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PRELIMINARY INVESTIGATION OF THE EFFECT OF FENTHION POLLUTION ON AQUATIC INVERTEBRATES

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INTRODUCTION

Fenthion, dimethyl-3-methyl-4-methylthiophenyl phosphorothionate, is an avicide widely used to control Red-billed finches (*Quelea quelea*) in South Africa. Control of these birds involves spraying of areas where they roost at night, *i.e.* mainly along riversides and in other wet land areas. Resulting pollution of water invariably occurs from such treatments and freshwater Crustacea and Insecta can be acutely influenced by such pesticide pollution[1].

Fenthion is known to be slowly degraded in pure water[2] and this persistence may present health hazards for humans. It may also prevent the use of water by animals and it is thus important to know how soon the effects of spraying will wear off. Fenthion residues in water can be determined by use of chemical analysis or sophisticated biological analysis[3]. Small towns and farmers usually do not have access to these methods and it is therefore convenient for them to rely on certain indicators of water purity such as aquatic invertebrates.

Aquatic insects were previously studied as indicators of stream environmental quality[4] and found to be particularly useful. The aim of the present study was to find possible indicator groups of species that were highly sensitive to fenthion pollution.

For such purposes the organisms would have to be sufficiently abundant where spraying operations were to take place. These were to include an inland lake of standing water or pan, a small river, slow flowing and the same river during a flood and also a large river. The selected areas were sprayed with fenthion and the effect on aquatic invertebrates of the subsequent pollution was studied.

EXPERIMENTAL

Field experimental designs

The areas sprayed included one along the lower Orange river which was fully discussed previously[1], Rietpan lake on a farm near Heilbron, and an area along the Rhenoster river near Koppies in the Orange Free State province of South Africa. The current flow of the Orange river during the experiment was 100 cumec. In the small Rhenoster river a normally slow current of 750 m^3/h was measured during the first experimental spraying, but during the spraying experiment in the flooded river the current flow decreased from 17,07 cumec directly after spraying to 2,5 cumec five days later.

Fenthion was applied by aircraft as a 1:1 mixture of 40 percent active ingredient oil miscible formulation and diesoline at all three experimental sites at 25 ℓ/ha. At Rietpan lake five sampling sites were chosen for the monitoring program. On the Rhenoster river twelve sites were chosen of which six were situated in the sprayed area and six were 2 km downstream.

On the Orange river two sample sites were in the sprayed areas and two downstream from these areas[1]. Samples of both water and the invertebrate fauna were collected before and immediately after spraying and then consecutively on certain days for up to twenty days after spraying.

All experiments were conducted in mid-summer and early autumn when fenthion spraying against birds is usually undertaken.

Fenthion residue analysis

Water samples (2 ℓ) were collected in brown cork-stopped glass bottles. These samples were extracted with 200 mℓ purified hexane in the glass bottles and the phases separated in a separating funnel. The hexane extracts were filtered through phase-separating filter paper into graduated cylinders and the volumes recorded and used as correction factors in the calculations. The extract was concentrated to 10 mℓ.

A 2 m glass column with 3 mm inner diameter was packed with 3% SE 30 on 80/100 mesh Chromosorb Q, in a Tracor MT 220 gas chromatograph. A flame photometric detector was used in the phosphorus mode. The temperature of the inlet, oven and detector were 210, 215 and 200°C, respectively. The flow rates for the carrier (nitrogen), hydrogen, oxygen and air were 70, 150, 20 and 40 mℓ/min, respectively. The minimum detectability was 0,1 ng i.e. 100 ng/ℓ water for fenthion and 0,5 ng i.e. 500 ng/ℓ water for fenthion sulfoxide, however, no sulfoxide was found in the water samples.

Population density determinations

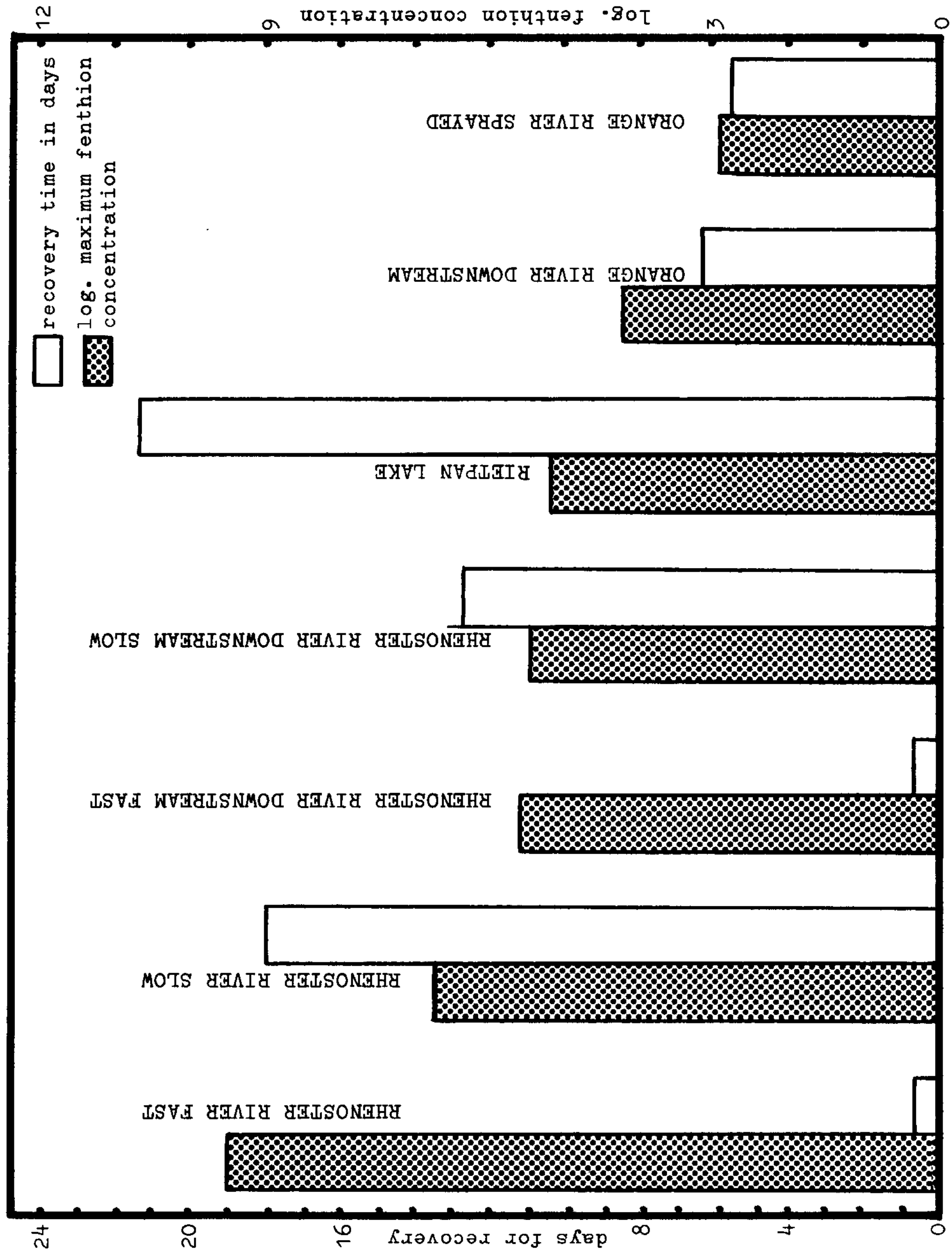
Biological samples were made by hand net with a 10 000 mesh. At each sampling site two samples were taken and killed directly in 40% formalin. The samples were then thoroughly washed with water in the laboratory with the aid of a hand net and sieve with a 22 mesh. The macroscopic sample, i.e. the sample collected on the sieve, was washed into a Perspex holder and the volume adjusted by adding water to 200 mℓ. A blender rotating at a slow speed of 30 rev/min. was used to give a homogenous distribution for microscopic analysis. Separate groups of species were identified and counted. The total population density was calculated as a combination of the macro- and microscopic population density counts as discussed previously[1,5]. The population density was calculated as number of organisms x 18,83. The constant 18,83 is derived from the mesh openings of the net divided by the surface of the hand net, in this case 541,14 cm^2.

RESULTS AND DISCUSSION

Total invertebrate population density

The total population density of aquatic invertebrates is a sensitive indicator of fenthion pollution. At Rietpan lake the invertebrate population

FIGURE 1: RECOVERY TIME AND MAXIMUM FENTHION CONCENTRATION IN SEVEN RIVER AND LAKE SYSTEMS



required about 22 days to recover to its former level (Figure 1). In the directly sprayed and downstream areas of the Orange river the total population density required about six days to recover. In the slow-flowing Rhenoster river the recovery required 17 days in the downstream area, but in the flooded and swift flowing Rhenoster river it took less than one day in both the sprayed and downstream areas for the total population density to recover.

No correlation between the total population density and the concentration of fenthion used, was found, however, it was clear that the flow rate of the water had a bearing on the dilution and toxicity of fenthion. Thus it was found in Rietpan lake where there was no flow, the population density took longer to recover. The maximum fenthion concentration of 145 000 ng/ℓ was detected only three days after spraying, suggesting that there was slow mixing of the lake waters.

The rapid recovery of the invertebrate population in the sprayed and downstream areas of the Orange river was obviously due to the rapid flow of 100 cumec during the experiment which dispersed the avicide. The maximum fenthion concentration found directly after spraying was 19 000 ng/ℓ in comparison with the 145 000 ng/ℓ at the lake.

Similarly it was found that in the slow flowing Rhenoster river, recovery took longer than in the Orange river, moreover, the invertebrate population recovered more rapidly in downstream areas than in the sprayed areas (Figure 1). This correlates with the maximum fenthion concentration found in these areas. The highest concentration in the sprayed area directly after spraying was 48×10^5 ng/ℓ and in the unsprayed downstream area one day after spraying 32×10^4 ng/ℓ (Figure 1).

Recovery of the total invertebrate population on the day following spraying in the swift flowing and flooded Rhenoster river exceeded the pre-spraying density. This may be due to the drastic effect of high current flow in a small flooded river on the population density. During the pre-spraying counts habitats were flooded and this may have been the reason for the low population counts It will be recalled that current flow was 17 cumec during spraying but decreased to 2,5 cumec five days after spraying when the higher densities were recorded (Figure 1). The recovery rate of the total invertebrate population density in the swift flowing river may be an artefact caused by flooding.

Population densities of specific groups of aquatic invertebrates

The population density of the groups of species which constitute the total invertebrate population densities may or may not reflect the general trend as expressed by the total invertebrate population density. The Crustacea (mainly *Caridina nilotica*) reflected the general trend in the Orange river, Rietpan lake and the slow flowing Rhenoster river (Tables 1, 2 and 3). This may be due to the fact that the Crustacea generally formed the bulk of the population sampled. The Crustacea were never wiped out completely in a spraying operation.

TABLE 1: RELATIVE POPULATION DENSITIES AT RIETPAN LAKE[a]

Days after spraying	Crustacea	Hemiptera	Diptera	Coleoptera
Before	100	100	100	100
1	110	100	50	200
2	55	0	100	200
3	46	0	0	100
9	57	0	0	50
20	95	0	0	100

[a] Relative population density expressed as a percentage of the population density on the day before spraying.

The Odonata (mainly *Pseudagrion* spp.) were only found in flowing waters and recovered rapidly in the areas directly sprayed in the Orange river, but slowly in downstream areas (Table 2). The Odonata population showed a similar trend in the slow flowing Rhenoster river where the population dropped to zero six days after spraying (Table 3) at a time when the mean fenthion concentrations of 5570 and 1670 ng/ℓ, respectively, could still be detected in sprayed and downstream areas. From the twelfth day onwards the population recovered. In the fast flowing Rhenoster river no visible effect of the application could be discovered (Table 4). At Rietpan lake no Odonata were present before or after spraying of fenthion.

TABLE 2: RELATIVE POPULATION DENSITIES IN THE ORANGE RIVER[a]

Days after spraying	Crustacea	Odonata	Ephemeroptera	Hemiptera	Diptera	Coleoptera
Sprayed area						
Before	100	100	100	100	100	100
1	10	59	23	9	88	9
4	67	82	11	6	6	16
6	134	113	1	1	1	14
Unsprayed downstream area						
Before	100	100	100	100	100	100
1	82	30	7	25	50	53
4	57	9	8	20	8	9
6	170	17	30	54	44	4

(a) Relative population density expressed as a percentage of the population density on the day before spraying.

In the Orange river Ephemeroptera (mainly Baetis spp.) were shown to be very susceptible to fenthion pollution (Table 2). No Ephemeroptera were counted in Rietpan lake before or after spraying of fenthion. In the slow flowing Rhenoster river the Ephemeroptera population remained depressed even after 20 days (Table 3). In the swift flowing Rhenoster river the Ephemeroptera population was not affected by fenthion pollution but the fast current flow may have had an influence (Table 4). The Ephemeroptera population is thus very susceptible to fenthion pollution and may also serve as a good indicator.

TABLE 3: RELATIVE POPULATION DENSITIES IN THE SLOW FLOWING RHENOSTER RIVER[(a)]

Days after spraying	Crustacea	Odonata	Ephemeroptera	Hemiptera	Diptera	Coleoptera
Sprayed area						
Before	100	100	100	100	100	100
0	66	37	0	13	106	100
1	140	16	0	6	40	300
6	68	0	0	1	0	0
12	191	0	0	0	0	0
20	241	8	0	8	41	277
Unsprayed downstream area						
Before	100	100	100	100	100	100
0	90	34	21	48	61	100
1	84	34	0	27	155	1 238
6	202	0	0	1	0	100
12	230	0	0	0	0	0
20	266	8	0	10	51	444

(a) Relative population density expressed as a percentage of the population density on the day before spraying.

At Rietpan lake only a few aquatic Hemiptera were counted before and on the first day after spraying (Table 1). On the second day after spraying no more Hemiptera could be found and the population stayed depressed up to the end of the observation period (Table 1). In the Orange river the Hemiptera population decreased in both the directly sprayed and downstream areas. The Hemiptera population in the slow flowing Rhenoster reflected the same trend and decreased until the twelfth day after spraying (Table 3). In the swift flowing Rhenoster river there was a decrease in the Hemiptera population immediately after spraying, but recovery was rapid from the fifth day onwards (Table 4). The Hemiptera population is thus susceptible to fenthion pollution and recovery is rapid in downstream areas and swift flowing river systems.

The aquatic Diptera population such as Chironomid larvae in the Rietpan lake seemed susceptible to fenthion pollution although only a few individuals were sampled and it is therefore difficult to determine the influence of fenthion from this data (Table 1). In the Orange river the Diptera population decreased for up to four days after spraying in the directly sprayed areas and then rapidly increased. In the unsprayed areas the increase was less rapid (Table 2). It is difficult to determine the effect of fenthion pollution on Diptera populations in the slow flowing Rhenoster, because the density fluctuated drastically (Table 3). Recovery in the swift flowing Rhenoster was rapid and less erratic (Table 4). The Diptera population is susceptible to fenthion pollution, but due to erratic population fluctuations probably not a good indicator.

TABLE 4: RELATIVE POPULATION DENSITIES IN THE FAST FLOWING RHENOSTER RIVER[a]

Days after spraying	Crustacea	Odonata	Ephemeroptera	Hemiptera	Diptera	Coleoptera
Sprayed area						
Before	100	100	100	100	100	100
0	2 134	148	105	33	64	42
1	5 154	200	102	14	16	0
5	675	243	115	22	76	0
Unsprayed downstream area						
Before	100	100	100	100	100	100
0	17 977	200	105	20	22	33
1	49 150	48	174	1	18	78
5	4 794	100	26	17	22	0

(a) Relative population density expressed as a percentage of the population density on the day before spraying.

The susceptibility of aquatic Coleoptera to fenthion pollution could not be ascertained. In the Orange river it was found to be a useful indicator (Table 2) but in Rietpan lake and in the Rhenoster river big fluctuations in the populations counts occurred (Tables 1, 2, 3 and 4).

CONCLUSIONS

The recovery rates of the total invertebrate population densities differ from one river system to another and it is therefore necessary to have a detailed knowledge of the specific system and its invertebrate fauna before meaningful results can be obtained. Neither the total invertebrate population density nor the Crustacea population are useful indicators in small flooded systems. The presence or absence of Odonata especially Pseudagrion spp. is probably the best indicator of the fenthion pollution. Ephemeroptera and Hemiptera populations are also sensitive to this avicide but take much longer to recover from contamination. Fast flowing flooded systems make the use of indicator organisms nearly impossible.

Care must be exercised when spraying near dams and lakes as it is here that the effects of fenthion contamination will be most acute. A recommended withholding period of 21 days after spraying of birds in such habitats is suggested.

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