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THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

Fungicides inhibit feeding of Colorado potato beetles

By J. Daniel Hare

The Colorado potato beetle once was rare, native to northern Mexico and the American Southwest, and confined to feeding on an unimportant weed—the buffalo bur or *Solanum rostratum*. As pioneers moved west, however, they eventually brought the potato beetle a new, suitable, and valuable host plant, the cultivated potato. The beetle was first reported on potato in Kansas in 1861. From here, it leap-frogged north and east, from one potato field to the next, arriving in Connecticut in 1874. By 1876, it was firmly established throughout New England. Around World War I, the potato beetle was carried to Europe, where it continued its eastward migration. It was first reported in the Soviet Union in 1964 and is now making its way through southern Eurasia.

Potato growers have tried many techniques to limit the damage potato beetles inflict on potato fields. The first was to remove the insects by hand. Later, they were sprayed with some of the earliest insecticides, such as "Paris green." DDT was widely used with some success until beetles developed resistance to it. DDT was then replaced by more modern insecticides, including the synthetic pyrethroids. Unfortunately, the beetle has developed resistance to all but the newest of these materials, and, given sufficient time and exposure, there is no reason to doubt that the Colorado potato beetle will become resistant to these as well.

To provide growers an alternative to insecticidal control, I have conducted a series of ecological investigations on the relationship between the beetle and potato and its wild relative in Connecticut. One intriguing result of these investigations was that I found the size of the second generation of beetles was variable on the most common wild host, bittersweet, or *Solanum dulcamara* (Fig. 1).

Through a series of weekly experiments, I found that survival of larvae on bittersweet after the end of June was only one-third that on the same plants earlier in the spring. Furthermore, few summer-generation adults feeding on bittersweet reproduced; most burrowed into the soil without reproducing. By analyzing foliage of bittersweet, I determined that both the quantities of leaf protein and alkaloids, a group of chemical compounds that inhibit feeding by the potato beetle, changed during the season. "Summer" bittersweet leaves are both less nutritious because they have much less protein and less acceptable because they have more feeding deterrent than "spring" bittersweet leaves. These results suggest that if either the nutritional quality or the acceptability ("taste") of potato leaves could be reduced, the second generation of potato beetles may be reduced or even eliminated from potato, as it is from the wild host.

Many chemical compounds are known to inhibit feeding by the potato beetle when applied to potato leaves. Copper sulfate, for example, inhibits feeding at a concentration of 1.37×10^{-6} oz/sq. in. Salts of organo-tin compounds are even more effective. Curiously, these are also the active ingredients in some fungicides used for control of potato disease.

Potato is susceptible to the fungal diseases, early blight and late blight. Most fungicides do not "cure" these diseases, they merely protect the plants from initial infection. For optimal protection, potato plants should be sprayed frequently (every 7-10 days, depending on weather conditions), so that plant leaves have a sufficient quantity of fungicide on them to keep disease spores from germinating.

The need for frequent, regular fungicide applications,

Adults of the Colorado potato beetle overwinter in soil in and around potato fields. These adults, about ½ inch long with ten pairs of black and cream stripes along their wing covers (elytra), emerge from the soil about the middle of May and seek newly-sprouted potato plants. Adults feed for 5 to 10 days before females start reproducing. Orange or yellow oblong eggs are deposited in masses of about 20 to 60 on the lower surfaces of their host plants. All hatch simultaneously after about a week. Females may lay over 4,000 eggs during their lifetimes.

Newly-hatched larvae begin feeding on potato foliage immediately. They pass through four stages, known as instars, in from 9 to 17 days, depending on temperature. After the fourth-instar larva ceases feeding, it falls to the ground and burrows in, where it sheds its skin and enters a resting stage known as a pupa. After about 10 days, the pupa molts into an adult beetle, which emerges from the soil to complete the life cycle. The first or summer-generation adults, which emerge about the end of June, produce a second generation. The second generation adults emerge in late August, feed for a few days, then burrow back down into the soil to pass the winter.

coupled with the fact that the active ingredients of *some* fungicides inhibit potato beetle feeding, suggests that by carefully selecting their fungicides, growers may be able to simultaneously protect potato plants from disease and also reduce their susceptibility to the Colorado potato beetle.

I conducted several experiments to determine if currently-registered and available fungicides formulated from copper or organo-tin compounds inhibited potato beetle feeding when used at the recommended rates. In laboratory experiments, I dipped leaves in various fungicide solutions and then measured the area of leaf tissue consumed by adults in two weeks. Solutions of maneb, mancozeb, and chlorothalonil at their maximum concentrations used for potato disease control did not significantly reduce potato beetle feeding compared to leaves dipped in distilled water. A fungicide containing copper hydroxide, however, reduced feeding by 50% and 61% at concentrations equivalent to 1 and 2 pounds per 100 gallons per acre. These concentrations are low to moderate rates for potato disease control. A second fungicide formulated with the organo-tin salt, triphenyltin hydroxide (TPTH), reduced feeding by 95% at its minimum recommended rate of 5 ounces per 100 gallons per acre (Table 1).

Table 1. Foliage consumption and egg production of adult Colorado potato beetles fed potato leaves treated with various fungicides.

Treatment	Concentration (lb./100 gal.)	Consumption (cm^2)[1]	No. Eggs[2]
Distilled water		175 ± 10 a[3]	466 ± 50 a
Maneb	2.0	161 ± 14 a	385 ± 66 a
Chlorothalonil	2.0	161 ± 16 a	397 ± 57 a
Mancozeb	2.0	161 ± 12 a	403 ± 81 a
Copper hydroxide	1.0	87 ± 7 b	45 ± 19 b
	2.0	68 ± 10 b	4 ± 4 b
TPTH	0.3	9 ± 2 c	0 b

[1] Mean (± S.E.) consumption over 1st 14 days of adulthood for 10 pairs.
[2] Mean (± S.E.) egg production over 1st 28 days of adulthood for 20 pairs.
[3] Means followed by the same letter do not differ significantly at $p \leq .05$ by Duncan's multiple range test.

I monitored egg production for the first 28 days of adult life. The differences in egg production paralleled differences in feeding (Table 1). Neither maneb, mancozeb,

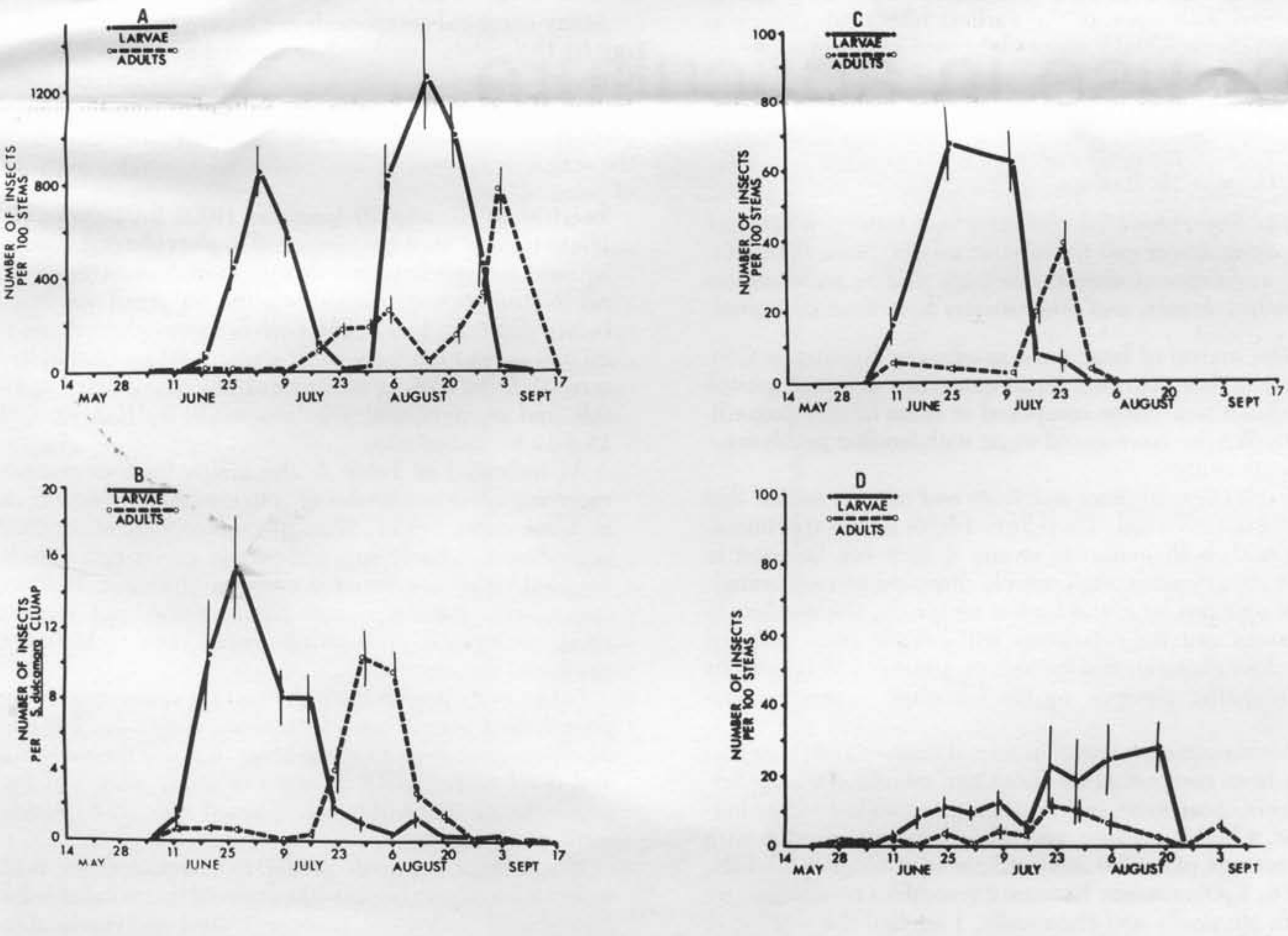

Figure 1. Seasonal abundance of Colorado potato beetle adults (dashed lines and open circles) and larvae (solid lines and circles) on potato in 1978 (Graph A), and on bittersweet in 1978-80 (Graphs B-D). Means and standard errors are plotted.

nor chlorothalonil affected egg production compared to distilled water, but fungicides containing copper hydroxide or TPTH reduced egg production up to 100%. No eggs were produced by adults fed leaves dipped in TPTH solutions because all insects starved before any eggs were produced. Therefore, even at the minimum rates recommended for potato disease control, fungicides formulated with either copper hydroxide or TPTH inhibited potato beetle feeding and egg production in the laboratory.

So far, I have only been able to perform a few small-scale field experiments, and they have been encouraging. Large-scale field tests using related compounds have been performed in Europe, and they show that when used in a regular treatment program, antifeedant fungicides often make it unnecessary to use insecticides to control potato beetle. I plan further field experiments to learn how Connecticut potato growers can incorporate antifeedant fungicides most effectively and economically into their potato pest control programs.

Historically, copper-based fungicides, such as Bordeaux mixture, were widely used, not only for potato disease control, but also for control of aphids, leafhoppers, and flea beetles. My results suggest that such fungicides also contributed to potato beetle control. We know that the potato beetle has been a Connecticut resident since 1874, however, it reached its current prime potato pest status only in the early 1960s. We know that many agricultural practices changed during the late 1940s and 1950s. Among them was the gradual replacement of copper-based fungicides with more effective maneb-type fungicides. We can only speculate as to how much changes in fungicide usage contributed to the current pest status of the Colorado potato beetle. Present results indicate, however, that fungicides that also inhibit potato beetle feeding and egg production may once again play an important role in the integrated management of potato insect pests and pathogens.

Reclaiming nutrients in wastes for use in agriculture

By Thomas M. Rathier

The Experiment Station has a long history of developing agricultural uses for organic wastes. Since the 1940s, the usefulness of manures, sewage sludge, fermentation residues, leaves, and other wastes have been evaluated.

The arrival of large-scale mushroom farming in Connecticut has provided large quantities of spent growth media, a new waste composed of some familiar ingredients. We also have an old waste with familiar problems—sewage sludge.

Each contains plant nutrients and organic matter that could improve soil. Therefore, I have been experimenting with both materials to see if they can be used in agriculture rather than merely disposed or incinerated.

If uses can be found for the materials, the mushroom growers and municipalities will benefit from reduced need for disposal, and farmers or growers will benefit by substituting cheaper wastes for more expensive materials.

Mushrooms are grown in animal manure and straw that has been composted for about two months. Organic fertilizers, peat moss and limestone are added. After harvest, a highly organic, partially-composted residue with an average pH of 7.0 and fertilizer equivalent of 1-1-1 (N, P_2O_5, K_2O) remains. Because it resembles animal manure both physically and chemically, I applied the residue to fields like manure, both in the winter and in the spring, just before planting. I used two rates: 10 tons/acre (500 lbs/1000 sq ft), and 20 tons/acre (1000 lbs/1000 sq ft). These treatments were compared to plots planted in similar field soil receiving no organic amendments (control). All treatments were turned into the soil about one week before planting. Just before each crop was planted, modest amounts of fertilizer were applied: 10-10-10, 700 lbs/acre (17.5 lbs/1000 sq ft) for tomatoes, cucumbers, spinach, and peppers, and 400 lbs/acre (10 lbs/1000 sq ft) of 15-8-12 for sweet corn.

As indicated in Table 1, the yields from most plots receiving spent mushroom growth media were as good, or in some cases better, than plots receiving no organic amendments. Early spinach, which grows fast, nearly doubled yields as compared to the control plot. Pickling cucumbers, tomatoes, and peppers also had greater yields in treated plots, while sweet corn yields were similar to the control.

Other experiments have shown that spent mushroom growth media can be used for growing shrubs and flowers. Addition of mushroom waste helps improve the moisture and nutrient retention qualities of sandy soils, can improve the drainage of poorly drained soils, and provide some plant nutrients.

If mushroom growth media is composted for 6-12 weeks it becomes a humus-like material that is suitable for mixing with garden soil, peat moss, sand, and vermiculite or perlite. In an experiment with containers outdoors, I found that rhododendrons flowered more profusely in

Table 1. Yields of vegetables grown in spent mushroom compost.

Soil treatment	Early spinach lb/A	Pickling cucumbers lb/A	Tomatoes lb/A	Peppers lb/A	Sweet corn doz. ears/A Early	Late
control	1170	39300	18750	5750	1925	1150
10 tons/A applied in winter	2080	73200	21750	6225	1825	1125
20 tons/A applied in winter	2485	55425	20400	6250	1950	1200
10 tons/A applied in spring	2480	52000	19625	6600	1950	1050
20 tons/A applied in spring	3380	39350	19525	5725	1950	1150

soils containing composted mushroom growth media than in soils containing conventional mixes. In greenhouse experiments, I found that chrysanthemums and bedding plants can be ready for market about a week sooner in potting soils containing mushroom compost.

Sewage sludge poses a difficult disposal problem for many municipalities. Ocean dumping, once widely used, is now restricted, leaving incineration, landfill dumping, and direct application to land. Incineration is expensive and landfills are beset with difficulties. Direct application to land is becoming more common, with due consideration for toxic metals that might enter the food chain. Application to non-food crops avoids concerns about heavy metals.

The heavy, wet, poorly draining sludge that is produced at most treatment plants is difficult to work with. This problem has been overcome by a method of forced-aeration composting known as the "Beltsville Pile," which is used in South Windsor. This technique composts raw sludge in about 28 days and is believed to destroy pathogens in the process. The finished compost has a humus-like texture and appearance, and has an average pH of 6.5-7.0 and a fertilizer analysis of 1-2.3-0.25.

I decided to explore ways to use composted sewage sludge in container nurseries, a steadily growing horticultural industry. Composted sludge mixes well with sand, peat moss, perlite or vermiculite, and like mushroom wastes, enhances water and nutrient retention as well as providing plant nutrients. I used two varieties of hardy, garden chrysanthemums, a fast growing one (Nor'easter) and a slower growing one (Minnautumn), in various combinations of sludge compost, peat moss, perlite, and sand. These were compared to plants growing in standard potting mixes composed of peat moss, perlite, garden soil, and sand (Table 2). All plants received a complete liquid fertilizer regularly. As each plant matured, I recorded the number of days it took to flower and its height.

Potting mixes containing sludge compost generally brought Nor'easter to flower sooner than the standard mixes, but had no effect on Minnautumn (Table 2). There were no significant trends in the heights of either variety. These results suggest that sludge compost can be used in container culture of hardy, garden chrysanthemums. In ongoing experiments, composted sludge also appears to be useful in establishing turf and conservation plantings.

Thus, both wastes can be used directly in the field where they improve the physical properties of the soil and provide valuable plant nutrients. When composted, these wastes are also useful in container culture. They can help bring some varieties to market quicker, enabling growers to cut expenses. Additional savings are possible by using the composted wastes as a suitable substitute for more expensive potting mixtures. Finally, the producers of the materials now have uses for wastes that are otherwise difficult to dispose.

Suggested Reading

Rathier, T.M. 1982. Use of spent mushroom growth media in the greenhouse. Conn. Greenhouse Newsletter, No. 109. February, 1982.

*Sawhney, B.L. and W.A. Norvell. 1980. Sewage sludge for plant growth: Benefits and potential hazards. Conn. Agr. Exp. Sta. Bull. 788. 22 p.

*Available free from Publications, The Connecticut Agricultural Experiment Station, P.O. Box 1106, New Haven, CT. 06504-1106.

Table 2. Growth of chrysanthemums in sewage sludge compost.

Potting Soil Mix Components—Total Volume					Growth data: Nor'easter		Minnautumn	
Sludge compost	Peat moss	Perlite	Sand	Field soil	Days to flower	Plant ht (cm)	Days to flower	Plant ht (cm)
1/3	1/3	1/3	—	—	73	48.6	90	31.5
1/3	1/3	—	1/3	—	75	50.2	88	31.1
1/4	1/4	1/4	1/4	—	76	52.5	87	30.6
1	—	—	—	—	72	49.2	88	30.9
—	1/3	1/3	—	1/3	79	51.7	90	30.0
—	1/3	1/3	1/3	—	76	46.3	94	23.2

Four registered pesticides effective against gypsy moth

By Robert E.B. Moore

Citizens of Connecticut have been battling the gypsy moth for more than 75 years. During this time a band of control techniques has come upon the scene and some have been touted as the cure-all, only to fall into disfavor as they were pitted against the persistent gypsy moth.

Currently there are five readily available registered insecticides for homeowners to use against this insect. With an array to choose from, however, homeowners wishing to control these caterpillars are often in a quandary as to which insecticide to use. I have tested all five pesticides to determine their efficacy.

The test was conducted in South Windsor in the spring of 1981. I selected a site that would more or less duplicate a typical yard. Each treatment was replicated three times. I selected 21 young red oak trees on open land. The trees, 10 to 20 feet in height, did not touch one another. There were no large trees overhanging the test trees, and there was little other vegetation that would allow caterpillars to develop and eventually migrate to the test trees.

I applied the insecticides on May 19, when the caterpillars were in their second growth stage and were too large to be blown about by the wind. Only small areas of the leaves had been consumed at the time I applied the treatments. No measurable rain fell during the 10 days following spraying.

The insecticides were applied with a 30-gallon, hydraulic Bean sprayer (equipment readily available to the homeowner) using 30 pounds of pressure. All trees were sprayed until insecticide began to run off the leaves. The trees were not drenched, but the foliage was thoroughly covered. Concentrations recommended on the labels were used.

I used two techniques to evaluate the effectiveness of the test insecticides. First, I recorded the number of larvae on four 30-cm branch tips at weekly intervals from the time of spraying until the larvae started to pupate. Then, I estimated the percentage of foliage that the gypsy moth caterpillars removed from each tree. The second evaluation is the bottom line for the homeowner or for anyone looking for a suitable insecticide for controlling the gypsy moth. The table lists each treatment and the percentage of defoliation that was experienced. Because each insecticide was applied to three trees, the percent reduction is an average.

Dipel is a formulation of the bacterum *Bacillus thuringiensis*, an insecticide used to control caterpillars on various food crops and ornamental plantings. Some choose to use this insecticide because it is specific for caterpillars and therefore has less impact on parasites and predators of the gypsy moth. The other insecticides tested are chemicals.

Table 1. Treatments and percent defoliation observed.

Insecticide	Concentration*	Percent defoliation
Check (water spray)		72
Imidan 50 WP	1¼ lb/100 gal water	43
Dipel 4L (8800 IUP/mg)	1½ pints/100 gal water	18
Orthene 75 WP	⅓ lb/100 gal water	13
Malathion/Methoxychlor	1½ pints/2½ lb/100 gal water	10
Methoxychlor 50 WP	2½ lb/100 gal water	5
Sevin 50 WP	1 lb/100 gal water	5

*The rate or concentration used was that recommended on the insecticide label. Where a range was given, e.g., 1–2 pounds insecticide per 100 gallons of water, the mid range used was 1½ pounds.

Caterpillars caused 72% defoliation on trees sprayed only with water. Defoliation was 5% on trees sprayed with Sevin and methoxychlor, 10% on trees treated with a combination of methoxychlor and malathion, 13% on trees sprayed with Orthene, 18% on trees sprayed with Dipel, and 43% on trees sprayed with Imidan. Since most homeowners would find 20% or less defoliation an acceptable level, four of the five insecticides tested and the one combination of insecticides provided that level of protection.

Dishwashing detergent sprays no solution to gypsy moth

During 1981, some people attempted to control the caterpillars with dishwashing detergent solutions. I tested one liquid (Palmolive) on caterpillars that were approximately half grown, using concentrations of from two tablespoons to two cups of detergent in one gallon of water. The sprays were applied with a 2-gallon hydraulic sprayer to 3 to 4-foot American chestnut sprouts that were heavily infested with caterpillars.

I found that two tablespoons in a gallon of water did not reduce caterpillar numbers. At higher concentrations, large numbers of caterpillars fell from the leaves, but were returning to feed within two hours of spraying. At the highest concentration, two cups of dishwashing detergent to one gallon of water, the numbers of caterpillars were reduced by 40 percent, but the leaves were burned.

Due to the potential damage to leaves and poor performance, it is clear that dishwashing liquid solutions are not effective substitutes for the five pesticides I tested.

R.E.B. Moore

Tests of groundwater determine organic pollutants

By Brij L. Sawhney and Richard K. Kozloski

Because of concern that toxic organic wastes disposed in landfills may be contaminating water under these sites, we collected and analyzed samples of groundwater from several landfills in Connecticut.

Most samples were obtained by Experiment Station staff from monitoring wells installed at the landfills by the Department of Environmental Protection. These wells are 2-inch diameter polyvinylchloride pipes inserted through the landfill soil into the groundwater. To sample groundwater, a 2-foot section of 1-inch metal tubing stoppered at the bottom is lowered into the well until it is below the groundwater. Filled with water, the tube is retrieved. The water in the tube is transferred to glass vials, which are filled to capacity to remove any air above the sample and prevent the loss of volatile organic compounds to the air. The vials are closed with a cap fitted with a teflon-faced silicone septum and refrigerated until the samples are analyzed. Where no monitoring wells were installed, samples were collected from the drainage water at the base of the landfill.

The water was analyzed for both volatile and non-volatile organic compounds, using gas chromatography. Since only two samples contained non-volatile organic compounds, and then only in traces, our discussion will concern the volatile organic pollutants that were found in all samples.

The nature and amount of the volatile organic compounds in the water samples were determined by the "purge and trap" procedure. Essentially, gas is bubbled through the water to purge the volatile organics into the gas stream, which then passes through a resin called Tenax where the organics are adsorbed or "trapped." The Tenax is then heated to remove the organics, which pass in a stream of gas to a chromatographic column. The material in the chromatographic column, a polyethylene glycol of large molecular size coated on specially treated carbon, adsorbs the compounds to be separated as they are released from the Tenax. The column is then slowly heated and the individual compounds are driven off the column one by one and are burned in an hydrogen flame. The ionization caused by burning the compounds causes an electrical current to flow between two high-voltage electrodes. This current is recorded as a peak on a moving chart. Thus, a record of peaks and retention times (RTs) of organic compounds, called a gas chromatogram, is obtained.

Retention times identify the organic compounds, and the heights of their peaks show abundance.

Because two compounds may have similar RTs, their peaks can overlap, causing incorrect identification. In such cases, confirmation is accomplished by using a second column containing a solvent in which solubilities of the two compounds differ.

Concentrations of organic compounds in water are obtained from comparisons of the peak heights with heights from standards.

To determine non-volatile organics, the water sample is extracted with hexane or petroleum ether, and after the extract is concentrated, it is directly injected into the gas chromatographic column.

We have tentatively identified several volatile organic pollutants and determined their concentrations. These concentrations are conservative estimates since some loss of volatiles is likely to occur during handling of samples.

The U.S. Environmental Protection Agency estimates that 60 million tons of hazardous wastes were discarded in 1980. These wastes, mostly organic, are produced during the manufacture of many products that we use daily, including plastics, medicines, paints, textiles, leather, pesticides, petroleum and coal products. Disposal of these wastes at improperly managed landfills and in lagoons and ponds has damaged our environment. In particular, the groundwater at several sites across the country has been found to be contaminated with toxic organic chemicals.

Groundwater contamination is serious because groundwater is a source of drinking water for half of the population of the United States and about one third of the population in Connecticut and also because decontamination of a polluted aquifer is not only prohibitively expensive but may require years to accomplish or be impossible. For these reasons, it is important, even urgent, that we learn which groundwater is contaminated, how organic pollutants move through soils to groundwater, and how to mitigate contamination.

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Table 1. Volatile organic pollutants in groundwater from landfills in Connecticut.

Organic Pollutant	Concentration, parts per billion				
	Cheshire	Norwich	Southington	Watertown	Danbury
Dichloromethane	12	110	—	10	15
Acetone	32	—	5,500	1,350	—
Isopropyl alcohol	—	—	2,800	—	—
Tetrahydrofuran	1,200	20	200	—	330
Chloroform	—	70	—	—	30
Methyl ethyl ketone	—	—	7,000	100	—
2-Butyl alcohol	—	—	700	—	—
Benzene	3	—	71	30	—
Methyl isobutyl ketone	—	—	245	30	—
1,2-Dichloroethane	22	—	—	—	—

Table 1 shows the concentrations of some organic compounds in ground water from the landfills. Most are common solvents used in industry.

Evaluating the significance of the concentrations of the organic chemicals found in these samples is difficult. In a few instances, EPA has tentatively established concentrations that are thought to cause no adverse response in drinking water. No concentration limits have been established for water used for other purposes. In our study, we found that the concentrations of methyl ethyl ketone and benzene in samples from the Southington site greatly exceed concentrations permitted in drinking water. However, their concentrations in any nearby water supply would be expected to be less, depending on the volume and direction of flow of the water beneath the landfill.

In addition to these chemicals, water samples from the Southington landfill contained several organic compounds present in gasoline. Amongst the gasoline constituents, however, there was an enrichment of the less volatile components. Apparently, a relatively greater loss of the more volatile components occurs as the organic compounds move through the soil to groundwater. This complicates determining the source of any particular contaminant.

Clearly, several organic pollutants can move through landfills into groundwater. We are now investigating how these chemicals are adsorbed by soils in the hope that we can prevent further contamination of our groundwater.

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