LOSS OF COMPOUND 1080 (SODIUM MONOFLUOROACETATE) FROM CARBOPOL GEL SMEARED ON FOLIAGE TO POISON DEER

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ABSTRACT

Compound 1080 (sodium monofluoroacetate) in a gel carrier was applied to the leaves of broadleaf (**Griselinia littoralis** Raoul) baits (cuttings) to poison deer. In two trials on Stewart Island, assays for F^- showed that the poison disappeared during rain, 90% being lost in 207 mm of rain and 81 mm of rain in the respective trials. In one trial significant losses of Compound 1080 also resulted from biodegradation in storage.

Baits set to kill deer were sampled after 0, 15, 30, and 45 days of weathering. Only 10% of the treated leaves retained toxic gel after 45 days. About 1.4% of the Compound 1080 was lost from the leaves per millimetre of rainfall. This rate was similar to loss rates for Compound 1080 from other baits commonly used in animal control operations.

Keywords: sodium monofluoroacetate; Compound 1080; Carbopol; carboxyvinyl polymer; foliage bait; poisoning; leaching; biodegradation.

INTRODUCTION

Since 1975, a toxic hydrophilic gel formulation containing 10% Compound 1080 (sodium monofluroacetate), developed by J. A. Peters (Forest Research Institute), has been used for poisoning deer and other mammals in New Zealand. Each litre contains 100 g of 1080, 50 g of "Carbopol" (a carboxyvinyl polymer, B.F. Goodrich Co.), and 0.3 g of Lissamine V200 green dye (ICI Ltd) dissolved in 760 ml H_2O and buffered to pH 8.5 with 90 g of triethanolamine (Agricultural Chemicals Board Registration No. 2345). The gel is applied to the foliage of preferred food plants.

This toxic Carbopol gel (referred to hereafter as "the gel") has been used successfully to control red deer (*Cervus elaphus* L.) on Secretary Island, Fiordland (Forest Research Institute 1977), goats (*Capra hircus* L.) in the Motu Catchment, Bay of Plenty (Parkes 1983), white-tailed deer (*Odocoileus virginianus* (Boddaert)) on Stewart Island (Forest Research Institute 1984), and Bennett's wallaby (*Macropus rufogriseus*) in the Hunter Hills, South Canterbury (K. G. Tustin unpubl. data). However, it has been suspected by field staff that the Compound 1080 leaches rapidly from the gel when used in areas with moderate to heavy rainfall.

In the summer of 1980–81 the gel was used to poison white-tailed deer in a 20-km^2 area on the east coast of Stewart Island where mortality of coastal forest was causing concern (Forest Research Institute 1984). The opportunity was taken to assess the loss of Compound 1080 from baits which were protected from the deer, and from baits which were set to kill them. The results of these assessments are presented in this report.

MATERIALS AND METHODS

Sampling and Analysing Protected Baits

The gel was smeared on the abaxial surfaces of 35 leaves on each of 10 baits (cut branches with 200–400 leaves) of broadleaf in two locations (i.e., 700 leaves in total). The first trial (A) was laid out on 15 February 1981 in a sheltered site beneath an intact forest canopy; the second trial (B) was laid out on 21 February 1981 on an exposed ridge with an open canopy and no understorey. The baits were placed out of the reach of deer, with the treated surfaces lowermost.

One leaf was harvested from each bait on the day it was laid, and each second day thereafter. The 10-leaf samples from each trial were packed in plastic bags and stored at air temperature on the island. As opportunities offered, samples were sent to the Forest Research Institute in Christchurch where they were stored at –14°C until required for analysis. Twenty samples were harvested from Trial A up to 25 March, and 23 from Trial B up to 6 April.

Daily rainfall was measured in five 158-mm-diameter funnel gauges located in clearings within 2 km of the trial sites.

In the laboratory, the samples were chopped up and assayed for Compound 1080 by an alkali fusion F^- specific ion electrode method (C. L. and D. Batcheler unpubl. data). Measured F^- was converted to milligrams of 1080 per leaf on the assumption that the 1080 was 93% pure (C. L. Batcheler unpubl. data). Any background F^- in the leaves was ignored.

The reliability of the assay method was checked by adding known amounts of 1080 to broadleaf leaves smeared with about 0.4 g of non-toxic gel. Recoveries exceeded 95%, provided the weight of fresh leaves was ≤ 4 g.

Two spike tests were conducted during the assays to check the accuracy of the analysts. Known amounts of 1080 were added to samples of about 0.4 g of non-toxic gel and 4 g of chopped broadleaf leaves. Average recoveries for each batch of six assays were 97% $\pm$ 4.5% and 99% $\pm$ 1.6% ($p = 0.05$) of the expected amounts.

Samples collected from Trial A on the tenth to fourteenth days were ruined during assay and were excluded from the analysis.

Sampling and Analysing Operational Baits

Between 16 February and 16 March 1981, about 2600 toxic broadleaf baits were laid in the 20-km^2 study area. Field staff were instructed to apply 0.15–0.25 g of gel to 20 leaves on each bait. Amounts actually applied per leaf were estimated from samples

of 10 leaves taken from 15 randomly chosen baits on the days they were laid. Amounts of 1080 applied per bait were estimated on the assumption that 20 leaves/bait had been treated. To estimate the loss of 1080 after 15, 30, and 45 days' exposure, all leaves with visible traces of gel were harvested from 25 unbrowsed baits. Treated leaves that had fallen from the baits were ignored. The samples were stored in plastic bags at air temperature until they were sent to the Forest Research Institute and frozen.

The method used for preparing protected baits proved to be unduly vulnerable to accidents in the laboratory. Therefore, for operational baits, leaves were oven dried at 95°C and homogenised. Duplicate 0.8 g samples of homogenate were analysed by the F^- electrode method. Further samples were analysed when duplicates varied by more than 10% of their average. Recoveries were checked by spike tests, as above; over 90% of the amounts added were recovered.

Statistical Analysis

Accumulated rainfall, rainfall during the 24 h before harvesting, and the duration of storage were treated as independent variables for regression analysis of their effects on ln (natural log) of milligrams of 1080 in the leaves. The independent variables were then introduced into step-wise multiple regressions in the order of their decreasing importance (as judged by r values), and the effect of each extra term was assessed by F-ratio tests (Hinkle *et al.* 1979).

The multiple linear regressions for residual 1080 on accumulated rainfall were then used to estimate the amounts of 1080 expected if baits had been harvested on dry days and frozen immediately (i.e., regression coefficients for storage and rainfall during the 24 h before harvesting were set to zero). These derived 1080 estimates were then used in equations for 1080 (mg) $= a.b^w$, where a = estimate of the amount of 1080 applied to the leaves, b = estimated rate of loss per millimetre of rainfall, and w = accumulated rainfall (in millimetres).

Confidence intervals for estimates of 1080 are given for 95% probability, from $t.S/\sqrt{N}$, where N is number of samples, t is Students t for N − 1 degrees of freedom, and S is standard deviation.

RESULTS

Compound 1080 Loss from Protected Baits

Rain fell during the first 6 days of exposure of Trial A baits, from the nineteenth to twenty-sixth days, and on the thirty-first day. Most 1080 was lost during these rainy periods (Fig. 1, Trial A). However, the amounts of 1080 in samples collected on the second to sixteenth days, and the twenty-fourth to thirty-fourth days of exposure, seemed to increase rather than decrease in the manner we expected during rain. These sequences suggested that 1080 was also being lost during storage. Trial B was laid out in dry weather, and most rain fell on the thirteenth to twentieth, twenty-fifth, and thirty-third to thirty-fifth days of exposure. As with Trial A, amounts of 1080 declined during the rain periods, but there was no indication of loss in storage (Fig. 1, Trial B).

These apparent trends were confirmed by regression analyses (Table 1). For Trial A, accumulated rainfall was the most important factor, accounting for 79% of the variation.

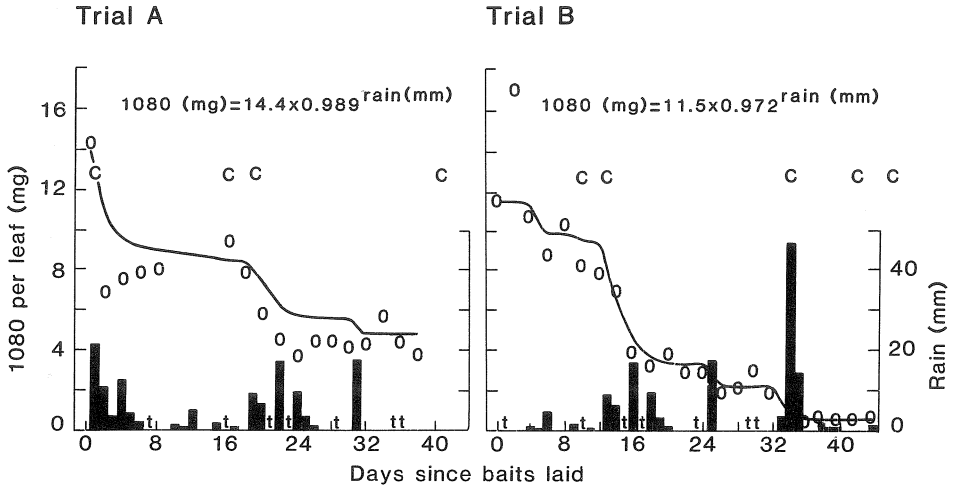

FIG. 1—Observed amounts of 1080 in the two trials with broadleaf baits (open circles) and amounts expected by regression on accumulated rainfall, after eliminating the effects of storage and rain during the 24 h before harvesting (solid lines). Daily rainfall (histograms, "t" = traces), and days on which samples were sent to Christchurch (C) are shown.

Days in storage also significantly affected the loss of 1080, but rainfall during the 24 h before harvesting did not. For Trial B also, accumulated rainfall was by far the most important variable, accounting for 96% of the variation. Storage did not significantly affect the loss of 1080. Surprisingly, however, in view of the low correlation ($r = -0.09$, Table 1), rainfall for the 24 h before harvesting did significantly affect the residual amounts of 1080. This suggests that the qualitative distinction between leaves being wet or dry when they were harvested – rather than the quantity of rain during the preceding 24 h – was the important factor.

TABLE 1—Effects on ln 1080 of accumulated rainfall, rain during the 24 h before harvesting of leaves, and days baits were stored in plastic bags

	r	r^2	SS_E	F to add	df	P
Trial A						
Accumulated rain	–0.89	0.79	21.8	—	—	—
Days' storage	–0.40	0.89	8.0	12.9	1,14	< 0.005
Rain last 24 h	–0.12	0.90	7.3	1.0	1,13	ns
Trial B						
Accumulated rain	–0.98	0.96	40.9	—	—	—
Days' storage	0.24	0.96	40.7	0.02	1,20	ns
Rain last 24 h	–0.09	0.97	45.2	4.4	1,19	< 0.05

r = coefficient of correlation between ln 1080 and stated variable
r^2 = coefficient of determination up to the stated variable
SS_E = Sum of squares of errors

It is of interest, therefore, to note that only six of the 40 observed amounts of 1080 in the two trials were greater than those predicted if baits were sampled on dry days and frozen immediately (Fig. 1). Evidently, although rainfall on the day and period of storage were inconsistent in their effects, they tended to produce low estimates of the amounts of 1080 present.

Amounts of 1080 applied to the leaves, and rates of loss per millimetre of rain, were calculated from the values expected from the regressions of 1080 on accumulated rainfall, assuming the samples were collected dry and frozen immediately. These indicated that: 14.4 mg 1080/leaf had been applied in Trial A and it was lost at a rate of 1.1%/mm rain; 11.5 mg 1080/leaf was applied in Trial B and was lost at a rate of 2.8%/mm rain.

Compound 1080 Loss from Operational Baits

The amount of 1080 applied to each leaf in the control operations averaged 30.2 mg Loss of 1080 after exposure was similar to that from protected baits (Table 2). The average amount of 1080 remaining on intact leaves declined by 70% during the first 15 days of exposure, a further 3% disappeared during the sixteenth to thirtieth days, and 18% disappeared during the thirty-first to forty-fifth days. These estimates indicate an over-all loss per intact leaf of 91% in 45 days.

Laying and sampling dates were not recorded for individual baits, so it was not possible to relate rainfall to individual samples. However, since baits were laid more-or-less continuously between 16 February and 16 March, and 285 mm of rain fell between 15 February and 24 April, the loss of 1080 from intact leaves was about 1.4%/mm rainfall.

TABLE 2—Numbers of operational baits examined, toxic leaves found, and amounts of 1080 remaining in the Stewart Island trial, February 1981

Days elapsed	Baits sampled	No. intact leaves (mean)	1080 mg/intact leaf		1080 mg/bait Mean ± 95% c.l.
			Mean	Remaining (%)	
0	15	20	30.2	100	604 ± 100
15	25	13.4	8.9	29	120 ± 27
30	25	9.6	8.0	26	76 ± 25
45	25	1.9	2.6	8.6	5.0 ± 4.7

DISCUSSION

From the results it seems that accumulated rainfall was the principal cause of loss of 1080 from leaves. Further, the correlation analyses involving storage time and rain during the 24 h before harvesting indicated that biodegradation of 1080 had occurred by the time the samples reached the laboratory.

S. J. Henry (unpubl. data) isolated a *Penicillium* species from broadleaf samples from Stewart Island that degraded 1080 at pH 5.4 and 23°C, and grew vigorously on 10% gel on leaves. Other work has established that a variety of micro-organisms are

capable of degrading 1080 (Atzert 1971; Bong *et al.* 1979). It appears, therefore, that the storage of samples in plastic bags, especially when wet, may have provided conditions suitable for biodegradation by micro-organisms, at least during summer and autumn. Regression analysis of the apparent loss in Trial A samples against days in storage indicates that about 90% of the 1080 could be biodegraded in about 80 days.

The loss of 1080 at the sheltered site occurred at less than half the rate which was recorded on the ridge (Trial A, 1.1%/mm rain; Trial B, 2.8%/mm rain). The most likely reason for this difference was the greater degree of exposure to rain and wind on the ridge. Exposure to wind would increase the movement of water and gel along the leaves during rainstorms, increasing leaching and causing some gel to be washed off. The rate of loss from intact leaves on the operational baits was similar (1.4%/mm rainfall) to the *in situ* loss from Trial A protected baits (1.1%/mm rainfall). This would be expected, as most baits were laid within forest. On average, the Trial A, Trial B, and remaining leaves on operational baits, had lost 90% of their 1080 in 207 mm, 81 mm, and 160 mm rainfall respectively. However, when loss due to abscission of leaves is taken into account, operational baits would have lost 90% of their 1080 in 91 mm rainfall.

Analysis of data reported in earlier New Zealand studies shows similar loss rates for other carriers and baits. Compound 1080 in a polyvinyl acetate emulsion disappeared at about 1.9%/mm rain (M. L. J. Barnett *et al.* unpubl. data). Carrot baits soaked in 1080 solution lost about 3.8%/mm in light rain and 1.2%/mm in a downpour (Daniel 1966). Carrot slices lost between 1.3% and 2.5%/mm, depending on size, and carrot cubes lost about 2.3%/mm rain (Staples 1968). These estimates correspond to 90% losses in 91 mm to 176 mm rainfall.

Higher rates of loss of 1080 are indicated by finite exponential calculations using the data from Australian studies. For carrot baits Griffiths (1959) reported the loss of 5.9%/mm rain, equivalent to 90% in 38 mm, and Corr & Martire (1971) reported losses of 6.4%/mm and 8.1%/mm rain, equivalent to 90% in 35 mm and 27 mm. For oat baits, Griffiths reported a loss of 1.8%/mm rain and Corr & Martire (1971) losses of 3.3%/mm and 5%/mm rain. Corr & Martire also reported losses of 3.4%/mm and 4.5%/mm rainfall from cereal pellet baits.

Thus, the loss of 1080 from the gel applied to broadleaf is similar to or less than losses from most other baits currently used in Australasia for vertebrate pest control. The gel can therefore be regarded as suitable for use in relatively dry climates or in areas with high rainfall where, for reasons such as public safety, a "short-life bait" is desirable. More durable carriers are currently being developed and tested by the Forest Research Institute for use in areas with moderate to high rainfall.

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REFERENCES

ATZERT, S. P. 1971: A review of sodium monofluoroacetate (compound 1080): Its properties, toxicology, and use in predator and rodent control. **US Department of the Interior Special Wildlife Report 146.**

BONG, C. L.; COLE, A. L. J.; WALKER, J. R. L.; PETERS, J. A. 1979: Effect of sodium fluoroacetate ("compound 1080") on the soil microflora. **Soil Biology and Biochemisty 11:** 13–8.

CORR, P. V.; MARTIRE, P. 1971: Leaching by rain of sodium fluoroacetate ("1080") from baits used for rabbit control. **Australian Journal of Experimental Agriculture and Animal Husbandry 11:** 278–81.

DANIEL, M. J. 1966: Early trials with sodium monofluoroacetate (compound 1080) for the control of introduced deer in New Zealand. **New Zealand Forest Service Technical Paper 51.**

FOREST RESEARCH INSTITUTE 1977: Secretary Island – a problem in deer control. **New Zealand Forest Service, What's New in Forest Research No. 50.**

——— 1984: Deer control and vegetation response on Stewart Island. **New Zealand Forest Service, What's New in Forest Research No. 126.**

GRIFFITHS, M. E. 1959: The effect of weathering on the toxicity of baits treated with sodium fluoroacetate. **CSIRO Wildlife Research 4:** 93–5.

HINKLE, D.; WIERSMA, W.; JURS, S. G. 1979: "Applied Statistics for the Behavioural Sciences". Rand McNally, Chicago. 490 p.

PARKES, J. P. 1983: Control of feral goats by poisoning with Compound 1080 on natural vegetation baits and by shooting. **New Zealand Journal of Forestry Science 13:** 266–74.

STAPLES, E. L. J. 1968: The reduction of the monofluoroacetate ("1080") content of carrot baits of various thicknesses by weathering. **New Zealand Journal of Agricultural Research 11:** 319–29.