining popularity for termite control (Termidor®). It is also the active ingredient in tick and flea collars (Frontline Plus®).

Occurrence and Land Use

To no one's surprise, U.S. Geological Survey (U.S.G.S.) analysis of patterns in pesticide use across the nation as part of the National Water Quality Assessment (NAWQA) program (Gilliom et al. 1999) revealed that concentrations of herbicides and insecticides in agricultural streams of the nation followed use patterns. Herbicide concentrations were greatest in central U.S. streams, where use is most extensive. Urban streams had the highest insecticide concentrations; 7 of 11 urban streams had total insecticide concentrations in the upper 25% of all streams sampled, although some agricultural streams in irrigated agricultural areas of the western United States also had high levels. Total pesticide concentrations in streams draining urban areas are generally lower than concentrations in agricultural areas, but seasonal pulses may last longer and the concentrations are more dominated by insecticides. Preliminary analysis of Mississippi data during this study indicated low predictability of contamination by land use.

Frequency of detection of pesticides increased predictably from winter to spring and then declined as vegetative ground cover increased and rainfall amount declined. Oddly, occurrence increased in September. Information on pesticide occurrences, concentrations of specific pesticides, farming practices and rainfall patterns in July, August, and September highlighted late August and September field conditions somewhat similar to conditions found in spring. Early spring generally produces minimum ground cover, maximum runoff, and both the greatest occurrence and highest concentrations of pesticides (Cooper 1990). In most agricultural areas, the highest concentrations of pesticides occur as seasonal pulses--usually during spring and summer--lasting from weeks to months during and following high-use periods.

Nationwide, a relatively small number of heavily used compounds accounted for most detections. The combined use of three most commonly applied herbicides, atrazine, metolachlor, and alachlor, in 1993 was 175-190 million pounds. This represented about 27% to 29% of all the herbicides used in the U.S. The combined use of the three most commonly used insecticides chlorpyrifos, diazinon, and malathion, in 1993, was approximately 23-33 million pounds or 9 to 13% of the total amount of insecticides used in the U.S. (Aspelin 1994).

In the U.S.G.S. NAWQA program the most frequently detected pesticide compounds in agricultural areas were the herbicides atrazine, metolachlor, cyanazine, and alachlor, ranked first, second, fourth, and fifth in national herbicide use for agriculture. The most heavily used herbicides also accounted for most of the detections in rivers and major aquifers and many of the detections in urban streams and shallow groundwater (Gilliom et al. 1999). In our Mississippi study, atrazine was the only herbicide found in more than 20 % of the collections. Several pesticides that are used extensively in agriculture were infrequently detected. These include the herbicides metolachlor, cyanazine, trifluralin, alachlor and the insecticide chlorpyrifos.

Concentrations – The Worst and the Best

Eighty-five percent of pesticide detections were <0.01µg/L. These low concentrations were similar for herbicides (89 %) and insecticides (82 %). Ninety-three percent of all detections were <0.05 µg/L. Only two percent of detections were ≥0.1 µg/L and less than 1.0 µg/L. Detections >1.0 µg/L comprised only 0.20 % (16 observations) of the 8,041 analyses. When pesticides with the highest concentrations were compared to occurrence, atrazine (mean = 0.1639 µg/L) replaced ∑DDT (mean = 0.0474 µg/L) as the compound with the highest detection reading. Of the currently used compounds examined, metolachlor, a grass and broadleaf herbicide was third, moving the pyrethroid bifenthrin to fourth. Fipronil sulfone, a degradation product of fipronil, replaced the parent compound. Lambda cyhalothrin remained in the top group in fifth and pendimethalin (Prowl®), an annual grass and broadleaf herbicide used in both agriculture and urban settings was sixth. Most pesticides had frequent occurrence but low concentrations. Mean values were elevated by a few high concentrations. Fipronil and fipronil sulfone were exceptions. In both agricultural and urban watersheds, a large proportion of observed concentrations of these two compounds were distributed medially, unlike patterns seen for other analytes.

Mean concentrations of each pesticide analyte were calculated separately for each lake. Lakes having the top 10 highest mean concentrations of each analyte were tabulated, and frequency of occurrence for each lake was calculated. Overall, two lakes had highest occurrence of high mean concentrations of pesticides; Aberdeen Lake and Horseshoe Lake. Aberdeen Lake data was in the highest 10 mean concentrations of each analyte for 12 of the 17 pesticides studied. Horseshoe Lake data was among the highest 10 concentrations of analytes for 10 pesticides. Other lakes with frequent occurrence of high concentrations of pesticides (frequency in parentheses) included Montgomery Pool of the Tennessee-Tombigbee (Tenn-Tom) Waterway (6 analytes), Turkey Fork Reservoir (6 analytes), Lake Bolivar (5 analytes), Tchula Lake (5 analytes), and Wasp Lake (5 analytes).

Aberdeen Lake has a very large watershed area of over 1.26 million acres that is predominantly in pasture (46%) and forest (37%), with smaller portions in agriculture (10%) and urban (1.5%) uses. The 1600 acre watershed of Horseshoe Lake is predominantly wetlands and water (77%), with an almost even mix of agriculture (13%) and pasture (10%) making up the remainder. Montgomery Pool of the Tenn-Tom Waterway includes nearly 40,000 acres of mostly forest (53%) and pasture (43%), with very small relative influences of agriculture (0.95%) and urban (0.12%) land uses. Turkey Fork Reservoir is very similar to Montgomery pool, with 56% of land use in forest and 42% in pasture. The 6,600 acre watershed has little or no agricultural and urban use. Agriculture is the predominant use in both Lake Bolivar (73% of 14,200 acres) and Wasp Lake (70% of 83,000 acres). Lake Bolivar has a small percent of land in pasture (6%) and the rest is either water or wetlands. No data were available for land use in Tchula Lake watershed.

Sources

~~Cooper~~(1990) found agricultural soils to be a continuing source of DDT in Mississippi. Coupe et al. (2000) studied pesticide occurrence in air and rain from an urban site and an agricultural site in Mississippi. Every sample collected from either site had detections of multiple pesticides although total concentration was five to 10 times higher at the agricultural site. Methyl parathion had the highest concentration in rain at both sites. It also had the highest concentration in air at the agricultural site. However, the urban site's highest concentration was from diazinon followed by chlorpyrifos. The DDT metabolite *p,p'*-DDE was present in all air samples collected from the agricultural site and in more than half on the air samples from the urban site.

There were six pesticides in current use that were found in more than 20 % of the samples taken. Of those six, all but one were insecticides. The herbicide was atrazine, the most-used herbicide in the United States. The University of California Berkeley (2002) provided quotes that expressed "there seems to be no atrazine-free environment." The European Union recently withdrew regulatory approval for atrazine due to groundwater contamination. Conversely, U.S. EPA re-approved the registration of atrazine in January, 2003.

Of the five most common insecticides, in order of occurrence, the pyrethroid bifenthrin is used in agriculture on cotton. It is one of the most common household insecticides and is a common turf, nursery, and fire ant insecticide. Chlorfenapyr is used in residential/industrial applications, especially as a household termiticide and insect pesticide (Raid Roach and Ant Killer®). It is not registered for row crop agriculture. Lambda-cyhalothrin, another pyrethroid, is a broadly used agricultural compound used to control a wide range of pest in a variety of applications. Methyl parathion is totally restricted to agriculture and is used on 63 percent of the cotton and 70 percent of the rice in Mississippi (Crop Life America, 2003). The last of the group, fipronil is the latest termiticide and fire ant bait to be marketed and is also gaining market share in agriculture. To summarize, only one of the top five insecticides is restricted to agriculture. One compound is gaining popularity in both agriculture and urban settings. Two insecticides have common residential/industrial applications, and one is almost entirely residential/industrial.

Environmental Significance

~~Pesticides are a concern fo~~r human health if they affect a drinking water source or occur where there is recreational use. They also are a potential concern for aquatic life in streams and lakes. Primary issues include toxicity, drinking water quality, and cancer or other illnesses. For protection of drinking water and aquatic life, water quality criteria have been established for some pesticides. Of the pesticides that have EPA or state of Mississippi water quality criteria, only ten collections from this study were excessive. Criteria only provide starting points for evaluating the potential effects of exposure, and most pesticides still do not have criteria.

Concerns over pesticide persistence and effects on wildlife are also environmental focal points. The story of DDT and its consequences when accumulated is still cause for concern. Chlorfenapyr was not registered but was cancelled for possible agricultural use in 2002 because of its detrimental effects on avian metabolism.

Misuse provides both regulatory and environmental challenges. The example of methyl parathion which has been used illegally in the Mississippi to rid homes and businesses of insect infestations highlights the need for greater awareness. In previous years, two similar events occurred. In 1994, homes and businesses were sprayed with methyl parathion in Lorain County, Ohio. EPA "decontaminated" 232 homes to "habitable conditions" at a cost of more than US$20 million. In April, 1995, another incident was discovered in Detroit, Michigan. Four residences, including a homeless mission, required "decontamination and restoration," costing approximately US$1 million. EPA staff compiled records of 22 accidental deaths since the mid-1960s caused by illegal home use of methyl parathion or ethyl parathion.

REFERENCES

Aspelin, A.L. 1994. Pesticide industry sales and usage: 1992 and 1993 market estimates. Biological and Economic Analysis Division, Office of Pesticide Programs, Office of Prevention, Pesticides, and Toxic Substances, U. S. Environmental Protection Agency. Washington, D.C.

Bennett, E.R., M.T. Moore, C.M. Cooper, and S. Smith, Jr. 2000. Method for the simultaneous extraction and analysis of two current-use pesticides, atrazine and λ-cyhalothrin, in sediment and aquatic plants. Bulletin of Environmental Contamination And Toxicology 64:825-833.

Caro, J.H. 1976. Pesticides in agricultural runoff. *In*: Steward, B. (Ed) Control of water pollution from cropland. An Overview. USDA Report No. ARS-H-5-2 2: 91-119.

Cooper, C.M. 1990. Persistent organochlorines and current use insecticide concentration in major watershed components of Moon Lake, Mississippi, USA. Archiv Für Hydrobiologie 121:103-113.

Cooper, C.M., S. Smith, Jr., S. Testa, III, J.C. Ritchie and T.D. Welch. 2002. A Mississippi USA flood control reservoir: Life Expectancy and Contamination. International Journal of Ecology and Environmental Science 28: 151-160.

Coupe, R.H., M.A. Manning, W.T. Foreman, D.A. Goolsby, and M.S. Majewski. 2000. Occurrence of pesticides in rain and air in urban and agricultural areas of the Mississippi, April – September, 1995. Science of the Total Environment 48: 227 - 240.

Crop Life America, 2003. Insecticide Use-Mississippi. (URL address: http://www.croplifeamerica.org/public/issues/fqpa/index.html).

CSE. 2003. Analysis of pesticide residues in soft drinks. Centre for Science and Environment, Pollution Monitoring Laboratory, New Delhi, India. (URL address: http://www.cseindia.org/html/cola-indepth/softdrinks_report.pdf)

Gilliom, R.J., J.E. Barbash, D.W. Kolpin, and S.J. Larson. 1999. Testing Water Quality for Pesticide Pollution. Environmental Science and Technology 33(7):164 A-169 A.

Kidd, H. and D.R. James, Eds. 1991. The Agrochemicals Handbook, Third Edition. Royal Society of Chemistry Information Services, Cambridge, UK, pp.2-13.

Lyon, L. 1996. Pesticide Impacts. Endangered species Bulletin 21(2): Organic Consumer Association. 2003. EU bands toxic atrazine herbicide still widely used in US corn belt. (URL address: http://www.organicconsumers.org/foodsafety/atrazine102703.cfm).

Moses, M. 1995. Home Pesticide Use and Storage in Sarasota County, Florida, Pesticide Education Center, November 24, 1995, p. 11.

University of California Berkeley. 2002. UC Berkeley Media Relations Press Release. 04 April 2002.

Smith, S., Jr., R.F. Cullum, and J.D. Schreiber. 1994. Pesticides in runoff and shallow groundwater from upland corn production in north Mississippi, USA. Second International Conf. on Groundwater Ecology. TSP94-1. Jack Stanford & Maurice Vallett (eds.). AWRA, Herdon, VA. Pp.247-258.

Tvedten, S. 2001. Pesticide Exposure During Pregnancy. Get Set Inc. 4pp. (URL address: www.getipm.com)

U.S. Census Bureau. 2002. Mississippi: 2000 summary population and housing characteristics. 2000 census of population and housing. PHC-1-26. United States Department of Commerce. 321 pp.

U.S. Department of Agriculture. 2002. Census of Agriculture. Preliminary Report AC-02-A-PR, pp. 73-75.

U.S. Environmental Protection Agency. 1996. "EPA Considers Suspending Pesticide Used in Illicit Spraying in South," Inside EPA, November 29, 1996.

U.S. Environmental Protection Agency. 1997a. National Home and Garden Pesticide Use Survey, March 1992, p. 6.

U.S. Environmental Protection Agency. 1997b. ibid, p. 16.

U.S. Environmental Protection Agency. 1997c. ibid, p. 9.

U.S. Environmental Protection Agency. 1997d. ibid, p. 12.

U.S. EPA. 2001. About pesticides. 1998-1999 pesticide market estimates: usage. Section: 3.1-3.10. URL address: http://www.epa.gov/oppbead1/pestsales/99pestsales/usage1999_4.html.

ACKNOWLEGEMENTS

Recognition is given to MDEQ staff who braved the elements to obtain these samples, including; Emily Cotton, Ann-Marie Denman, Barbara Viskup, D. Barnes, Al Gibson, Jenny Ulmer, Alice Dossett, Otis Clark, Charles Thompson, Will Green, Mike Beiser and Chip Bray. Alisa Liggins, Amanda White, Michelle Burns, (MDEQ), Charles Bryant, Terry Welch and Sam Testa (NSL) assisted with sample routing and delivery. Jennifer Swint meticulously handled sample extraction and cataloguing at the NSL. Sam Testa assisted with data analysis.