The effects of dicyandiamide (DCD) leaching and runoff on aquatic environments

Scientific evidence based on a stream survey and field experiments

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Background

Prior to its withdrawal from the market in 2013, use of the nitrification inhibitor dicyandiamide (DCD) to farmland had been increasing in New Zealand, mainly on dairy farms, as one of the strategies to reduce nitrogen losses from soils and enhance efficiency of nitrogen use by farm plants. However, DCD itself is readily water soluble and can be leached to streams and wetlands draining farmland, where it can interact with the nitrogen cycle to potentially affect freshwater ecosystems.

When this research project started in 2012, the effects of DCD on freshwater ecosystems were unknown, both as a single stressor and when combined with other important agricultural stressors such as fine sediment, elevated nutrients and stream water abstraction for farm irrigation. Addressing these knowledge gaps is important given the ongoing expansion of the dairy industry in New Zealand and the associated need to maintain or improve the physicochemical water quality and ecological integrity of our streams, rivers and wetlands.

Approaches and Methods

Scientists at Otago University and NIWA examined the effects of DCD in combination with other agricultural stressors using a survey of 43 Southland streams and rivers, three manipulative experiments in 128 small circular stream channels on the banks of a North Otago river, and one experiment in mesocosms installed in a headwater seepage wetland on a Waikato dairy farm. The biological responses studied included both structural indicators (stream algae, bacteria, invertebrates and fish) and ecosystem processes (e.g. algal biomass accrual and organic matter decomposition), to provide a comprehensive assessment of the potential impacts of DCD.

Figure 1. *The Southland stream and river sites (indicated by red dots; stream orders mainly 4-6, stream widths about 3-50 m) sampled during the survey (left), the setup with 128 circular stream channels in North Otago used for the three stream channel experiments (middle), and the mesocosm experiment in a headwater seepage wetland on a Waikato dairy farm (right).*

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Key Results

In the Southland stream/river survey, none of the fairly large sites (widths 3-50 m or more) contained DCD concentrations above the detection limit of the HPLC method (10 µg/L). However, this result may have been due to downstream dilution and/or rapid degradation of DCD, because concentrations of up to 5 mg/L were observed in two small streams (width 0.2-0.5 m) on a Waikato dairy farm after DCD application to pasture land (Richard Storey; NIWA, unpublished data).

For stream algae and invertebrates, which are widely used in stream health assessment in New Zealand and overseas, our combined findings indicate that DCD appears to be a relatively benign stressor (in terms of effect frequency and effect size) compared to the known agricultural stressors of deposited fine sediment, stream flow velocity reduction and nutrient enrichment.

- Experiment 1: DCD applied constantly; treatments included the highest concentrations observed in farmland streams plus two higher values, to simulate uncontrolled surface runoff from farms with recent DCD application. Significant effects of DCD always weakly negative (4 of 4 cases).
- Experiments 2 and 3: Lower DCD concentrations were applied in one constant treatment plus two pulsed treatments, mimicking concentration pulses observed in real farmland streams. Here more positive (6 of 9 cases) than negative (3 of 9 cases) significant responses to DCD occurred.
- Interactions of DCD with other stressors were generally uncommon and weak, implying that DCD addition rarely made other stressor effects worse, in contrast with stronger interactions between elevated fine sediment and nutrient levels or elevated sediment and flow reduction resulting in more negative combined outcomes (synergistic interactions) in the same three experiments.

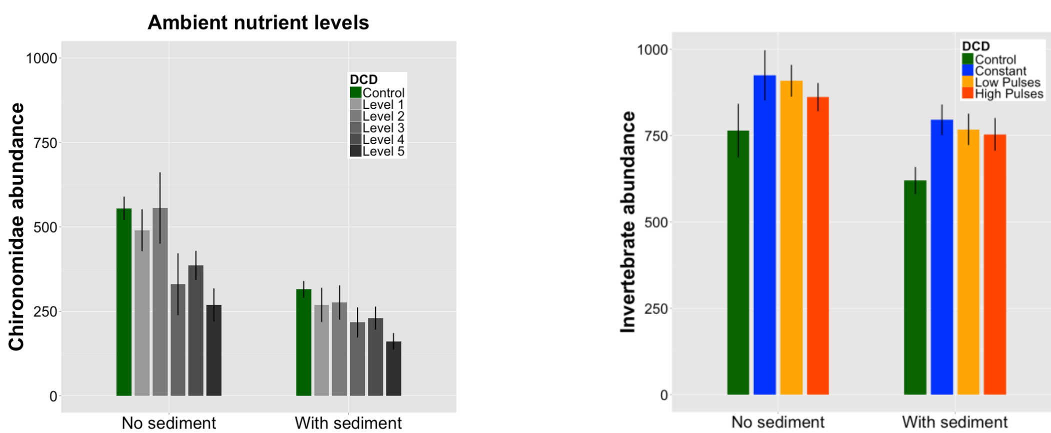

***Figure 2**: Examples of negative effects of DCD addition on the common stream invertebrate family Chironomidae (larval midges) in Experiment 1 (spring 2012, low to very high DCD concentrations applied continuously; left panel), and positive effects on the total abundance of stream invertebrates (via positive effects on mud snails, oligochaete worms and larval midges) in Experiment 2 (autumn 2013, lower DCD concentrations including two pulsed treatments; right panel).*

For wetlands, the results of our experiment in a grassy headwater wetland suggest that DCD is likely to reduce the export of inorganic nitrogen to streams, probably because any ammonium accumulating due to the inhibition of nitrification by DCD is rapidly taken up by wetland plants.

Management Implications

In conclusion, our findings imply that due to the relatively benign nature of DCD as a stressor, reducing or preventing DCD leaching and runoff to waterways might not be as pressing as mitigating deposited fine sediment, stream flow reduction and nutrient enrichment. However, mitigation measures aimed at restoring intact riparian vegetation are likely to be a efficient way to reduce multiple-stressor impacts on farmland streams in general, not just DCD impacts. Thus, establishing riparian buffers would help reduce inputs of fine sediment, nutrients and possibly also DCD from farmland, stabilize stream banks and prevent livestock access to waterways.

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