INSECTICIDES USED ON DAIRY CATTLE AND IN DAIRY BARS: TOXICITY TO MAN AND CATTLE, HAZARDS TO THE CONSUMER AND THE ENVIRONMENT

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ABSTRACT

Insecticides currently in use for pest control on dairy cattle offer little hazard of toxicity to the cow, dairyman, consumer, or the environment. Pesticides that cause significant residues in milk cannot be used on dairy cattle or in dairy barns. Since the cow rapidly excretes pesticides from her circulating blood into milk, it is evident that only pesticides that are metabolized rapidly, and are safe to mammals, may be used. This consideration rules out use of the persistent pesticides that are hazardous by magnification in the food chain. The insecticides we rely on, mainly rapidly degraded organophosphorus compounds, are discussed according to: method of use; toxicity to cattle, laboratory rats, birds, fish, wildlife; degradation time; tolerance in milk; and hazard to the consumer of dairy products. Only a small amount of these insecticides enters soil and water following proper use on dairy farms. Their persistence is short. Degradation products are explored, noting their very low hazard for toxic environmental contamination.

INTRODUCTION

I shall limit myself in this discussion to insecticides used on dairy cattle or in dairy barns. These are the pesticides of most concern to dairy sanitarians. It should be noted, however, that the hazard of pesticide residues in dairy products, and of environmental contamination, are more likely to result from pesticides used to protect growing crops of dairy cattle forages, grains, and pastures.

My discussion will be from the standpoint of the compounds used and the purpose of their use, mammalian toxicity considering both cow and man, and potential for environmental contamination. At the outset, let me say that insecticides currently in use for pest control on dairy cattle present little hazard of toxicity to the cattle, the dairyman, the consumer, or the environment. Pesticides that cause significant residues in milk cannot be used on dairy cattle or in dairy barns. Since the cow rapidly excretes pesticides from her circulating blood into milk, it is evident that only pesticides that are metabolized rapidly may be used. This consideration rules out use of the persistent pesticides that are hazardous by magnification in the food chain. Thus DDT and other persistent chlorinated hydrocarbons have not been used for dairy cattle pest control for many years. We rely mainly on rapidly metabolized or degraded organophosphorus compounds such as crotoxyphos (Ciodrin), dichlorvos (Vapona), naled (Dibrom), trichlorfon (Neguvon), or botanicals such as pyrethrins and their very low toxicity synergists, or repellents. Somewhat more stable organophosphorus compounds [e.g., dimethoate (Cygon), fenthion (Baytex), roten (Korlan)] are used for residual fly control by treating barn walls, ceilings, etc. but only when no cows are in the barn. Even these compounds are rapidly degraded in manure, soil, and water so that hazard to the environment is minor.

A WORD ABOUT DDT

Despite the fact that chlorinated hydrocarbon insecticides in general are no longer used on or near dairy cattle, a word about DDT residues is in order. You may ask why we have a tolerance for DDT in milk – 0.05 ppm DDT + DDD + DDE in milk and 1.25 ppm in manufactured dairy products – when practically all use of DDT has been banned? The reason is that enough DDT, DDD, and DDE remain in soil, water, and air so that milk, and other food products, cannot be produced without a small residue of DDT or its metabolites. The amount allowed in milk and other food products is innocuous. It is far below a toxicological maximum "no effect" level, and far below levels fed in total diet to man in long term experiments, or rats in total life span trials, with no discernible ill effects whatsoever (21). Also, I might add that there no longer is any purpose in using chlorinated hydrocarbons for house fly control in dairy barns, because our flies are highly resistant to these insecticides, and have been so for over 20 years.

The complexity of the environmental contamination problem is well illustrated by the PCB-DDT story. Research by gas chromatographic analysis for DDT delved into most conceivable environmental situations to study distribution and food chain effects. As a result, DDT was blamed for decreases in bird and fish populations, and shown to have circumworld distribution, even in antarctic penguins and arctic tundra. Some of the research was good,
but some employed poor analytical procedures that confused polychlorinated biphenyls (PCBs) with DDT and DDT degradation products (46). Then it was found that PCBs at very low levels had drastic effects on bird reproduction (41). Some, but not all, of the onus was thereby removed from DDT and correctly placed on PCBs.

But the story has not ended there. Very recently it has been shown by Moilanen and Crosby (33) that intense ultraviolet radiation, of the same wavelength as in sunlight, photoconverts DDT vapor through DDE into PCBs. Some of the unexplained disappearance of DDT degradation products from the world system might be explained in this manner, as might the odd worldwide distribution of PCBs coincident with DDT and degradation products. The main point for us is that the onus for deleterious effects of DDT on wildlife cannot be shifted entirely to the PCBs that we have used, because the PCBs in the environment may have originated partially from DDT pesticide application. And, when we largely absorb residues and metabolites of organophosphorus compounds of deleterious environmental effects, because they are not persistent, we may be oversimplifying.

**Organophosphorus Compounds and Cholinesterase**

All of the organophosphorus insecticides now in use poison insects or mammals by inhibiting the enzyme cholinesterase. This enzyme is vital to continued successful transmission of nerve impulses. So long as the insecticide, or those products of it which can inhibit cholinesterase, are present at the site of action, poisoning occurs. Cholinesterase is regenerated by the body, so that after the insecticide or its cholinesterase inhibiting metabolites are removed, return to normalcy can occur. Organophosphorus insecticides are not stored in the body for long periods as are chlorinated hydrocarbons. They are not cumulative poisons and are not passed on any distance through the food chain. Thus their action is short-lived so that they are not persistent environmental contaminants.

One hazard most important to pesticide applicators is related to rate of regeneration of cholinesterase. If a sprayman is exposed to a large but sublethal single dose of one of the more toxic organophosphorus compounds, he may have great depression of cholinesterase without experiencing very serious illness. In this condition, a second exposure to a similar dose could be fatal. In other words, although the insecticide is not cumulative, its effect over a period of several days may be. This effect has no bearing on low-level residues in food, which cause no cholinesterase depression.

**Toxicity and Tolerance Table**

Table 1 presents the various types of insect control used on dairy farms, the insecticides involved, their toxicities to laboratory rats and to cattle, rate of degradation, and tolerance in milk. These control methods plus precautions in using the pesticides and their tolerances are presented in detail by Matthysse (31). In New York State, of all the insecticides used on or around cattle, only dichlorvos, fenthion and famphur in highly concentrated solutions are considered toxic enough to require a state permit to purchase them.

**Fly Control by Residual Deposits**

(Table 1, Section 1)

A mainstay of fly control on dairy farms has been residual deposits of insecticides on walls, ceilings, posts, partitions, etc. Flies walk on treated surfaces and pick up a lethal dose. For such a treatment to be practical, the insecticide must be stable and of low volatility so that a single application will continue to kill flies for several weeks. The amounts used are relatively large, commonly 1% insecticide in a spray applied at 1 gal to 300 to 1000 ft² of surface. Thus the barns for a 100 cow herd might have 50 gal of spray applied, containing 4 lb. actual insecticide. The several sprays for fly control through the fly season could result in as much as 8 to 20 lb. insecticide applied in 1 year. Fly resistance to these insecticides increases over a period of years, resulting in more frequent application. There is a severe practical limit, however, Eventually fly resistance increases until the insecticide no longer provides control, as happened with chlorinated hydrocarbons and diazinon, malathion, and others.

For an understanding of possible hazard to the environment, we must put these amounts of insecticide in perspective. Suppose 20 lb. of insecticide was applied in a barn in 1 year on a medium-sized dairy farm, say 100 cows. If it all washed down into the manure, this could result in a maximum of about 0.2 lb. insecticide per acre on soil of some fields of the farm. My reasoning assumes that most of the insecticide left the barn via the manure, and that manure from 1 cow was spread on about 1 acre of farm land. This contrasts strongly with intensive pesticide use such as orchards where as much as 50 lb. of pesticide may be applied per acre annually. Actually only a fraction of this 0.2 lb. per acre on a dairy farm would reach soil or water as the insecticides now in use are rapidly degraded in manure, soil, or animals. To date, there is no evidence of significant accumulation of these insecticides in the...
TABLE 1. INSECTICIDES COMMONLY USED ON DAIRY CATTLE OR IN DAIRY BARNs

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>LD₅₀ oral mg/kg</th>
<th>Older cattle</th>
<th>Young calves</th>
<th>Kind of compound</th>
<th>Degradation time</th>
<th>Ppm tolerance in milk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Used for spraying barns (residual fly control)</strong>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimethoate (Cygon)</td>
<td>215</td>
<td>1% spray not toxic; 15 mg/kg toxic</td>
<td>1% spray not toxic; 50 mg/kg toxic</td>
<td>Organophosphorus</td>
<td>Moderate</td>
<td>0.002</td>
</tr>
<tr>
<td>Fenthion (Baytex)</td>
<td>215-245</td>
<td>25 mg/kg toxic</td>
<td>0.2% spray not lethal but cholinesterase reduced</td>
<td>Organophosphorus</td>
<td>Moderate</td>
<td>0.01</td>
</tr>
<tr>
<td>Ronnel (Korlan)</td>
<td>1250-2690</td>
<td>100 mg/kg toxic</td>
<td>100 mg/kg toxic</td>
<td>Organophosphorus</td>
<td>Moderate</td>
<td>1.25 (fat)</td>
</tr>
<tr>
<td>Rabon</td>
<td>4000-5000</td>
<td>100 mg/kg toxic; 0.5% spray not toxic</td>
<td>100 mg/kg toxic; 2% spray toxic</td>
<td>Vinyl organophosphorus</td>
<td>Rapid</td>
<td>0.5 (fat)</td>
</tr>
</tbody>
</table>

| **II. Used for spraying lactating cattle or into air in occupied barns (flies or lice and chorioptic mange mites)**. |                |              |              |                  |                  |                     |
| Pyrethrins (Pyrethrum) | 820-1870       | Safe because low dose used | Safe because low dose used | Botanical | Rapid          | 0.5 (fat)           |
| Dichlorvos (Vapona)  | 56-80           | 25 mg/kg toxic | 10 mg/kg toxic | Vinyl organophosphorus | Rapid          | 0.02                |
| Crotoxyphos (Ciodrin) | 125            | >2% spray toxic | <2% spray toxic | Vinyl organophosphorus | Rapid          | 0.02                |
| Naled (Dibrom)      | 250             | ?             | 1% spray toxic | Vinyl organophosphorus (yields vinyl) | Rapid          | 0.05 (int.)         |
| Synergists and repellents (piperonyl butoxide, MGK 264, MGK 326) | 2800-7500       | Relatively safe | Relatively safe | Various | Rapid          | piperyl butox 0.25 (fat) |
|                    |                 |              |              |                  |                  | MGK 264 0.01 (int.) |
|                    |                 |              |              |                  |                  | MGK 326 0.004      |

| **III. Used in milk rooms (fly control)**. |                |              |              |                  |                  |                     |
| Pyrethrins plus synergists and dichlorvos No-Pest Strips. See II. |                |              |              |                  |                  |                     |

| **IV. Used in dust bags or backrubbers outside the milking barn, for lactating dairy cattle (flies and lice)**. |                |              |              |                  |                  |                     |
| Ronnel, Rabon, dichlorvos, crotoxyphos. See I, II. |                |              |              |                  |                  |                     |
| Coumaphos (Co-Ral) | 13-230⁹         | 25-50 mg/kg toxic; 0.25% spray not toxic; 150 mg/kg pour-on toxic | 0.25% spray toxic | Organophosphorus | Moderate          | 0.05 (fat)          |
I. Toxicity Classes (based on rat oral LC50 are: 1. Highly toxic 1-50, 2. Moderately toxic 50-500, 3. Slightly toxic 500-5000, 4. Relatively non-toxic over 5000. Dermal toxicity 4 times higher in each class. Toxicity in Classes 3 and 4 are considered low hazard, acceptable for home owner use with no protective equipment).

1. Highly Toxic 1-50 mg/kg:
   - Malathion 1000-1875 mg/kg toxic; 2% spray not toxic
   - Crufomate (Ruelene) 460-635 mg/kg toxic; 2% spray not toxic
   - Trichlorfon (Neuvon) 560-630 mg/kg toxic; 2% spray not toxic
   - Famphur (Warbex, Famix) 35-62 mg/kg toxic; 50 mg/kg max. safe

2. Moderately Toxic 50-500 mg/kg:
   - Methoxychlor 5000 Spray not toxic
   - Malathion 220-350 mg/kg toxic; 2% spray max. safe
   - Crufomate (Ruelene) 460-635 mg/kg toxic; 2% spray not toxic
   - Trichlorfon (Neuvon) 560-630 mg/kg toxic; 75 mg/kg toxic; 2% spray not toxic

3. Slightly Toxic 500-5000 mg/kg:
   - Diazinon 76-108 mg/kg toxic; 0.25% spray not toxic

4. Relatively Non-toxic over 5000 mg/kg:
   - DDT 113-118 mg/kg min. toxic dose; 22g/steer
   - Lindane 89-91
   - Parathion 4-18 mg/kg weekly lethal; 0.3% spray lethal; 50 mg/kg not toxic; 1% spray toxic; 50 mg/kg max. safe; 2.5 mg/kg toxic; 0.1% spray toxic
   - Malathion 250 mg/kg min. toxic dose, 8% spray not toxic
   - Diazinon 0.05 (fat) 0.3% spray toxic

Note: Toxicity in Classes 3 and 4 are considered low hazard, acceptable for home owner use with no protective equipment.

2. "Toxic" indicates symptoms of poisoning produced, but not necessarily death. "Lethal" means that the dose in question will cause death of some treated cattle.

3. Coumaphos—Sex difference in toxicity to rats; male LC50 56-230 mg/kg, female 13-80 mg/kg.

Toxicity to cattle derived from Radeleff (44), from unpublished data of J. S. Palmer of the U.S. Department of Agriculture at Kerrville, Texas, and from manufacturers' reports. The rat toxicity is from a compilation by J. E. Dewey, Pesticiue Coordinator, Entomology Department, Cornell University, Ithaca, N.Y.
**Insecticides Used On Dairy Cattle**

Environment, in the food chain, or in agricultural produce. And their degradation products are of a very low order of toxicity, and short-lived in the environment.

The mammalian toxicities of insecticides used for residual fly control fall into two groups. Dimethoate and fenthion are moderately toxic, requiring greater caution in use than rommel or Rabon which are only slightly toxic.

As to contamination of dairy products — all insecticides that have been approved by the federal Office of Pesticide Programs, Registration Division, Environmental Protection Agency for residual fly control have been thoroughly tested for residues in milk and found to produce either no residues, or negligible residues of no toxicological significance and well below tolerances in dairy products. Poulsen (43) states that use of organophosphorus insecticides in barns does not, as a rule, cause residues in tissues and milk of animals, provided the feeding and watering troughs and the feed and water are not contaminated with the insecticide and the insecticide is not applied to the animals. He states that cows should be removed from buildings and the milk processing rooms should not be sprayed. All precautions should be taken to prevent direct contamination of milk and utensils.

**Spraying Dairy Cows or Misting in the Barn**

*(Table 1, Section II)*

Insecticides used for direct spraying of dairy cows, or misting into the air of occupied barns, are all rapidly degradable compounds that offer no significant hazard of environmental contamination or toxic residues in dairy products. Pyrethrum, synergists (compounds that increase the effectiveness of pyrethrum) and repellents are of a very low order of mammalian toxicity. Metcalf (34) notes that pyrethrins are generally regarded as among the safest of insecticides and that this safety is partly due to an inherent lack of toxicity and partly due to the instability of the compounds in light and air so that toxic residues quickly disappear. Pyrethrins were fed to rats for 2 years at 1000 ppm without causing any tissue damage. Also, the low concentration and small volume (1 to 2 fl oz per cow maximum) used in spraying dairy cows insure against hazard of toxicity or significant contamination. Pyrethrum was the insecticide of choice for oil-base fly sprays because its rapid knock-down of flies quickly cleared barns of these pests. In the past 10 years, pyrethrum has been partially replaced by vinyl or vinyl-producing organophosphorus insecticides. Dichlorvos (Vapona), naled (Dibrom), and crotoxyphos (Ciodrin) give quick kill of flies, and undergo very rapid degradation to innocuous products. These compounds are in the moderately toxic class, warranting greater caution in their use.

The quantity of these spray ingredients used on dairy farms is small. For example, 1% crotoxyphos spray is commonly used at 1 to 2 fl oz per cow. About 0.1 lb. crotoxyphos would be used for one spraying of a 100-cow dairy herd. Even with daily use during a 5-month fly season (far more than dairy farmers use in practice), the total poundage used (15 lb.) is approximately the same as calculated previously for residual fly control. And these spray ingredients are of less contamination significance than the insecticides used for residual fly control.

A slight shadow on safety of synergists has been cast by Falk and Kotin (8) who noted their possible general action in blocking or delaying the metabolic degradation of hormones, pharmaceutical agents, and toxicants including carcinogens. However, at rates used on cattle, residues of synergists in milk and dairy products are either non-existent or so low as to preclude probability of such side effects.

The vinyl organophosphorus compounds dichlorvos and crotoxyphos, and naled which is activated to dichlorvos, produce no detectable residues in milk when used properly. Dichlorvos is not stored in the body nor excreted in the milk to any appreciable extent even when administered in doses that produce severe poisoning (10). Cows fed diets containing up to 2000 ppm dichlorvos for 8 days did not excrete dichlorvos or toxic metabolites in the milk (Shell Development Co., unpublished report).

**Insecticides in the Milk Room**

*(Table 1, Section III)*

Insecticide use in milk rooms has been severely restricted, to prevent all possibility of direct milk contamination. The relatively safe natural botanical, pyrethrum, is used along with synergists. Recently, dichlorvos Pest-Strips (20% dichlorvos in a polymer) have been approved for residual fumigation. It is conceivable that milk could absorb dichlorvos from air containing dichlorvos in vapor phase. However, no significant residues result in milk because of rapid hydrolysis. Gillett et al. (16, 17) conclude “experiments to date and a critical review of literature and information available on dichlorvos resin strips do not reveal any substantial hazardous effect on human beings.”

**Fly Baits** *(Table 1, Section VI)*

A number of the insecticides previously discussed are also used in sugar-base fly baits, commonly call-
ed “scatter-baits”. Fly baits are more universally used by dairymen than any other fly control device. The organophosphorus insecticides used in baits are all rapidly degradable vinyl or vinyl producing compounds, or have very low mammalian toxicity. An exception may be diazinon. In general, baits are eventually swept into manure where degradation of these compounds is rapid. We think that baits should not be used in the milk room where direct contamination of milk is always a possibility. A saucer of bait and a cat on top of a bulk tank is simply an inexcusable practice.

**Dust Bags and Backrubbers (Table 1, Section IV)**

A slightly more expanded list of organophosphorus insecticides is accepted for use in dust bags and backrubbers as self-treatment devices for milking cows. Absorption through the skin from these low insecticide concentration dusts, and from oil solutions used in very small volumes, is rather limited. Residue studies have proven either no excretion into milk, or residues well below tolerance. Hazard to the environment is most unlikely because of the small amount of low-toxicity degradable insecticide used in these devices.

**Insecticides for Use Only on Non-lactating Cattle (Table 1, Section V)**

Despite the rapid mammalian metabolism of organophosphorus compounds, many of them will cause residues, albeit extremely small, in milk subsequent to dermal or oral application to lactating dairy cows. Compounds which should be used only on non-lactating dairy cattle (calves, heifers, dry cows, bulls) and beef cattle for control of flies, lice, and cattle grubs include famphur (Warbex, Famix), trichlorfon (Neguvon), crufomate (Ruelene), malathion, fenthion (Tiguvon, Baytex), and certain formulations of coumaphos (Co-Ral) and ronnel (Korlan). The unusually rapidly metabolized chlorinated hydrocarbon methoxychlor is also used in this manner against lice and flies. These insecticides are “slightly toxic” or “moderately toxic” except for famphur and coumaphos which border on the highly toxic category. These insecticides do accumulate for a short time in the tissues of cattle, and are excreted into milk. To prevent milk contamination, they must not be used close to freshening. This period varies from 3 days for crufomate (Ruelene) to 28 days for fenthion (Tiguvon).

MacDougall (30) reviewed milk residue data for various applications of coumaphos, fenthion, ronnel, trichlorfon, crufomate, and famphur. Of the 11 treatments considered, 3 gave residues of < .01 ppm in milk immediately after treatment, and 2 more were < .01 ppm 1 day after treatment. By 3 days, 7 of 11 treatments gave residues of < .01 ppm, and by 7 days only 1 treatment gave a residue > .01 ppm. Note that these were strong concentration treatments (.25% to 12.5% insecticide in sprays, pour-ons, and backrubbers), mainly of the type used against cattle grubs and not recommended for use on lactating dairy cows. Recommended treatment for lactating dairy cows produce negligible or extremely low residues of no toxicological importance.

Of course, all insecticides accepted for use on lactating cows may also be used on non-lactating cattle, with no period required between treatment and freshening. However, none of the insecticide concentrations allowed on lactating cows are effective against cattle grubs. Rotenone, a rapidly degraded botanical insecticide of low mammalian toxicity, was used for many years on milking cattle for grub control. Recently, all livestock uses of rotenone were cancelled because of inadequate data on metabolism, and lack of residue tolerances. We have no accepted insecticide for use against cattle grubs on lactating dairy cattle.

**Treating Manure to Kill Fly Maggots**

Dimethoate (Cygon), Rabon, and ronnel (Korlan) are labelled for application to manure to kill fly maggots. We do not recommend such larvicide treatment as a general practice because it is a most efficient way to produce insecticide resistance in house flies, and because of destruction of parasites and predators of house fly eggs and larvae. Larviciding requires a large amount of insecticide applied frequently, whenever fresh manure is added to a pile, or pack builds up under penned cattle. A common dose is 1 lb. actual insecticide per 1250 ft.³ of manure surface. Weekly applications during a 4-month fly season requires 17 lb. of actual insecticide on one 25 by 50 ft. pen of cattle. Even though environmental contamination is greater than any of the previously discussed uses, it is still unlikely because of rapid degradation of these organophosphorus compounds. However, killing arthropod fauna of manure spread on fields or in patties on pasture might delay return of the nutrients to the soil and decrease pasture and crop productivity. For the same reason, use of insecticides as feed additives for fecal fly control may be a poor practice.

**Insecticides That Should Never Be Used on the Dairy Farm (Table 1, Section VII)**

DDT and lindane are two chlorinated hydrocarbons that should never be used on cattle because of...
illegal residues resulting in milk and meat. Note that DDT is not very toxic to cattle and that lindane is much more toxic. Parathion is also presented for comparison in this table. Its extreme toxicity to rats and calves is evident, but it appears from these data to be relatively safe on cows. Do not be mislead. As a spray it is highly toxic. Because of breakdown in the rumen by microorganisms, it is not so extremely dangerous by oral dose to cattle.

ENVIRONMENTAL CONTAMINATION HAZARD BY INSECTICIDES AND THEIR METABOLITES

Insecticides applied in or around dairy barns may be toxic hazards to man or the environment by departing the site in milk or meat, in manure and thereby the soil, in effluent water, or in air. Metabolites and degradation products must be included in evaluating this hazard.

The organophosphorus compounds in general are converted rapidly to water soluble ionizable compounds that are not cholinesterase inhibitors and are relatively non-toxic. Hydrolysis of the phosphor ester bonds is usual, producing methyl or ethyl mono- or di-phosphates or thiophosphates from the phosphorus containing moiety of the parent compound (9-12, 14, 15, 22, 30, 36-38). Oxidative metabolism also occurs with these compounds (6, 29), finally producing water soluble metabolites of little toxicological significance. Further degradation produces phosphoric acid with much of the phosphorus entering, indistinguishably, the phosphorus pool of the body or of the environment. None of these degradation products offer significant toxicity hazard.

The remainder of the organophosphorus insecticide molecule varies greatly. Nevertheless, in general, water soluble, ionizable, relatively innocuous degradation compounds are produced. Most rapid degradation occurs with the vinyl compound dichlorvos, and with trichlorfon and naled which rearrange to dichlorvos, with loss of HCl and HBr, respectively. The non-phosphorus moiety degrades through dichloroacetaldehyde, dichloroacetic acid, and dichloroethanol. Glyoxal is also produced by further reaction. As with phosphorus, much of the carbon ends up as normal body components of intermediary metabolism (Shell Development Co. unpublished report). Toxicity of the dichloro metabolites is low. Dichloroacetaldehyde and dichlorobromoacetaldehyde given orally to rats at 200 and 120 mg/kg/day respectively, showed no evidence of toxicity (Chevron Chemical Co. unpublished reports).

The vinyl phosphates Rabon and crotoxyphos are somewhat more stable, but degradation in animals and in the environment is adequately rapid. Crotoxyphos is very rapidly absorbed and excreted by animals (44). Maximum blood concentration of crotoxyphos in sheep occurred 6 h post oral dosing, and declined to 1/10 the concentration at 48 h. Almost 80% of the dose was eliminated as urinary metabolites within 48 h. Dimethyl phosphoric acid comprised 90% of the detectable phosphorus excretion. Rabon fed to rats at 125 ppm or less daily for 2 years caused no adverse effect (Shell Chemical Co., unpublished report). Benyon and Wright (4) determined degradation products of Rabon in soil and concluded that "the breakdown products are of low toxicity to rats and apart from the α isomer, none...inhibits cholinesterase."

The following are examples of degradations of the non-phosphorus moieties of several of the more complex organophosphorus compounds. The carboxethoxy moieties of malathion hydrolyze to mono- and di-carboxylic acids (37). The N-methyl-carbamoyl methyl moiety of dimethoate is metabolized to the carboxyl derivative (14, 37). These are water soluble, rapidly excreted, ionizable compounds that are not cholinesterase inhibitors and are relatively innocuous. With coumaphos, the chloromethyl coumarin radical is metabolized to chlorferron, which is of a low order of toxicity (12). The trichlorophenyl radical of ronnel is metabolized and excreted as trichlorphenol (12). Trichlorphenol fed to rats at 1000 ppm or less daily for 98 days caused no adverse effects. Ronnel itself fed to rats at 15 mg/kg or less per day for up to 2 years caused no adverse effects. The hydrolytic metabolite of the 4-tert-buty-2-chloro-phenyl radical of crufomate, the corresponding phenol, fed to rats at 1000 ppm or less daily for 2 years caused no adverse effects (12).

PERSISTENCE IN SOIL

The organophosphorus insecticides used in or around dairy barns may enter soil through the spreading of manure. They are classed as nonpersistent in the U.S. Department of Health, Education and Welfare Secretary's Commission Report (2). Half lives in soil for several pertinent pesticides are: malathion—8 days; dimethoate—2½ to 4 days; diazinon—17 to 18 days; Rabon—5 to 11 days (4); crotoxyphos—1 h to 3 days; (5, 27, Shell Development Co. unpublished report). However, soil type markedly affects persistence of insecticides.

Harris (19) divided insecticides into 3 groups according to persistence in soil, as assessed by biological activity. Group 1, chlorinated hydrocarbons such as DDT, persisted more than 48 weeks without significant decrease in activity. Compounds in Group
2 are not pertinent to this discussion. Group 3 which included diazinon, disappeared within 2 to 4 weeks. This research was done in the laboratory. Harris and Hitchon (20) confirmed < 4 weeks persistence for diazinon in the laboratory and added a persistence period of slightly over 24 weeks for dimethoate. Read (45) however, working in the field, found rapid loss of diazinon during the first month, but persistence at low levels for up to 3 months. Kearney et al. (25), in their review of persistence of residues in soil, concluded that phosphate insecticides are short-lived in soil. They state that diazinon is the most persistent, remaining for only 3 months, and show malathion as persistent for < 1 week. In contrast, some chlorinated hydrocarbon insecticides persist for many years in soil. Accumulation of organophosphorus compounds in soil to a significant degree for toxic pollution is most unlikely. The degradation products, as noted previously, do not present a significant hazard. Duff and Menzer (7), concerning dimethoate degradation products in soil, stated: "This material does not contain neutral phosphorus esters, and it is, therefore probably non-toxic."

Contamination of Water

Insecticides in general are unlikely to contaminate ground water because they bind tightly to soil particles. Lichtenstein et al. (28) analyzed percolation and found little or no pesticide, but noted that runoff transport of soil particles will carry pesticides into streams. Again, most dairy insecticides break down rapidly in water, for example the half life of dichlorvos in water is 8 h and dibrom is destructively hydrolyzed in about 2 days (35). Trichlorfon half life for conversion to dichlorvos is 6 h. in water (15). However, we must guard against direct contamination of watery effluent from barns. Insecticides used for residual treatments for fly control are longer-lived in water. Nevertheless, the degradation products likely to be spread on soil and washed into streams are not considered hazardous to fish or wildlife.

Hazard to Fish and Wildlife

Considering hazard of toxic effects on fish and wildlife, this does not always parallel the toxicity to rats or cows that I have stated previously. Fenthion is one of the more toxic compounds to birds. Heath et al. (23) give LC₅₀'s for fenthion to 4 bird species (2-3 weeks old) as 20-231 ppm in feed, fed 5 days. The following are approximate average dose ratios compared to fenthion for LC₅₀'s to several wild bird species (the higher the figure the less toxic the insecticide): diazinon 1.3, parathion 1.6, coumaphos 2.5, dimethoate 4, DDT 6, trichlorfon 10, naled 16, malathion 27 or more, and methoxychlor and dichlorvos over 36 (23). It should be noted that susceptibility differs among bird species. Regardless, trichlorfon, naled, methoxychlor, dichlorvos, and malathion are relatively safe in food of birds but care should be exercised against exposure of poultry or wild birds to fenthion, diazinon, coumaphos, or dimethoate. Care should also be exercised with crustaceans and shellfish. Also relatively safe are Rabon, crotoxyphos, rotenone, pyrethrins, synergists, and repellents. Rabon up to 800 ppm in the diet of quail for two weeks caused no observable toxicity. Acute oral LD₅₀ of crotoxyphos to mallard ducks is 790 mg/kg (Shell Development Co. unpublished report).

The order of decreasing dermal toxicity to chickens (by dipping the birds completely) according to Foulk and Matthysse (13) is: diazinon (lethal at < 0.035%), fenthion, dichlorvos, naled, coumaphos, dimethoate, crotoxyphos, malathion, rotenone (lethal at 5% or more). Nevertheless, coumaphos is labelled for direct use on chickens at proper dosages.

I have shown previously that but a small amount of insecticide, much < 1 lb. per acre, is likely to be put on land by manure from barns in which pesticide is applied. Anon (1) states that 1 lb. of diazinon per acre is not hazardous to pheasants—and diazinon is one of our most toxic insecticides to birds.

Fish are very susceptible to most of the insecticides we are discussing. Willford (48), using six species of fish, found 24-h LC₅₀ (ppm in water) that averaged: rotenone 1.2, coumaphos 3.7, fenthion 7.4, cru­mfoate 35.1, trichlorfon 53.3. Naled is toxic to fish, crustaceans, and shellfish; LC₅₀ values vary from 0.8 ppm to 4 ppm (Chevron Chemical Co. unpublished report). LC₅₀ for dichlorvos is < 10 ppm. It is evident that careless use of rotenone, coumaphos, naled, or fenthion, resulting in direct contamination of water with spray or immediate barn effluent, could be dangerous to fish. Trichlorfon and crufomate are less hazardous. Hair and Howell (18) found no deleterious effects by Rabon on fish from direct application of 1 lb. per acre.

Pimentel (42) reviewed toxicities to fish showing considerable variation among species and from the data by Willford (48). We must add the following to the list of insecticides that are very hazardous to fish: pyrethrins and pyrethroids, rotenone, diazinon, malathion, methoxychlor, naled, and dichlorvos. Dimethoate is less toxic to fish but by degree only. None of these insecticides must be allowed to contaminate streams, ponds, or lakes.

Contamination of waters would also be detrimental to arthropod stream fauna that is vital as food for fish. Pimentel's (42) review showed that all the
pesticides we use in and around dairies are very toxic to these beneficial insects and crustaceans. It is obvious that there is need for caution against direct contamination of streams and effluent water by barn spray run-off, spray or dust drift during outdoor treatment of cattle, or contamination from draining or cleaning sprayers. The toxicity of pesticides to non-target species has been summarized by Pimentel (42).

CONCLUSION

In conclusion, insecticides currently in use for pest control on the dairy farm will not produce hazardous or illegal residues in milk or manufactured dairy products, when used as directed. The trend is towards pesticides of low toxicity to man and animals, and those which undergo rapid metabolism or degradation to products offering no hazard to man or to the environment. However, these conditions are true only if the farmer or commercial pesticide applicator adheres strictly to the label directions and cautions. Overdose, wrongly timed application, or violation of cautions can produce excessive residues or even hazard to the cattle or the applicator. The new Federal Environmental Pesticide Control Act, now in force, makes it illegal to apply pesticides other than as directed on the label.

REFERENCES


32. Matthysee, J. C., and D. Lisk 1968. Residues of diazinon, coumaphos, Ciodrin, methoxychlor and rotenone in cow's milk from treatments similar to those used for ectoparasite and fly control on dairy cattle, with notes on safety of diazinon and Ciodrin to calves. J. Econ. Entomol. 61:1394-1398.