

## A TLC screening program for 170 commonly used pesticides using the corrected $R_f$ value ( $R_f^c$ value)

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**Summary.** This article reports TLC data (corrected  $R_f$  values;  $R_f^c$  values) of 170 commonly used pesticides which are regularly encountered in toxicological analysis. Silica gel was used as the stationary phase and three binary systems were chosen as solvents.

**Key words:** Pesticides – TLC data, corrected  $R_f$  values –  $R_f^c$  values, pesticides

**Zusammenfassung.** Es werden DC-Daten (korrigierte  $R_f$ -Werte;  $R_f^c$ -Werte) für 170 gebräuchliche Pestizide mitgeteilt, die häufig im Rahmen toxikologischer Analysen anfallen. Als stationäre Phase wurde Silicagel gewählt; als Fließmittel dienen drei binäre Systeme.

**Schlüsselwörter:** Pestizide – DC-Daten, korrigierter  $R_f$ -Wert –  $R_f^c$ -Werte, Pestizide

### Introduction

Simple, but reliable screening methods for the recognition of a special compound or class of substance are becoming more and more important because of the continuously increasing number of toxicologically relevant chemicals (e.g., drugs, pesticides, herbicides, bactericides, household products, cosmetics, and doping agents); the need for forensic- and clinical toxicological analyses is growing. Therefore, it is one of the major tasks of the Senate Commission for Clinical-Toxicological Analysis of the Deutsche Forschungsgemeinschaft (DFG)<sup>1</sup> to collect, evaluate and develop screening and detection methods for substances frequently encountered in cases of

human intoxication. Also, one of the primary aims of the Committee for Systematic Toxicological Analysis (STA) of the International Association of Forensic Toxicologists (TIAFT)<sup>2</sup> is to compile current reliable data to facilitate the detection of drugs, poisons, and other toxicologically and forensically relevant substances, particularly those that fall into the category of “generally unknown.” This category is regarded as one of the most difficult analytical challenges.

In the early 1980s, the STA Committee and the DFG Senate Commission for Clinical-Toxicological Analysis began a cooperative venture, which resulted in several startling publications dealing with screening strategies and exhaustive compilations of reliable and comparable chromatographic data [7–9].

This article reports TLC data (corrected  $R_f$  values, i.e.  $R_f^c$  values) of 170 commonly used pesticides, that are regularly encountered in toxicological analysis. These data were collected as a contribution to the current investigations of the organizations mentioned above, especially the different task groups of the Senate Commission for Clinical-Toxicological Analysis of the DFG.

### Materials and methods

**Materials.** Of the 170 pesticides tested 152 were purchased from Dr. Siegmund Ehrenstorfer (Augsburg, FRG). The other compounds come from the reference collection of the Institut für Rechtsmedizin, Giessen. The TLC plates (Silicagel 60 F<sub>254</sub>) and all chemicals (p.a.) were purchased from Merck (Darmstadt, FRG).

**Methods.** *Thin-layer chromatography – the concept of the corrected  $R_f$  value ( $R_f^c$  value).* The reproducibility of the  $hR_f$  value is governed by many factors (e.g., activity of the adsorbent, state of saturation of the development tank, running distance, amount of drug applied to the chromatogram, geometry of the chamber, tempera-

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ture, etc.). With the aim of eliminating some of these parameters, Galanos and Kapoulas [10] and de Zeeuw et al. [14] recommended a multiple correction graph (linear interpolation), which can be carried out graphically or by calculation using the following equation [9]:

$$R_f^c(p) = \frac{\Delta^c}{\Delta} [R_f(p) - R_f(t_n)] + R_f^c(t_n)$$

wherein

$$\Delta^c = R_f^c(t_{n+1}) - R_f^c(t_n)$$

$$\Delta = R_f(t_{n+1}) - R_f(t_n)$$

$R_f^c(p)$ : corrected  $R_f$  value of the unknown substance  $p$

$R_f(p)$ : measured  $R_f$  value of the unknown substance  $p$

$R_f^c(t_n)$ : corrected  $R_f$  value of the reference substance nearest to  $p$  (lower value, possible starting point = 0)

$R_f^c(t_{n+1})$ : corrected  $R_f$  value of the other reference substance nearest to  $p$  (higher value, possible solvent front = 100)

Note:  $R_f^c(t)$  values are taken from tables (see Table 1, last column)

$R_f(t_n)$  and  $R_f(t_{n+1})$ : measured  $R_f$  values of the reference substances  $t_n$  and  $t_{n+1}$ , respectively.

$\Delta^c$ : Difference of the corrected  $R_f$  values of the reference substances, which are situated nearest to the  $R_f$  value of the unknown compound  $p$  (taken from tables; see Table 1, last column).

$$\Delta^c = R_f^c(t_{n+1}) - R_f^c(t_n)$$

$\Delta$ : Difference of the measured  $R_f$  values of the reference substances, which are situated nearest to the  $R_f$  values of the unknown compound  $p$

$$\Delta = R_f(t_{n+1}) - R_f(t_n).$$

The components of this equation are schematically depicted in Fig. 1. For additional details see [13]. The 10 running systems of report VII of the DFG Commission for Clinical-Toxicological Analysis [9] were mainly developed for the optimal separation of commonly used drugs and metabolites. At the start of these investigations it was soon obvious that special running systems had been chosen for efficient screening of pesticides as the  $R_f^c$  values of many important pesticides were near the solvent front. On the basis of some former publications [1] and our own investigations, the running systems and reference substances shown in Table 1 were selected.

The eluent composition is given in vol:vol ratios, and saturated systems were used. The solutions of the four reference compounds were used at a concentration of approximately 2 mg/ml for each substance.

The distance from origin to solvent front was 10 cm, and the ascending development method was applied. Note that horizontal

development can result in completely different  $R_f^c$  values than are obtained with the vertical development mode [11].

Most of the substances were detected by UV visualization at 254 nm using silica gel plates with  $F_{254}$  indicator. Special detection methods based on spraying and scanning will be reported in a forthcoming publication. The influence of different parameters, such as prechromatographic treatment of the TLC plate, different temperatures during development, salts and fat in biological extracts and the effect of multiple use of the solvents were investigated by Bogusz et al. [2–5] and Borchert et al. [6]. Bogusz et al. [2–5] found that co-extracted materials generally decrease  $R_f$  values and increase the standard deviation, resulting in larger error windows. Nevertheless, the concept of the corrected  $R_f$  value ( $R_f^c$  value) has proven its enormous pragmatic usefulness.

The  $hR_f^c$  values listed in the tables are mean values of at least five determinations obtained by different investigators and under the influence of various atmospheric conditions.

## Results and discussion

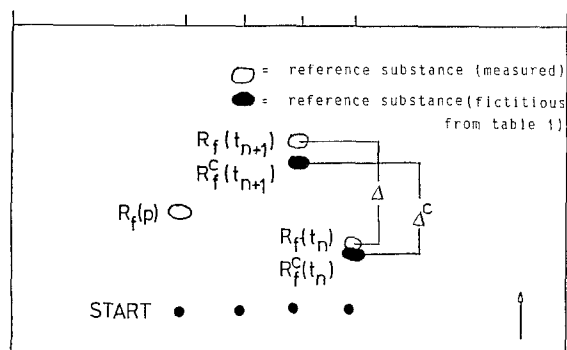
The  $hR_f^c$  values of 170 commonly used pesticides are listed in Tables 1–3 below. The classification is that based on the system of Klimmer [12].

**Table 1.** Three standardized systems for pesticide TLC screening

| Running system                                             | Adsorbent | Reference compound | $hR_f^c$ |
|------------------------------------------------------------|-----------|--------------------|----------|
| Solvent 1 (S1):<br><i>n</i> -Hexane/acetone<br>80:20 (v/v) | Silica    | Quintozene         | 84       |
|                                                            |           | Pirimiphos-methyl  | 49       |
|                                                            |           | Parathion-methyl   | 30       |
|                                                            |           | Triazophos         | 21       |
| Solvent 2 (S2):<br>Toluene/acetone<br>95:5 (v/v)           | Silica    | Parathion-ethyl    | 85       |
|                                                            |           | Methidathion       | 56       |
|                                                            |           | Azinphos-methyl    | 42       |
|                                                            |           | Carbofuran         | 20       |
| Solvent 3 (S3):<br>Chloroform/acetone<br>50:50 (v/v)       | Silica    | Methabenzthiazuron | 85       |
|                                                            |           | PCP                | 60       |
|                                                            |           | Ioxynil            | 39       |
|                                                            |           | Nicotine           | 11       |

**Table 2.**  $hR_f^c$  Values of different classes of pesticides

|                                    | S1<br>$hR_f^c$ | S2<br>$hR_f^c$ | S3<br>$hR_f^c$ |
|------------------------------------|----------------|----------------|----------------|
| <i>Organophosphate derivatives</i> |                |                |                |
| Acephate                           | 0              | 0              | 42             |
| Azinphos-ethyl                     | 24             | 48             | 100            |
| Azinphos-methyl <sup>a</sup>       | 20             | 42             | 94             |
| Bromophos-ethyl                    | 69             | 93             | 95             |
| Bromophos-methyl                   | 58             | 92             | 99             |
| Chlorfenvinphos <sup>b</sup>       | 23             | 22             | 99             |
| Chlorfenvinphos <sup>b</sup>       | 28             | 28             | 99             |
| Chlormephos                        | 64             | 91             | 99             |
| Chlorpyrifos-ethyl                 | 64             | 95             | 97             |
| Chlorpyrifos-methyl                | 56             | 89             | 98             |



**Fig. 1.** Calculation of the  $R_f^c$  value from measured TLC data (○). The black spots (●) except for the starting points, indicate fictitious values that must be taken from tables (see Table 1, last column)

Table 2. Continued

|                                | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|--------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Chlorthion                     | 31                                 | 71                                 | 97                                 |
| Chlorthiophos                  | 55                                 | 91                                 | 97                                 |
| Coumaphos                      | 27                                 | 61                                 | 96                                 |
| Demeton <sup>b</sup>           | 17                                 | 17                                 | 93                                 |
| Demeton <sup>b</sup>           | 83                                 | 81                                 | 96                                 |
| Demeton-S-methyl               | 18                                 | 13                                 | 91                                 |
| Demeton-S-methylsulphone       | 1                                  | 3                                  | 70                                 |
| Diazinon                       | 47                                 | 50                                 | 96                                 |
| Dichlorvos                     | 20                                 | 20                                 | 90                                 |
| Dimethoate                     | 4                                  | 4                                  | 72                                 |
| Disulfoton                     | 58                                 | 89                                 | 96                                 |
| Ethoprophos                    | 33                                 | 28                                 | 96                                 |
| Etrimfos <sup>b</sup>          | 3                                  | 0                                  | 52                                 |
| Etrimfos <sup>b</sup>          | 52                                 | 67                                 | 97                                 |
| Fenitrothion                   | 32                                 | 76                                 | 95                                 |
| Fenthion                       | 41                                 | 81                                 | 96                                 |
| Fonofos                        | 59                                 | 89                                 | 97                                 |
| Heptenophos                    | 20                                 | 18                                 | 92                                 |
| Isofenphos                     | 41                                 | 67                                 | 99                                 |
| Malathion                      | 31                                 | 53                                 | 96                                 |
| Methamidophos                  | 1                                  | 0                                  | 37                                 |
| Methidathion <sup>a</sup>      | 29                                 | 56                                 | 95                                 |
| Mevinphos <sup>b</sup>         | 10                                 | 7                                  | 99                                 |
| Mevinphos <sup>b</sup>         | 15                                 | 13                                 | 99                                 |
| Monocrotophos <sup>b</sup>     | 1                                  | 1                                  | 12                                 |
| Monocrotophos <sup>b</sup>     | 1                                  | 1                                  | 47                                 |
| Omethoate                      | 0                                  | 0                                  | 39                                 |
| Oxydemeton-methyl              | 18                                 | 0                                  | 26                                 |
| Parathion-ethyl <sup>a</sup>   | 41                                 | 85                                 | 96                                 |
| Parathion-methyl <sup>a</sup>  | 30                                 | 73                                 | 100                                |
| Phosalone                      | 31                                 | 67                                 | 97                                 |
| Phosphamidon                   | 7                                  | 2                                  | 79                                 |
| Phoxim                         | 42                                 | 86                                 | 97                                 |
| Pirimiphos-methyl <sup>a</sup> | 49                                 | 75                                 | 100                                |
| Pyrazophos                     | 32                                 | 47                                 | 96                                 |
| Sulfotepp                      | 50                                 | 84                                 | 96                                 |
| Temephos                       | 23                                 | 75                                 | 98                                 |
| Terbufos                       | 63                                 | 90                                 | 99                                 |
| Tetrachlorvinphos              | 25                                 | 29                                 | 97                                 |
| Tolclofos-methyl               | 52                                 | 89                                 | 99                                 |
| Triazophos <sup>a</sup>        | 21                                 | 38                                 | 94                                 |
| Trichlorfon                    | 4                                  | 2                                  | 62                                 |
| <i>Phenylurea derivatives</i>  |                                    |                                    |                                    |
| Benzthiazuron                  | 8                                  | 3                                  | 65                                 |
| Buturon                        | 20                                 | 29                                 | 93                                 |
| Chlorbromuron                  | 22                                 | 30                                 | 92                                 |
| Chloroxuron                    | 10                                 | 7                                  | 88                                 |
| Chlortoluron                   | 15                                 | 9                                  | 87                                 |
| Cycluron                       | 13                                 | 5                                  | 79                                 |
| Difenoxuron                    | 8                                  | 5                                  | 83                                 |
| Diiflubenzuron                 | 18                                 | 24                                 | 93                                 |
| Diuron                         | 15                                 | 10                                 | 87                                 |
| Fenuron                        | 11                                 | 7                                  | 81                                 |

Table 2. Continued

|                                             | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|---------------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Fluometuron                                 | 16                                 | 9                                  | 87                                 |
| Linuron                                     | 22                                 | 31                                 | 93                                 |
| Methabenzthiazuron <sup>a</sup>             | 18                                 | 22                                 | 85                                 |
| Metobromuron                                | 23                                 | 31                                 | 92                                 |
| Metoxuron                                   | 7                                  | 4                                  | 83                                 |
| Monolinuron                                 | 23                                 | 30                                 | 94                                 |
| Monuron                                     | 13                                 | 7                                  | 83                                 |
| Neburon                                     | 26                                 | 24                                 | 95                                 |
| Thiazafluron                                | 10                                 | 4                                  | 80                                 |
| <i>Carbamate derivatives</i>                |                                    |                                    |                                    |
| Butocarboxim                                | 15                                 | 11                                 | 90                                 |
| Butocarboxim-sulfoxide                      | 0                                  | 13                                 | 24                                 |
| Butoxycarboxim                              | 3                                  | 2                                  | 63                                 |
| Carbaryl                                    | 18                                 | 25                                 | 92                                 |
| Carbofuran <sup>a</sup>                     | 17                                 | 20                                 | 92                                 |
| Carbosulfan                                 | 49                                 | 66                                 | 97                                 |
| Ethiofencarb                                | 21                                 | 25                                 | 94                                 |
| Formetante <sup>b</sup>                     | 1                                  | 1                                  | 19                                 |
| Formetante <sup>b</sup>                     | 1                                  | 1                                  | 73                                 |
| Methomyl                                    | 6                                  | 6                                  | 83                                 |
| Phenmedipham                                | 11                                 | 17                                 | 93                                 |
| Pirimicarb                                  | 26                                 | 17                                 | 92                                 |
| Propham                                     | 39                                 | 57                                 | 94                                 |
| Propoxur                                    | 20                                 | 21                                 | 92                                 |
| Thiofanox                                   | 20                                 | 17                                 | 94                                 |
| Thiram                                      | 19                                 | 51                                 | 94                                 |
| Triallate                                   | 82                                 | 90                                 | 97                                 |
| <i>Triazine derivatives</i>                 |                                    |                                    |                                    |
| Ametryn                                     | 26                                 | 23                                 | 92                                 |
| Aziprotryne                                 | 42                                 | 50                                 | 96                                 |
| Cyanazine                                   | 16                                 | 12                                 | 90                                 |
| Desmetryn                                   | 21                                 | 16                                 | 88                                 |
| Dipropetryn                                 | 35                                 | 35                                 | 95                                 |
| Hexazinone                                  | 4                                  | 2                                  | 77                                 |
| Isomethiozine                               | 50                                 | 55                                 | 96                                 |
| Metamitron                                  | 5                                  | 4                                  | 67                                 |
| Methoprotryn                                | 19                                 | 11                                 | 88                                 |
| Prometryn                                   | 32                                 | 31                                 | 94                                 |
| Simazine                                    | 22                                 | 18                                 | 88                                 |
| Terbutylazine                               | 32                                 | 27                                 | 94                                 |
| Terbutryn                                   | 32                                 | 32                                 | 95                                 |
| Trietazine                                  | 43                                 | 42                                 | 95                                 |
| <i>Halogenated carbohydrate derivatives</i> |                                    |                                    |                                    |
| Aldrin                                      | 89                                 | 98                                 | 99                                 |
| DDT                                         | 76                                 | 98                                 | 99                                 |
| Dicofol                                     | 43                                 | 80                                 | 97                                 |
| Diieldrin                                   | 65                                 | 87                                 | 99                                 |
| Endosulfan <sup>b</sup>                     | 40                                 | 77                                 | 98                                 |
| Endosulfan <sup>b</sup>                     | 77                                 | 95                                 | 98                                 |
| Endrin                                      | 71                                 | 90                                 | 99                                 |
| Heptachlor                                  | 84                                 | 97                                 | 99                                 |

**Table 2.** Continued

|                                          | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|------------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Lindane                                  | 51                                 | 92                                 | 98                                 |
| Methoxychlor                             | 43                                 | 84                                 | 96                                 |
| Quintozene <sup>a</sup>                  | 84                                 | 95                                 | 95                                 |
| <i>Phenoxy-carbonic acid derivatives</i> |                                    |                                    |                                    |
| Clpyralid                                | 0                                  | 0                                  | 0                                  |
| 2,4-D                                    | 0                                  | 2                                  | 7                                  |
| Dichlorprop                              | 3                                  | 2                                  | 9                                  |
| Fenoprop                                 | 1                                  | 1                                  | 6                                  |
| MCPA                                     | 0                                  | 0                                  | 3                                  |
| MCPB                                     | 8                                  | 6                                  | 59                                 |
| MCPP (mecoprop)                          | 5                                  | 2                                  | 16                                 |
| Naptalam                                 | 21                                 | 52                                 | 94                                 |
| Picloram                                 | 0                                  | 0                                  | 0                                  |
| Thiocyclam                               | 26                                 | 11                                 | 56                                 |
| <i>Other pesticides</i>                  |                                    |                                    |                                    |
| Alachlor                                 | 40                                 | 45                                 | 97                                 |
| Amitrole                                 | 0                                  | 0                                  | 6                                  |
| Azocyclotin                              | 1                                  | 0                                  | 16                                 |
| Bioallethrin                             | 48                                 | 52                                 | 97                                 |
| Bitertanol                               | 10                                 | 3                                  | 81                                 |
| Bromoxynil                               | 8                                  | 16                                 | 40                                 |
| Chlorophacinone                          | 0                                  | 1                                  | 45                                 |
| Coumatetralyl                            | 14                                 | 30                                 | 90                                 |
| Cyfluthrin                               | 37                                 | 89                                 | 97                                 |
| Cyhexatin                                | 0                                  | 0                                  | 3                                  |
| Cypermethrin                             | 41                                 | 91                                 | 96                                 |
| Deltamethrin                             | 40                                 | 90                                 | 98                                 |
| Dichlofluanid                            | 30                                 | 64                                 | 94                                 |
| Dichlorophen                             | 12                                 | 16                                 | 90                                 |
| Diclofop-methyl                          | 43                                 | 76                                 | 98                                 |
| Dinoseb acetate                          | 40                                 | 81                                 | 98                                 |
| DNOC                                     | 6                                  | 38                                 | 45                                 |
| EPTC                                     | 69                                 | 63                                 | 97                                 |
| Ethofumesate                             | 25                                 | 50                                 | 95                                 |
| Fenarimol                                | 16                                 | 12                                 | 88                                 |
| Fenpropathrin                            | 50                                 | 88                                 | 96                                 |
| Fenpropimorph                            | 77                                 | 34                                 | 97                                 |
| Fenvalerat                               | 41                                 | 92                                 | 98                                 |
| Flamprop-isopropyl                       | 29                                 | 35                                 | 95                                 |
| Flamprop-methyl                          | 22                                 | 29                                 | 95                                 |
| Fluazifop-butyl                          | 46                                 | 66                                 | 98                                 |
| Fuberidazole                             | 9                                  | 8                                  | 80                                 |
| Furmecycloz                              | 49                                 | 42                                 | 97                                 |
| Imazalil                                 | 5                                  | 2                                  | 53                                 |
| Ioxynil <sup>a</sup>                     | 4                                  | 19                                 | 39                                 |
| Iprodione                                | 34                                 | 54                                 | 98                                 |
| Lenacil                                  | 15                                 | 8                                  | 90                                 |
| Metribuzin                               | 24                                 | 31                                 | 94                                 |
| Nicotine <sup>a</sup>                    | 4                                  | 1                                  | 11                                 |
| p-Nitrophenol                            | 14                                 | 20                                 | 88                                 |
| PCP <sup>a</sup>                         | 22                                 | 32                                 | 60                                 |
| Pendimethalin                            | 60                                 | 92                                 | 97                                 |

**Table 2.** Continued

|                 | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|-----------------|------------------------------------|------------------------------------|------------------------------------|
| Permethrin      | 61                                 | 94                                 | 98                                 |
| Pindone         | 17                                 | 45                                 | 80                                 |
| Propiconazole   | 18                                 | 11                                 | 91                                 |
| Propyzamide     | 33                                 | 52                                 | 95                                 |
| Pyridate        | 47                                 | 64                                 | 97                                 |
| Quinomethionate | 70                                 | 82                                 | 97                                 |
| S-421           | 78                                 | 97                                 | 99                                 |
| Sethoxydim      | 50                                 | 48                                 | 98                                 |
| Sulfachinoxalin | 2                                  | 2                                  | 70                                 |
| Thiabendazole   | 7                                  | 3                                  | 67                                 |
| Tolylfluanid    | 33                                 | 67                                 | 97                                 |
| Triadimefon     | 22                                 | 23                                 | 94                                 |
| Triadimenol     | 11                                 | 3                                  | 78                                 |
| Trifenmorph     | 58                                 | 73                                 | 96                                 |
| Trifluralin     | 72                                 | 97                                 | 97                                 |
| Triforine       | 19                                 | 2                                  | 87                                 |
| Vinclozolin     | 42                                 | 76                                 | 99                                 |
| Warfarin        | 12                                 | 11                                 | 91                                 |

<sup>a</sup> Compound serves as reference substance<sup>b</sup> Two spots observed**Table 3.** hR<sub>f</sub><sup>c</sup> Values of the 170 pesticides listed in alphabetical order

| Compound                     | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Acephate                     | 0                                  | 0                                  | 42                                 |
| Alachlor                     | 40                                 | 45                                 | 97                                 |
| Aldrin                       | 89                                 | 98                                 | 99                                 |
| Ametryn                      | 26                                 | 23                                 | 92                                 |
| Amitrole                     | 0                                  | 0                                  | 6                                  |
| Azinphos-ethyl               | 24                                 | 48                                 | 100                                |
| Azinphos-methyl <sup>a</sup> | 20                                 | 42                                 | 94                                 |
| Aziprotryne                  | 42                                 | 50                                 | 96                                 |
| Azocyclotin                  | 1                                  | 0                                  | 16                                 |
| Benzthiazuron                | 8                                  | 3                                  | 65                                 |
| Bioallethrin                 | 48                                 | 52                                 | 97                                 |
| Bitertanol                   | 10                                 | 3                                  | 81                                 |
| Bromophos-ethyl              | 69                                 | 93                                 | 95                                 |
| Bromophos-methyl             | 58                                 | 92                                 | 99                                 |
| Bromoxynil                   | 8                                  | 16                                 | 40                                 |
| Butocarboxim                 | 15                                 | 11                                 | 90                                 |
| Butocarboxim-sulphoxide      | 0                                  | 13                                 | 24                                 |
| Butoxycarboxim               | 3                                  | 2                                  | 63                                 |
| Buturon                      | 20                                 | 29                                 | 93                                 |
| Carbaryl                     | 18                                 | 25                                 | 92                                 |
| Carbofuran <sup>a</sup>      | 17                                 | 20                                 | 92                                 |
| Carbosulfan                  | 49                                 | 66                                 | 97                                 |
| Chlorbromuron                | 22                                 | 30                                 | 92                                 |
| Chlorfenvinphos <sup>b</sup> | 23                                 | 22                                 | 99                                 |
| Chlorfenvinphos <sup>b</sup> | 28                                 | 28                                 | 99                                 |
| Chlormephos                  | 64                                 | 91                                 | 99                                 |

Table 3. Continued

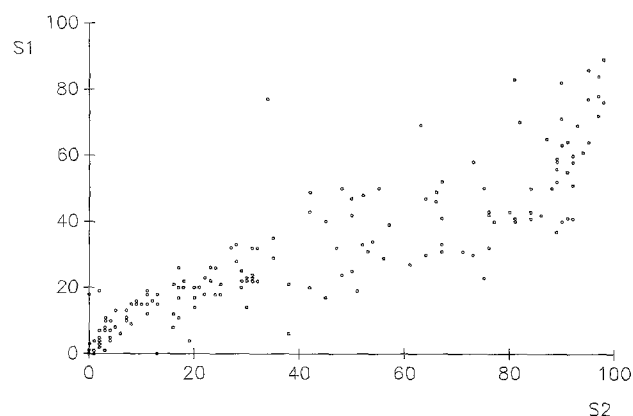
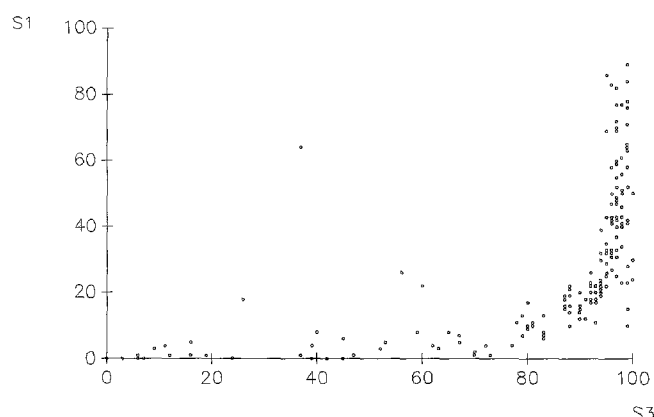
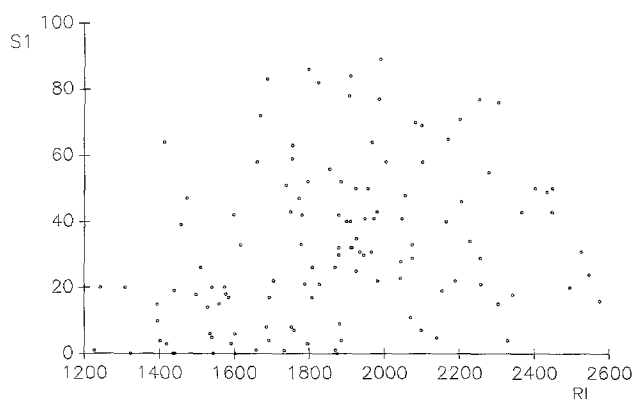
| Compound                 | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|--------------------------|------------------------------------|------------------------------------|------------------------------------|
| Chlorophacinon           | 0                                  | 1                                  | 45                                 |
| Chloroxuron              | 10                                 | 7                                  | 88                                 |
| Chlorpyrifos-ethyl       | 64                                 | 95                                 | 97                                 |
| Chlorpyrifos-methyl      | 56                                 | 89                                 | 98                                 |
| Chlorthion               | 31                                 | 71                                 | 97                                 |
| Chlorthiophos            | 55                                 | 91                                 | 97                                 |
| Chlortoluron             | 15                                 | 9                                  | 87                                 |
| Clopyralid               | 0                                  | 0                                  | 0                                  |
| Coumaphos                | 27                                 | 61                                 | 96                                 |
| Coumatetralyl            | 14                                 | 30                                 | 90                                 |
| Cyanazine                | 16                                 | 12                                 | 90                                 |
| Cycluron                 | 13                                 | 5                                  | 79                                 |
| Cyfluthrin               | 37                                 | 89                                 | 97                                 |
| Cyhexatin                | 0                                  | 0                                  | 3                                  |
| Cypermethrin             | 41                                 | 91                                 | 96                                 |
| 2,4-D                    | 0                                  | 2                                  | 7                                  |
| DDT                      | 76                                 | 98                                 | 99                                 |
| Deltamethrin             | 40                                 | 90                                 | 98                                 |
| Demeton <sup>b</sup>     | 17                                 | 17                                 | 93                                 |
| Demeton <sup>b</sup>     | 83                                 | 81                                 | 96                                 |
| Demeton-S-methyl         | 18                                 | 13                                 | 91                                 |
| Demeton-S-methylsulphone | 1                                  | 3                                  | 70                                 |
| Desmetryn                | 21                                 | 16                                 | 88                                 |
| Diazinon                 | 47                                 | 50                                 | 96                                 |
| Dichlofluanid            | 30                                 | 64                                 | 94                                 |
| Dichlorophen             | 12                                 | 16                                 | 90                                 |
| Dichlorprop              | 3                                  | 2                                  | 9                                  |
| Dichlorvos               | 20                                 | 20                                 | 90                                 |
| Diclofop-methyl          | 43                                 | 76                                 | 98                                 |
| Dicofol                  | 43                                 | 80                                 | 97                                 |
| Dieldrin                 | 65                                 | 87                                 | 99                                 |
| Difenoxyuron             | 8                                  | 5                                  | 83                                 |
| Diflubenzuron            | 18                                 | 24                                 | 93                                 |
| Dimethoate               | 4                                  | 4                                  | 72                                 |
| Dinoseb-acetate          | 40                                 | 81                                 | 98                                 |
| Dipropetryn              | 35                                 | 35                                 | 95                                 |
| Disulfoton               | 58                                 | 89                                 | 96                                 |
| Diuron                   | 15                                 | 10                                 | 87                                 |
| DNOC                     | 6                                  | 38                                 | 45                                 |
| Endosulfan <sup>b</sup>  | 40                                 | 77                                 | 98                                 |
| Endosulfan <sup>b</sup>  | 77                                 | 95                                 | 98                                 |
| Endrin                   | 71                                 | 90                                 | 99                                 |
| EPTC                     | 69                                 | 63                                 | 97                                 |
| Ethiofencarb             | 21                                 | 25                                 | 94                                 |
| Ethofumesate             | 25                                 | 50                                 | 95                                 |
| Ethoprophos              | 33                                 | 28                                 | 96                                 |
| Etrimfos <sup>b</sup>    | 3                                  | 0                                  | 52                                 |
| Etrimfos <sup>b</sup>    | 52                                 | 67                                 | 97                                 |
| Fenarimol                | 16                                 | 12                                 | 88                                 |
| Fenitrothion             | 32                                 | 76                                 | 95                                 |
| Fenoprop                 | 1                                  | 1                                  | 6                                  |
| Fenpropathrin            | 50                                 | 88                                 | 96                                 |

Table 3. Continued

| Compound                        | S1<br>hR <sub>f</sub> <sup>c</sup> | S2<br>hR <sub>f</sub> <sup>c</sup> | S3<br>hR <sub>f</sub> <sup>c</sup> |
|---------------------------------|------------------------------------|------------------------------------|------------------------------------|
| Fenpropimorph                   | 77                                 | 34                                 | 97                                 |
| Fenthion                        | 41                                 | 81                                 | 96                                 |
| Fenuron                         | 11                                 | 7                                  | 81                                 |
| Fenvalerat                      | 41                                 | 92                                 | 98                                 |
| Flamprop-isopropyl              | 29                                 | 35                                 | 95                                 |
| Flamprop-methyl                 | 22                                 | 29                                 | 95                                 |
| Fluazifop-butyl                 | 46                                 | 66                                 | 98                                 |
| Fluometuron                     | 16                                 | 9                                  | 87                                 |
| Fonofos                         | 59                                 | 89                                 | 97                                 |
| Formetante <sup>b</sup>         | 1                                  | 1                                  | 19                                 |
| Formetante <sup>b</sup>         | 1                                  | 1                                  | 73                                 |
| Fuberidazole                    | 9                                  | 8                                  | 80                                 |
| Furmecyclox                     | 49                                 | 42                                 | 97                                 |
| Heptachlor                      | 84                                 | 97                                 | 99                                 |
| Heptenophos                     | 20                                 | 18                                 | 92                                 |
| Hexazinone                      | 4                                  | 2                                  | 77                                 |
| Imazalil                        | 5                                  | 2                                  | 53                                 |
| Ioxynil <sup>a</sup>            | 4                                  | 19                                 | 39                                 |
| Iprodione                       | 34                                 | 54                                 | 98                                 |
| Isofenphos                      | 41                                 | 67                                 | 99                                 |
| Isomethiozin                    | 50                                 | 55                                 | 96                                 |
| Lenacil                         | 15                                 | 8                                  | 90                                 |
| Lindane                         | 51                                 | 92                                 | 98                                 |
| Linuron                         | 22                                 | 31                                 | 93                                 |
| Malathion                       | 31                                 | 53                                 | 96                                 |
| MCPA                            | 0                                  | 0                                  | 3                                  |
| MCPB                            | 8                                  | 6                                  | 59                                 |
| MCPP (mecoprop)                 | 5                                  | 2                                  | 16                                 |
| Metamitron                      | 5                                  | 4                                  | 67                                 |
| Methabenzthiazuron <sup>a</sup> | 18                                 | 22                                 | 85                                 |
| Methamidophos                   | 1                                  | 0                                  | 37                                 |
| Methidathion <sup>a</sup>       | 29                                 | 56                                 | 95                                 |
| Methomyl                        | 6                                  | 6                                  | 83                                 |
| Methoprotryn                    | 19                                 | 11                                 | 88                                 |
| Methoxychlor                    | 43                                 | 84                                 | 96                                 |
| Metobromuron                    | 23                                 | 31                                 | 92                                 |
| Metoxuron                       | 7                                  | 4                                  | 83                                 |
| Metribuzin                      | 24                                 | 31                                 | 94                                 |
| Mevinphos <sup>b</sup>          | 10                                 | 7                                  | 99                                 |
| Mevinphos <sup>b</sup>          | 15                                 | 13                                 | 99                                 |
| Monocrotophos <sup>b</sup>      | 1                                  | 1                                  | 12                                 |
| Monocrotophos <sup>b</sup>      | 1                                  | 1                                  | 47                                 |
| Monolinuron                     | 23                                 | 30                                 | 94                                 |
| Monuron                         | 13                                 | 7                                  | 83                                 |
| Naptalam                        | 21                                 | 52                                 | 94                                 |
| Neburon                         | 26                                 | 24                                 | 95                                 |
| Nicotine <sup>a</sup>           | 4                                  | 1                                  | 11                                 |
| p-Nitrophenol                   | 14                                 | 20                                 | 88                                 |
| Omethoate                       | 0                                  | 0                                  | 39                                 |
| Oxydemeton-methyl               | 18                                 | 0                                  | 26                                 |

**Table 3.** Continued

| Compound                       | S1<br>$hR_f^c$ | S2<br>$hR_f^c$ | S3<br>$hR_f^c$ |
|--------------------------------|----------------|----------------|----------------|
| Parathion-ethyl <sup>a</sup>   | 41             | 85             | 96             |
| Parathion-methyl <sup>a</sup>  | 30             | 73             | 100            |
| PCP <sup>a</sup>               | 22             | 32             | 60             |
| Pendimethalin                  | 60             | 92             | 97             |
| Permethrin                     | 61             | 94             | 98             |
| Phenmedipham                   | 11             | 17             | 93             |
| Phosalone                      | 31             | 67             | 97             |
| Phosphamidon                   | 7              | 2              | 79             |
| Phoxim                         | 42             | 86             | 97             |
| Picloram                       | 0              | 0              | 0              |
| Pindone                        | 17             | 45             | 80             |
| Pirimicarb                     | 26             | 17             | 92             |
| Pirimiphos-methyl <sup>a</sup> | 49             | 75             | 100            |
| Prometryn                      | 32             | 31             | 94             |
| Propham                        | 39             | 57             | 94             |
| Propiconazole                  | 18             | 11             | 91             |
| Propoxur                       | 20             | 21             | 92             |
| Propyzamide                    | 33             | 52             | 95             |
| Pyrazophos                     | 32             | 47             | 96             |
| Pyridate                       | 47             | 64             | 97             |
| Quinomethionate                | 70             | 82             | 97             |
| Quintozene <sup>a</sup>        | 84             | 95             | 95             |
| S-421                          | 78             | 97             | 99             |
| Sethoxydim                     | 50             | 48             | 98             |
| Simazine                       | 22             | 18             | 88             |
| Sulfachinoxalin                | 2              | 2              | 70             |
| Sulfotepp                      | 50             | 84             | 96             |
| Temephos                       | 23             | 75             | 98             |
| Terbufos                       | 63             | 90             | 99             |
| Terbuthylazine                 | 32             | 27             | 94             |
| Terbutryn                      | 32             | 32             | 95             |
| Tetrachlorvinphos              | 25             | 29             | 97             |
| Thiabendazole                  | 7              | 3              | 67             |
| Thiazafluron                   | 10             | 4              | 80             |
| Thiocyclam                     | 26             | 11             | 56             |
| Thiofanox                      | 20             | 17             | 94             |
| Thiram                         | 19             | 51             | 94             |
| Tolclofos-methyl               | 52             | 89             | 99             |
| Tolyfluanid                    | 33             | 67             | 97             |
| Triadimefon                    | 22             | 23             | 94             |
| Triadimenol                    | 11             | 3              | 78             |
| Triallate                      | 82             | 90             | 97             |
| Triazophos <sup>a</sup>        | 21             | 38             | 94             |
| Trichlorfon                    | 4              | 2              | 62             |
| Trietazine                     | 43             | 42             | 95             |
| Trifenmorph                    | 58             | 73             | 96             |
| Trifluralin                    | 72             | 97             | 97             |
| Triforine                      | 19             | 2              | 87             |
| Vinclozolin                    | 42             | 76             | 99             |
| Warfarin                       | 12             | 11             | 91             |

<sup>a</sup> Compound serves as reference substance<sup>b</sup> Two spots observed**Fig. 2.** Plot:  $hR_f^c$  values in solvent 1 (*S1*) versus  $hR_f^c$  values in solvent 2 (*S2*)**Fig. 3.** Plot:  $hR_f^c$  values in solvent 1 (*S1*) versus  $hR_f^c$  values in solvent 3 (*S3*)**Fig. 4.** Plot:  $hR_f^c$  values in solvent 1 (*S1*) versus retention index (*RI*) on OV-1

The plot of  $hR_f^c$  values in solvent 1 (*S1*) versus  $hR_f^c$  values in solvent 2 (*S2*) demonstrates the ability of these two systems to discriminate many compounds (see Fig. 2). System 3 (*S3*) should be used as an additional tool for the separation of special compounds as demonstrated by the plot of *S1* versus *S3* (see Fig. 3).

However, a more satisfying separation can be obtained by the additional use of gas chromatography. This is illustrated in Fig. 4 (plot *S2* versus retention index *RI*).

on OV-1). The GLC data and many other analytical data on pesticides will be published in the near future.

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