Bull. Environ. Contam. Toxicol. (1996) 56:942-947

Environmental Contamination and Toxicology

Effect of Temperature on the Biodegradation of Sodium Monofluoroacetate (1080) in Water and in *Elodea canadensis*

S. C. Ogilvie, F. Hetzel, C. T. Eason

Manaaki Whenua—Landcare Research, P.O. Box 69, Lincoln, New Zealand

Received: 25 July 1995/Accepted: 14 December 1995

The introduced arboreal marsupial brushtail possum (*Trichosurus vulpecula*) is regarded as New Zealand's number one vertebrate pest, with an estimated $27 million spent on control in 1993/94 (Livingstone 1994). Large-scale possum control is based on the aerial application of toxic baits containing sodium monofluoroacetate (1080), which is highly toxic to mammals, including marsupials (Morgan 1994). Sodium monofluoroacetate is extremely water soluble and may be leached by rainfall from toxic baits into the environment. This has generated public concern about the contamination and persistence of 1080 in aquatic systems, particularly after aerial application of 1080 baits (Thomas 1994).

Various micro-organisms have the ability to catalyse the cleavage of the C-F bond of fluoroacetate, degrading fluoroacetate to glycolate and fluoride ions (e.g., Goldman 1965, Goldman et al. 1968, Bong et al. 1979, Wong et al. 1992). For aquatic systems, degradation of 1080 has been shown in aquaria containing plants and invertebrates, where the concentration of 1080 declined by approximately 70% in 24 h and to below detectable levels (0.0003 µg/mL) after 100 h (Eason et al. 1993). Although these experiments indicated that significant contamination of waterways is unlikely, they were undertaken at a temperature of 20°C. Water temperatures in winter in New Zealand, when possum control operations are often scheduled, are likely to be less than this. This paper therefore presents a preliminary study on the influence of both 21°C and 11°C temperatures on the biodegradation of 1080 in the water and plant components of an aquatic ecosystem.

MATERIALS AND METHODS

Streamwater and plant material (the introduced aquatic plant *Elodea canadensis*) were collected in November 1993 from the Waimakariri River, Canterbury, New Zealand. Sodium monofluoroacetate (95% purity) was obtained from the Sigma Chemical Company St. Louis, USA.

Two experimental aquaria containing 80 L of streamwater and approximately 1.5 kg of *E. canadensis* and a third containing deionised water (control) were set up in each of two controlled temperature rooms at 11 °C and 21 °C. All aquaria were left to equilibrate for 4 days before experiments began. The water temperature stabilised in the controlled

Correspondence to: S. C. Ogilvie

temperature rooms at 11 ±0.5°C and 21 ±0.5°C. The mean overall pH was 6.98 (S.E. = 0.02) in the experimental aquaria and 5.58 (S.E. = 0.07) in the control aquaria. The mean dissolved oxygen concentration for all aquaria was 93.3% (S.E. =0.51).

Sufficient 1080 was added to each aquarium to give an initial concentration of 0.12 µg 1080/mL, which is equivalent to three possum baits (4 g baits containing 0.08% 1080 w/w) falling into 80 L of water. This is 40 times greater than the highest concentration measured in field samples after control operations (Eason 1995), and so is representative of a scenario which is likely to be worse than expected in a field situation. Temperature, pH, and dissolved oxygen were monitored daily. Water samples were taken from all aquaria at 0, 2, 24, 48, 72, 101, and 141 h after the addition of 1080. Plant samples were taken at 0, 2, 8, 24, 32, 77, 192 and 240 h from four random sites within each aquarium. All samples were stored at -20°C for later analysis.

Concentrations of 1080 were measured and quantified by gas chromatography based on procedures developed by Ozawa and Tsukioka (1987). In the water samples, 1080 was acidified with hydrochloric acid and converted to the dichloraniline derivative, using dicyclohexylcarbodiimide and 2,4-dichloraniline. The derivative was extracted with ethyl acetate, cleaned with a silica column, and quantified by gas chromatography using electron capture detection. In the plant tissue samples, the 1080 concentration was determined the same way, with the addition of an initial extraction in which the aqueous content of the plant material was obtained by dispersing it in an alcohol/water mixture, then deproteinsing, centrifuging, filtering and passing it through an ion exchange column. Using these techniques, the limit of detection is 0.0001 µg/L in water and 0.0015 µg/kg in plant tissue.

The fluoride ion concentration of the water samples was determined using a fluoride ion specific electrode. A volume of 20 mL of the water sample was added to 20 mL of buffer and the reading of the electrode was recorded. Fluoride ion concentration was subsequently calculated from a standard curve.

The rate of change of 1080 concentration in each experiment was compared using repeated-measures Analysis of Variance with temperature as the categorical variable.

RESULTS AND DISCUSSION

Although the concentration of 1080 remained relatively constant in the deionised water at both temperatures, the concentration in streamwater decreased with time (Figs 1 & 2). This degradation of 1080 in streamwater suggests that micro-organisms with the ability to break down 1080 are present in aquatic ecosystems in New Zealand.

The overall rate of degradation of 1080 in streamwater was significantly different at the two temperatures ($P<0.001$). During the first 24 h the concentrations of 1080 declined by approximately 25% at both temperatures (Figs 1 & 2). However, between 24 and 48 h the streamwater maintained at 21°C showed a significantly larger decrease in 1080 concentration than that at the lower temperature ($P=0.042$). The different rate of degradation was maintained for the 48 to 72 h time period ($P=0.023$). No 1080 could be detected in the warm water after 141 h, but approximately 30% of the initial dose was still present in the cool water.

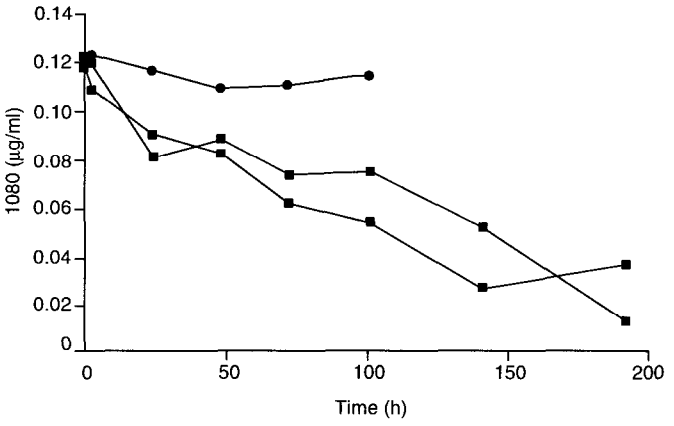

Figure 1. Degradation of 1080 in streamwater (■) (two replicates) and deionised water (•) at 11°C.

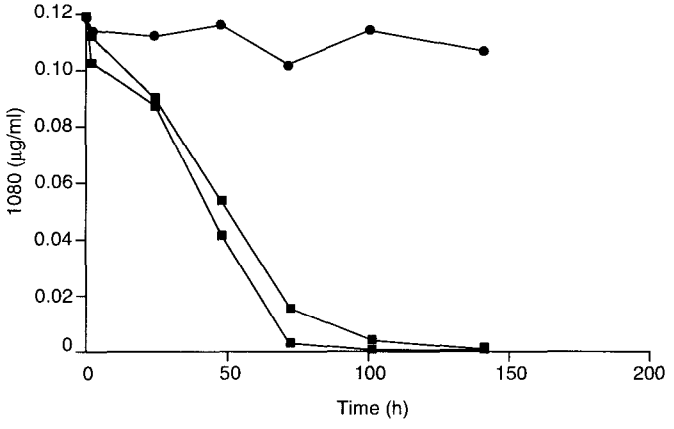

Figure 2. Degradation of 1080 in streamwater (■) (two replicates) and deionised water (•) at 21°C.

The amount of inorganic fluoride ions measured in streamwater increased with time at both temperatures. The highest rate of fluoride ion release was measured between 24 and 72 h in the water at 21°C which corresponded with the highest rate of 1080 degradation. The amount of 1080 and fluoride ions present at given time points formed a stoichiometric relationship (Table 1). This relationship provides further evidence that some micro-organisms degrade 1080 by cleaving the carbon-fluorine bond to yield fluoride ions and glycolate (Meyer et al. 1990; Wong et al. 1992).

The 1080 concentrations in the plant samples indicated that *E. canadensis* plays a mediating role in the degradation of 1080 in aquatic systems. The 1080 concentration in *E. canadensis* reached a maximum at about 24 h for both temperatures (Figs 3 & 4). The subsequent degradation of 1080 was temperature-dependent; it was significantly faster at 21°C than at 11°C (P=0.022). After 192 h 1080 was undetectable in the plant samples at 21°C but traces of 1080 were still detectable at 11°C.

Table 1. Stoichiometry of 1080 and fluoride ion abundance. Amount (mol) of 1080 disappearing and fluoride ions being formed over time at two temperatures.

	11 °C		21 °C	
Time (h)	1080	Fluoride	1080	Fluoride
0	0	0	0	0
2	5.2	8.4	10	19.0
24	28.1	37.9	24.3	37.9
72	42.6	59.0	88.8	88.4
141	65.9	67.4	96	105.3
192	77.2	88.4	-	-

- Data not recorded

Our study could not distinguish the relative role of plants and micro-organisms in the degradation of 1080, but other plants such as the peanut (*Archis hypogeae*) are able to cleave the carbon-fluorine bond of fluoroacetate and liberate inorganic fluoride (Preuss & Weinstein 1969). Determining whether *E. canadensis* has the same capacity is worthy of further investigation, as is the possible role of endemic plant species in the biodegradation of 1080 in New Zealand.

The strong evidence from our study that biodegradation of 1080 in this aquatic ecosystem is temperature-dependent indicates that it is likely that any 1080 falling into streams will persist longer when it is applied at colder times of the year.

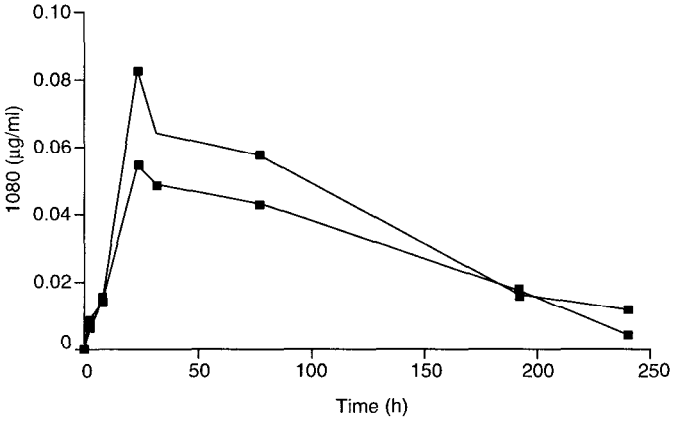

Figure 3. Uptake and persistence of 1080 in *E. canadensis* at 11°C (two replicates).

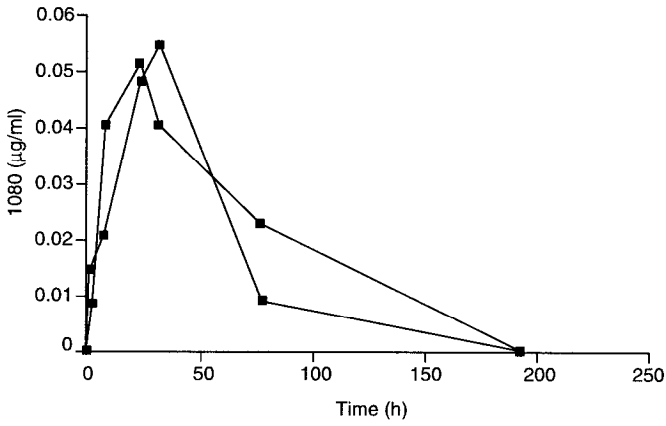

Figure 4. Uptake and persistence of 1080 in *E. canadensis* at 21°C (two replicates).

Acknowledgements. We thank the Department of Entomology and Animal Ecology, Lincoln University for the use of their controlled temperature rooms. Mandy Morgan and Geoff Wright are thanked for analytical support, Joanna Orwin and James Ataria for editorial comment, and Manjula Arulchelvam for statistical analyses. This research was supported by the Foundation for Research, Science and Technology (C09307).

REFERENCES

Bong CL, Cole ALJ, Walker JRL (1979) Effect of sodium monofluoroacetate (compound 1080) on the soil microflora. Soil Biol Biochem 11: 13-18.

Eason CT, Gooneratne R, Wright GR, Pierce R, Frampton CM (1993) The fate of sodium monofluoroacetate (1080) in water, mammals, and invertebrates. Proc 46th NZ Plant Prot Conf 297-301.

Eason CT (1995) Sodium monofluoroacetate (1080): an update on recent environmental toxicology data and community concerns. Proc 10th Australian Vert Pest Conf 39-43.

Goldman P (1965) The enzymatic cleavage of the carbon-fluorine bond in fluoroacetate. J Biol Chem 240:3434-3438.

Goldman P, Milne GWA, Keister DB (1968) Carbon-halogen bond cleavage-III. Studies on bacterial halidohydrolases. J Biol Chem 243:428-438.

Livingstone PG (1994) The use of 1080 in New Zealand. In: Seawright, A.A.; Eason, C.T. eds. Proceedings of the Science Workshop on 1080. Royal Society of New Zealand miscellaneous series 28:1-9.

Meyer JJ, Gobelaar N, Steyn PL (1990) Fluoroacetate-metabolizing pseudomonad isolated from *Dichapetalum cymosum.* Appl. Environ Microbiol 2152-2155.

Morgan DR (1994) Improved cost-effectiveness and safety of sodium monofluoroacetate (1080) possum control operations. In: Seawright, A.A.; Eason, C.T. eds. Proceedings of the Science Workshop on 1080. Royal Society of New Zealand miscellaneous series 28:144-150.

Ozawa H, Tsukioka T (1987) Gas chromatographic determination of sodium monofluoroacetate in water by derivatization with dicyclohexylcarbodiimide. Anal Chem 59:2914-2917.

Preuss PW, Weinstein LH (1969) Studies on fluoro-organic compounds in plants. II. Defluoroination of fluoroacetate. Contrib Boyce Thompson Inst 24:151-155.

Thomas MD (1994) Possum control in native forest using sodium monofluoroacetate (1080) in bait stations. Proc 47th NZ Plant Prot Conf 107-111.

Wong DH, Kirkpatrick WE, King DR, Kinnear JE (1992) Defluorination of sodium monofluoroacetate by microorganisms isolated from Western Australian soils. Soil Biol Biochem 24(9):833-838.