THE FATE OF SODIUM MONOFLUOROACETATE (1080) IN WATER, MAMMALS, AND INVERTEBRATES

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SUMMARY

Studies on the persistence of 1080 in water, mammals, and invertebrates show that it is readily degraded. Significant water contamination is extremely unlikely after aerial distribution of 1080 baits for control of possums. The rapid elimination of 1080 from animal tissue confirms that 1080 residues are most unlikely in meat. Our analysis of residues in invertebrates indicates there is no long-term contamination of invertebrates and little risk of significant amounts of 1080 passing through the food chain to birds.

Keywords: sodium monofluoroacetate, 1080, environment, non-target species

INTRODUCTION

Sodium monofluoroacetate (1080) has been used in New Zealand since 1954 and is still an essential pesticide for limiting forest and crop damage and for containing the spread of tuberculosis to livestock by possums. Fluoroacetate, from which 1080 is derived, is a naturally occurring plant toxin in 33 toxic species of *Gastrolobium* and *Oxylobium* in Australia. Air-dried leaves of *Oxylobium parviflorum* contain as much as 2.5 g fluoroacetate/kg leaf material, and even higher concentrations are found in the seeds of *Gastrolobium bilobum*, which can have more than of 6.5 g fluoroacetate/kg (Twigg and King 1991). These amounts equate to a concentration of 0.25 and 0.65% fluoroacetate, respectively, which are an order of magnitude higher than the concentration of 1080 (0.08%) used in possum baits. Despite the success of operations using baits containing 1080 to control possums, the use of 1080 continues to provoke controversy about its persistence in the environment.

The fate of 1080 in the soil has been extensively studied. It is water soluble and residues from uneaten baits leach into the soil, where they are degraded to non-toxic metabolites such as glycolate by soil micro-organisms, including the bacterium *Pseudomonas* and the common soil fungus *Fusarium solani* (Walker and Bong 1981; Marion-Meyer *et al.* 1990; Wong *et al.* 1992). Nevertheless, because of the continuing public concern we recently initiated a re-evaluation of the safety of 1080. Initially we focused on the potential of 1080 to contaminate waterways by analyzing water samples after two major possum control operations in 1990. Our analyses detected no 1080 in samples from the streams and rivers of the Waipoua forest or in the surface and ground water of Rangitoto Island after these operations (Eason *et al.* 1992). Our next priority was to determine whether 1080 could contaminate meat. Preliminary analysis of blood samples from animals suggested that 1080 is completely eliminated within 1 to 5 days (Eason and Gooneratne 1993).

This paper summarises new data on the fate of 1080 in water and the persistence of 1080 in mammals and invertebrates.

MATERIAL AND METHODS

Sodium monofluoroacetate (95% purity) was obtained from the Sigma Chemical Company, St Louis, USA. Residues of 1080 were measured as a dichloroaniline

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derivative and quantified by gas chromatography with electron capture detection, based on procedures developed by Ozawa and Tsukioka (1987). Using this technique, more than 90% of the 1080 is recovered from water and biological samples, and the limit of detection is 0.002 µg/g in tissue, 0.010 µg/g in plasma, and 0.0003 µg/g in water.

Two aquaria containing 80 litres of stream water, the common aquatic plants *Myriophyllum triphyllum*, *Potamogeton cheesemanii*, *Elodea canadensis*, and *Nitella* spp., and small aquatic animals, such as *Potamopyrgus*, *Hydra*, and *Trichoptera* spp. and a third aquarium containing only distilled water were spiked with 0.1 ppm of 1080 (equivalent to adding two or three possum baits to each aquarium). The water temperature in the aquaria equilibrated at approximately 20°C. Water and plant samples were taken from all three tanks at 5 min and 1, 24, 100, 170, and 330 h after the addition of 1080.

Sheep, goats, and possums were dosed via a gastric cannula with a near-lethal amount of 1080 (0.1 mg/kg). Blood samples were taken at regular intervals after dosing. The following pharmacokinetic parameters were assessed:

- Maximum observed plasma concentration (C_{max}).
- Time taken to reach T_{max} .
- Half-lives ($t_{1/2}$) estimated from the slope (K_{el}) of the semi-log plots of the terminal phase of the plasma concentration against time curve.

Liver, kidney, plasma, and muscle samples were analysed for 1080 residues from three sheep killed at 2.5 h and at 96 h after dosing.

TABLE 1: Invertebrates analysed.

Common name	Class	Order	Family/Genus
Spiders	Arachnida	Araneae	Araneidae, Lycosidae
Centipedes	Chilopoda	Scolophendromorpha/ Geophilomorpha	Cormocephalus
Millipedes	Diplopoda	Oniscomorpha/Juliaforma	
Earthworms	Oligochaeta	Lumbricina	
Cave weta	Insecta	Orthoptera	Rhaphidophoridae
Tree weta	Insecta	Orthoptera	Stenopelmatidae
Black beetles	Insecta	Coleoptera	Carabidae, Lucanidae and unid.
Cockroaches	Insecta	Blattodea	Blattidae

Invertebrates were collected at six sampling stations in the field before and after application of “Wanganui No.7” possum baits containing 0.8% 1080 and sown at 5 kg per hectare. The invertebrates comprised nine Orders spanning five Classes (Table 1). Except for the insects, animals from each station were analysed by Class (i.e., pooled Orders and Families). For the insects however, analyses were at the Order or Family level.

The sample numbers of some species varied slightly at each collection, reflecting the difficulty in collecting some species. For example, the average sample number for tree wetas and cockroaches was six, but for cave wetas it was three. In our laboratory individual wetas were dosed orally with 15 µg/g 1080 using a micro-syringe (Sutherland *et al.* 1982), and then killed at various times after dosing.

All water and biological samples were stored at -20°C pending analysis.

RESULTS

The concentration of 1080 in water declined by approximately 70% in 24 h in the aquaria containing plants and invertebrates, and after 100 h no further 1080 could be detected in the water. Residues were detected in plant material but these also declined rapidly, and no 1080 could be detected in plants after 330 h. In contrast, 1080

concentration remained comparatively stable in the control aquarium containing distilled water (Table 2).

TABLE 2: Sodium monofluoroacetate concentrations ($\mu\text{g}/\text{ml}$ or $\mu\text{g}/\text{g}$) in individual aquaria and plants.

Time	Biologically active aquaria (1) (2)		Distilled water	Plants
5 min	0.105	0.096	0.100	NS
1 h	0.099	0.089	0.097	0.051
24 h	0.038	0.026	0.081	0.027
100 h	ND	ND	0.074	0.005
170 h	ND	ND	0.084	0.002
330 h	NS	NS	NS	ND

ND = None detected; NS = Not sampled

Sodium monofluoroacetate was readily absorbed in the three animal species dosed with near-lethal amounts, then rapidly eliminated, with only traces detectable after 18 h in goat plasma, 24 h in possum plasma, and after 96 h in sheep plasma and tissue. The plasma elimination half-life ($t_{1/2}$) ranged from 5.5 h in possums to 11 h in sheep (Table 3). For the plasma and tissues analysed in sheep at 2.5 h after dosing, plasma contained the highest concentration of 1080 and the liver the lowest. Only traces were still present in plasma, kidney, and muscle after 96 h (Table 4).

TABLE 3: Plasma pharmacokinetics of 1080 in sheep, goats, and possums, after oral administration of 0.1 mg 1080/kg (range in brackets).

Species (n)	$C_{\max}$ ($\mu\text{g}/\text{ml}$)	$T_{\max}$ (h)	$t_{1/2}$ (h)
Sheep (6)	0.27 (0.16-0.33)	2.50 (0.5-4.0)	10.8 (6.6-13.3)
Goats (2)	0.24 (0.22, 0.26)	0.75 (0.5, 1.0)	5.5 (3.9, 6.9)
Possums (6)	0.18 (0.11-0.31)	0.50 (0.5-4.0)	9.1 (5.8-13.6)

TABLE 4: Mean 1080 concentration ($\mu\text{g}/\text{g}$) in plasma and tissues (range in brackets) from three sheep killed at 2.5 and 96 h after an oral 1080 dose (0.1 mg/kg).

	Plasma	Kidney	Muscle	Liver
2.5 h	0.098 (0.033-0.141)	0.057 (0.046-0.064)	0.042 (0.038-0.050)	0.021 (0.011-0.039)
96 h	0.002 (0.001-0.005)	0.002 (0.001-0.003)	0.002 (0.001-0.002)	0.000 (0.000-0.000)

No residues of 1080 were found in spiders, beetles, millipedes, centipedes, or earthworms at any stage. Residues of 1080 were present in some cave and tree wetas, and in cockroaches for up to 3 weeks after the baits had been sown (Table 5). The highest concentrations detected in cockroaches and cave wetas were 2 and 4 $\mu\text{g}/\text{g}$, respectively. The highest residue concentrations of 1080 occurred in tree wetas (46 $\mu\text{g}/\text{g}$).

g) at one sampling station 2 days after poisoning (Table 5). However, in the laboratory study 1080 was eliminated from wetas (>90%) within 4-6 days after dosing (Table 6).

TABLE 5: Mean sodium monofluoroacetate concentration ($\mu\text{g/g}$) in bush wetas, cave wetas, and cockroaches after aerial sowing of 1080 baits (range in brackets).

Time after sowing	Tree wetas	Cave wetas	Cockroaches
Before sowing	0.0 (0-0)	0.0 (0-0)	0.0 (0-0)
2 days	12.0 (0-46.0)	0.0 (0.0-0.0)	1.0 (0.17-1.83)
1 week	1.4 (0-6.4)	2.1 (1.1-4.1)	0.8 (0.06-2.14)
2 weeks	1.1 (0-4.5)	1.2 (0-2.5)	0.6 (0.07-1.49)
3 weeks	0.8 (0-4.5)	0.0 (0-0)	0.02 (0-9.11)
4 weeks	0.2 (0-1.2)	0.0 (0-0)	0.0 (0-0)
8 weeks	0.0 (0-0.01)	0.0 (0-0)	0.0 (0-0)
16 weeks	0.0 (0-0)	NS	0.0 (0-0)

TABLE 6: Sodium monofluoroacetate concentrations in individual tree wetas after oral dosing with 15 $\mu\text{g/g}$.

Time after dosing	1h	4h	12h	24h	2d	4d	6d	10d	14d
h = hours d = days									
Concentration ($\mu\text{g/g}$)	5.5	5.8	5.8	5.0	2.8	4.5	0.2	0.033	0.038

DISCUSSION

These studies have shown that 1080 control operations will not cause any long-term environmental contamination. If small amounts of baits fell into water courses any 1080 would be rapidly diluted and biodegraded by macro and micro-organisms. Our analyses validate Peters' (1975) conclusions that the levels of 1080 used in possum control operations impose an exceedingly small toxic burden on the environment and that the chances of significant contamination of either rural or suburban water supplies are remote.

Our results for livestock and possums also showed extremely rapid elimination of 1080, which is consistent with a recent study in mice (Sykes *et al.* 1987). In all previous studies, 1080 was found at higher concentrations in plasma than in major organs or tissues (Gal *et al.* 1961; Egekeze and Oehme 1979; Sykes *et al.* 1987). We found a similar pattern of 1080 distribution in sheep (Table 3). The rapid elimination of 1080 from animal tissue and plasma is not surprising since the toxin is highly water soluble and is readily excreted unchanged in the urine or broken down in animal tissue to liberate free fluoride and a range of non-toxic metabolites (Gal *et al.* 1961). The occurrence of 1080 residues in meat intended for human consumption is therefore highly unlikely.

Our field and laboratory results for invertebrates show that 1080 is taken up by some of the terrestrial invertebrate groups monitored in our study, however, in those

that do, 1080 is present in the tissues for only short periods. The risk to insectivorous birds is therefore confined to a short period. Spurr (1990) reviewed data on impacts of 1080 operations on common forest birds and concluded that whilst individuals of several bird species have been killed by 1080 operations there was no evidence of detrimental effects to populations of birds including insectivorous birds. Recent studies of some additional species (kiwi *Apteryx australis*, morepork *Ninox novaeseelandiae* and fernbird *Bowdleria punctata*) indicated no significant changes in populations shortly after a 1080 operation (Pierce and Montgomery 1992). The impact of 1080 on populations of terrestrial invertebrates is currently being studied (E. Spurr and M. Meads, pers. comm.).

Further monitoring of residue in different groups of invertebrates and in waterways after aerial sowing of bait is advisable. In addition we will be repeating our aquaria study, varying temperature and varying the amount of biota in each aquarium.

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