Undermining Weeds TECHNICAL NOTE

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Environmental fate of terbuthylazine and hexazinone: Two New Zealand case studies

Summary

Two of the most commonly used and effective herbicides used in New Zealand planted forests are terbuthylazine and hexazinone. There is limited information on the environmental fate of these herbicides in the planted forest environment. Two field studies were undertaken to test these herbicides' environmental fate in forest litter, soil and stream water following aerial application. The first month after spray application was found have the greatest potential risk of herbicide movement off-site. After this time the risks were low due a rapid half-life resulting in low amounts of the herbicide on site. Forest floor litter played an important role in limiting the movement of terbuthylazine down the soil profile, indicating the importance of harvest residues in determining the environmental fate of this herbicide. Highest concentrations in stream water occurred either on the day of herbicide application, or during rainfall events shortly thereafter, and up to one month after application. Spray application according to manufacturers' instructions and forest companies' requirements, and the retention of a 'no-spray' margin along stream channels were important factors minimising herbicide entry into waterways. The risk to drinking water and aquatic organisms was low under these circumstances.

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Introduction

Weed control during the establishment of planted forests is critical to the uniformity and economic viability of the final tree crop. Herbicides play an important role in the management of competing vegetation, and currently provide the most efficient and cost-effective method for achieving this in New Zealand's planted forests [1]. However, there is insufficient information to be confident on the environmental fate of herbicides commonly used in New Zealand planted forests.

To date, two field studies have been undertaken for the two herbicides commonly used by the forest industry for post-plant weed control; terbuthylazine and hexazinone [2-5]. These herbicides were aerially applied to two planted forest soil types, Pumice and Recent soils, to determine their behaviour and fate in the planted forest environment.

This technical note provides a summary of the results of this research [2-5].

Study trial sites and method

Two experimental catchment study sites were selected in the Bay of Plenty region of New Zealand; one on a Pumice soil (Fig. 1) and the other on a Recent soil (Fig. 2). Both these soil types make up a significant area of New Zealand planted forests (25% and 13%, respectively) and are considered vulnerable to terbuthylazine and hexazinone movement off-site due to their low soil carbon concentrations.

The sites were aerially sprayed for post-planting weed control in the spring; the Pumice soil site with Release KT™ (Orion Crop Protection Limited, Christchurch; 435 g L^{-1} terbuthylazine and 65 g L^{-1} hexazinone) applied at 17 L ha^{-1}; and the Recent soil site with Agpro Valzine Extra (AGPRO NZ Ltd, Auckland; 400 g L^{-1} of terbuthylazine and 100 g L^{-1} of hexazinone) applied at 15 L ha^{-1}.

Figure 1: Pumice soil site showing soil profile.

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Monitoring was under taken pre- and post-spray application:

- *Terrestrial environment* – Monitoring of herbicides in the forest floor (which included harvest residues from the previous crop) and mineral soil to 1 m depth to determine movement down the soil profile and persistence.
- *Aquatic environment* – Monitoring of herbicide residues in stream water, sediment and algae (Pumice soil site only) at the treated area and at various points downstream to determine the persistence of these two herbicides in the aquatic environment.
- *Monitoring length* – The trials were monitored for at least six months post-spray application. The Pumice soil site had two spray applications, the first in spring 2012 and the second in spring 2013 while the Recent soil site had one spray application in spring 2014.

Figure 2: Recent soil site showing steep terrain.

Movement down the soil profile

The presence of the forest floor layer (litter and harvest residues) played a significant role in herbicide retention in the upper soil profile, particularly for terbuthylazine. The majority of the herbicide was retained in the forest floor layer and the upper 0-10 cm of soil depth at both the Pumice (Fig. 3) and Recent soil sites.

Drainage events resulted in movement of herbicide down the soil profile. However, only small amounts were detected at the lowest monitoring depth (50–100 cm) indicating that movement in general was limited to the upper 1 m. Detailed results were:

- *Pumice soil site 2012:* No drainage past 1 m depth within the first five months after the first spray application due to a regional drought. This resulted in very limited movement of both terbuthylazine and hexazinone down the soil profile.
- *Pumice soil site 2013:* Three drainage events occurred after spray application, 30 mm of drainage occurred at 7–8 days, 32 mm occurred at 36–37 days and 24 mm occurred 170 days after spray application. Even with drainage, both terbuthylazine and hexazinone were located predominantly in the forest floor and top-soil (0–10 cm) layers with only small amounts detected at the lowest monitoring depth (50–100 cm). See Figure 1 and Figure 3.
- *Recent soil site 2014:* There was no drainage in the first month after spray application. The following month there were six drainage events ranging from 12–36 mm. Both active ingredients were mostly found at 0–10 cm, followed by the forest floor layer (the amount of forest floor on site was much less when compared to the Pumice soil site). Following the month of drainage events, hexazinone was detected at a soil depth of 10–50 cm. Relatively little terbuthylazine was found at depths below 10 cm during the sampling period.

The above results suggest that the forest floor and soil organic carbon are capable of binding terbuthylazine and reducing its mobility. Hexazinone is more mobile than terbuthylazine due to its greater water solubility and therefore moved more readily down the soil profile with drainage events. However, hexazinone movement was mostly from upper depth to the 10–50 cm soil depth and only small amounts below to 50 cm to 1 m depth at both trial sites.

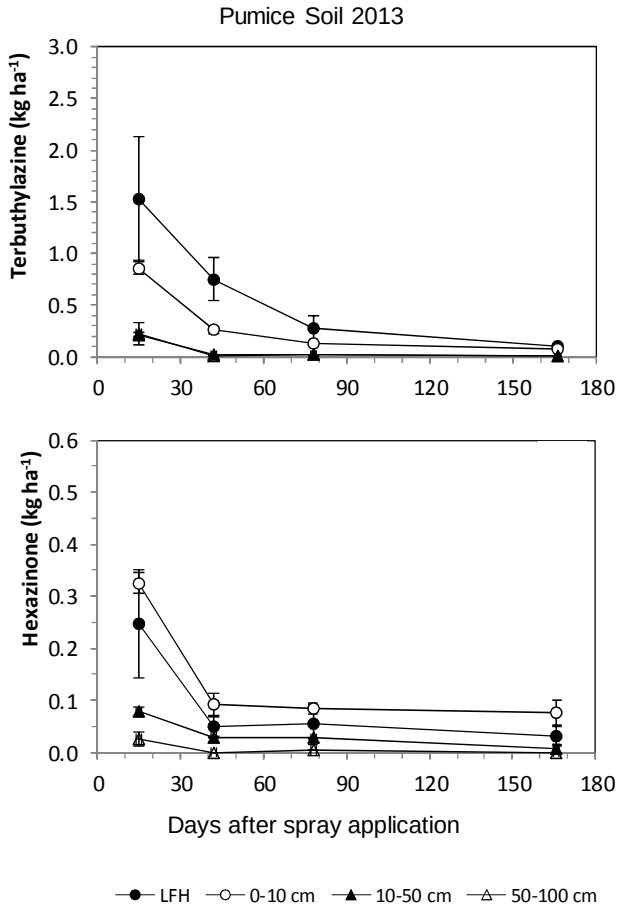

Figure 3: Pumice soil 2013 shown as an example of the distribution and average amount of terbuthylazine and hexazinone (kg ha^{-1}) within the forest floor layer (LFH) and at different soil depths.

Persistence in the terrestrial environment

The persistence of a herbicide, also described as its half-life, is important for assessing its environmental fate as it determines how long it will stay within the environment.

The measured half-lives at the Pumice soil site were up to 10 days for terbuthylazine and up to 18 days for hexazinone. These values are much shorter than accepted international values reported as 30-60 days and 30-180 days, respectively. These rapid half-lives are comparable to measured half-lives under laboratory conditions of 20°C which reflect late spring temperatures at this site [3].

The measured half-life for the Recent soil site was less than one day for both herbicides and it is unclear why this site should have much higher rates [2] (Fig. 4).

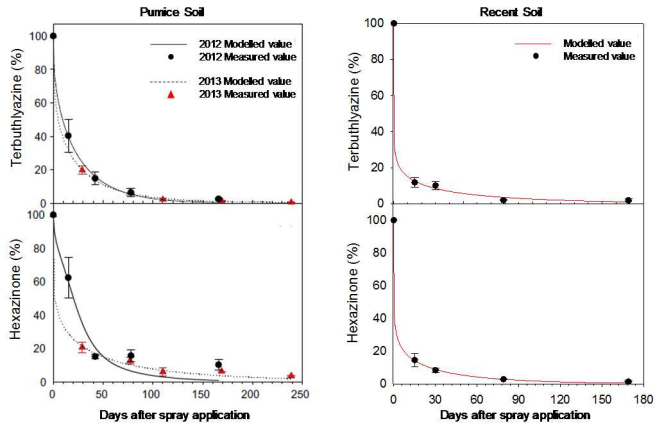

Figure 4: Changes in per cent remaining over time since spray application of terbuthylazine and hexazinone.

As a result of the short half-lives of both herbicides, the first month after spray application was found to pose the greatest potential risk of movement off-site. Potential risks were low after this period as the amount of herbicide on-site was also low.

Concentrations and persistence in the aquatic environment

At the Pumice soil site, a 10 m 'no-spray' margin was retained along the stream edge. In the first year of herbicide application, highest concentrations of both herbicides were detected in the stream water (Fig. 5), sediment and algal samples on the day of herbicide application, mainly as a result of spray drift.

In the second year of herbicide application, the stream water concentrations of both herbicides were 1-2 orders of magnitude lower than in previous year due to a smaller treated area and maintaining a more conservative boundaries along the stream edge. Instead, the highest concentrations of both herbicides were recorded in stream water during a rainfall event of 32 mm, seven days after application (Fig. 6). Possible sources included wash-off from logging slash and vegetation, and mobilisation of residues within the stream channels. Thereafter, herbicide concentrations in stream water declined rapidly at the treatment site for both years.

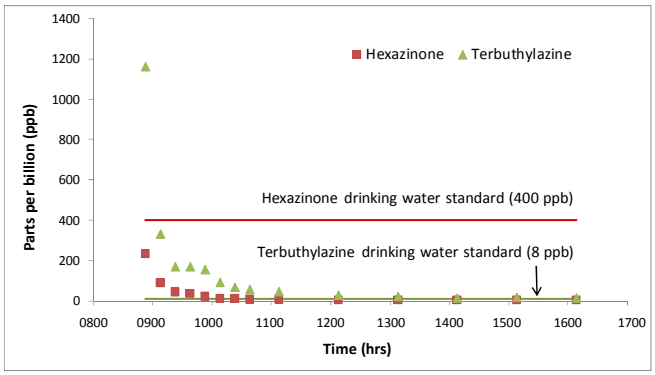

Figure 5: Concentrations of terbuthylazine and hexazinone detected in stream water on the day of application at the Pumice soil site in Year 1.

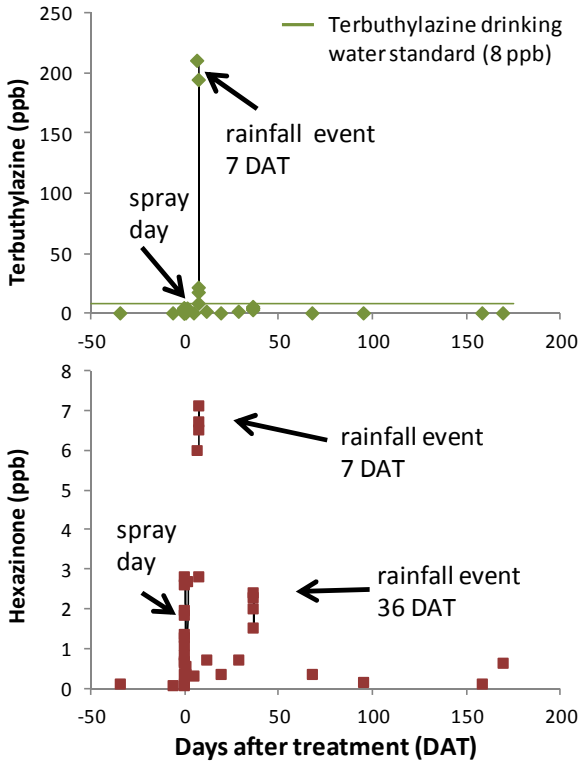

Figure 6: Concentrations of terbuthylazine and hexazinone in stream water at the Pumice soil site in Year 2. New Zealand drinking water standard for hexazinone of 400 ppb not shown graph.

Concentrations of terbuthylazine were higher in sediment samples, and persisted for longer, compared with hexazinone in both years of the Pumice soil trial (Year 1 – four months; Year 2 – at least five months). Both herbicides were only detected in algal samples on the day of herbicide application in Year 1. In Year 2, while no hexazinone was detected, terbuthylazine was present in algal samples for one month after application.

At the Recent soil steepland site, a 30 m no-spray margin was retained along the stream edges. The 30 m buffer provided variable protection from spray drift with added protection provided by the layer of logging slash in the stream channel.

Stream water monitoring (Fig. 7) recorded the highest concentrations of both herbicides on the day of herbicide application (<10 ppb). Herbicide concentrations in stream water increased slightly around one month after application which was two days after the highest daily rainfall event (52 mm). Only terbuthylazine was detected in the sediment samples for up to two months after herbicide application.

Figure 7: Water quality monitoring at the Recent soil steepland site.

Concentrations of both herbicides in stream water at both the Pumice soil and Recent soil sites declined downstream and were below detection limits at the base of the two catchments for most of the monitoring period.

Managing the risks

Organic matter management in planted forestry, including forest floor and harvest residue retention, plays an important role in determining the environmental fate of both terbuthylazine and hexazinone. These factors should be considered in risk-based management decision making in the future.

The day of spray application and any significant rainfall events within the first month potentially pose the greatest risk to receiving aquatic environments. After the first month the risks were low due a rapid half-life of the herbicides resulting in low amounts of the herbicides on site.

Any rainfall event that results in significant drainage during the first month will likely result in movement down the soil profile of hexazinone and, to a lesser extent, terbuthylazine. However, the risk of herbicide transfer to waterways via leaching processes at these sites was likely to be low due to the limited movement of these two herbicides down the soil profile.

The risk to drinking water following aerial application of these two active ingredients was low based on the results of these two studies. The New Zealand drinking water limit for terbuthylazine of 8 ppb is based on an adult with a body weight of 60-70 kg, consuming 2 L of water per day over an average lifetime of 70 years. The duration that terbuthylazine concentrations exceeded this limit was <24 hours, indicating a very low risk to human health. The New Zealand drinking water standard for hexazinone was never exceeded during the trials. When assessing both the concentrations and persistence of these two herbicides in the aquatic environment against environmental standards for aquatic organisms, the risk to the aquatic receiving environment was also low.

Management factors that contribute to minimising entry of herbicides into water ways include the precision application of herbicides using latest technologies, according to manufacturers' instructions and operational requirements. Retention of a 'no-spray' zone along the stream edges is critical in minimising the amount of herbicide residues reaching the stream channel and potentially available for transfer into the stream channel during rainfall events. Logging slash resides in the stream channel, also provide additional protection from potential spray drift.

Conclusions

Risks from terbuthylazine and hexazinone to receiving soil and aquatic environments should be minimal as long as herbicides are applied according to manufacturers' instructions and forest operational requirements.

References

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Acknowledgements

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