



Forestry Commission

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The effect of aerial applications of urea fertiliser on stream water quality

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Abstract

The effect on stream water quality of aerial applications of urea fertiliser to forests was investigated in three forest districts in Scotland. Results suggest that applications to more than 15% of a catchment have the potential to cause ammonium concentrations in receiving streams to exceed the mandatory water quality standards set for the protection of freshwater fish. The Forestry Commission's *Forests and water guidelines* have recently been amended to ensure that future applications pose little threat to the freshwater environment.

Introduction

Two incidents arose during 1990 where a standard aerial application of urea fertiliser polluted local streams. Both were caused by a period of very heavy rainfall shortly after the application. This resulted in the direct wash-off of the fertiliser, causing ammonium concentrations within local stream waters to exceed mandatory water quality standards for a period of several days.

Strict standards are set for ammonium in surface waters to protect drinking water supplies and freshwater life. Although ammonium is not toxic in itself, it has a number of indirect effects. These range from its conversion to highly toxic ammonia under alkaline conditions, to its contribution to nutrient enrichment and increased growth of bacteria and algae.

Following discussions with the National Rivers Authority a monitoring programme was initiated in autumn 1991 to determine the threat posed by routine aerial applications of urea fertiliser to water quality. This Note summarises the results of the monitoring and considers the implications for fertiliser practice.

Monitoring programme

Six applications of urea fertiliser, comprising the complete fertiliser programme in three Forestry Commission districts (Loch Awe, Lorne and Easter Ross), were selected for monitoring in 1991. The fertiliser was applied by helicopter to areas ranging from 43-200 ha in extent at the standard rate of 350 kg ha⁻¹ (150 kg N ha⁻¹) in September or October. Applications are usually carried out in late spring or early summer but were delayed that year due to operational problems. The sites were located in upland areas (200-450 m elevation) with slopes ranging from gentle to steep and soils comprising peaty gleys, peat and peaty podzols. All applications were carried out on dry days, but were preceded by a period of wet weather. Each site was drained by a number of streams; the catchments of these streams varied in the proportion receiving fertiliser treatment. Samples were collected

from fertilised and control streams before and at frequent intervals after an application, by local staff. Refrigerated samples were sent overnight to the Forestry Commission's research station at Alice Holt for chemical analysis. Ammonium was determined in water samples by an automated colorimetric technique. Daily rainfall totals were obtained from local meteorological stations.

Results

The results for three of the fertiliser applications (Cononish, Lorne; Inverinan, Loch Awe; Ardross, Easter Ross: site and sampling locations in Figure 1) are presented in Figures 2-4. These exemplify the

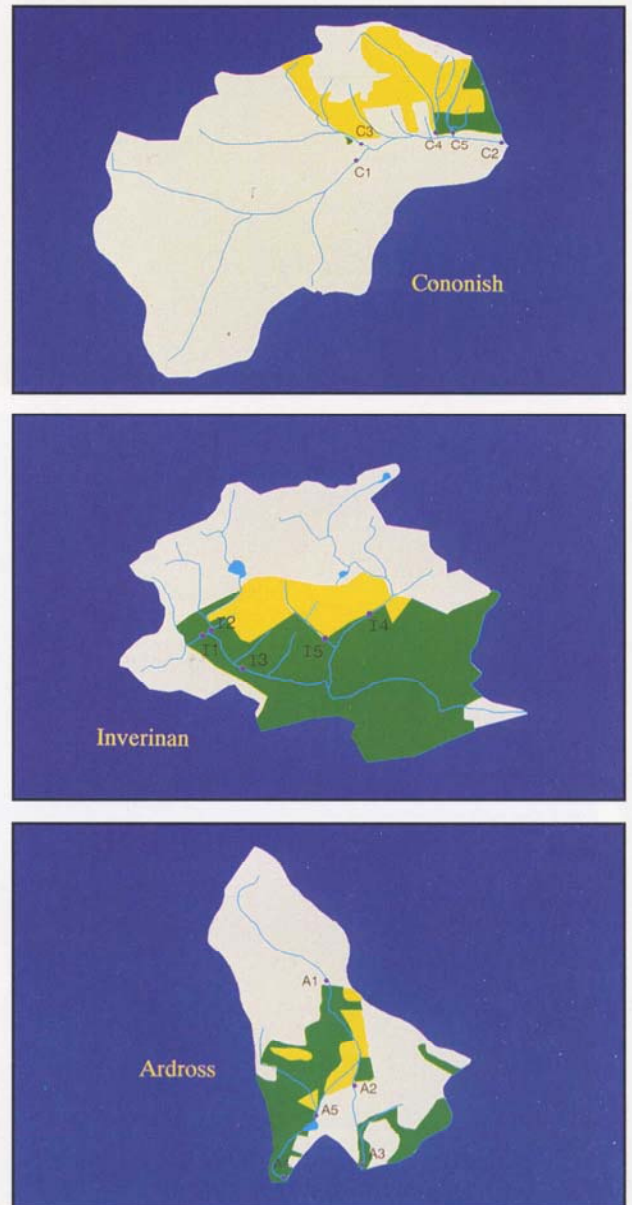


Figure 1. Location of stream water sampling sites and the area of forest receiving an aerial application of urea fertiliser within the catchments at (a) Cononish, (b) Inverinan and (c) Ardross. The fertilised area is shaded yellow and the unfertilised forest area shaded green.

range in response that was recorded across the full set of six sites. At all sites there was a rapid increase in the concentration of ammonium in receiving streams. The response was clearly affected by the wet ground conditions at the time. Concentrations generally increased with the extent of application and remained undetectable in all control streams.

The greatest initial response was recorded at the Cononish site, where the application was preceded by an extremely wet period (249 mm of rain in the previous 13 days). Concentrations peaked on the day of the application, reaching a maximum of 1.9 mg NH₄-N l⁻¹ in the C4 stream catchment which had 51% of its area treated. There was no obvious reason why this response should have exceeded the larger scale 60% treatment in the adjacent C5 stream catchment. A second, smaller peak in concentration occurred during the first period of heavy rainfall, four days after the application. By the end of this period, however, concentrations had declined to near the background value of <0.01 mg NH₄-N l⁻¹ and failed to respond to subsequent rainfall events.

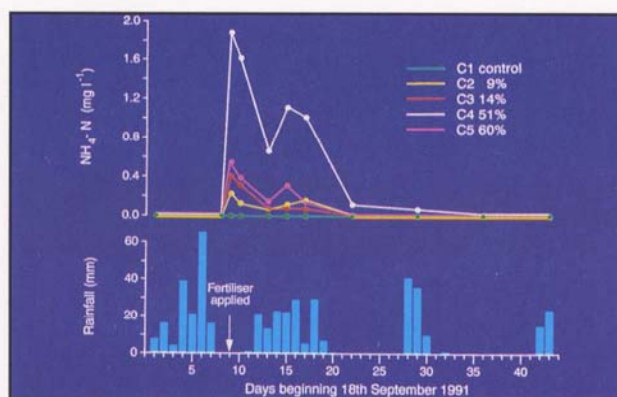


Figure 2. A comparison of the concentration of ammonium in streams draining control and treated areas with daily rainfall totals at Cononish. Total catchment areas of individual treated streams were 2051 ha (C2), 289 ha (C3), 175 ha (C4) and 38 ha (C5). Percentage values in this and subsequent figures refer to the proportion of the individual stream catchments that received an aerial application of urea.

At Inverinan the maximum concentrations occurred seven days after the application, during the first period of very heavy rainfall (87 mm over three days). Concentrations peaked at 4.66 mg NH₄-N l⁻¹ in the 70% treatment of the I5 stream catchment. Thereafter, they declined towards the background value and, as at Cononish, were unaffected by subsequent rainfall.

The small scale of the fertiliser applications at Ardrross resulted in a much lower response at this site. A maximum concentration of 0.35 mg NH₄-N l⁻¹ was recorded in the 11% treatment of the A5 stream catchment during the first period of rainfall after the application.

Overall, the response time of the fertiliser applications was very short, with concentrations returning to background levels in two to four weeks.

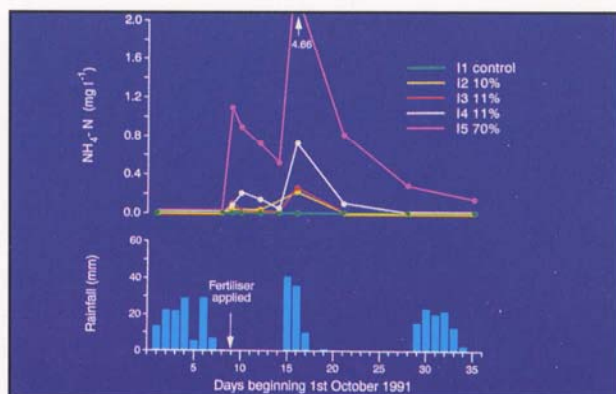


Figure 3. A comparison of the concentration of ammonium in streams draining control and treated areas with daily rainfall totals at Inverinan. Total catchment areas of individual treated streams were 325 ha (I2), 551 ha (I3), 384 ha (I4) and 60 ha (I5).

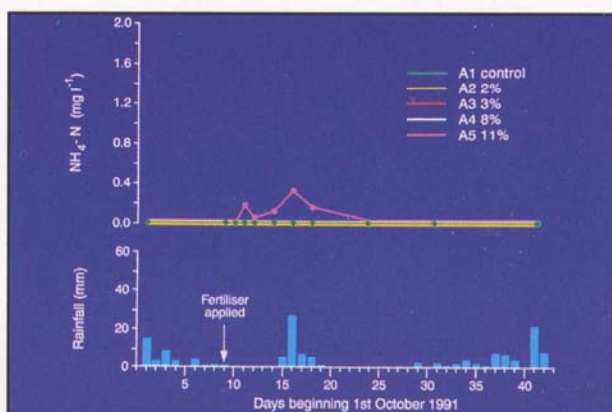


Figure 4. A comparison of the concentration of ammonium in streams draining control and treated areas with daily rainfall totals at Ardrross. Total catchment areas of individual treated streams were 478 ha (A2), 847 ha (A3), 252 ha (A4) and 163 ha (A5).

Discussion

The European Union Water Directive (78/659/EEC) sets a mandatory maximum concentration for ammonium of 0.78 mg NH₄-N l⁻¹ for the protection of freshwater fisheries. This is also the guide standard concentration which is specified in a second directive (75/440/EEC) concerning the abstraction of surface water for potable supply (where normal water treatment facilities are available). At both the 51% catchment fertiliser treatment at Cononish and the 70% treatment at Inverinan, this standard was exceeded by a significant margin (a factor of 2 to 6) for a period of around nine days. The standard was not exceeded where applications were made to less than 15% of a catchment.

The nature of the response in ammonium concentrations to the applications suggests that the main mechanism controlling the losses was the direct wash-off of the fertiliser. Any fertiliser that fell on saturated areas of ground, including the drainage system and adjacent riparian zones, would have been

the most susceptible to removal in run-off. The ammonium that was released following hydrolysis of the urea would have had little opportunity of being absorbed and fixed by the soil in such areas. The results from Cononish showed that the presence of very wet ground conditions at the time of the application was sufficient to produce a marked response; it did not require a subsequent period of heavy rainfall. Support for the direct wash-off mechanism is also provided by overseas studies, which have found ammonium concentrations in run-off to be directly related to the amount of fertiliser falling on areas of surface water and their immediate borders (Frediksen *et al.*, 1975; Neary and Leonard, 1977).

It follows from the above that losses of urea fertiliser in run-off are likely to be small where applications are made during drier periods of the year. This is supported by the results of a monitoring study in east Scotland by the North East River Purification Board in 1991. A standard aerial application of urea to 60% of a headwater catchment during a relatively dry period in August had little effect on ammonium concentrations in stream water. However, applications should not be made after a prolonged dry period, since moisture levels will be insufficient for the urea to dissolve and be incorporated into the soil. Conditions are likely to be best suited for minimising the risk of fertiliser run-off in late spring and early summer.

Implications for fertiliser practice

The results of the monitoring programme suggest that aerial applications of urea fertiliser to greater than 15% of a catchment have the potential (if preceded or followed by heavy rainfall) to cause ammonium concentrations in receiving streams to temporarily exceed the mandatory water quality standards. While urea fertiliser is usually only applied on a relatively small scale, applications could easily exceed the 15% figure in small, first order headwater catchments. In view of these findings, discussions were held with the National Rivers Authority to consider the threat posed by such applications.

A review of the subject found no evidence that applications of urea fertiliser have ever posed a danger to public health through the contamination of drinking water supplies. Similarly, evidence was lacking of any significant impact on the freshwater biota. For example, the Clyde River Purification Board monitored one of the previously reported pollution incidents in 1990 and found no effect on the stream invertebrate or fish populations. It is likely that the conditions of high and turbulent flows, low temperature and low pH which characterise headwater streams, are not conducive to the indirect effects associated with enhanced concentrations of ammonium. This view is also reflected by the European Union Water Directive (78/659/EEC), which states that in particular geographical or climatic

conditions, particularly in cases of low water temperatures and reduced nitrification, a higher standard for ammonium may be fixed.

Despite the above, the fact remains that aerial applications of urea fertiliser can contaminate watercourses with possible implications for downstream users. Consequently, the water regulatory authorities remain concerned about the application of urea fertiliser in surface water catchments. These are the key points for action.

1. Contact the water regulatory authority and water undertaker when planning aerial applications of fertiliser.
2. In catchments with sensitive water bodies, consider applying fertiliser by hand or ground machine, or phasing aerial treatments over several years.
3. Do not apply fertiliser during periods of very wet weather or if heavy rain is forecast. Do not apply if the ground is frozen, snow covered, or baked dry, when the risk of wash-off is very high.
4. Avoid application to riparian and aquatic zones.

The *Forests and water guidelines* publication has been revised to incorporate these points.

References

- FORESTRY COMMISSION (1993). *Forests and water guidelines*. HMSO, London.
- FREDIKSEN, R.L., MOORE, D.G. and NORRIS, L.A. (1975). Impact of timber harvest, fertilisation and herbicide treatment on stream water quality in Western Oregon and Washington. In: B. BERNER and C.H. WINGET, eds. *Forest soils and forest land management*. Proceedings of the North American Forest Soils Conference. Les Presses d'Universite Laval, Quebec, pp. 195-321
- NEARY, D.G. and LEONARD, J.H. (1977). Environmental aspects of forest fertilisation. In: R. BALLARD, ed., *Use of fertilisers in New Zealand forestry*. Proceedings of the Forest Research Institute Symposium No. 19. Rotorua, New Zealand, pp. 247-266.

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